MATÍAS ESCUDERO
MARTÍN GONZALEZ-ROZADA
MARTÍN SOLÁ

Toward a "New" Inflation-Targeting Framework: The Case of Uruguay

Empirical studies in the late 1980s, suggesting that monetary policy might influence the short-run dynamics of the real economy, contributed to the widespread use of inflation-targeting policy rules by central banks. More recent research on monetary economics provide a theoretical framework for the implementation of such rules. For example, Taylor (1993) recommends the use of a simple interest rate rule that is a function of inflation and the output gap. Nowadays it is standard to use the dynamic stochastic general equilibrium (DSGE) model and New Keynesian models to evaluate the effects of Federal Reserve policies. The success of alternative policy rules is usually assessed in terms of the short-run dynamics of the relevant macroeconomic variables.

Many central banks use the reference interest rate as a conventional instrument to signal to the public changes in the monetary policy stance. In this way they attempt to achieve the convergence of inflation, and its expectation, upon a given target. Recently several central banks in Latin American countries (LAC) adopted stabilization policies using conventional and unconventional tools to meet their inflationary or financial stability objectives. Among the unconventional tools are reserve requirements (see Glocker and Towbin, 2012, and the references there for several emerging countries outside Latin America; for LACs, see Carvalho and Acevedo, 2008; Ocampo and Tovar, 2003; Ribeira

Escudero is with Northwestern University; Gonzalez-Rozada is with the Universidad Torcuato Di Tella; and Solá is with the Universidad Torcuato Di Tella and Birkbeck University of London.

We would like to thank the following for their useful comments: an anonymous referee; Roberto Bernal, Roberto Chang, Luis Catao, Andres Fernandez, Andrew Powell, and Alessandro Rebucci; and all the participants in the workshop Rethinking Inflation Targeting in Latin America, which was held at the Central Bank of Peru, 21–22 October 2013. The authors gratefully acknowledge financial support from the Inter-American Development Bank.

and Barbosa, 2005; Vargas and others, 2010). In highly dollarized LAC, changes in reserve requirements have been used as a macroeconomic prudential tool, with the main objective of accumulating liquidity being to address financial stress (see León and Quispe, 2010; Vargas and Cardozo, 2012; Tovar, Garcia-Escribano, and Vera Martin, 2012; Carrera and Vega, 2012) and to complement the use of the reference interest rate in order to achieve the inflation target objective (see Comunicados del COPOM, 2007–12, for Uruguay; Glocker and Towbin, 2012). However, most of the literature on the use of reserve requirements in LAC is not only empirical but is mostly focused on the impact of these requirements on interest spreads and bank profits. The main conclusion from those studies is that an increase in reserve requirements induces an increment in interest rate spreads and a fall in bank profits. An increment in reserve requirements acts as a tax on the banks and widens the spread between lending and deposit rates (see Glocker and Towbin, 2012).

Monetary policy shocks typically generate a short-run fall in inflation through a contractionary effect on economic activity. Furthermore, in highly dollarized economies, these shocks may also have undesirable effects on the foreign exchange market (Montoro and Moreno, 2011). Therefore, the use of reserve requirements may be an important unconventional monetary policy tool, since it could help to achieve the inflationary target without having major effects on the exchange rate market (that is, without attracting capital inflows), and it may also reduce the negative impact of the increase in interest rates on output.

Nevertheless, the short-run effects of this type of policy are not obvious, since it depends on, among other things, the combination of instruments chosen to achieve the target and the type of target under consideration. The main objective of this paper is to describe the impact of using conventional and unconventional tools to meet inflationary or financial stability objectives in a dollarized economy. This paper explores, for the Uruguayan economy, the impact of these policies, using a relatively standard model of a small open economy with sticky prices, financial frictions, and a banking sector that is subject to legal reserve requirements.[1]

The three main findings of the paper are as follows. One, reserve requirements can be used to achieve the inflationary objectives of the central bank.

1. To the best of our knowledge this is the first paper that tackles the use of reserve requirements in a general equilibrium setting not only as a macroeconomic prudential tool but also as an unconventional instrument to achieve the inflationary target in a highly dollarized Latin American economy.

However, reducing inflation using this instrument also produces a real appreciation of the Uruguayan peso. Two, when the central bank uses the monetary policy rate as an instrument, the effect of the reserve requirements is to reduce the negative impact on consumption, investment, and output of an eventual increase in the interest rate. Nevertheless, the quantitative results in terms of lowering inflation are rather poor. Three, the monetary policy rate becomes more effective in reducing inflation when the reserve requirements instrument is solely directed toward achieving financial stability and the monetary policy rate toward reaching the inflationary target.

The paper is organized as follows. The next section describes the characteristics of monetary policy and the evolution of the main macroeconomic variables of Uruguay from 2002 to 2012. The following section describes the theoretical framework used to evaluate the impact of the different policies that the Central Bank of Uruguay used to achieve its inflation, output, and financial stability objectives. The data, the calibration strategy used for some of the parameters, and the Bayesian estimation methodology are described. The section that follows describes the impulse response analysis.

The concluding section presents our policy recommendations. The main policy conclusion of the paper is that an unconventional policy instrument, when well targeted, can help control inflation. Reserve requirements can also be instrumental in offsetting the impact of monetary policy on the real exchange rate.

Several technical appendixes presenting the theoretical model, its calibration, and its estimation are in the working paper version of this paper.[2] That version also includes prior and posterior distributions of the estimated parameters and some of the impulse response functions not described in this paper.

Inflation Targeting in Uruguay

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. Over the next ten years the Central Bank of Uruguay used different

2. Gonzalez-Rozada and Sola (2014).

instruments to achieve financial and economic stability for an economy highly dollarized and vulnerable to the effects of external shocks, like the global financial crisis of 2007–09. This context provides a unique opportunity not only to study 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.

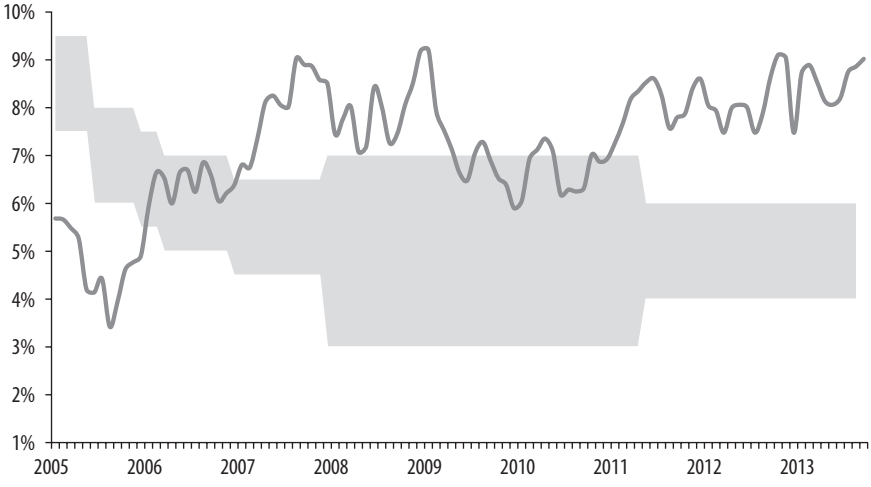
Monetary Policy

The crisis in Argentina had real effects on the economy of neighboring Uruguay, reflected in a drastic reduction of exports to Argentina. Deposits of foreign currency in Uruguay's financial sector decreased significantly as spillover effects from the bank run in Argentina. In June 2002, to help maintain monetary control with the new floating exchange rate regime, Uruguay implemented an inflation-targeting policy. It abandoned the exchange rate peg and started to use the monetary base as the nominal anchor for the economy.

Since that time Uruguay has pursued important monetary and financial reforms. It improved financial prudential norms and supervision of the banking system and 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 toward 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 keep an inflation target moving from a point target for the monetary base to a band, with the objective of fulfilling inflation targets. In November 2004 the central bank announced a targeted inflation range of 6 to 8 percent by September 2005 (figure 1). In 2005 the central bank abandoned the monetary base target, keeping inflation as the only target of 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 a significant pass-through from the policy rate to both the 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 that changes in the money market rate are, in turn, transmitted to deposit and lending rates, thus affecting the consumption and

FIGURE 1. Annual Inflation and Inflation Target Zone, 2005–12



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

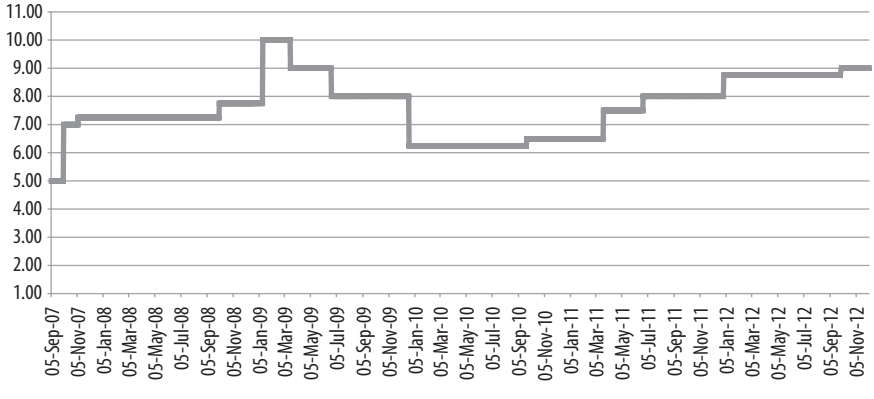
saving decisions of individuals and firms—and hence, aggregate demand and inflation. Moreover, as domestic and foreign interest rates in Uruguay differ in comparable assets, arbitrage between them gives rise to nominal exchange rate fluctuations, which in turn affect inflation and economic activity through the so-called exchange rate channel.

The country was able to introduce and maintain an inflation-targeting regime in a framework of greater prudential norms, and supervision by the banking sector, larger 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 4.0 percent in September 2005, had by September 2007 begun to rise, reaching around 9 percent (see figure 1). The Macroeconomic Coordination Committee (Comité de Coordinación Macroeconómica) was created to set 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 members and three staff members), is in charge of setting the parameters of the monetary policy 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 percent. This rate

held through October 3, when it was raised to 7 percent. 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 (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 the wider range of 3 to 7 percent. According to the committee, the reasons behind this change were the high volatility in the international financial markets and the vulnerability of the Uruguayan economy to external shocks (see Comunicados del COPOM, 2007–12). In July of that year the committee held the inflation range at 3 to 7 percent for the next eighteen 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 nonconventional tool, reserve requirements, to complement the policy rate. In June 2008 the central bank increased the reserve requirements for deposits in domestic currency to 25 percent and deposits in foreign currency to 35 percent. For deposits by the public sector in the Banco de la República Oriental del Uruguay (BROU), reserve requirements were set at 100 percent. Moreover, the central bank decided to eliminate the reserves remuneration, and it established penalties for those banks not fulfilling the reserve requirements. The central bank president at that time, Walter Cancela, explained that the objective of the increment in reserve requirements was twofold: first, to contain inflation, and second,

FIGURE 2. Policy Interest Rate, 2007–12



Source: Central Bank of Uruguay.

to dedollarize the economy (see Archivos de la Presidencia de la República Oriental del Uruguay, 2002–11).

By the beginning of 2008 the inflationary situation improved, despite the fact that 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 raise the policy rate from 7.75 percent to 10.0 percent. It is interesting that this rise coincided with the shock of the collapse of Lehman Brothers, which we know, ex post, would mean a strong downward pressure. This is consistent with the experience of other Latin American countries (such as Colombia, Chile, Mexico, and Peru; see Céspedes, Chang, and Velasco, 2014). 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 its target band, and the central bank decided to cut the policy rate from 9 to 8 percent.

In December 2009 the central bank reduced the policy rate to 6.25 percent (see figures 1 and 2). Additionally, 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, in January 2010 the reserve requirements for deposits in domestic currency were cut from 20 to 12 percent, and in July 2010 the reserve requirements for deposits in foreign currency (maturity of less than 180 days) were set at 15 percent—and for deposits of larger maturity at 9 percent. At the beginning of 2010 the inflationary situation worsened, and the possibility that inflation would be above the target band 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; 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 midyear 2011, the central bank decided to strengthen monetary policy and raised the average reserve requirements on deposits. This pushed the marginal reserve requirements 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 requirements ranges for domestic and foreign currency deposits.

Marginal reserve requirements were created in April 2011 for those banks holding deposits in excess of average deposits. The marginal reserve

TABLE 1. Reserve Requirements Rates, Deposits in Domestic and Foreign Currency

	Deposits in domestic currency			
Maturity	*Old*	*New*	*Marginal*	*Total requirements*
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 requirements*
Less than 180 days	15	18	27	45
More than 180 days	9	14	27	41

Source: Central Bank of Uruguay.

requirements were set at 15 percent 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 old and new remuneration rates.

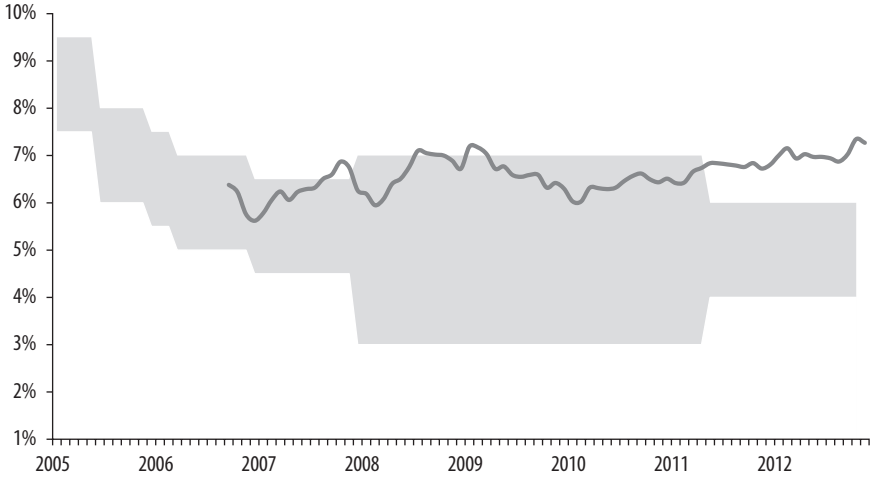
As can be seen from the table, the central bank raised the remuneration for the average reserve requirements from 2 to 5 percent and established a remuneration rate of 2.5 percent for marginal reserve requirements in domestic currency. The central bank also established remuneration rates of 0.15 and 0.25 percent for marginal reserve requirements in U.S. 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 8.0 percent. In spite of these policies, the inflation rate was well over the inflation target band during all of 2011. This situation prompted the central

TABLE 2. Reserve Requirements Remuneration Rates

	Reserve requirements remuneration		
Currency	*Old rate*	*Average rate*	*Marginal rate*
Pesos	2.00	5.00	2.50
Dollars	Federal Reserve rate	0.15	0.15
Euros	0.25	0.25	0.25

Source: Central Bank of Uruguay.

FIGURE 3. Inflation Expectations and Inflation Target Zone, 2005–12[a]



Source: Authors' calculations using data from the Central Bank of Uruguay.
a. Horizon is eighteen months.

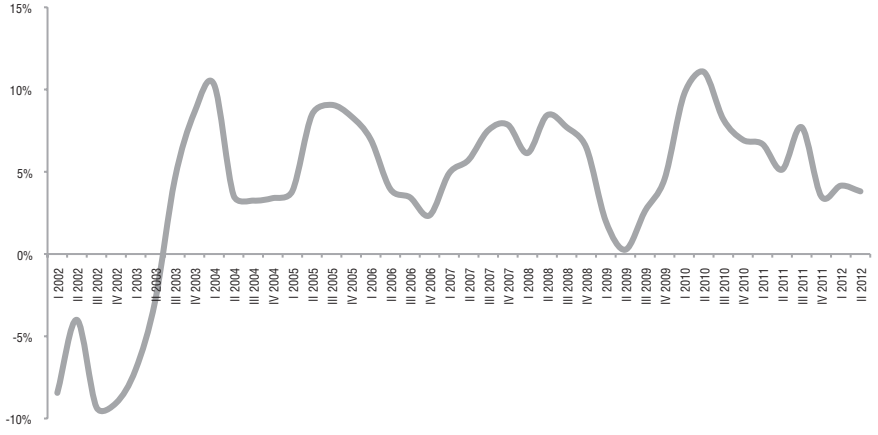
bank to raise the policy rate again, on the last day of December 2011. The new policy rate was set at 8.75 percent. By August 2012 the inflation rate still was two points above its target band, and the central bank—continuing with its contractionary monetary policy—decided to increase, by 20 and 40 percent respectively, the marginal reserve requirements for deposits in domestic and foreign currency. In early October 2012 the Monetary Policy Committee raised the policy interest rate from 8.75 to 9 percent. Even with these changes, the inflation rate was over its target band for the whole of 2012 (figure 3).

At the beginning of the implementation of the inflationary targeting regime, the central bank was able to keep inflation within its target band; but from the end of 2010 to early 2011 the inflation rate was well over its target. During the same period, the central bank had more success with inflation expectations. As can be seen in figure 3, these expectations were mostly within the target band. By October 2010 inflation expectations began to be above the target band for inflation.

Economic Activity

In 2002, in the midst of a serious economic and financial crisis, economic activity dropped sharply. Gross domestic product fell by 12 percent (figure 4).

FIGURE 4. GDP, Year-to-Year Change, 2002–12



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

After the 2002 crisis, 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 recovery in 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 economy recorded a GDP average growth of 5 percent. Unlike that in 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 sectors of industry, with the most dynamic branches being food, beverages, tobacco, chemicals, and metal products, specifically machinery and equipment. In 2005 the economy regained the levels of production experienced before the crisis that began in 1999. The manufacturing industry continued to expand at a rapid rate, together with the commerce and service sectors.

The country's economic growth in 2006, an annual average rate of 4.2 percent, was attributable to the robust performance of all sectors of the economy, especially manufacturing, construction, transport, communications, and agriculture. The economy continued to expand rapidly in 2007, with a GDP

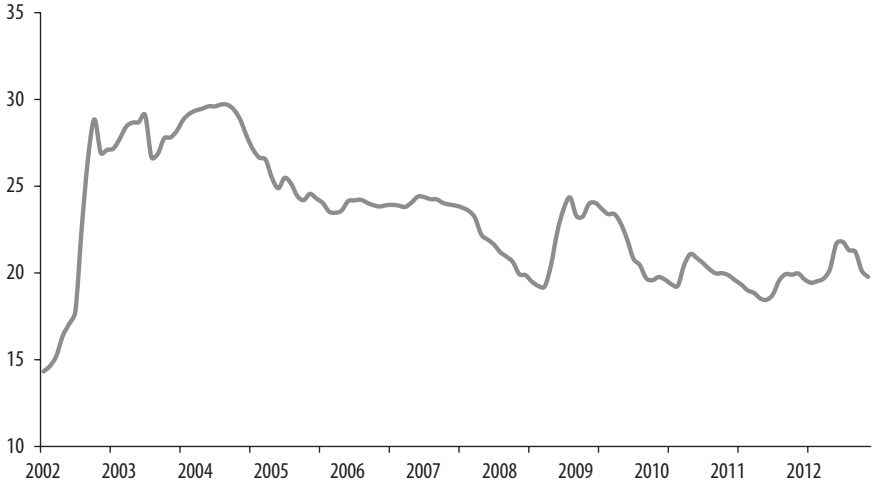
average annual growth rate of 6.5 percent. This performance was led by transport, storage, and communications, commerce, restaurants and hotels, and manufacturing. This rise in output was stimulated by growing external demand and domestic consumption, which was 7.2 percent higher than in 2006. With a GDP annual average growth rate of 7.2 percent in 2008, the economy expanded 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 the economy began to feel the impact of the international crisis. GDP that grew 8.4 percent and 7.7 percent, respectively, in the second and third quarters of 2008, fell to 6.5 percent in the last quarter of the year (see figure 4).

In the first quarter of 2009 the economy grew only 2.0 percent, contracting 2.33 percent with respect to the last quarter of 2008. Nevertheless, the country posted a 2.4 percent average annual rise in GDP in 2009, making it one of the few economies in the region to remain on a growth path that year. 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, with an 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 to recover from the sharp decline in 2009. In 2011, the 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, respectively, in the first and second quarters of 2011, the economy began to slow in the second semester, its output growing by about 8 and 7 percent, respectively, 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 in the second part of 2011 continued through the first half of 2012.

In sum, economic activity between 2004 and the first semester of 2012 was very impressive. 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," in reference to the inflation rate outside its target zone.[3]

3. 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, 2002–12



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

The Exchange Rate

During the crisis of 2001 in neighboring Argentina, there was a huge depreciation of the Argentine peso, which affected 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 to 12 percent in January 2002. By June authorities began to float the exchange rate after twelve 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. Toward 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 (figure 5). In mid-2003, as 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 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 growth.

In real terms, the peso appreciated by 8.9 percent in 2005 (figure 6). In 2006 it appreciated, on average, by 1.7 percent in nominal terms against the 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 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.

FIGURE 6. Real Exchange Rate Index, 2002–12

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

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, the local currency dropped 12.5 percent against the dollar in 2008, 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 to the dollar 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 pesos to the dollar 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 peso 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 (see figure 6) fell by almost 7 percent in 2011, compared with the previous year, evidencing the strengthening of the peso in the second half of the year. This decline in the index reflected a loss of Uruguayan 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, a value almost equal to the one in December 2011.

In the period analyzed here, the Uruguayan peso appreciated almost continuously against the dollar, with shorter periods of depreciation. In this context, the use of nonconventional tools, like reserve requirements, become of greater importance because they can make monetary policy more restrictive without undesirable effects on the exchange rate.

Summing up this section, first, the central bank was able to keep inflation expectations mostly within the target zone until 2010 but had problems doing the same with inflation. Output growth between 2004 and the first semester of 2012 was very impressive, but at the same time the Uruguayan peso appreciated almost continuously against the dollar. Since the Central Bank of Uruguay used the reference interest rate and reserve requirements to achieve the inflationary target, this country provides a unique context to empirically

evaluate the effectiveness of these policy instruments. In this line of thinking, the next section introduces a theoretical model that can be used to compute the costs and benefits of the alternative policies implementing inflation targeting. In particular, our model tries to duplicate Uruguay's monetary policy in the period analyzed here. In the model presented below, the central bank uses two instruments to conduct its monetary policy: the interest rate and reserve requirements. We compare the effects of monetary policy over several macroeconomic variables. In this way, the results can be used not only to assess the performance of an inflation-targeting policy but also to provide evidence for policy recommendations.

Theoretical Framework

In this section we describe the proposed theoretical framework to evaluate whether the policy tools used in Uruguay since 2002 allowed for greater countercyclicality and reduced economic volatility. The short-run dynamic of the policies crucially depends on the parameters of the model. The methodology proposed here allows us to analyze the impact of conventional and nonconventional monetary policies.

The Economy

The theoretical framework here relies on the dynamic stochastic general equilibrium model presented in Christiano, Trabandt, and Walentin (2011). That model 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.[4]

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

4. The complete model description and its equations can be found in Gonzalez-Rozada and Sola (2014).

approach, commercial flows perform an important role in the economy. On the one hand, exports involve a continuum of exporters, each of whom 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 consist of a homogeneous foreign good that is bought by specialized domestic importers. These specialized importers transform this homogeneous good into a specialized good that is sold to domestic retailers. The result is homogeneous goods used as inputs in the production of investment goods, consumption goods, and specialized export goods. The interaction between the external sector and the domestic economy also allows for trade of riskless 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, Gertler, and Gilchrist (1999). Financial frictions are introduced by differentiating 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 requirements. 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, the asymmetric information between borrowers and lending banks (who cannot see the idiosyncratic shock up to a monitoring cost) provides incentives to entrepreneurs to underreport their earnings, which justifies the existence of an external finance premium in addition to the risk-free interest rate. As can be noticed, the monitoring cost and asymmetric information introduce a financial accelerator mechanism that is responsible for the financial frictions in the model.

Although we abstract from the labor market setup 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 funding from households and lend them to entrepreneurs. Instead of using only one banking unit to do 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.

The 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

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

subject to

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

where

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

where $\zeta_t(j)$ represents the fraction of deposits that deposit unit j puts into an account in the central bank, ζ_t^{MP} is the legal required reserve ratio, and $G_t^{\zeta}(j)$ 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 requirements (parameter $\psi_1 < 0$). The quadratic term is associated with the central bank punishing large deviations from its reserve requirements target (parameter $\psi_2 > 0$). Deposit units benefits come from two sources: one, 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 two, 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 by the cost function described above.

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 they 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 needed 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 nonrisky 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. We use a bank structure that allows it to incorporate legal reserve requirements as an instrument of monetary policy. Christiano, Trabandt, and Walentin (2011) describes a monetary policy that is specified in terms of a Taylor rule that sets the level of the monetary policy interest rate as a function of its past value, targeted and actual inflation, and output:

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

In this baseline model, reserve requirements are nonexistent, 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, which encompasses both borrowing and lending.

In our model, the central bank has two instruments to conduct its monetary policy: the interest rate and reserve requirements. The institution can modify the risk-free interest rate, R_t, and it can also make use of reserve requirements to change the amount of available credit. 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: one, the relationship between the current value of the inflation target and its steady state level; two, the relationship between the value of current inflation and the current value of the inflation target; three, the relationship between the current level of GDP and its steady state level; and four, 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 over macroeconomic 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 policy rules. Thus the monetary policy rules used in our model can be expressed as

$$(2)\quad \log\left(\frac{R_t}{R}\right)=\rho_R\log\left(\frac{R_{t-1}}{R}\right)+\left(1-\rho_R\right)\times\left[\log\left(\frac{\overline{\pi}_t^c}{\overline{\pi}^c}\right)+r_\pi\log\left(\frac{\pi_t^c}{\overline{\pi}_t^c}\right)+r_y\log\left(\frac{gdp_t}{gdp}\right)+r_L\log\left(\frac{B_{t+1}}{B}\right)\right]+\varepsilon_t^R$$

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

where ε_t^R and ε_t^ζ 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, $\overline{\pi}_t^c$ 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 rule also allows us to evaluate a situation where tasks are separated in terms of monetary policy and the central bank's 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,

$$(3)\quad \log\left(\frac{R_t}{R}\right)=\rho_R\log\left(\frac{R_{t-1}}{R}\right)+\left(1-\rho_R\right)\times\left[\log\left(\frac{\overline{\pi}_t^c}{\overline{\pi}^c}\right)+r_\pi\log\left(\frac{\pi_t^c}{\overline{\pi}_t^c}\right)+r_y\log\left(\frac{gdp_t}{gdp}\right)\right]+\varepsilon_t^R$$

$$\log\left(\frac{\zeta_t^{MP}}{\zeta^{MP}}\right)=\rho_\zeta\log\left(\frac{\zeta_{t-1}^{MP}}{\zeta^{MP}}\right)+\left(1-\rho_\zeta\right)\left[\zeta_L\log\left(\frac{B_{t+1}}{B}\right)\right]+\varepsilon_t^\zeta.$$

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

The interaction between the two instruments could help us 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 macroeconomic variables (inflation, output, investment, and consumption) than those 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 financial side of the economy negatively reacts to interest rate shock. The drop in reserve requirements could translate into a small fraction of deposits being held as reserves and in that way could help avoid 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 on the reserves deposit that banks hold. In our model we assume the following interest rate relationship:

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

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

The Data

We calibrate our model and then estimate a subset of its parameters based on Uruguayan data for the period incorporating the first quarter of 2007 through

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 2011, quarter 4	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 Gonzalez-Rozada and Sola (2014, app. D)
Foreign output	See Gonzalez-Rozada and Sola (2014, app. D)
Foreign inflation	See Gonzalez-Rozada and Sola (2014, app. D)
Foreign interest rate: 3-month 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.

the fourth quarter of 2012.[5] The time unit in our model is a quarter, so we collect quarterly data for the Uruguayan economy. Table 3 summarizes the data and their respective sources. Several steps are required for the calculation of the foreign-sector-related variables (foreign inflation, output and interest rate, and the real effective exchange rate index); these are explained in Gonzalez-Rozada and Sola (2014, 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,

5. 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. Therefore, matching our model with the appropriate data imposes a constraint in terms of the length of the sample we can use for the estimation.

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 differ 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 used in the estimation.

Calibration and Estimation

We calibrate several of the parameters of the model using data from Uruguay and estimate the rest of the parameters using a random walk Metropolis-Hastings chain. Using Bayesian techniques we estimate a subset of seventy-two model parameters, which include nineteen shock standard deviations, sixteen VAR parameters for the foreign economy, twenty-nine structural parameters, and eight AR(1) coefficients for the exogenous processes. The model comprises twenty-three stochastic variables, which are used to generate the impulse response functions discussed below. (For the complete description of our calibration and estimation procedure, see Gonzalez-Rozada and Sola, 2014, appendix A.)

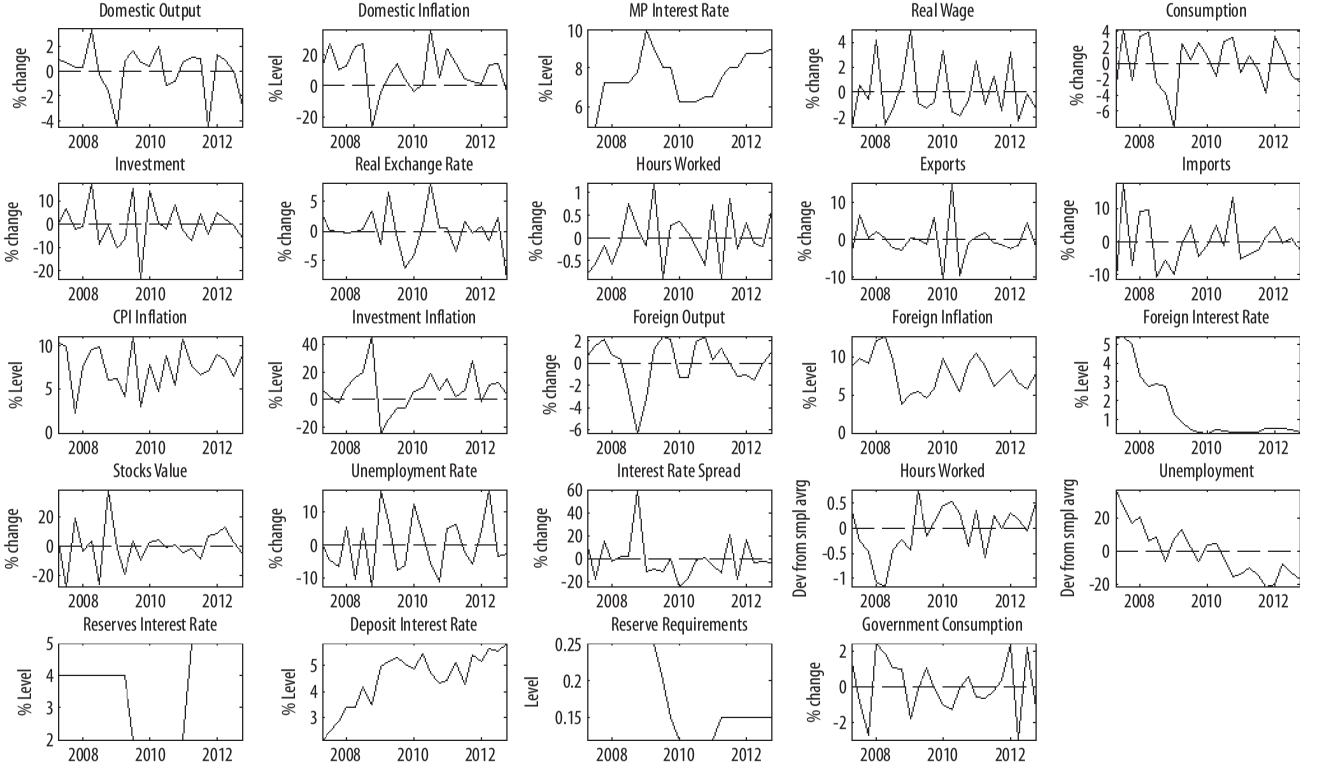
Impulse Response Function Analysis

Selected five-year-horizon impulse response functions for the shocks of the model are analyzed here.[6] 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 into account inflation and output deviations from their steady state level targets (see equation 1). In this baseline model, reserve requirements are nonexistent, and the bank structure

6. For the rest of the impulse response functions, see Gonzalez-Rozada and Sola (2014, appendix F).

FIGURE 7. Data Used in the Estimation, 2008, 2010, 2012



Source: Authors' calculations using data from the Central Bank of Uruguay, the National Institute of Statistics of Uruguay, and the International Financial Statistics database.

is the same as that described in Christiano, Trabandt, and Walentin (2011). Hereafter, we 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, is labeled model 2. This is our general specification in equation 2, and it represents, from our point of view, the policy rule used by the Central Bank of Uruguay during the period analyzed here.

Finally, we consider a third model, using a monetary policy rule in which the instrument's tasks are separated: while reserve requirements respond only to deviations in the stock of entrepreneurial loans, the monetary policy interest rate accounts only for changes in output and inflation (see equation 3). This is labeled model 3.

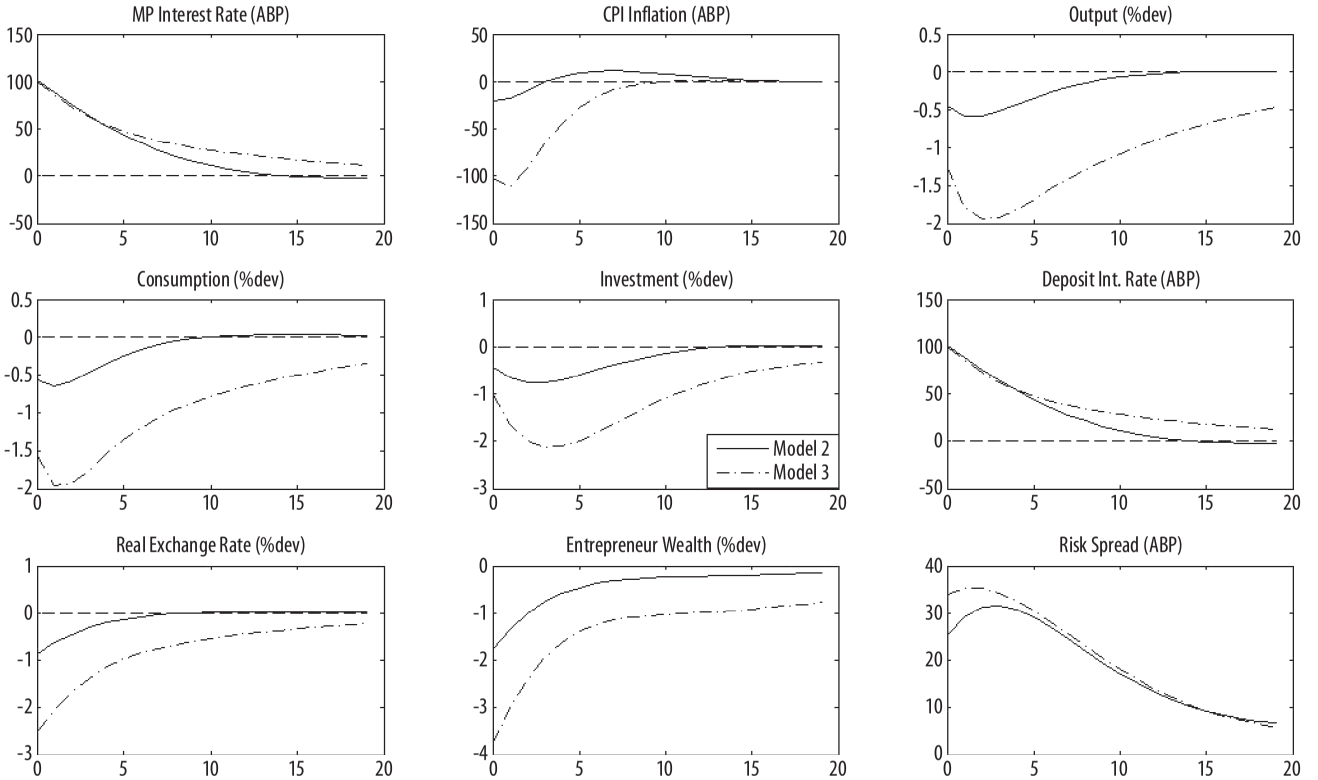
Comparisons among the impulse response functions that result from these three models allow us to assess the role of reserve requirements in different economic environments and evaluate its convenience in terms of the objectives defined by the central bank. In the following figures, almost all units on the y-axis are in terms of percent deviation from steady state levels. Interest rates, spreads, and inflation are measured in terms of annualized basis points deviations. (Impulse response functions can be found in Gonzalez-Rozada and Sola, 2014.)

An Interest Rate Shock

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

The results of the rise in interest rates over 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 responds to demand shocks, resulting in a modest

FIGURE 8. Interest Rate Shock 1, Impulse Response Functions for Models 2 and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

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.

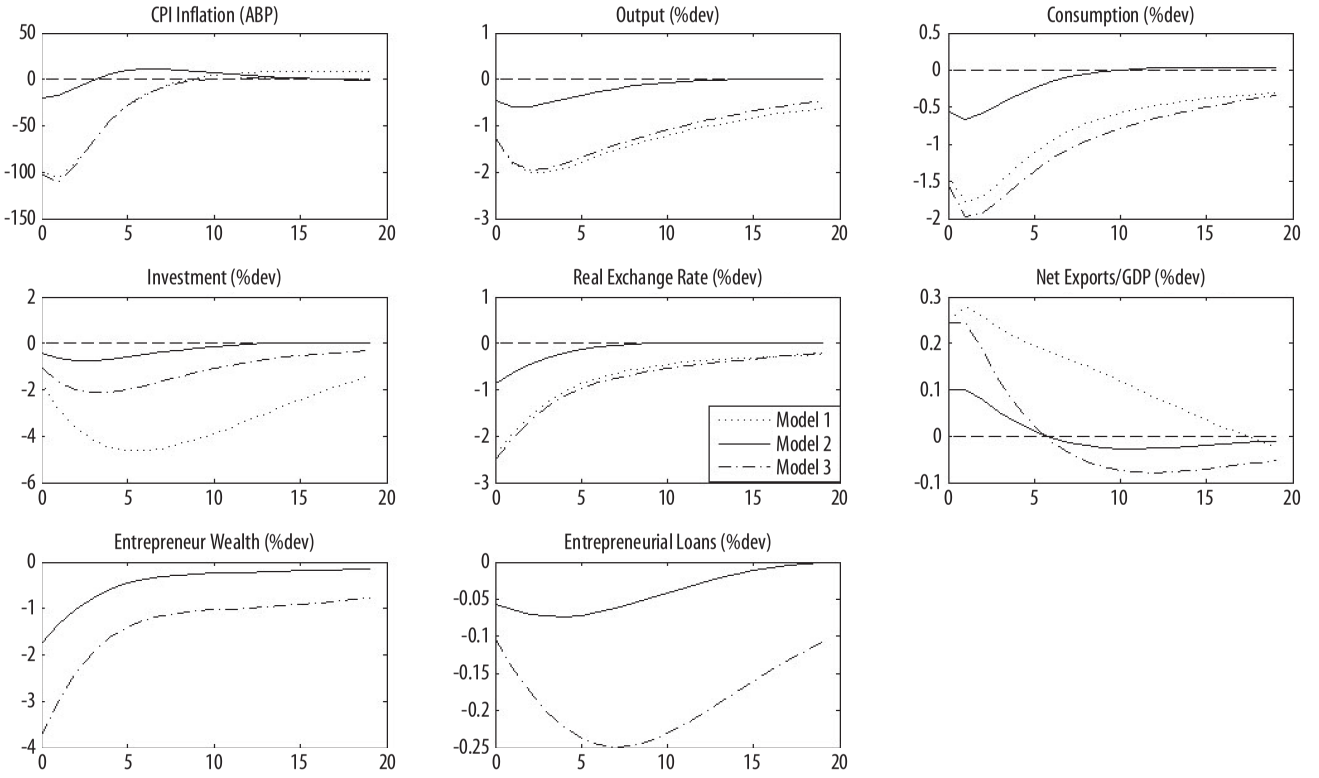
In addition, entrepreneurs' net wealth decreases as a result of three mechanisms: first, the increase in lending rates makes it more expensive for entrepreneurs to pay their existing debts; second, the price of capital falls; and third, the surprise disinflation increases the real value of nominal debts.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

Continuing with the impulse response function 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 helps avoid a larger fall in the real stock of entrepreneurial loans. The contractions in both entrepreneurs' net wealth and entrepreneurial loans are smaller than those 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 over 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 requirements rule that reacts to changes in inflation, output, and entrepreneurial loans. As can be noticed from the comparison with the two other models, inflation does 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 assume only 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 achieve 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 a reserve requirements 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).

FIGURE 9. Interest Rate Shock 2, Impulse Response Functions for Models 1, 2, and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

As we calibrate the parameter that describes the importance of the financial accelerator mechanism, it is important to evaluate the performance of the model when financial friction varies. Figure 10 presents the impact of the same positive interest rate shock in model 2 on key macroeconomic variables for the case in which bank monitoring costs imply a loss of 15 percent, 40 percent, and 70 percent of bankrupted entrepreneurs' assets. As can be seen in the figure, the differences in terms of the impact of this shock over macroeconomic variables (consumption, output, and inflation) are practically negligible. However, as financial frictions increase (bigger value of the parameter μ), this also increases the importance of reserve requirements as an instrument to achieve financial stabilization. A reduction in reserve requirements prevents a larger effect on the real stock of entrepreneurial loans.

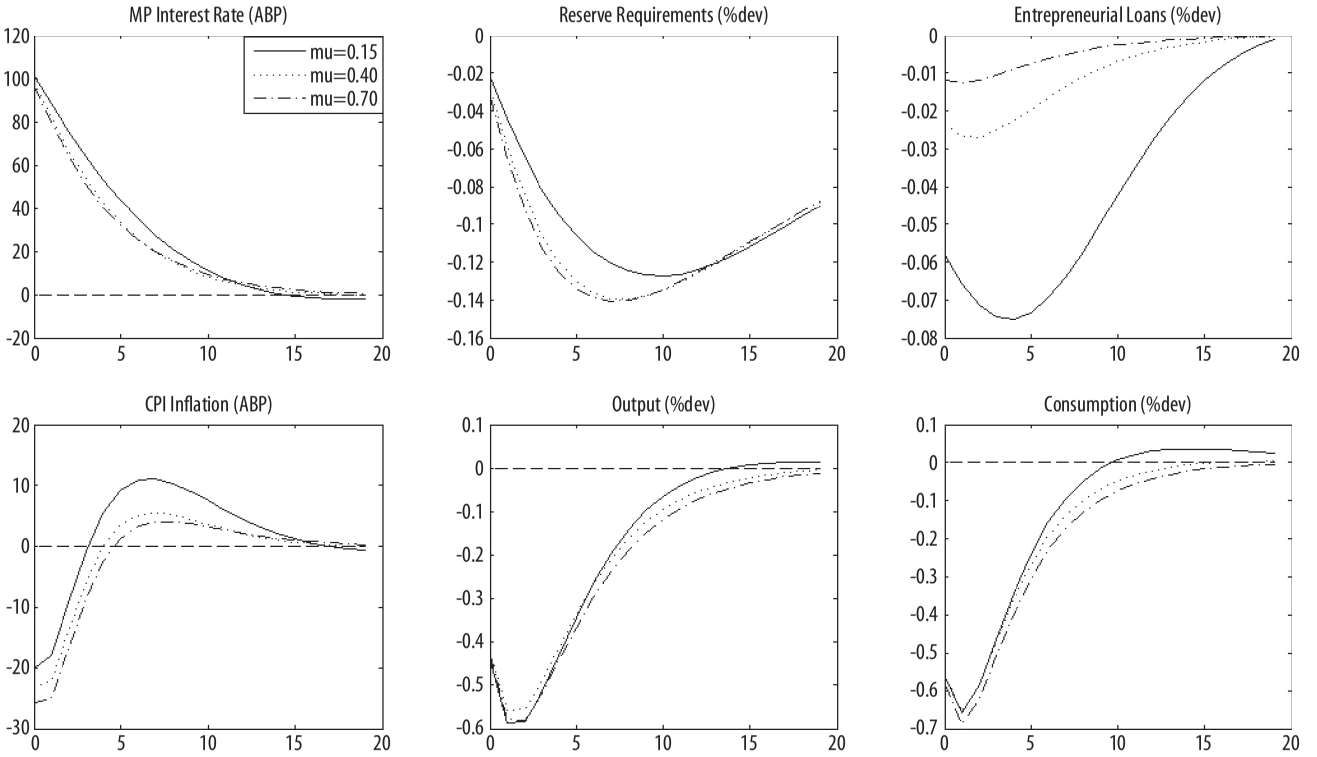
In table 4, we present the sacrifice ratios for models 1, 2, and 3. We compute sacrifice ratios that measure the relative cost, in terms of output sacrifice, of achieving a reduction in inflation,

$$SR_k = \frac{\sum_{j=1}^{k} \Psi_j^{Output}}{\sum_{j=1}^{k} \Psi_j^{Inflation}},$$

where Ψ^i is the impulse response for i = Output, Inflation; and SR_k is the sacrifice ratio of period k (see Boone and Mojon, 1998). Table 4 shows these measures for different horizons. The longest horizon may be interpreted as the total cost of the policy. For model 2 the impulse response that evaluates the effect of inflation for an interest rates shock converges to the long run taking positive values. For this reason we compute for that model only the one-year sacrifice ratio, since for longer periods (when inflation converges to the long run taking positive values) it is not well defined.

Nevertheless, our results show that the sacrifice ratio for model 2 is the highest of all the models under consideration. Higher sacrifice ratios imply higher costs for the policy. As can be seen in the table, the relative cost in terms of output of reducing inflation at any horizon is lower for model 3, where the objectives of the monetary policy are separated: reserve requirements responding only to deviations in the stock of entrepreneurial loans, and the policy interest rate accounting for changes in both output and inflation. This seems to suggest that the use of reserves requirements as a policy instrument is successful only when there is a clear separation of the objectives;

FIGURE 10. Interest Rate Shock 3, Impulse Response Functions for Models 1, 2, and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

TABLE 4. Interest Rate Shock, Sacrifice Ratios, Models 1, 2, and 3

	Sacrifice ratios		
Period	*Model 1*	*Model 2*	*Model 3*
4	2.22	6.00	2.10
8	3.33	–	3.10
12	4.52	–	3.99
16	5.74	–	4.64

Source: Authors' estimations.

otherwise, the results are poorer than those obtained using only the interest rate as an instrument, as in model 1.

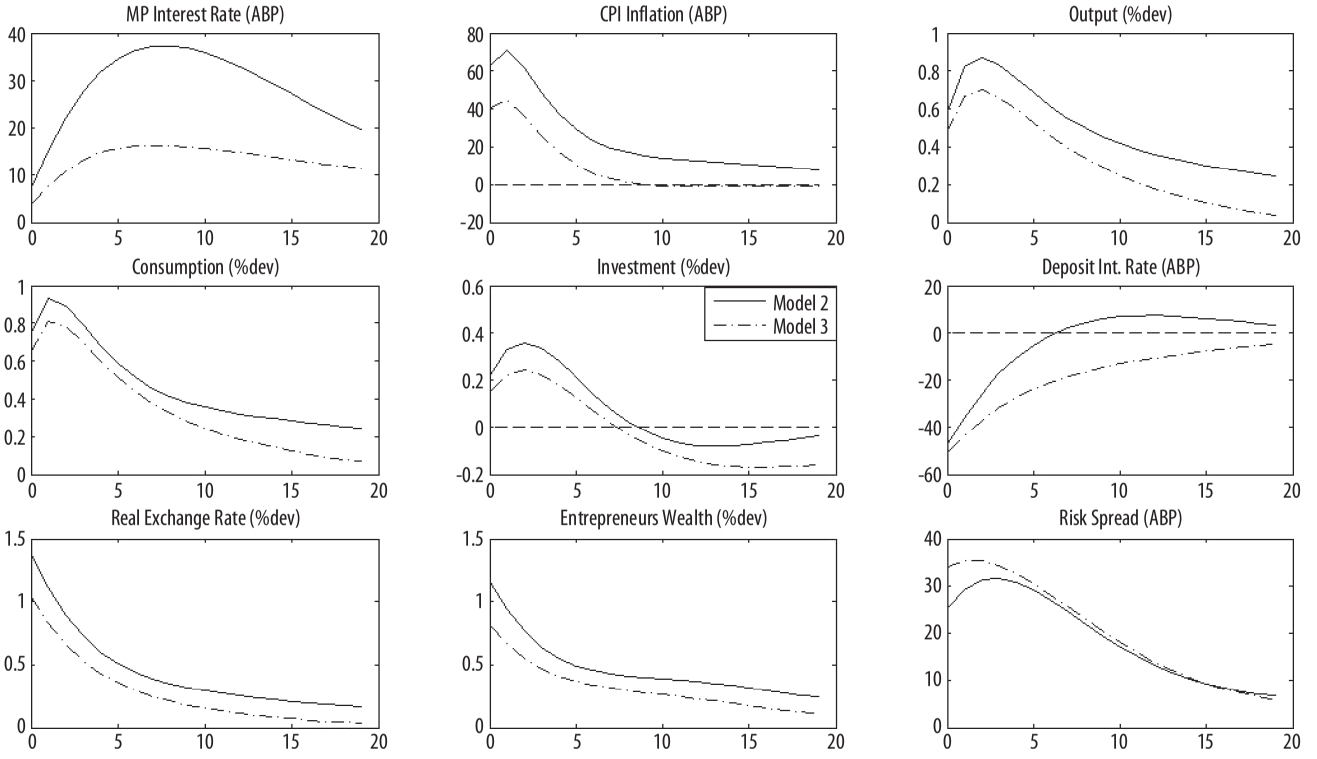
A Reserve Requirements Shock

Figure 11 shows macroeconomic 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 assume 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 under this scenario (an increment in reserve holdings), the banks would want to react by increasing the lending rate, but as this rate is equal to the reference rate in our model, they can only reduce their deposit rate.

An alternative is that the lending rate also adjust. In this alternative scenario the amount of loans is pinned down by the choice of the deposit rate, so reserve requirements become endogenous and must adjust to be consistent with the chosen values of the interbank rate and the spread. Since one of the objectives of the model is to analyze the reserve requirements as a policy tool, we need to fix the interbank rate in our model. Since in this context, legal reserve requirements must be consistent with the interest rate spread and the choice of the (out of control of the central bank) interbank rate, there is no longer any point in having a monetary policy rule for the coefficient of legally required reserves.

Moreover, both of these effects, increasing the lending rate and reducing deposit rates after an increment in reserve requirements, are reported in the literature. In Montoro and Moreno (2011) and Vargas and others (2010), banks react to an increase in reserve requirements that reduce their profits by

FIGURE 11. Reserve Requirements Shock, Impulse Response Functions for Models 2 and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

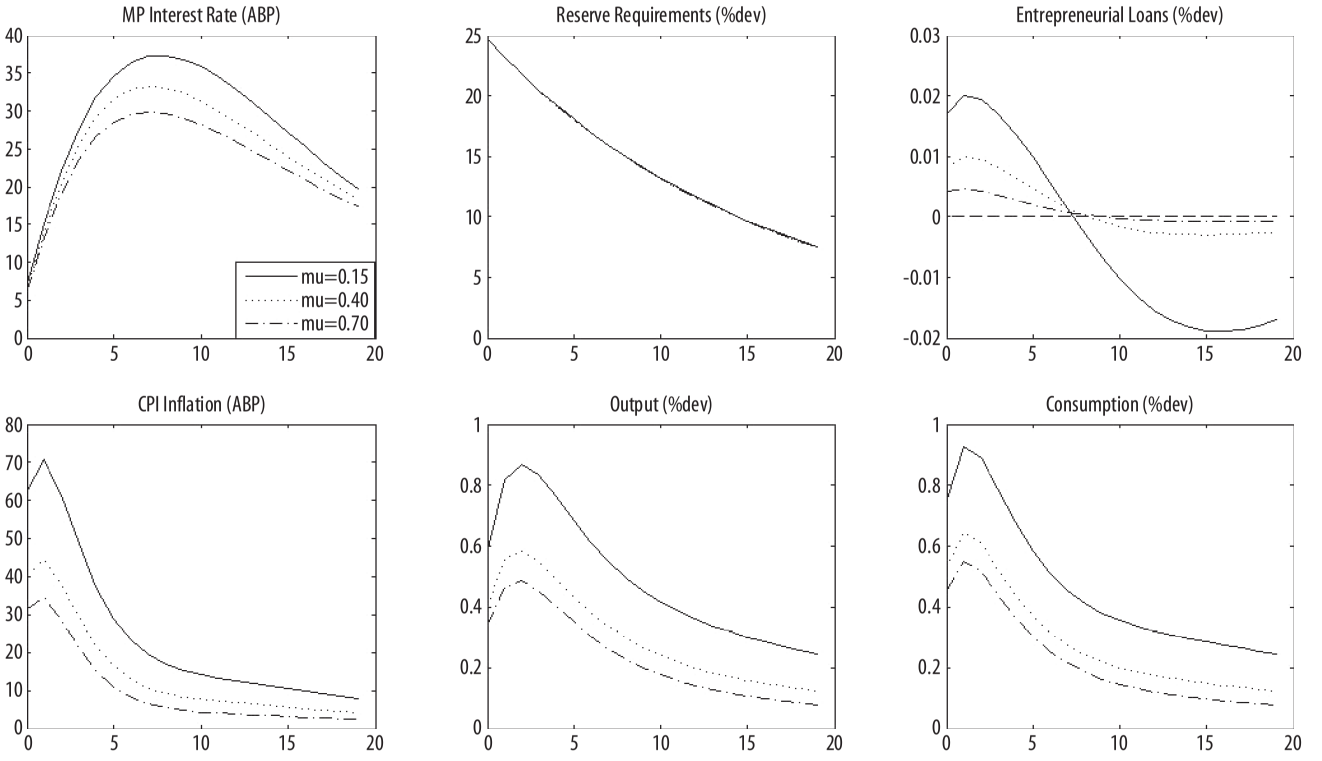
increasing their net interest margins through a rise in the lending rate. The effect of reducing the deposit rate comes from the assumption that the central bank credit is a close substitute for deposits as a source of funds for the banks (see Glocker and Towbin, 2012; Montoro and Moreno, 2011; Vargas and others, 2010). In our case, 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.

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 put upward pressures on the overall price level. The increase in reserve requirements initially reduces the deposit interest rate, which in turns triggers a real depreciation of the domestic currency. After this initial effect, the real exchange rate appreciates. This initial effect also contributes to the increase in inflation, given that the cost of imported inputs increases. In addition, changes in the required reserves ratio also affect the real side of the economy throughout the loan market. This increase in the ratio reduces the amount of money available to lend and, as a result, contracts investment. However, our estimations suggest that it only has a mild positive effect on real investments. This initial positive impact could be the result of a rising 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 monetary policy interest rule that takes this deviation into account, this initial effect on investment is offset after no more than ten 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 12 presents the responses of model 2 to a reserve requirements shock for different values of the parameter that describes the importance of the financial accelerator mechanism. The impact of an increase in reserve requirements over macroeconomic variables such as consumption, output, and inflation is similar under the assumption of a 40 percent and 70 percent loss due to monitoring costs faced by lending banks. Those responses seem to be slightly stronger as financial frictions become less relevant.

In table 5, we present the sacrifice ratios for models 2 and 3 when a reserve requirements shock hits the economy. We compute sacrifice ratios that measure the relative cost, in terms of output sacrifice, of achieving a reduction in inflation in the same way as described above. The table shows that the sacrifice in output to reduce inflation is lower for all horizons in model 2. This is

FIGURE 12. Reserve Requirements Shock, Differing Impulse Response Functions for Model 2[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

TABLE 5. Reserve Requirements Shock, Sacrifice Ratios, Models 2 and 3

	Sacrifice ratios	
Period	*Model 2*	*Model 3*
4	1.38	1.88
8	1.68	2.60
12	1.84	3.14
16	1.94	3.48

Source: Authors' estimations.

consistent with the fact that in model 2 the reserve requirements tool is used to achieve the inflationary target, while in model 3 the same instrument is solely directed to achieve financial stability. Therefore, in terms of output, the relative cost of reducing inflation is higher for model 3 than for model 2.

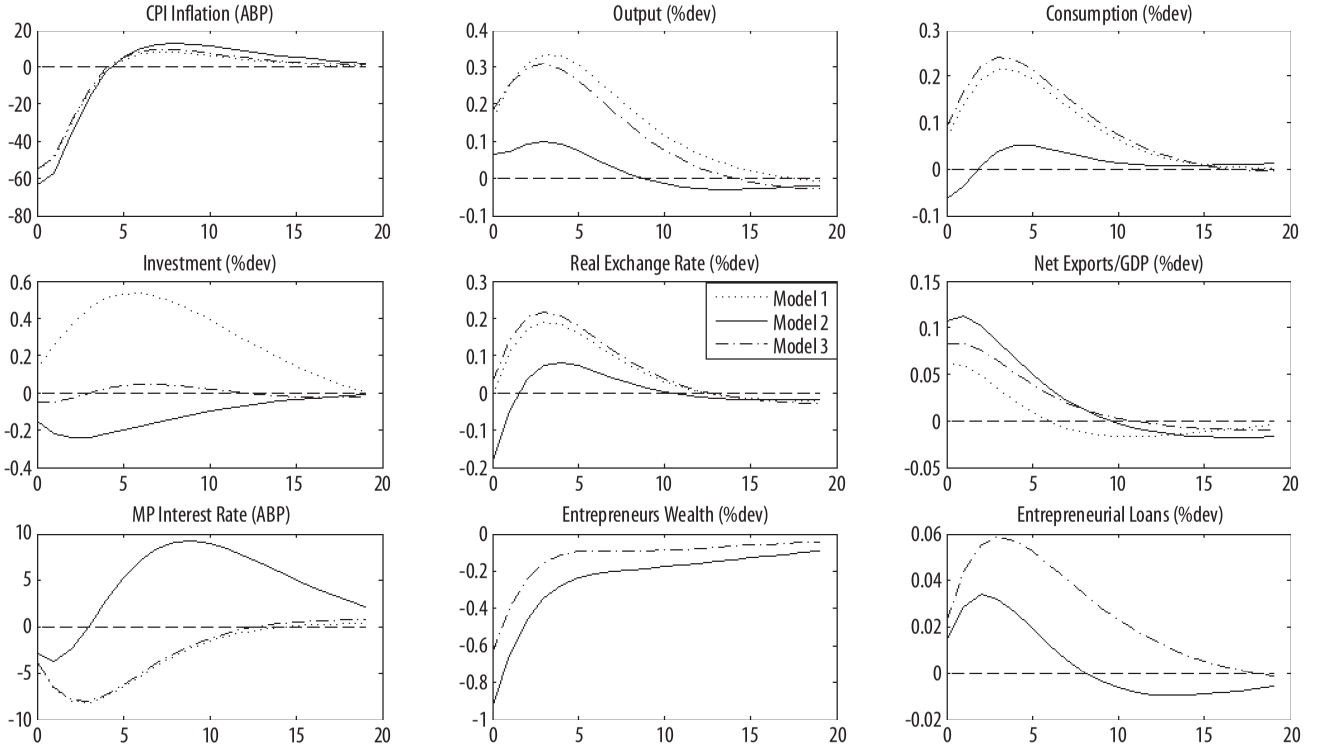
A Transitory Technological Shock

For a positive transitory technology shock in model 2, we see in figure 13 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 on the interest rates (not graphed). In a scenario where real interest rates are more attractive, 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 monetary policy rules. Those coefficients show a larger weight on 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: one channel is the changes in real interest rates; the second is the type of financial friction that governs 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 originated in the presence of nominal

FIGURE 13. Transitory Technology Shock, Impulse Response Functions for Models 1, 2, and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

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.

A Government Consumption Shock

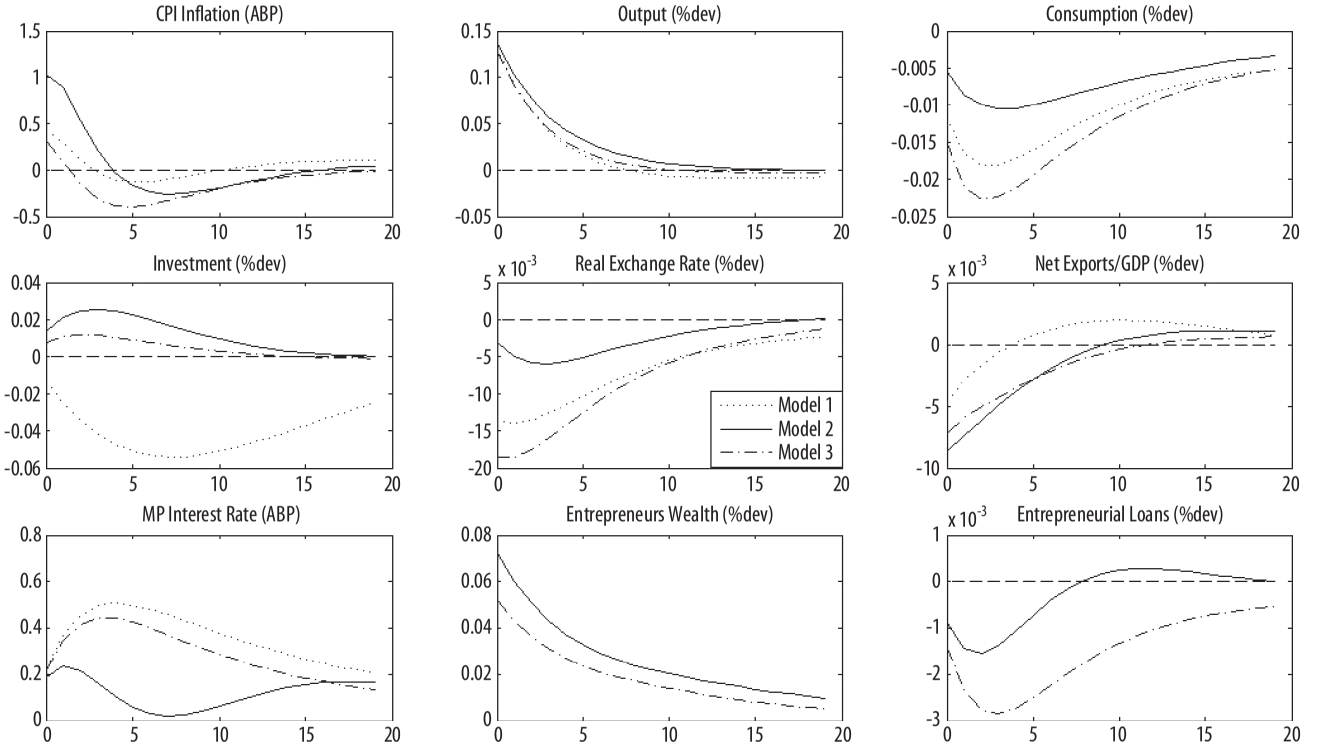
The results of a government consumption shock seem to be standard. A 1.25 percent increase in government expenditure initially expands both output and CPI inflation. Both effects trigger the Taylor rule mechanisms, so the monetary authority increases both the policy rate and the reserve requirements. 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 (see figure 14).

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 become initially 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 the demand of external financial assets and this induces a rise in the price of the foreign currency with respect to the domestic one.

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 to explain 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

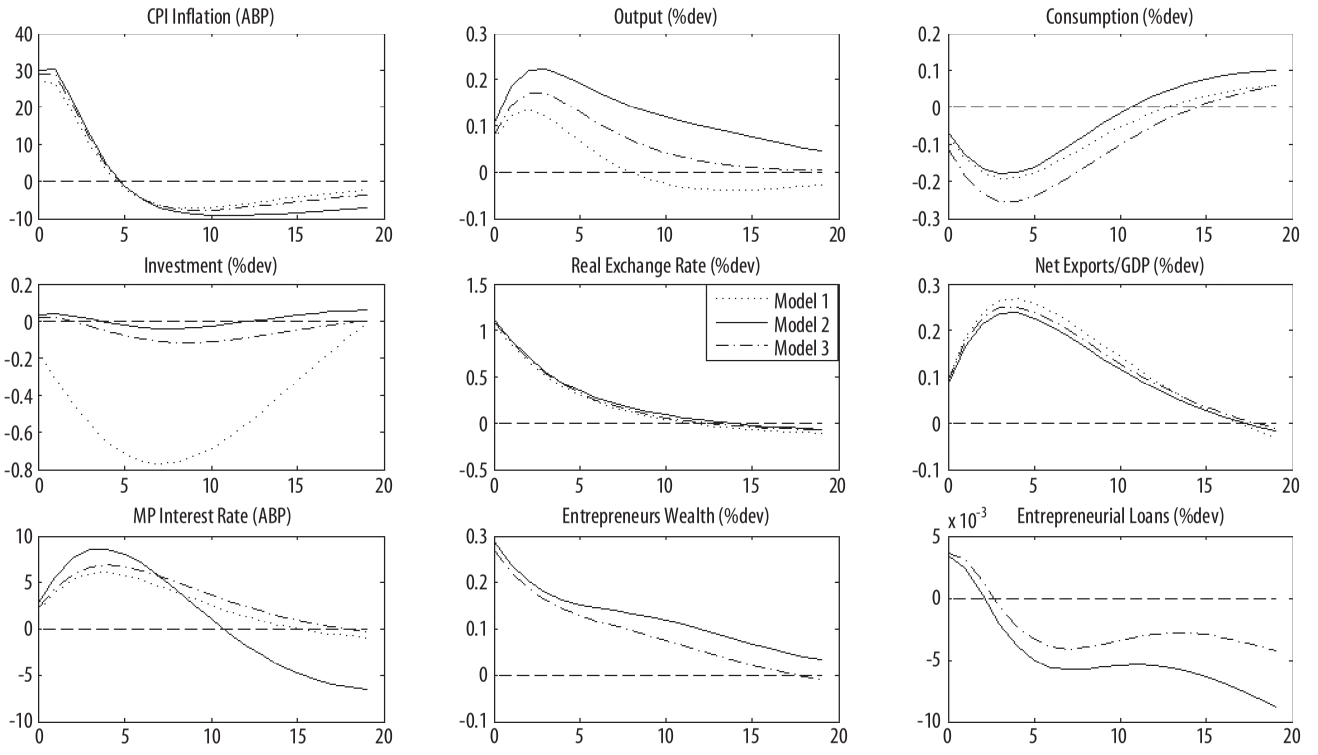
FIGURE 14. Government Consumption Shock, Impulse Response Functions for Models 1, 2, and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

FIGURE 15. Foreign Interest Rate Shock, Impulse Response Functions for Models 1, 2, and 3[a]



Source: Authors' estimations.

a. Units on the y-axis are in terms of either percent deviation from steady state or annualized basis points.

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 requirements in order to offset the effect of the shock on the domestic economy.

Conclusions and Policy Recommendations

Using a dynamic stochastic general equilibrium model for a small open economy, price rigidities à la Calvo, financial frictions in the accumulation and management of capital, a banking sector that includes deposit and lending units, and 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 inflationary and 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, seventy-two in total, using a random walk Metropolis-Hastings chain.

Then we compared the impulse response functions of three models. Model 1, a baseline model without financial frictions and a monetary rule, sets the monetary policy interest rate as a function of its past value, targeted and actual inflation, and output. Reserve requirements are not modeled.

Model 2 is a general model with financial frictions and a monetary rule with two instruments to set the central bank's monetary policy: interest rates and reserve requirements. Both instruments depend on their immediately previous value as well as on four measures of economic activity and inflation: one, the relationship between the current value of the inflation target and its steady state level; two, the relationship between the value of current inflation and the current value of the inflation target; three, the relationship between the current level of GDP and its steady state level; and four, the relationship between the current value of risky entrepreneurial loans and their steady state value.

Model 3 has financial frictions and a monetary policy rule in which tasks are separated in terms of the monetary policy and the central bank's objectives. In this third model we allow reserve requirements to respond only to deviations in the stock of entrepreneurial loans, and the monetary policy interest rate can react only to changes in both output and inflation.

There are six key findings from our research. One, in the general model, an increase of a hundred 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, and 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 reserve requirements rule that reacts to changes in inflation, output, and entrepreneurial loans in the general model.

Second, 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 a 1 percent increase in the interest rate over inflation is five times bigger when reserve requirements assume only the financial stability objective.

Third, 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's 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 increment in private consumption and the increase in investment produces a rise in output. There is an increase in inflation caused by this shock, which can be explained in terms of increasing overall production costs that put upward pressure on the overall price level. There is also a reduction in the deposit interest rate, which triggers a real depreciation of the domestic currency and an increase in the cost of imported inputs.

Fourth, the qualitative reactions of an increment in the reserve requirements rate, in the general model, are practically the same as those observed in the model with role separation. However, they are quantitatively smaller.

Fifth, 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.

Sixth, overall the impulse response exercises suggest that raising the policy interest rate tends to appreciate the currency, while raising the reserve require-

ments does the opposite. So there is scope for combining the two instruments to control demand and domestic inflation and to mitigate large swings in the nominal exchange rate, which can be riskier under liability dollarization.

The evidence suggests four policy recommendations, as follows:

One, having a nonconventional 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 induces a fall in output. Nevertheless, it also produces a real appreciation of the Uruguayan peso, which is perceived by Uruguayan authorities as perverse.

Two, when the central bank uses the interest rate as an instrument, the effect of the reserve requirements is to reduce the negative impact of an eventual increase in the policy rate on consumption, investment, and output. Nevertheless, the quantitative results in terms of inflation reduction are rather poor. This is what seems to have happened in Uruguay between 2007 and 2012.

Three, the monetary policy rate becomes more effective in reducing inflation when the reserve requirements instrument is solely directed at achieving financial stability and the monetary policy rate is used to achieve the inflationary target. This seems to suggest that if the Uruguayan monetary authorities want to keep inflation within the target zone, they should switch to a policy rule wherein the role of both instruments is separated, as in model 3.

Four, our main policy conclusion is that a nonconventional policy instrument, when well targeted, can help control inflation. Reserve requirements can also be instrumental in offsetting the impact of monetary policy on the real exchange rate.

References

Archivos de la Presidencia de la República Oriental del Uruguay. 2002–11 (http://archivo.presidencia.gub.uy/).

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics,* vol. 1, edited by J. B. Taylor and M. Woodford. Elsevier.

Boone, L., and B. Mojon. 1998. "Sacrifice Ratios in Europe: A Comparison." Working Paper 98-07. CEPII.

Carrera, C., and H. Vega. 2012. "Interbank Market and Macroprudential Tools in a DSGE Model." Working Paper 2012-14. Banco Central de Reserva del Perú.

Carvalho, F. A., and C. Azevedo. 2008. "The Incidence of Reserve Requirements in Brazil: Do Bank Stockholders Share the Burden?" Working Paper 160. Banco Central do Brasil.

Céspedes, L. F., R. Chang, and A. Velasco. 2014 (forthcoming). "Is Inflation Targeting Still on Target?" *International Finance.*

Christiano, Lawrence J., Mathias Trabandt, and Karl Walentin. 2011. "Introducing Financial Frictions and Unemployment into a Small Open Economy Model." *Journal of Economic Dynamics and Control* 35 (12): 1999–2041.

Comunicados del Comité de Poltica Macroeconómica del Banco Central de Uruguay. 2007–12 (www.bcu.gub.uy/Politica-Economica-y-Mercados).

Glocker, C., and P. Towbin. 2012. "Reserve Requirements for Price and Financial Stability: When Are They Effective?" *International Journal of Central Banking* 8 (1): 65–113.

Gonzalez-Rozada, Martin, and Martin Sola. 2014. "Towards a 'New' Inflation Targeting Framework: The Case of Uruguay." Working Paper 486. Inter-American Development Bank (http://publications.iadb.org/bitstream/handle/11319/6335/Towards%20a%20%C2%BFNew%C2%BF%20Inflation%20Targeting%20Framework%3a%20The%20Case%20of%20Uruguay.pdf?sequence=1).

International Monetary Fund. 2011. "Uruguay: Selected Issues Paper." Country Report 11/63. International Monetary Fund.

León, D., and Z. Quispe. 2010. "El encaje como instrumento no convencional de Política Monetaria." *Revista Moneda,* no. 143: 8–16.

Mancini Griffoli, Tomasso. 2011. "Dynare User Guide: An Introduction to the Solution and Estimation of DSGE Models." Public beta version, draft (August).

Montoro, C., and R. Moreno. 2011. "The Use of Reserve Requirements as a Policy Instrument in Latin America." *BIS Quarterly Review* (March): 53–65.

Ocampo, J. A., and C. E. Tovar. 2003. "La Experiencia Colombiana con los Encajes a los Flujos de Capital." *Revista de la Cepal* 81: 7–32.

Ribeira, Emundo Maia de Oliveira, and Fernando de Holanda Barbosa. 2005. "A Demanda de Reservas Bancarias no Brasil." *Ensaios Economicos* 581. Fundação Getulio Vargas.

Taylor, John B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39 (1): 195–214.

Tovar, C. E., M. Garcia-Escribano, and M. Vera-Martin. 2012. "Credit Growth and the Effectiveness of Reserve Requirements and Other Macroprudential Instruments in Latin America." Working Paper 12/142. International Monetary Fund, June.

Vargas, H., and P. Cardozo, 2012. "The Use of Reserve Requirements in an Optimal Monetary Policy Framework." Working paper. Banco de la República de Colombia, June.

Vargas, H., C. Varela, Y. Betancourt, and N. Rodriguez. 2010. "Effects of Reserve Requirements in an Inflation Targeting Regime: The Case of Colombia." Working Paper 587. Banco de la República de Colombia.