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Financial Stability and Macroprudential Policy: a Structural Model Evaluation of an Emerging Economy*

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Abstract

We build a small structural open economy model, augmented to depict the credit market and interest rate spreads (distinguishing by credit to firms and families); monetary policy with sterilized intervention in the foreign exchange market; and macroprudential policy as capital requirements. We estimate the model using Bayesian techniques with quarterly data for Argentina in 2003-2011; it can be extended to other emerging economies, allowing for comparative empirical analysis. Results indicate that shocks to lending rates and spread weigh on macroeconomic variables; likewise, the credit market is affected by macroeconomic shocks. Capital requirements, beyond their strictly prudential role, appear to have contributed to lower volatility of key variables such as output, prices, credit and interest rates. The interaction of monetary policy, foreign exchange intervention and prudential tools appears to be synergic: counting on a larger set of tools helps dampen volatility of both macroeconomic and financial system variables, taking into account the type of shocks faced during the estimation period.

JEL classification codes: E17, E51, E52, E58

Keywords: Macroprudential Policy, Semi-structural Model, Bayesian Estimation.

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1 Introduction

While financial stability has become increasingly important for monetary policy, standard models fail to reflect the integration of both dimensions. So called "financial frictions" are gradually being incorporated in Dynamic Stochastic General Equilibrium (DSGE) models, but the lack remains of a workable model of mid- to small scale that includes a representation of financial intermediation. Moreover, a wider set of tools, such as what has come to be known as "macroprudential" ones, is increasingly being used by central banks–while standard monetary models tend to focus on a single instrument, the short term nominal interest rate. We aim to incorporate financial stability aspects and macroprudential tools into a small open economy model of the Argentine economy, completely estimated and suitable for short-term forecasting and simulation exercises.

The financial side of the macroeconomy is built into central bank models in diverse ways, without a single unified and widespread framework. "Macro-modelling" options basically comprise financial accelerator effects, collateral constraints, and the explicit representation of banking intermediaries (see Roger and Vlcek, 2011, for a survey of central bank literature). Most current models have generally been developed in North America and Europe; in Latin America, modeling efforts have only recently been made for the depiction of financial issues in the macroeconomy. Perhaps the first fully fledged DSGE model with the explicit interaction of banks and monetary policy, designed and calibrated for a Latin American country before the international crisis brought these aspects to the foreground was that of Escudé (2008). He integrates both financial and real features of the Argentine economy, including intermediation through banks, that lend to families and whose deposits are subject to liquidity requirements. More recent modelling efforts, in line with the literature flourishing after the international financial crisis include Carvalho et al. (2013), Garcia-Cicco and Kawamura (2014), González et al. (2013), among others.

The very same lack of an agreed framework to deal with financial stability in macroeconomic models also justifies the use of small structural ones, specially for applied work in central banks and as a first approximation to the problem. As pointed out by Galati and Moessner (2011), models that link the financial sector to the macroeconomy are far from having reached a stage where they can be operationalized for analysis and simulation—but such tasks do call for workable solutions even before a new "consensus model" is reached. For instance, Sámano Peñaloza (2012) enlarges a small macroeconomic model for Mexico with a financial block in order to determine the interplay of macroprudential and monetary policy; the former is introduced through capital requirements. Szilagy et al. (2013) also add financial variables to a standard small model in order to enrich the depiction of the Hungarian macroeconomy. Both of these models, while not explicitly derived from first order conditions of an optimization problem, show the basic New Keynesian structure.

We present an extension of Aguirre and Blanco (2013), who in turn build on previous works done for Argentina (Elosegui et al, 2007; Aguirre and Grosman, 2010), while dealing with the financial dimension largely after Sámano Peñaloza (2012). We augment an open economy version of a semi structural New Keynesian model, to include explicit depiction of the credit market, active rates and interest rate spread; and an enriched description of monetary policy, with sterilized intervention in the foreign exchange market. We estimate it using Bayesian techniques, allowing us to incorporate our prior knowledge of the workings of this economy during the estimation period (2003-2011). We also enhance the baseline model, introducing capital requirements under different possible definitions, corresponding to alternative macroprudential rules, cyclical and not, based on quantities and on prices. We aim to assess whether the interaction between monetary, foreign exchange and macroprudential policy helps dampen macroeconomic fluctuations in any meaningful way during the estimation period.

Our modelling choices are closely related to our practical goals: if we had a theoretical interest, we would pursue another modelling strategy. In the first place, we take an empirical approach, in that a condition for model building is that parameters should all be estimated. This contrasts with actual design and implementation of large scale DSGE models which, for all the detail they provide, often rely to a substantial degree on calibration, and are naturally less appropriate for estimation. Likewise, such models tend to be less workable in terms of forecasting: typically, smaller models forecast better than larger ones, with different models being used for different purposes (Canova, 2009; see Aguirre and Blanco, 2013, for forecasting with our model). There is a place for representations of different sizes in a well-conceived modeling architecture, and enlarging semi-structural models already in use may be more useful than starting DSGE models from scratch (Roger and Vlcek, 2011). This is certainly relevant for central banks, where a pragmatic approach may be favoured for the sake of incorporating financial stability in formal models.

Thus, we have both descriptive and policy-oriented goals. As for the former, we wish to improve the depiction of an economy where real aspects may not be dissociated from financial ones, i.e. where the financial sector may play a role in either originating or transmitting shocks (Borio, 2012). In this sense, our model involves an improvement from conventional comparable ones in two ways: a richer description of monetary policy, with the central bank using both interest rates and sterilized foreign exchange intervention, the monetary repercussions of which are explicitly acknowledged; and credit market dynamics, capturing the interplay of credit and interest rate spreads with the rest of the economy.

This framework can also be taken as a first approximation to enquire whether macroprudential policy may lead to better performance of certain key variables. In particular, we include a macroprudential instrument (capital requirements) in addition to interest rates and foreign exchange intervention, so as to determine how it interacts with the other policy tools and whether it may help smooth short run macroeconomic and financial market fluctuations. It is in regard to the latter that our model contemplates financial stability considerations: reducing volatility of both macroeconomic and financial variables is incorporated in policy rules as well as in the criterion to evaluate their outcomes (see also section 2). As many emerging market economies implement monetary, foreign exchange and macroprudential policy, the model also provides a convenient framework for comparative empirical analysis.

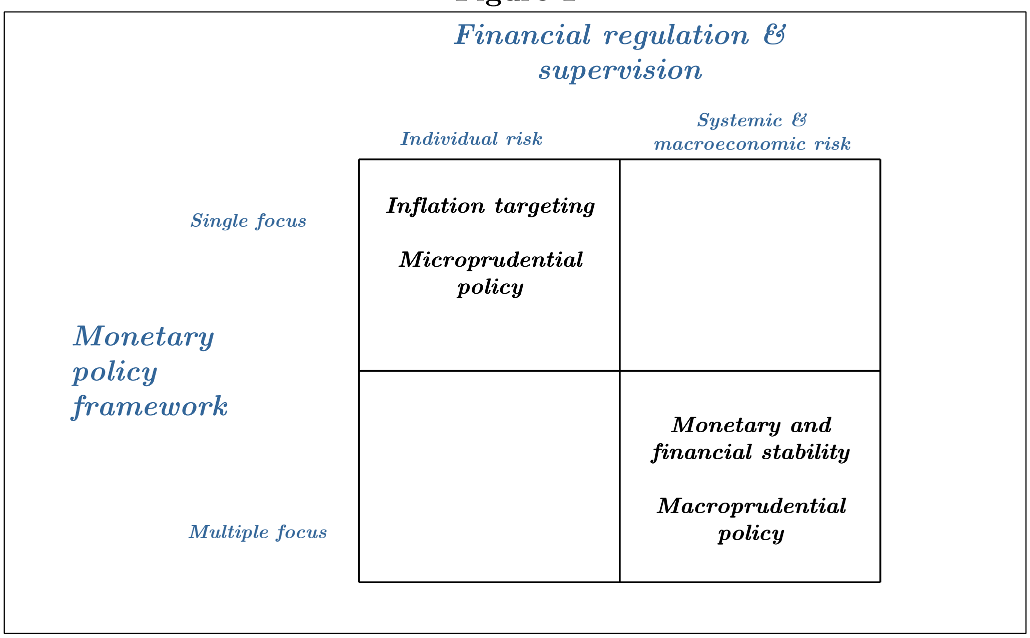
There are, as is well known, limitations to what structural models can provide in terms of policy and simulation exercises. However, we consider our proposal to be a reasonable trade-off between tractability and ability to take the model to the data. This is all the more important when we build and estimate a model that allows us to consider not only monetary policy and macroprudential instruments, but also foreign exchange policy. Within the class of emerging economies' central bank policy models, ours is one of the few to consider those three dimensions taken together. Indeed, emerging economies frequently use the exchange rate as a tool, but this is seldom reflected in policy models. Finally, to the best of our knowledge, this paper and Aguirre and Blanco (2013) are the first empirical assessments of the macroeconomic impact of prudential regulations in Argentina, carried out in a completely estimated macroeconomic model.

The rest of the paper is organized as follows. Section 2 introduces macroprudential policy and its features as applied in emerging market economies; and discusses alternative models and how they relate to ours. Section 3 describes the baseline model; section 4 presents estimation and impulse-response functions that illustrate the basic workings of the estimated model. Section 5 extends the model to include macroprudential policy in the form of capital requirements, considering alternative formulations of the latter, with emphasis on macroeconomic and financial performance associated to them. Section 6 concludes.

2 Macroprudential policy: a primer

Following the international financial crisis, there has been a change of perspective in monetary policy frameworks, with the conventional focus being gradually redefined. Financial cycles are becoming accepted as part of the functioning of market economies (Borio, 2012), whose consequences on stability have to be dealt with by central banks. Charging the central bank with responsibility for financial stability is not sufficient—appropriate tools, authorities and safeguards are also needed (CGFS, 2011). Consequently, a double mandate is surging, with monetary and financial stability as acceptable central bank targets. Roughly speaking, the introduction of a financial stability mandate for central banks involves a move from a single focus for monetary policy and a concern for the individual performance of financial institutions, to multiple targets together with the oversight of financial institutions based on their potential systemic impact, and even on the economy at large. This shift is schematically represented in Figure 1, where two dimensions are sketched: the monetary policy framework, with either a single or a multiple focus; and financial supervision and regulation, aimed at the individual risks of institutions or at their systemic impact. Such shift has brought on the need to incorporate in formal models a wider set of tools used by central banks, such as macroprudential measures.

Figure 1



Macroprudential policy is far from being a well-defined concept, but a generic term for measures whose goal extends beyond safeguarding the solvency or liquidity of financial institutions, to cover their link with macroeconomic performance—recognizing possible spillovers from the financial system to the economy at large, and vice versa. Many different measures can be considered as macroprudential, ranging from capital and liquidity requirements as a function of certain "cyclical" variables, to loan-to-value ratios, dynamic provisions and other tools that may incorporate to a certain extent the state of the financial system or the economy as an input to determine whether to soften or tighten regulations on banks. However broad in scope, measures taken under a macroprudential approach share a number of features: they are aimed at limiting systemic risk and spillovers from the financial system to the macroeconomy (and vice versa); they take into account externalities of individual financial firms, such as interconnection, procyclicality, and common exposures; as a consequence, the financial system is considered as a whole, and systemic risk is treated as endogenous.

A common theme running through macroprudential analysis is that prevention is key: central banks and supervisors should act before the turn of the cycle, as critical pressures build up but before a crisis breaks out. In particular, countercyclical macroprudential policy aims at: i) strengthening the financial system so that it is better prepared to face the downturn of the (financial and business) cycle; ii) smoothing the cycle, preventing imbalances from accumulating during the “boom” phase.

Emerging market economies have used macroprudential instruments more extensively, and earlier, than industrial economies (Lim et al., 2011), out of a long experience with crises. Indeed, one can trace elements of a macroprudential approach since at least the 1990s, used to address systemic risk following several episodes, such as the "Tequila" crisis in 1995, the Southeast Asia crisis in 1997, Russia in 1998, Brazil in 1999, Ecuador in 2000, Argentina in 2001. For these countries, such elements are part of a broader “macro-financial” stability framework that also comprises management of the exchange rate and the capital account, and which are part of the move from the Northeast to the Southwest quadrant of Figure 1. Moreover, the international financial crisis has increased the number of advanced countries that put in place macroprudential policies within a more formal framework; the European Systemic Risk board is a case in point. Thus, what we examine here may bear parallels with developing economies at large, and even be useful for industrial economies that are implementing broader sets of measures aimed at containing system-wide risk in financial markets.

Likewise, the role of the exchange rate for monetary and financial stability is substantial in emerging market economies, well beyond what is articulated in conventional frameworks. Actually, measures like systematic foreign exchange intervention or liquidity supply through multiple instruments have long been part of the policy "toolbox" in developing countries, even in those which implement inflation targeting regimes. Based on the experience of Brazil, Chile, Colombia and Perú, Chang (2008) shows that inflation targeting in Latin America differ systematically from the "Taylor rule cum pure floating" formula supposedly associated to the scheme. Far from being a deviation from "best practice" in monetary policy by the countries in the region, it obeys to the need to shield their economies from abrupt changes in international financial conditions through measures such as international reserve accumulation. This type of policies has been called "unconventional", but the label applies largely to industrial economies, whereas in the developing world such measures are not necessarily associated to exceptional responses in the face of the international financial crisis (Kawamura and García-Cicco, 2014, present a formal analysis of such responses). This is why we find it important to analyze the interplay of both macroprudential policy, monetary policy and foreign exchange intervention.

In Argentina, several crisis episodes have evidenced the close connection between financial system soundness and macroeconomic performance. The most traumatic one was perhaps the demise of the currency board, in place from 1991 to 2001. The main features of such experience exceed the scope of this paper; we note here that the so called "convertibility" regime showed bluntly how the implementation of microprudential policy, even by state-of-the-art standards, may not be enough to safeguard the financial system from both adverse shocks and the presence of "hidden" mismatches in a financially dollarized economy. In keeping with the maintenance of a peg to the US dollar, the private sector became progressively indebted in foreign currency, even if, on aggregate, its revenues were denominated in pesos. The government also became progressively indebted in foreign currency. Notably, both private and public agents displayed behaviour that seemed to consider that favourable external conditions, as seen in the first half of the 1990s, would last indefinitely. Successive emerging economies’ crises hit the country’s ability to access foreign financing, and deteriorated its competitiveness, ultimately leading to recession and a multiple crisis, on the fiscal, foreign exchange and banking fronts.

Since 2003, a major feature of the Argentine macroprudential policy toolkit have been direct and indirect measures limiting foreign currency exposure of financial institutions. In so far as foreign exchange intervention limits the variability of a certain class of assets that weigh on financial system dynamics, it can also be considered as part of the macroprudential "toolkit" in a broader sense. A similar reasoning applies to capital flows regulation. Macroprudential policy also includes building up a capital buffer through profit reinvestment mechanism; loan-to-value ratios for certain types of credit; valuation of public sector securities in financial institutions' balance sheets; liquidity requirements and deposit insurance. We find it particularly important to analyze how foreign exchange intervention interacts with monetary policy and more standard macroprudential tools such as capital requirements. In this paper, we look at capital requirements implemented in different ways: as a function of the credit-to-GDP gap, the output gap or interest rate spreads, or set exogenously from the point of view of the macroeconomy; this allows to gauge the potential efficacy of policy implemented with or without concern for cyclical variables, as well as based alternatively on price or quantity indicators.

Models that integrate the most widely used monetary policy analysis framework—the New Keynesian one—with macroprudential tools have only recently been developed, and a unified approach is lacking. Angeloni and Faia (2013) look at instruments and policy rules of a central bank that aims not only at price stability but also at financial stability in a Diamond-Dybvig setting: they examine how interest rate and capital ratio rules interplay. Covas and Fujita (2009) analyze how a productivity shock is transmitted when financial intermediaries are subject to alternative capital requirements. Angelini et al. (2010), Denis et al. (2010) are recent examples that inquire about the interaction between monetary policy and macroprudential tools, and find that introducing a new policy rule in coordination with monetary policy helps to reduce the variance of output and inflation. Indeed, a frequent concern is to what extent both types of policy may be considered complements or substitutes.

Cecchetti and Kohler (2014) propose an enlarged aggregate demand-aggregate supply system with both interest rates and capital requirements; they use a game-theoretic approach to investigate the optimal degree of coordination between both policy tools, in a static, theoretical framework. They show that both type of instruments are full substitutes, in the sense that if the ability to use one is limited, the other can “finish” the job. When a financial stability objective is contemplated, that characteristic depends on the coordination between them—under full coordination, substitutability remains. In turn, and in the context of a comprehensive discussion of financial stability and monetary policy, Agenor and Pereira da Silva (2013) analyze whether monetary and macroprudential policy are complementary in an small macroeconomic model: they find them to be so, and have to be calibrated jointly, accounting for the type of credit market imperfections observed in middle income countries and for the fact that macroprudential regimes may affect in substantial ways the monetary transmission mechanism. Végh (2014) argues that both foreign exchange intervention and reserve requirements act in the sense of allowing interest rate policy to achieve other goals: thus, for emerging market countries facing a sudden stop, exchange rate intervention may be used to “defend” the local currency, so that interest rates do not necessarily have to be raised with that aim, while reserve requirements are changed in order to influence credit market conditions—this gives monetary policy higher degrees of freedom to act countercyclically. Once again, none of these models are based on the same structure; and in the case of Cecchetti and Kohler (2014) and Agenor and Pereira da Silva (2013) nor are they derived from the explicit solution of microeconomic problems of households and firms[1].

Finally, a word is also in order regarding the isomorphism between financial stability issues, at which macroprudential measures aim, and DSGE models (or models like ours, which are based on them). Financial stability ultimately reflects the sustainability of financial intermediaries' operations and its interaction with the macroeconomy. For example, the subprime crisis put in the foreground the relationship between asset prices, credit growth and macroeconomic performance, and whether it may lead to unstable behavior of the variables involved. Such dynamics, however, are extremely difficult to represent in models based on linear approximations around steady states, and which are solved to yield stable solutions. Thus, "financial frictions" turn out to be a device that allows for explicit representation of credit market variables in DSGE models, but that does little by the way of modelling the potential transition from the normal functioning of the system to a financial crisis. Such transition calls for non-linear techniques applied to "macrofinancial" models, something that recent works are developing (Bianchi and Mendoza, 2013). Therefore, there certainly is a gap between financial stability analysis and what can be described by models that depict "well behaved" cyclical deviations around a steady state. With this caveat in mind, the following sections present a model inspired by the New Keynesian tradition that incorporates macroprudential policy.

3 The baseline model

Following work by Elosegui et al. (2007) and Aguirre and Grosman (2010), our baseline model is a small structural open economy model with a Taylor-type rule and foreign exchange market intervention, with the monetary effects that these imply. It already incorporates a money market equation, providing a natural starting point for the introduction of a simplified financial block, where we describe credit market conditions in the manner of Sámano Peñaloza (2012).

The standard macroeconomic block of the model comprises an IS-type equation (1), a Phillips curve (5) and a Taylor-type rule (6)—the first two of which can be obtained as log-linear approximations of first order conditions of consumers' and firms' optimization problems in a monopolistic competition setting where price adjustments are sluggish. The IS equation contains output growth, and not the output gap, as endogenous variable, due exclusively to empirical considerations; and it is augmented to reflect the impact of open economy variables, namely the real exchange rate, on consumption decisions and hence on output; it also includes a lagged growth term, that can be related to the assumption that preferences over consumption exhibit habit formation (Fuhrer, 2000). The IS (1) also contains the spread between the active rate of interest (charged for taking credit) and the short term interest rate; as in Sámano Peñaloza (2012) and Szylagy et al (2013), this term aims at capturing the impact of credit market conditions on aggregate demand, as it represents the extra cost above the short term interest rate that the non financial private sector has to pay to banks in order to obtain resources[2]; alternatively, the sum of the short term rate and the spread may be interpreted as the active rate that the private sector pays to obtain funds. The average spread is made up of those corresponding to firms and households' credit. An additional term in the IS corresponds to the effect of fiscal impulse on aggregate demand,which is just a convenient way of depicting fiscal shocks, but which serves no direct purpose to the exercises in this paper. We leave for further work more disaggregation of demand in the model (consumption, investment, exports and imports), which could help have

[1] Recent contributions to the study of macroprudential policy in macroeconomic models in the Latin American case include Carvalho et al (2013) and González et al. (2013)

[2] An alternative specification is to include credit directly in the IS curve; this is work in progress and will be incorporated in further versions.

a better characterization of credit to different agents and consider shocks to foreign demand in the analysis.

In turn, the Phillips curve (5) evidences the effect of foreign prices in the domestic economy, through an "imported inflation" component via the real exchange rate; the inclusion of the latter in both the IS and Phillips curves is derived analytically by Galí and Monacelli (2005). Lagged inflation in the Phillips curve has been found empirically significant by many studies and can be thought of as a consequence of the ability of firms to adjust prices according to lagged inflation (Galí and Gertler, 1999). Lagged output gap in the Phillips curve is basically due to empirical fit, something that turns up in estimates of other economies (Galí et al., 2001), and may be justified in relation to GDP data being released with lags (Pincheira and Rubio, 2010). The Taylor rule (6) also includes a coefficient on nominal exchange rate depreciation, so that the central bank's behavior not only depends on the output gap and inflation. Two terms account for the central bank's involvement with financial stability: the short term rate also depends on its own lagged values, showing a desire to smooth interest rate movements; and on the "credit gap", i.e. the difference between current credit to the private sector and its steady state value (more on this below).

Macroeconomic Block

$$g_t^y = \beta_1 \mathbb{E}_t g_{t+1}^y + \beta_2 g_{t-1}^y - \beta_3 \widehat{r}_t + \beta_4 \Delta \widehat{e}_t^{tri} - \beta_5 \widehat{sf}_t - \beta_6 \left(spread_{t-1} \right) + \varepsilon_t^y \quad (1)$$

g_t^y : output growth rate, r : real interest rate, e^{tri} : trilateral real exchange rate (RER), sf : fiscal surplus to GDP ratio, and interest rate spread is defined as[3]

$$\begin{aligned} spread_t &= \xi^H * spread_t^H + \xi^F * spread_t^F && (2) \\ & where && \\ spread_t^H &= \widehat{i}_t^{H,act} - \widehat{i}_t && (3) \\ spread_t^F &= \widehat{i}_t^{F,act} - \widehat{i}_t && (4) \end{aligned}$$

$spread_t^H$: spread - household credit, $spread_t^F$: spread - firms credit, $i_t^{H,act}$: nominal active rate - households, $i_t^{F,act}$: nominal active rate - firms,i_t: nominal (passive) interest rate

$$\begin{aligned} \widehat{\pi}_t &= \alpha_1 \mathbb{E} \widehat{\pi}_{t+1} + \alpha_2 \widehat{\pi}_{t-1} + a_3 y_{t-1} + a_4 \Delta \widehat{e}_t^{tri} + \varepsilon_t^{\pi} && (5) \\ & where && \\ \alpha_2 &= 1 - \alpha_1 && \end{aligned}$$

π_t : inflation, $\mathbb{E}\widehat{\pi}_{t+1}$: expected inflation, y_t: output gap

$$\widehat{i}_t = \gamma_1 \widehat{i}_{t-1} + \gamma_2 y_t + \gamma_3 \mathbb{E}_t \widehat{\pi}_{t+1}^a + \gamma_4 \widehat{\delta}_t + \gamma_5 \widehat{CR}_t + \varepsilon_t^i \quad (6)$$

π^a : annual inflation, δ : \$/USD depreciation rate, CR : Non financial private sector credit to GDP ratio defined as

$$\widehat{CR}_t = \widehat{CR}_t^H + \widehat{CR}_t^F \quad (7)$$

CR^H : Household's credit to GDP ratio, CR^F : Firm's credit to GDP ratio

[3] Where ξ^H and ξ^F are calibrated $\frac{1}{2}$.

Foreign exchange conditions and policy, as well as the money market, are described in equations (8)-(12). A modified uncovered interest rate parity (UIP) condition (8) considers the effects of central bank operations in the foreign exchange market: the nominal exchange rate depends on expected depreciation, the difference between the local and the international interest rate, and a country risk premium that is made up of an endogenous component and an exogenous shock. The former is determined by interventions in the currency market: the central bank intervenes by buying or selling international reserves, and issuing or withdrawing bonds from circulation in order to sterilize the effects of intervention on the money supply. Monetary effects naturally require an LM curve: equation (12) describes equilibrium in the money market, which may be estimated for narrower or broader definition of monetary aggregates. How exchange rate intervention is instrumented is described by equation (11), whereby the central bank buys or sells international reserves in reaction to nominal exchange rate variability; equation (9) shows to what extent such intervention is sterilized.

FX Policy Block

$$\widehat{i}_t = \widehat{i}^*_t + \omega_1 \mathbb{E}_t \widehat{\delta}_{t+1} + (1-\omega_1)\widehat{\delta}_t + \omega_2 \widehat{b}_t + \omega_3 \widehat{res}_t + \widehat{\lambda}_t \tag{8}$$

i^* : international interest rate, b : CB bonds to GDP ratio, λ : exogenous risk-premium, res : international reserves to GDP ratio

$$\widehat{b}_t = \frac{1}{1-\phi}\left(\widehat{res}_t + \widehat{e}^d_t\right) - \frac{\phi}{1-\phi}\widehat{m}_t \tag{9}$$

$$\phi = \frac{m}{m+b} \tag{10}$$

m: money to GDP ratio[4]

$$\widehat{res}_t = \kappa_1 \widehat{res}_{t-1} - \kappa_2 \widehat{\delta}_t + \varepsilon^{res}_t \tag{11}$$

$$\widehat{m}_t = -\eta_1 \widehat{i}_t + \eta_2 \widehat{\pi}_t + \eta_3 \widehat{b}_t + \eta_4 \widehat{\delta}_t + \varepsilon^m_t \tag{12}$$

This specification merits some further explanation. Introducing a policy of sterilized intervention can be thought of as "augmenting" or modifying the uncovered interest rate parity (8); actually, what we have is a new equation for the determination of the nominal exchange rate—after all, the purpose of sterilized intervention is precisely to "block" in a way the conditions imposed by UIP in its normal form. This modified UIP can be rationalized as follows: domestic agents may invest in both local and foreign currency-denominated bonds, which are not perfect substitutes; returns of bonds in pesos have to compensate for expected depreciation; in turn, bonds in foreign currency pay the international rate but reflect a liquidity risk. It may further be assumed that not all actors that participate in the foreign currency market optimize on the base of fundamentals; some of them decide on the past performance of the currency (and are called "chartists"); this is behind the expected depreciation term in (8), which corresponds to agents that act on fundamentals, and the current depreciation term, which corresponds to "chartists".

[4] The parameter ϕ is calibrated equal to 0.5833

In turn, the endogenous component of risk premium in (8) is determined by interventions in the currency market: the central bank buys or sells international reserves, and issues or withdraws bonds from circulation in order to sterilize the effects of intervention on the money supply. The consequent change in the endogenous risk premium may be rationalized as reflecting both counterparty ($\widehat{b}_t$) and exchange rate risk ($\widehat{\Delta res_t}$): to hold a higher stock of bonds, local investors demand a higher rate (this would not be the same as holding bonds issued abroad, reflecting a different counterparty); changes in international reserves are associated to changes in exchange rate risk, as when it intervenes, the central bank modifies the foreign currency volatility[5]. Other rationalizations could read as follows: regarding the presence of $\widehat{b}_t$, if central bank bond issuance is interpreted as postponed liquidity supply, higher bonds today may mean higher liquidity tomorrow and, therefore, a higher interest rate rate today; international portfolio adjustment could be considered costly, depending on the relative holdings of bonds in pesos and in foreign currency, and so central bank intervention using reserves actually changes the endogenous risk premium and, with it, the exchange rate (Sierra, 2008).

Central bank interventions are ruled by a "propensity" to avoid exchange rate movements to a certain extent as measured by the κ_2 coefficient in (11), in keeping with the aim of a managed floating regime of smoothing short term "excessive" fluctuations of the nominal exchange rate. Thus, any external financial shocks are smoothed by the central bank in line with its aim of minimizing short run disruption in the foreign exchange market. A desire to act gradually is reflected by the autoregressive κ_1 coefficient, which can be rationalized on the grounds of financial stability.

Having characterized the basic macroeconomic dynamics, together with central bank policy in the money and foreign exchange markets, the following step is to consider lending rates and credit. In the model, credit—strictly, the credit-to-GDP gap—is basically a function of output growth and the lending interest rate, as shown in both credit market equilibrium equations, one referred to household (consumption) credit and the other to corporate (commercial) credit (13). In turn, equation (15) describes active (lending) rates as a function of the output gap, non performing loans and the short term rate; the spread emerges naturally as the difference between the lending and money market rate. This specification is consistent with empirical results for the Argentine economy that spread depends negatively on growth and positively on non-performing loans (Aguirre et al, 2014). As before, lending rates are considered for both commercial and consumption loans. Non performing loans are a function of economic activity, in line with their observed cyclical behavior. Credit as previously defined also feeds back into the "macroeconomic block" of the model through its inclusion in the interest rate rule (6); this, of course, is not the only way in which the quantity of credit may directly affect the macroeconomy (it could, for instance, directly impact on output in (1)), but in this specification we consider only one channel that, albeit indirect, is related to financial stability considerations on the part of the central bank—a feature which, in our view, is relevant for the estimation period. As noted, lending rates as defined in (15) do affect economic activity through the inclusion of the interest rate spread in (1). Finally, exogenous variables follow autoregressive processes: the international interest rate, the exogenous component of risk premium in (8), foreign inflation, two measures of the bilateral exchange rate, the fiscal balance and potential output. Unless otherwise indicated, all variables are expressed as deviations from steady state values, denoted by a circumflex.

[5] Including exports and imports in the model, as pointed out earlier, could also help better characterize the evolution of international reserves.

Financial Block

$$\widehat{CR}^H_t = A^H_1 \widehat{g}^y_{t-1} - A^H_2 \widehat{i}^{H,act}_{t-1} + A^H_3 \widehat{CR}^H_{t-1} + \varepsilon^{HCR}_t \quad (13)$$

$$\widehat{CR}^F_t = A^F_1 \widehat{g}^y_{t-1} - A_2 \widehat{i}^{F,act}_{t-1} + A_3 \widehat{CR}^F_{t-1} + \varepsilon^{FCR}_t \quad (14)$$

$$\widehat{i}^{H,act}_t = B_1 \widehat{Delinq}^H_t - B_2 \widehat{g}^y_{t-1} + B_3 \widehat{i}_t + \varepsilon^{Hact}_t \quad (15)$$

$$\widehat{i}^{F,act}_t = B_1 \widehat{Delinq}^F_t - B_2 \widehat{g}^y_{t-1} + B_3 \widehat{i}_t + \varepsilon^{Fact}_t \quad (16)$$

$Delinq^H$: ratio of non performing loans to household credit, $Delinq^F$: ratio of non performing loans to firms credit

$$\widehat{Delinq}^H_t = \rho^{DH}_1 \widehat{Delinq}^H_{t-1} + \rho^{DH}_2 \widehat{g}^y_{t-1} + \varepsilon^{HDelinq}_t \quad (17)$$

$$\widehat{Delinq}^F_t = \rho^{DF}_1 \widehat{Delinq}^F_{t-1} + \rho^{DF}_2 \widehat{g}^y_{t-1} + \varepsilon^{FDelinq}_t \quad (18)$$

Identities

$$\widehat{e^{tri}_t} \equiv \widehat{e^d}_t + c_1 \widehat{e^{US,R}}_t + c_2 \widehat{e^{US,E}}_t \quad (19)$$

$$\widehat{r}_t \equiv \widehat{i}_t - E_t \widehat{\pi}_{t+1} \quad (20)$$

$$\widehat{\Delta e^d}_t \equiv \widehat{\delta}_t + \widehat{\pi^*}_t - \widehat{\pi}_t \quad (21)$$

$$\widehat{g}^y_t \equiv \Delta y_t + \widehat{g^{\overline{y}}}_t \quad (22)$$

$$\widehat{\mu}_t \equiv \Delta \widehat{m}_t + \widehat{\pi}_t + \widehat{g}^y_t \quad (23)$$

$e^{US,R}$: USD/REAL RER, $e^{US,E}$: USD/EURO RER, π^*: international inflation, $g^{\overline{y}}$: potential output growth rate, g^y : GDP growth rate, μ : money growth rate

Exogenous variables[6]

$$\widehat{i^*}_t = \rho_1 \widehat{i^*}_{t-1} + \varepsilon^{i^*}_t \quad (24)$$

$$\widehat{\lambda}_t = \rho_2 \widehat{\lambda}_{t-1} + \varepsilon^{\lambda}_t \quad (25)$$

$$\widehat{\pi^*}_t = \rho_3 \widehat{\pi^*}_{t-1} + \varepsilon^{\pi^*}_t \quad (26)$$

$$\widehat{e^{US,R}}_t = \rho_4 \widehat{e^{US,R}}_{t-1} + \varepsilon^{e^{US,R}}_t \quad (27)$$

$$\widehat{e^{US,E}}_t = \rho_5 \widehat{e^{US,E}}_{t-1} + \varepsilon^{e^{US,E}}_t \quad (28)$$

$$\widehat{sf}_t = \rho_6 \widehat{sf}_{t-1} + \varepsilon^{sf}_t \quad (29)$$

$$\widehat{g^{\overline{y}}}_t = \rho_7 \widehat{g^{\overline{y}}}_{t-1} + \varepsilon^{g^{\overline{y}}}_t \quad (30)$$

[6] Parameter ρ_7 is calibrated

4 Estimation

We estimate this baseline version of the model (equations 1-30) completely through Bayesian techniques[7], based on quarterly data and for the 2003Q3-2011Q3 period; this is the longest period spanning an homogeneous macroeconomic policy regime—the currency board regime adopted in 1991 was abandoned during the 2001-2002 crisis, after which a managed floating regime was adopted. The estimation period also includes the breakout of the international financial crisis and the response to it, such as the successive rounds of quantitative easing in the United States: this is relevant for any policy assessment in emerging markets, since the latter felt the impact of changing international financial conditions. In the case of Argentina, repercussions were felt since mid-2007, and managed floating exchange rate policy proved important in stabilizing the local money market following the external shock; also, several measures were put in place to provide liquidity in local currency to financial institutions. As noted, both foreign exchange operations and their effect on the money market are represented in our model. Also, shock λ_t in equation (8) can be thought of as representing the kind of exogenous increase in risk premium associated to the events from 2007 onwards.

Bayesian techniques prove particularly useful for the kind of situation described in the above paragraph: if one knows that structural change has taken place, this information can be included in a way not allowed by classical estimation methods. Bayesian statistics allows researchers to incorporate *a priori* information on the problem under study, thus potentially improving the efficiency of estimates—and reflecting a frequent concern of both analysts and policy makers regarding how to include what they know from experience about the economy in a formal framework. Under this approach, parameters are interpreted as random and data as fixed. Both features are particularly relevant when the sample size is small due to structural breaks, as it is the case of Argentine economy in the period we focus on. Define $\boldsymbol{\theta} \in \boldsymbol{\Theta}$ as the vector of parameters. Given the prior information $g(\boldsymbol{\theta})$, the observed data $Y_T = [Y_1, Y_2, ..., Y_T]$ and the sample information $f(Y_T/\theta)$, the posterior density—transition from prior to posterior—of the parameters is given by Bayes' rule:

$$g(\theta/Y_T) = \frac{f(Y_T/\theta)\, g(\theta)}{f(Y_T)}$$

$$g(\theta/Y_T) = \frac{f(Y_T/\theta)\, g(\theta)}{\int_{\Theta} f(Y_T/\theta)\, g(\theta)\, d\theta}$$

Notice that $f(Y_T)$ (the marginal likelihood) is constant, hence the posterior density is proportional to the product of the likelihood function $f(Y_T/\theta)$ and the prior density. The inclusion of prior information allows then to generate a more "concave" density, which is crucial for parameter identification when the information contained in the data is considered insufficient; in other words, if we want to know which alternative model parameters are more likely to have been obtained from the sample used, providing *a priori* information improves the ability to identify them correctly.

The modes of the posterior distributions can be easily computed using standard optimization routines—in our case we choose a Monte-Carlo based approach. However, obtaining the whole posterior distributions is considerably more difficult, requiring the calculation of complex multivariate integrals. For this reason, many algorithms have been developed to compute samples

[7] Model solution, estimation and stochastic simulations were performed using the Dynare 4.3.3 software platform in Matlab.

of the posterior distributions by efficiently using available information. The most popular is the Random Walk Metropolis-Hastings algorithm, which we use in our estimation. The algorithm applies a random walk as a jumping process to explore the posterior distribution of the parameters. We used two chains of 50,000 replications each. The variance of the jumps is calibrated to achieve an acceptation rate between 0.2 and 0.4, which is considered an acceptable target to ensure that the search is global.

The priors chosen are based on the posterior distributions from an estimation performed for the pre-crisis, currency board period. The set of observed variables Y is:

$$Y = [\widehat{\pi}, \widehat{i}, \widehat{i}^{*}, \widehat{\pi}^{*}, \widehat{g}^{y}, \widehat{\delta}, \widehat{m}, \widehat{res}, \widehat{sf}, \widehat{e}^{US,R}, \widehat{e}^{US,E}, \widehat{CR}^{H}, \widehat{CR}^{F}, \widehat{i}^{H,act}, \widehat{i}^{F,act}, \widehat{Delinq}^{H}, \widehat{Delinq}^{F}]$$

See Annex I for a description of variables' definitions and data sources.

Table 1 presents parameter estimates[8]; Table 2 contains the standard deviation of shocks.

Table 1: Baseline model

parameter estimates

parameters	prior mean	post. mean	conf. interval		prior	pstdev
α_1	0.300	0.264	0.233	0.305	*beta*	0.100
α_3	0.050	0.078	0.062	0.094	*norm*	0.035
α_4	0.100	0.065	0.051	0.078	*beta*	0.050
β_1	0.300	0.526	0.455	0.599	*beta*	0.100
β_2	0.500	0.397	0.340	0.456	*beta*	0.200
β_3	0.170	0.136	0.125	0.149	*norm*	0.050
β_4	0.200	0.109	0.084	0.133	*beta*	0.100
β_5	0.300	0.113	0.071	0.159	*beta*	0.100
β_6	0.300	0.123	0.075	0.169	*beta*	0.100
ρ_1	0.500	0.937	0.882	0.989	*beta*	0.200
ρ_2	0.500	0.741	0.617	0.873	*beta*	0.200
ρ_3	0.500	0.320	0.283	0.362	*beta*	0.200
ρ_4	0.700	0.972	0.945	0.999	*beta*	0.200
ρ_5	0.700	0.711	0.651	0.773	*beta*	0.200
ρ_6	0.500	0.658	0.544	0.764	*beta*	0.200
γ_1	0.700	0.573	0.519	0.623	*beta*	0.200
γ_2	0.000	0.021	−0.016	0.057	*norm*	0.200
γ_3	0.000	0.025	0.012	0.038	*norm*	0.200
γ_4	0.200	0.083	0.064	0.101	*beta*	0.100
γ_5	0.000	0.007	0.005	0.010	*norm*	0.200
ω_1	4.000	5.911	5.598	6.262	*norm*	1.500
ω_2	0.100	0.008	0.002	0.014	*beta*	0.050
ω_3	1.000	0.178	0.000	0.380	*norm*	1.000

[8] It is worth mentioning that we estimated alternative specifications of equations (10) and (11) in terms of lagged variables and signs of parameters of interest, and selected the one with the best goodness-of-fit, as measured by the posterior odds ratio.

Table 1 (cont.): Baseline model

parameter estimates

parameters	prior mean	post. mean	conf. interval		prior	pstdev
η_1	1.200	1.203	1.137	1.270	*norm*	0.300
η_2	0.500	0.553	0.477	0.623	*beta*	0.200
η_3	0.500	0.031	0.023	0.038	*norm*	0.300
η_4	0.500	0.665	0.635	0.695	*norm*	0.100
κ_1	0.700	0.982	0.964	0.998	*beta*	0.200
κ_2	0.100	0.138	0.116	0.159	*beta*	0.050
A_1^H	0.300	0.401	0.385	0.417	*beta*	0.050
A_2^H	0.100	0.066	0.056	0.078	*beta*	0.050
A_3^H	0.300	0.379	0.365	0.397	*beta*	0.050
B_1^H	0.300	0.069	0.048	0.092	*beta*	0.100
B_2^H	0.300	0.169	0.145	0.194	*beta*	0.100
B_3^H	0.300	0.228	0.179	0.279	*beta*	0.100
ρ_1^{DH}	0.500	0.810	0.761	0.856	*beta*	0.200
ρ_2^{DH}	0.300	0.472	0.419	0.518	*beta*	0.100
A_1^F	0.300	0.333	0.319	0.343	*beta*	0.050
A_2^F	0.100	0.110	0.091	0.129	*beta*	0.050
A_3^F	0.300	0.410	0.392	0.427	*beta*	0.050
B_1^F	0.300	0.018	0.010	0.025	*beta*	0.100
B_2^F	0.300	0.230	0.212	0.249	*beta*	0.100
B_3^F	0.300	0.215	0.153	0.275	*beta*	0.100
ρ_1^{DF}	0.500	0.912	0.894	0.929	*beta*	0.200
ρ_2^{DF}	0.300	0.455	0.424	0.485	*beta*	0.100

Table 2: Baseline model

standard deviation of shocks

	prior mean	post. mean	conf. interval		prior	pstdev
ε^{i}	0.050	0.003	0.002	0.004	*gamma*	0.035
$\varepsilon^{g^{\overline{y}}}$	0.050	0.024	0.014	0.040	*gamma*	0.035
ε^{y}	0.050	0.015	0.011	0.019	*gamma*	0.035
ε^{i^*}	0.050	0.002	0.001	0.002	*gamma*	0.035
ε^{π^*}	0.050	0.009	0.008	0.011	*gamma*	0.035
ε^{RP}	0.050	0.022	0.013	0.032	*gamma*	0.035
$\varepsilon^{e^{US,R}}$	0.050	0.073	0.061	0.082	*gamma*	0.035
$\varepsilon^{e^{US,E}}$	0.050	0.046	0.035	0.057	*gamma*	0.035
ε^{π}	0.050	0.011	0.008	0.013	*gamma*	0.035
ε^{m}	0.060	0.038	0.033	0.044	*gamma*	0.035
ε^{res}	0.050	0.105	0.096	0.115	*gamma*	0.035
ε^{sf}	0.050	0.005	0.003	0.005	*gamma*	0.035
$\varepsilon^{CR,H}$	0.100	0.114	0.101	0.127	*gamma*	0.035
$\varepsilon^{act,H}$	0.050	0.006	0.005	0.008	*gamma*	0.035
$\varepsilon^{Delinq,H}$	0.050	0.009	0.007	0.011	*gamma*	0.035
$\varepsilon^{CR,F}$	0.100	0.202	0.187	0.215	*gamma*	0.035
$\varepsilon^{act,F}$	0.050	0.007	0.005	0.009	*gamma*	0.035
$\varepsilon^{Delinq,F}$	0.050	0.011	0.008	0.013	*gamma*	0.035

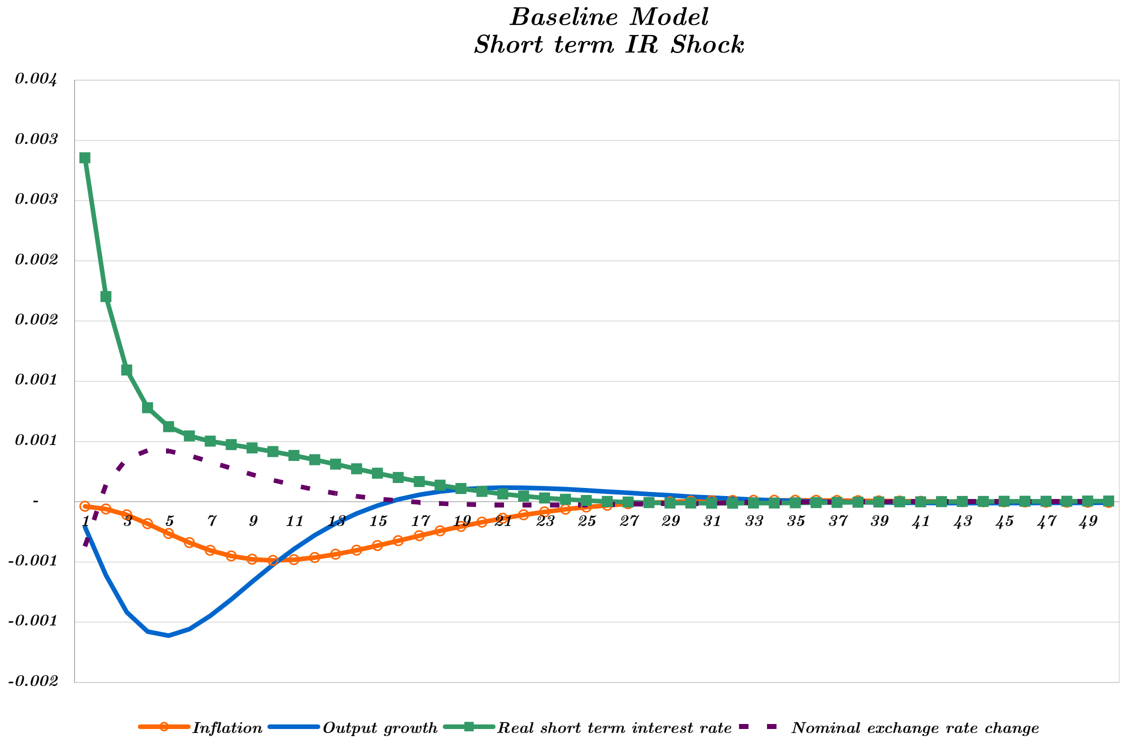
With this fully estimated model, we look at impulse-response functions in order to understand its basic dynamics, with emphasis on how the credit market block interacts with the rest of the economy. Following positive shocks to lending rates—both for commercial and consumption credit—(Figure 1), credit decreases and the interest rate spread increases—the short term interest rate increases, but to a lesser degree than the active rate. As expected, each line of credit reacts more strongly to an increase of its own rate. This affects the real side of the economy, with a negative effect on output growth. As the short term interest rate increases, the nominal exchange rate depreciates—the impact on UIP means that a higher local rate, with no change in the international interest rate, translates into a higher expected depreciation of the local currency. Pass-through from the exchange rate to domestic prices entails a fall on the real interest rate. The central bank acts by gradually increasing the short term rate and intervening in the foreign exchange market to reduce foreign exchange volatility.

A shock to the passive rate (Figure 2), translates immediately into a higher real (short term) interest rate, which goes together with (initial) nominal and real exchange rate appreciation; output is also affected. The central bank reacts by (initially) buying reserves and sterilizing the monetary effect of its operations by issuing bonds. In the credit market, lending rates go up while credit diminishes—spreads are reduced as the active rate is raised less than one-to-one with respect to the passive rate. We are aware that both exercises are just a crude approximation at describing the interplay between the credit market and the macroeconomy, and that certain aspects that are very relevant for financial stability analysis are omitted here—for example, the effect of passive rates on deposit growth[9].

[9] In this model, a higher passive rate means only a higher opportunity cost of holding transactional money, but, by construction, no effect on savings deposits (which are not included); however, this can be very significant.

Figure 2

Accumulated responses to 1 s.d. shock to the short term interest rate



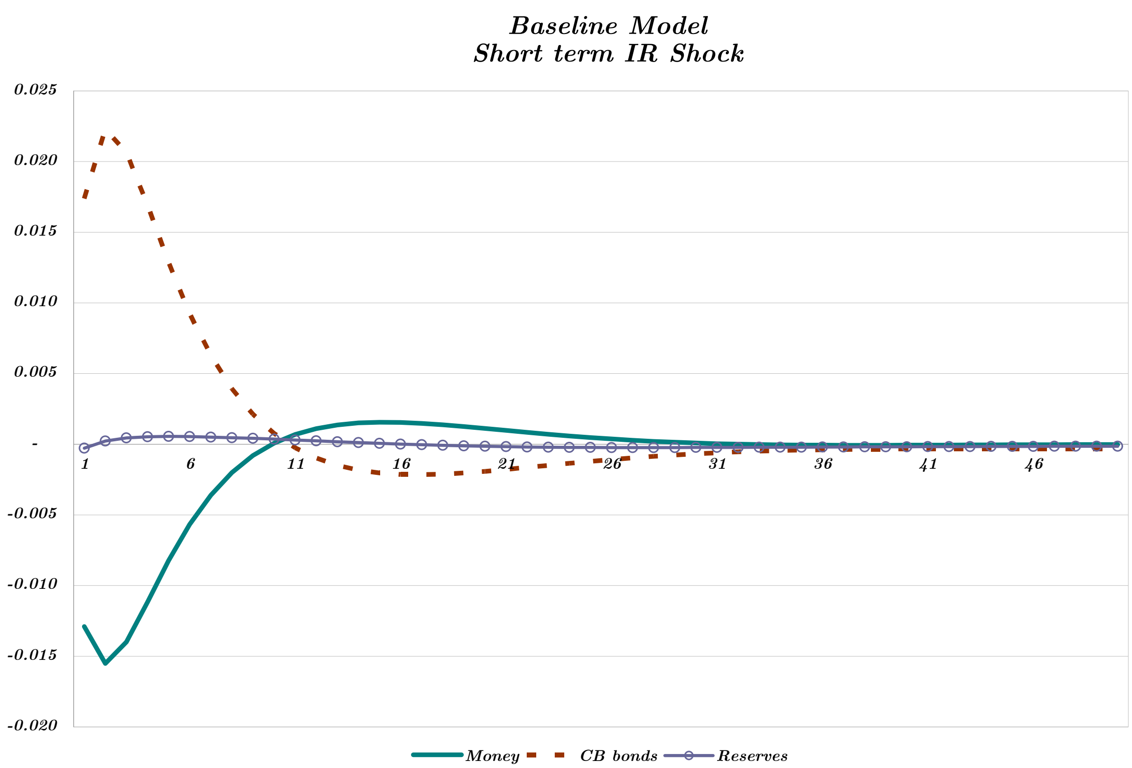


Figure 2 (cont.)

Accumulated responses to 1 s.d. shock to the short term interest rate

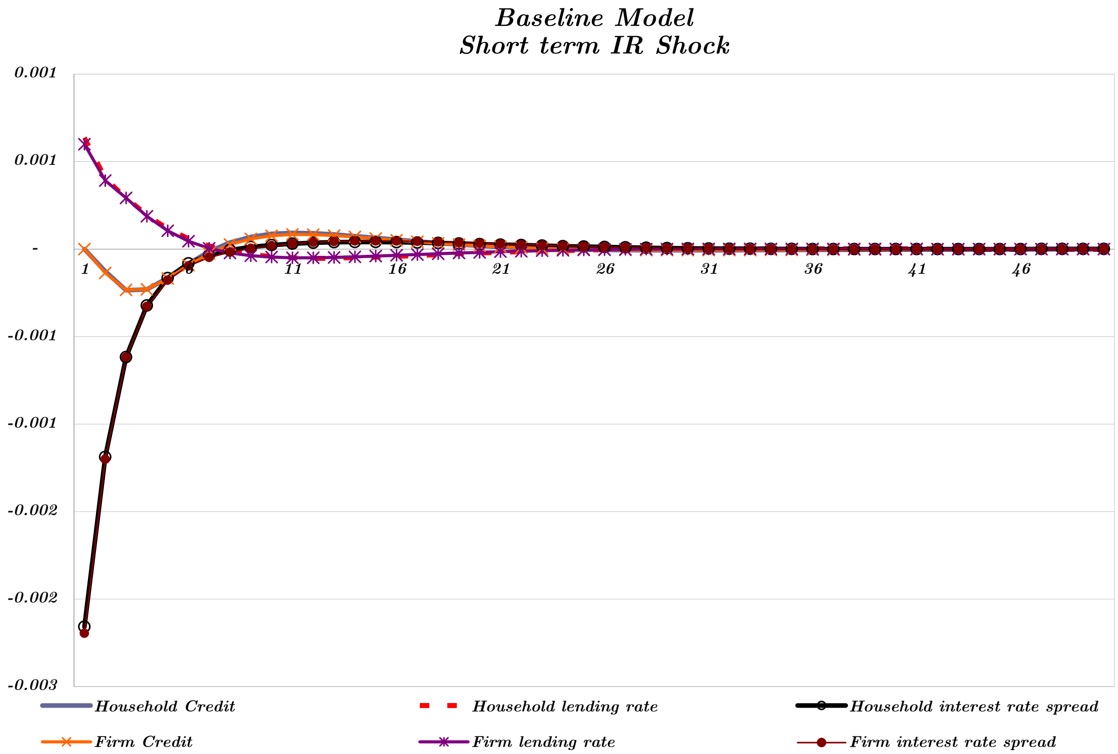


Figure 3

Accumulated responses to 1 s.d. shock to the Household lending rate

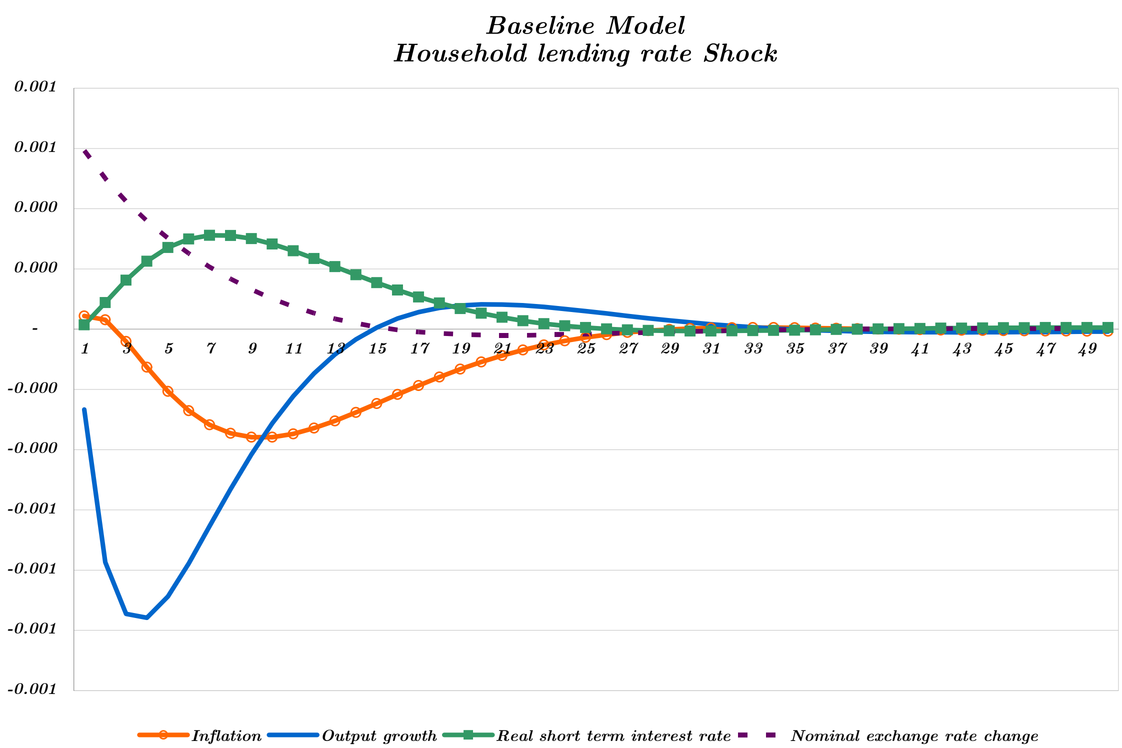
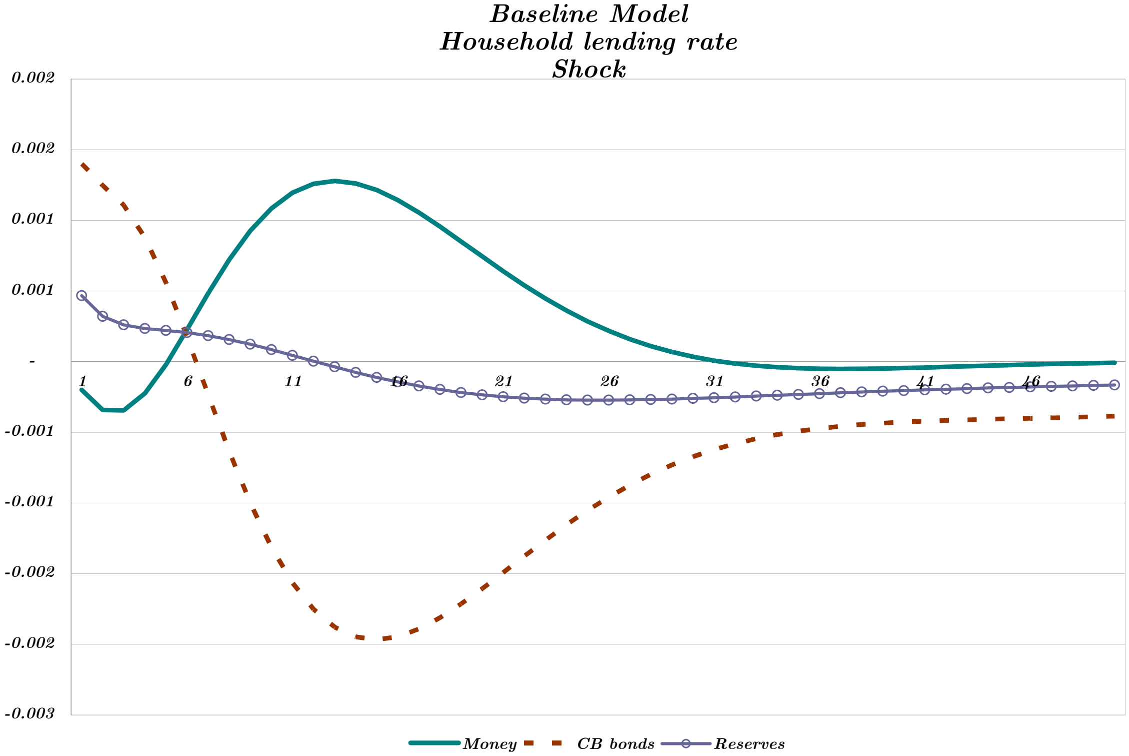


Figure 3 (cont.)

Accumulated responses to 1 s.d. shock to the Household lending rate



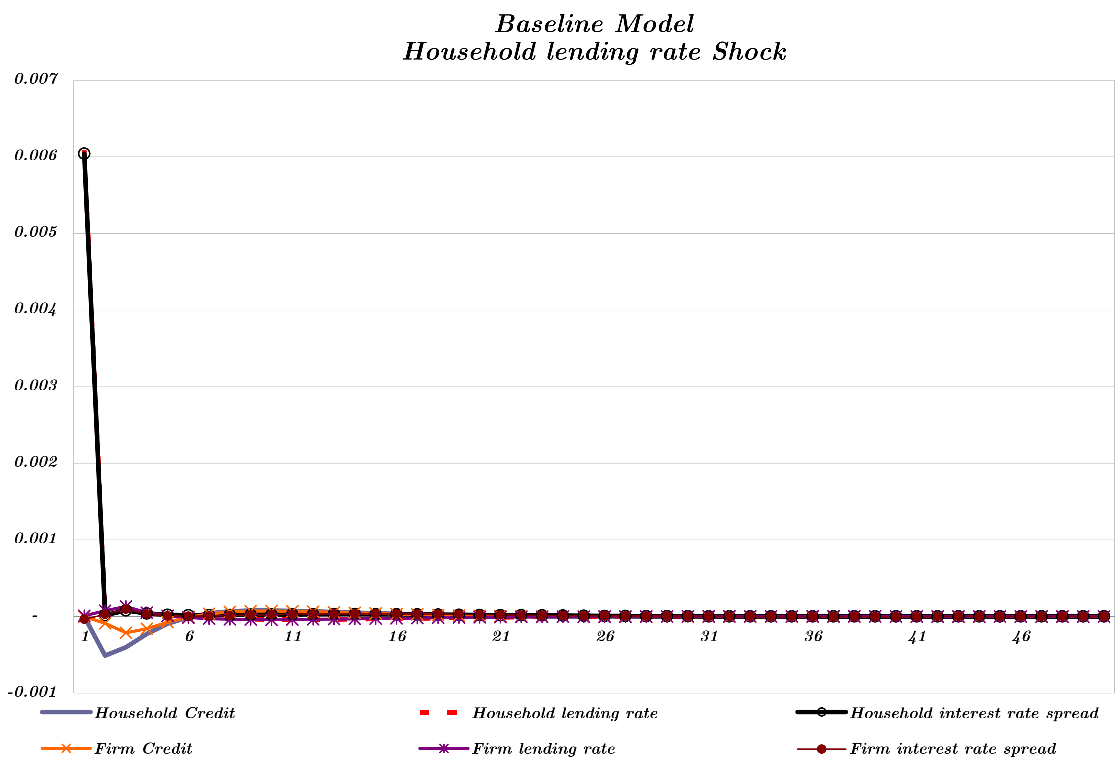
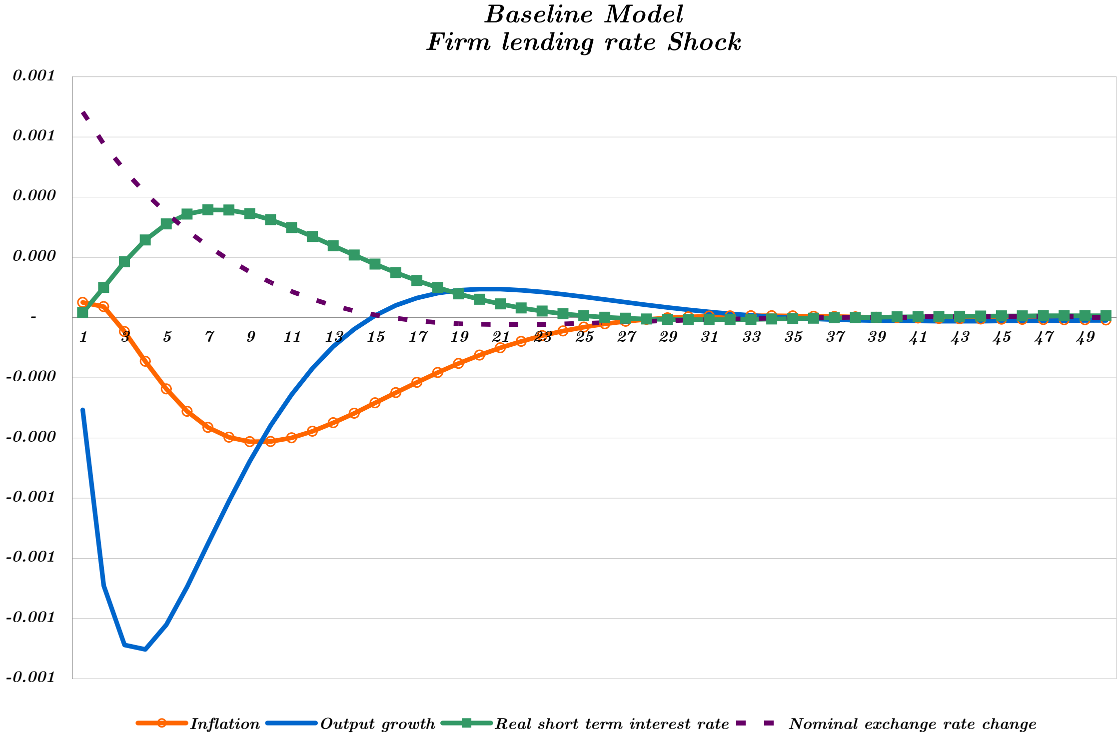


Figure 4

Accumulated responses to 1 s.d. shock to the Firm lending rate



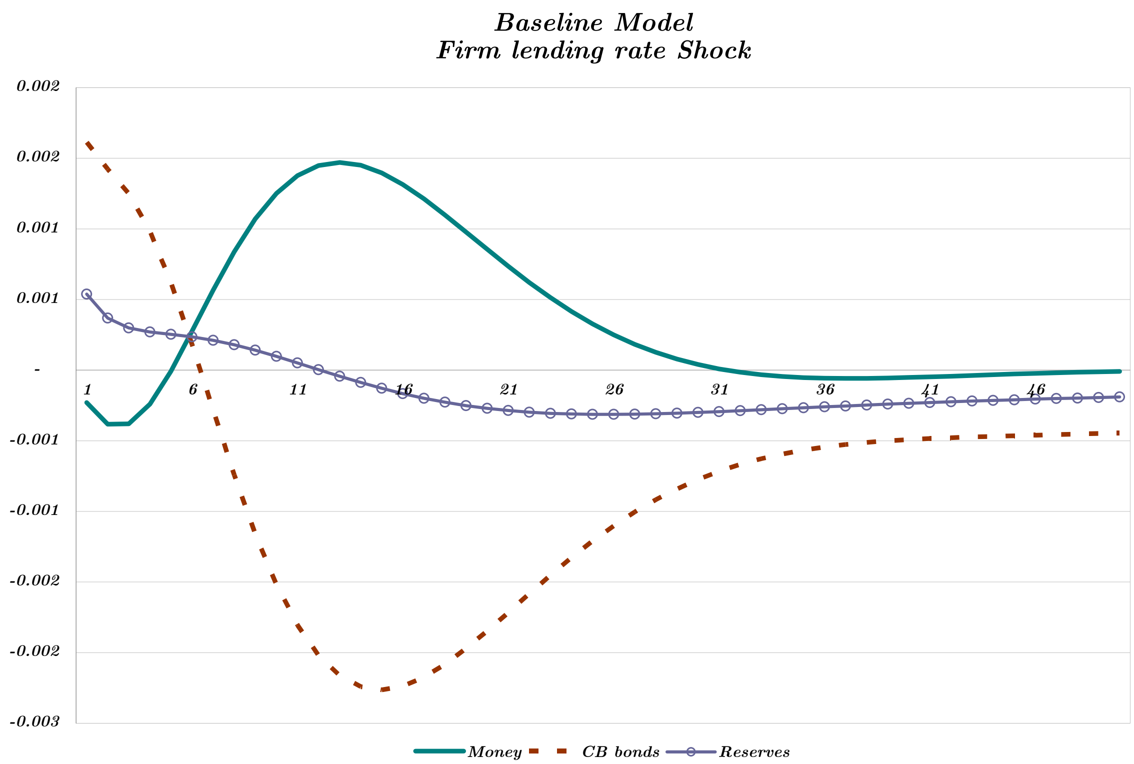
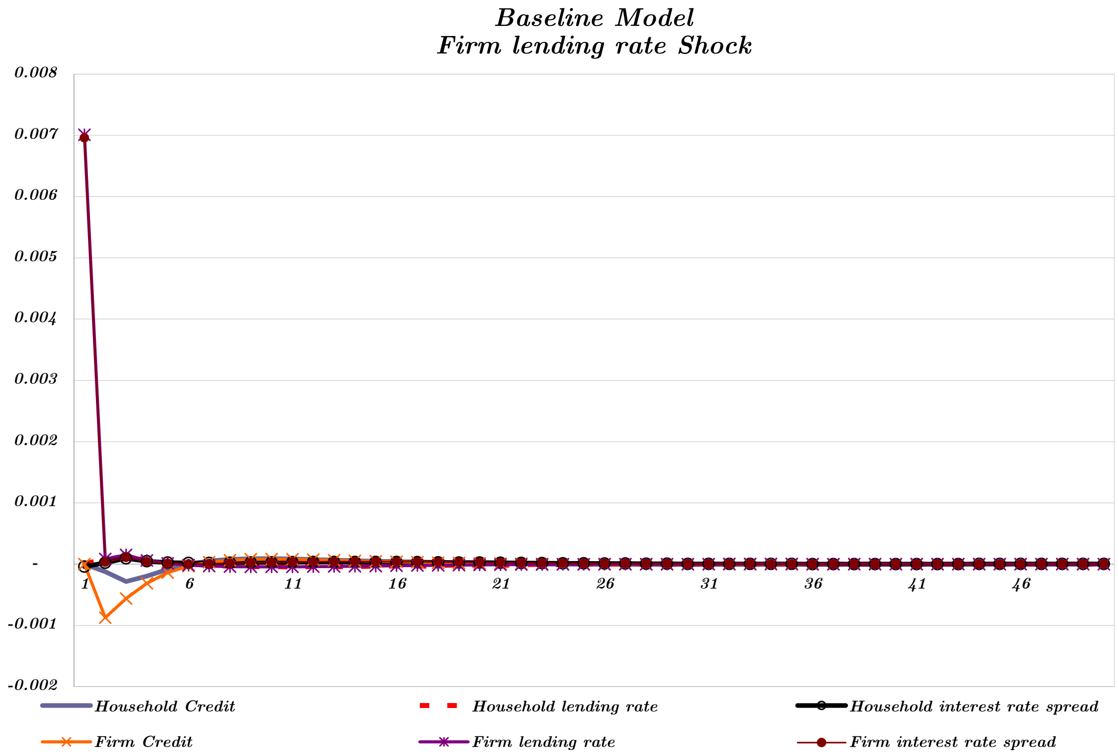


Figure 4 (cont.)

Accumulated responses to 1 s.d. shock to the Firm lending rate



This exercise can also be done to analyze how a real shock is transmitted throughout the rest of the economy and the credit market (Annex 2). A positive shock to the IS curve increases output and inflation; the short term interest rate increases, in nominal terms—basically due to the reaction required by the Taylor rule—but decreases in real terms. This leads to real exchange rate appreciation so the central bank buys reserves to "resist" it and issues bonds to sterilize the monetary effects of its operations. In turn, both types of credit increase, the lending rates fall, and so do both spreads.

It is worth noting that, in the cases of shock to the lending rate and to output, the spread is countercyclical in the sense that higher (lower) spread entails lower (higher) credit and output[10]. In contrast, when the short term interest rate is shocked, the spread appears to be procyclical—while credit also goes down, since the active rate is going up, the spread is reduced. Our interpretation is that in the latter case the effect of decreased credit demand, together with lower output associated to a higher real rate, more than offsets the direct expansionary impact of a lower spread. In all of the three cases, credit is procyclical.

Thus, even a relatively simple specification as this appears at least to be partly indicative of how the credit market interacts with the rest of the economy and with monetary policy. As shown by the exercises above, it is not only the traditional "transmission mechanism" of shocks that should be looked at, but the addition of both foreign exchange operations and the credit market reveal new channels that are relevant to the explanation of cyclical impulses.

Regarding how cycles are transmitted throughout the economy, we can also look at suggestive results from the relationship between the macroeconomic and the financial blocks of the model:

[10] This agrees with the empirical finding of Aguirre et al (2013) for the Argentine economy in 1996-2012, that output growth has a negative effect on interest rate spread, also indicating countercyclicality.

we compare the variability of credit following a shock to output growth, and the variability of the latter in the face of a credit shock. Table 3 shows the standard deviation of growth following shocks to consumption and commercial credit: growth is more variable in the face of a shock to corporate credit than one to household credit. But both types of credit are ten to twenty times more volatile following a shock to output growth than in the opposite case. This suggests that impulses coming from the real side of the economy weigh more heavily on the financial system than the other way around.

Table 3
Standard deviations of responses to shocks of selected variables after

	10 quarters	20 quarters	30 quarters
		Consumption credit	
Output	0.00015	0.00022	0.00022
		Corporate credit	
Output	0.00029	0.00042	0.00042
		Output growth	
Consumption credit	0.00338	0.00251	0.00204
Corporate credit	0.00297	0.00223	0.00181

5 The extended model: macroprudential policy

Of the many different measures that can be considered as "macroprudential", we will focus on one of the most basic financial system regulations—a capital adequacy ratio—, and will consider several variants. These range from a purely exogenous ratio from the macroeconomic point of view (thus akin to conventional prudential regulation) to rules according to which adequate capital depends on macroeconomic or financial system variables. This allows us to examine cyclical measures and others that do not directly depend on a cyclical variable, as well as price-based vis-a-vis quantity-based rules. Such measures are macroprudential in addition to the managed floating foreign exchange regime: in so far as such policy limits variability of a certain class of assets that weigh on financial system dynamics, foreign exchange intervention can also be considered part of the macroprudential "toolkit".

We enlarge the model's financial block by adding a capital adequacy ratio, which we first define as an exogenous rule (31)- its level does not depend on variables explicitly modelled[11]. We take this to be, a priori, the most representative way of depicting capital requirements in Argentina during the estimation period, as they were not defined as a function of macroeconomic variables, but of risk-weighted assets of financial institutions (BCRA, 2014) The capital adequacy ratio (CAR) is then included in the equation describing the actives rates (32) and (33); we hypothesize that higher capital requirements will be associated with higher lending rates, since each additional loan has to be "backed" by more equity. The new equations are as follows.

Capital Adequacy Ratio

First Option: Exogenous

$$\widehat{CAR}_t = \psi_0 + \psi_1 \widehat{CAR}_{t-1} + \varepsilon_t^{CAR} \tag{31}$$

where CAR : capital adequacy ratio

[11] Strictly speaking, of course, capital requirements are always endogenous from the point of view of financial institutions, as they depend on their risk-weighted assets.

$$\widehat{i}_t^{act,H} = B_1^H \widehat{Delinq}_t^H - B_2^H \widehat{g}_{t-1}^y + B_3^H \widehat{i}_t + B_4 \widehat{CAR}_t + \varepsilon_t^{Hact} \tag{32}$$

$$\widehat{i}_t^{act,F} = B_1^F \widehat{Delinq}_t^F - B_2^F \widehat{g}_{t-1}^y + B_3^F \widehat{i}_t + B_4 \widehat{CAR}_t + \varepsilon_t^{Fact} \tag{33}$$

We then estimate model 2 with macroprudential policy using Bayesian techniques; as with the baseline model, we estimate using quarterly data of the Argentine economy for the 2003Q3-2011Q3 period. Estimates of parameters and standard deviations are shown in Tables 4 and 5.

Table 4: Model 2, exogenous CAR

parameter estimates

parameters	prior mean	post. mean	conf. interval		prior	pstdev
α_1	0.300	0.215	0.180	0.246	*beta*	0.100
α_3	0.050	0.032	0.006	0.062	*norm*	0.035
α_4	0.100	0.141	0.118	0.170	*beta*	0.050
β_1	0.300	0.323	0.290	0.360	*beta*	0.100
β_2	0.500	0.459	0.401	0.518	*beta*	0.200
β_3	0.170	0.217	0.185	0.249	*norm*	0.050
β_4	0.200	0.158	0.108	0.211	*beta*	0.100
β_5	0.300	0.166	0.124	0.206	*beta*	0.100
β_6	0.300	0.260	0.161	0.354	*beta*	0.100
ρ_1	0.500	0.962	0.931	0.992	*beta*	0.200
ρ_2	0.500	0.709	0.609	0.832	*beta*	0.200
ρ_3	0.500	0.364	0.295	0.447	*beta*	0.200
ρ_4	0.700	0.962	0.928	0.998	*beta*	0.200
ρ_5	0.700	0.905	0.827	0.961	*beta*	0.200
ρ_6	0.500	0.220	0.113	0.317	*beta*	0.200
γ_1	0.700	0.626	0.533	0.743	*beta*	0.200
γ_2	0.000	0.013	-0.009	0.036	*norm*	0.200
γ_3	0.000	0.024	0.005	0.043	*norm*	0.200
γ_4	0.200	0.077	0.045	0.106	*beta*	0.100
γ_5	0.000	0.005	0.001	0.010	*norm*	0.200
ω_1	4.000	5.595	4.733	6.500	*norm*	1.500
ω_2	0.100	0.010	0.003	0.016	*beta*	0.050
ω_3	1.000	0.240	0.002	0.458	*norm*	1.000
η_1	1.200	0.952	0.828	1.061	*norm*	0.300
η_2	0.500	0.692	0.589	0.820	*beta*	0.200
η_3	0.500	0.027	0.020	0.035	*norm*	0.300
η_4	0.500	0.738	0.694	0.779	*norm*	0.100
κ_1	0.700	0.976	0.954	0.998	*beta*	0.200
κ_2	0.100	0.128	0.102	0.156	*beta*	0.050

Table 4 (cont.): Model 2, exogenous CAR

parameter estimates

parameters	prior mean	post. mean	conf. interval		prior	pstdev
A_1^H	0.300	0.377	0.360	0.390	*beta*	0.050
A_2^H	0.100	0.098	0.076	0.122	*beta*	0.050
A_3^H	0.300	0.414	0.396	0.436	*beta*	0.050
B_1^H	0.300	0.099	0.075	0.123	*beta*	0.100
B_2^H	0.300	0.254	0.230	0.281	*beta*	0.100
B_3^H	0.300	0.239	0.159	0.318	*beta*	0.100
B_4^H	0.300	0.145	0.120	0.170	*beta*	0.100
ρ_1^{DH}	0.500	0.819	0.787	0.850	*beta*	0.200
ρ_2^{DH}	0.300	0.374	0.328	0.419	*beta*	0.100
A_1^F	0.300	0.385	0.353	0.416	*beta*	0.050
A_2^F	0.100	0.099	0.070	0.132	*beta*	0.050
A_3^F	0.300	0.459	0.433	0.489	*beta*	0.050
B_1^F	0.300	0.023	0.011	0.033	*beta*	0.100
B_2^F	0.300	0.244	0.184	0.302	*beta*	0.100
B_3^F	0.300	0.261	0.186	0.303	*beta*	0.100
B_4^F	0.300	0.134	0.098	0.171	*beta*	0.100
ρ_1^{DF}	0.500	0.907	0.885	0.932	*beta*	0.200
ρ_2^{DF}	0.300	0.473	0.436	0.510	*beta*	0.100
ψ_0	0.500	0.011	0.010	0.012	*beta*	0.200
ψ_1	0.700	0.378	0.288	0.478	*beta*	0.200

Table 5: Model 4, exogenous CAR

standard deviation of shocks

	prior mean	post. mean	conf. interval		prior	pstdev
ε^i	0.050	0.003	0.002	0.004	*gamma*	0.035
$\varepsilon^{g^{\overline{y}}}$	0.050	0.019	0.011	0.028	*gamma*	0.035
ε^y	0.050	0.018	0.014	0.022	*gamma*	0.035
ε^{i^*}	0.050	0.001	0.001	0.002	*gamma*	0.035
ε^{π^*}	0.050	0.010	0.008	0.012	*gamma*	0.035
ε^{RP}	0.050	0.035	0.024	0.046	*gamma*	0.035
$\varepsilon^{e^{US,R}}$	0.050	0.062	0.054	0.069	*gamma*	0.035
$\varepsilon^{e^{US,E}}$	0.050	0.042	0.035	0.049	*gamma*	0.035
ε^π	0.050	0.013	0.010	0.016	*gamma*	0.035
ε^m	0.060	0.031	0.023	0.038	*gamma*	0.035
ε^{res}	0.050	0.109	0.095	0.122	*gamma*	0.035
ε^{sf}	0.050	0.004	0.003	0.005	*gamma*	0.035
$\varepsilon^{CR,H}$	0.100	0.122	0.111	0.131	*gamma*	0.035
$\varepsilon^{act,H}$	0.050	0.007	0.005	0.008	*gamma*	0.035
$\varepsilon^{Delinq,H}$	0.050	0.008	0.006	0.010	*gamma*	0.035
$\varepsilon^{CR,F}$	0.100	0.167	0.154	0.179	*gamma*	0.035
$\varepsilon^{act,F}$	0.050	0.007	0.005	0.009	*gamma*	0.035
$\varepsilon^{Delinq,F}$	0.050	0.012	0.009	0.014	*gamma*	0.035
ε^{CAR}	0.050	0.014	0.011	0.017	*gamma*	0.035

We use the estimated model to try to gain some understanding of the potentially stabilizing properties of prudential policy. Are capital adequacy ratios associated to less volatility in the macroeconomy and the financial system? In order to answer this question, we compute the estimated variability of selected variables under the "exogenous" CARs, and compare them with the baseline model (model 1). At this point, it is worth remembering that, by construction, estimated models reflect the type and magnitude of shocks that the economy underwent during the estimation period; so by showing variability under the estimated policy , we approximate the economy's performance associated to it in the face of the particular shocks occurred.

A number of objections to the exercise may be raised. One could argue to what extent we can use a small structural model, not explicitly derived from optimizing behavior of agents, to assess alternative policies. As policies change, so do responses of agents, something not necessarily captured by our behavioral equations. It should be noted, however, that the model is built with rational expectations so, at least at the level of aggregation we are working with, responses do incorporate expectations consistent with the model's structure.

In connection to the above, it could be pointed out that results in a structural model such as this one are subject to the "Lucas critique"—with estimated parameters being biased as there is no guarantee of invariance to policy changes. This requires some methodological clarification: using a "micro founded" model would not, in and of itself, assure such invariance and, with it, unbiased results—even if this is usually taken for granted in the use of DSGE models. This is a purely empirical question[12]—and as practitioners know, parameters in macroeconomic models are usually re-estimated or re-calibrated periodically, implicitly violating the same condition they are assumed to satisfy. Macroeconomic models, whether large or small, are in practice subject to this bias—the question is how large it is, and how it compares to that of alternative models. Large-scale DSGE frameworks, for instance, are ridden with problems of identification and estimation—with certain key parameters or relationships being neither "micro founded" nor estimated. So that while we cannot rule out that the model presented here is indeed subject to the Lucas critique, in our view it represents an acceptable trade-off between empirical tractability (with all parameters being estimated) and full analytical development that can (only theoretically) bring the model closer to invariance to selected policy interventions.

With the previous points in mind, we compute standard deviations of macroeconomic and financial variables under models 1 and 2. We do the exercise for: inflation, output growth, local short term interest rates, the real trilateral (trade-weighted) exchange rate, money growth, international reserves, credit (total and by line), lending interest rates (average and by credit line), non performing loans (by credit line) and capital requirements. The comparison in Table 6 suggests a lower volatility during the estimation period under an exogenous capital requirement for most of the variables considered.

[12] As found by Ericsson and Irons (1995), macroeconomic models are typically subject to the Lucas critique in practice; the econometric condition to be satisfied is that of superexogeneity, something that is independent of whether the model was derived from first order conditions of an optimization problem or not.

Table 6 : *Observed and estimated standard deviations of selected variables*

Variable	**Model 1** *Baseline*	**Model 2** *Exogenous CAR*
π	0.058	0.031
i	0.013	0.012
g^y	0.057	0.047
e^{tri}	0.096	0.057
m	0.220	0.184
res	0.550	0.507
CR	0.262	0.239
CR^H	0.128	0.137
CR^F	0.224	0.191
i^{act}	0.017	0.016
$i^{act,H}$	0.018	0.019
$i^{act,F}$	0.018	0.015
$Delinq^H$	0.115	0.076
$Delinq^F$	0.197	0.157
CAR		0.015

These results suggest that capital requirements do fulfill their expected role of decreasing risk-taking: non performing loans' volatility is between 20% and 35% lower when capital requirements are implemented than when they are not. Volatility of credit is reduced on average 9% under capital adequacy ratios, a result driven by lower volatility of firms' credit; in the same breath, lending rates to firms are 14% lower when prudential policy is implemented (but the same does not apply to consumption lending rates). In addition, there appears to be a macroeconomic impact of capital requirements: growth volatility is 17% lower under CARs than without them; and inflation volatility appears to be reduced by half when CAR is put in place. While we are fully aware of the suggestive nature of our results, we believe they point in a direction of macroeconomic significance of macroprudential measures; indeed, our figures are of the same order of magnitude that Covas and Fujita (2009) find for growth volatility reduction with countercyclical capital requirements.This leads to discuss alternative rules to "exogenous" CARs, that are a function of macroeconomic or financial variables, with cyclical behaviour or not.

5.1 Examining alternative capital adequacy rules

Using as a starting point the results obtained in model 2, we propose three alternative CAR rules: **(i)** a function of the output gap (34); **(ii)** a function of the credit-to-GDP gap (35), which is the standard way in which countercyclical capital regulation is currently being designed under Basel III (Drehmann and Tsatsaronis, 2014); or **(iii)** the interest rate spread (36). These alternatives, labeled respectively as models 3, 4 and 5, correspond to different policy concerns: risk taken by banks is moderated by higher requirements, which may be more related to macroeconomic (model 3) or financial system performance (models 4 and 5). The main difference in motivation between models 4 and 5 is whether quantity-based or price-based indicators perform better in terms of early warning of crises (Shin, 2013).

Second Option: Endogenous

$$\widehat{CAR}_t = \psi_0 + \psi_1 \widehat{CAR}_{t-1} + \psi_2 \hat{y}_t + \varepsilon_t^{CAR} \quad (34)$$

$$\widehat{CAR}_t = \psi_0 + \psi_1 \widehat{CAR}_{t-1} + \psi_2 \widehat{CR}_t + \varepsilon_t^{CAR} \quad (35)$$

$$\widehat{CAR}_t = \psi_0 + \psi_1 \widehat{CAR}_{t-1} + \psi_2 spread_t + \varepsilon_t^{CAR} \quad (36)$$

For each model, we: use the estimated parameters of model 2[13]; and change the capital adequacy ratio in order to implement the three alternative rules outlined in the previous paragraph, taking estimated coefficients for each of them (such coefficientes are obtained from estimations of models 3-5). We once again compute the standard deviation of selected variables for all the for models we compare. Certainly, there are well-known limits to this strategy (see previous section), but we believe it is a useful first approximation to the assess potential gains associated to implemeting explicit macroprudential rules. Results generally indicate that capital requirements as a function of macroeconomic (output gap) or financial system variables (credit gap, interest rate spread) deliver lower volatility than purely "exogenous" ones. For most macroeconomic and monetary variables (inflation, growth, real exchange rate, money and the short term interest rate), a capital adequacy rule that changes with the output gap delivers the lowest volatility. Instead, for most financial system variables (credit and lending rates), it is capital requirements as a function of interest rate spread that are associated to lower variance; the exception here is non-peforming loans, with lower variability under model 3 (CAR as function of output gap). Perhaps not surprisingly, a CAR that depends on output performs better (under this criterion) for macroeconomic variables, while a rule that depends on interest rates works better for financial system variables.

Table 7 : *Standard deviations of selected variables - Calibrated Models*

Variable	**Model 2** *Exogenous CAR*	**Model 3** *Endogenous CAR (y)*	**Model 4** *Endogenous CAR (cred)*	**Model 5** *Endogenous CAR (spread)*
π	0.0307	**0.0301**	0.0312	0.0312
i	0.0116	**0.0111**	0.0117	0.0122
g^y	0.0473	**0.0471**	0.0475	0.0476
e^{tri}	0.0572	**0.0571**	0.0574	0.0572
m	0.1836	**0.1762**	0.1822	0.1937
res	0.5065	0.5067	**0.5043**	0.5072
CR	0.2392	0.2392	0.2393	**0.238**
CR^H	0.1372	0.1372	0.1373	**0.1369**
CR^F	0.1907	0.1907	0.1908	**0.1902**
i^{act}	0.0164	0.0179	0.0172	**0.016**
$i^{act,H}$	0.0191	0.0206	0.0199	**0.0186**
$i^{act,F}$	0.0152	0.0165	0.0159	**0.015**
$Delinq^H$	0.0757	**0.0755**	0.0759	0.0757
$Delinq^F$	0.1571	**0.157**	0.1574	**0.157**
CAR	**0.0153**	0.0233	0.020	0.0465

[13] See Table A.3 and Table A.4 in Annex 3 for the same exercise with estimated (instead of calibrated) models.

In order to gain a comprehensive assessment of these results and the policies associated to them, we aggregate the different variability measures by summing up variances of the variables considered—thereby using ad hoc "loss" functions. As those functions are not derived from the utility of a representative consumer, they do not indicate anything in terms of social welfare, but we interpret them instead as embodying alternative evaluation criteria of an analyst or policymaker whose concern is for the volatility of selected macroeconomic and financial variables. Generally, the loss function we use here is defined as follows.

We considered several loss functions, combining different macro $\left(g^y, \pi, e^{tri}\right)$ and financial $\left(i, i^{act}, i^{act,H}, i^{act,F}, CR^H, CR^F, CAR\right)$ variables. Thus, an example of loss function could be:

$$L \equiv \omega^{g^y} * \sigma^2_{g^y} + \omega^{\pi} * \sigma^2_{\pi} + \omega^{i} * \sigma^2_{i} + \omega^{CAR} * \sigma^2_{CAR}$$

where $\sigma^2_{g^y}$ is the variance of output gap, σ^2_{π} is the variance of inflation, σ^2_{i} is the variance of short term interest rate and σ^2_{CAR} is the variance of the capital adequacy ratio, and ω are the corresponding weights such as $\left(\omega^{g^y} + \omega^{\pi} + \omega^{i} + \omega^{CAR}\right) = 1$.

Initially, we assign equal weights to all components of the function, considering in all cases inflation, output growth, the short term interest rate and real exchange rate depreciation, together with: consumption credit, commercial credit, and commercial credit and capital requirements. To consider lending rates, we also look at the sum of inflation, output growth, real exchange rate depreciation and: consumption lending rate and credit; commercial lending rate and credit. To focus on macroeconomic variables and central bank's instruments, we consider output growth, inflation, the short term interest rate and capital adequacy ratios. When only macroeconomic variables and interest rates are involved, capital requirements that vary with the output gap tend to yield lower volatility, whereas when financial system variables are included, either CAR as a function of spread or of the credit gap obtain lower aggregate variability. However, when the variabiliy of capital requirements themselves is considered, "exogenous" requirements yield lower "losses" (Table 8, panel a).

A related exercise has to do with changing weights in the terms of the loss function. First, we compute aggregate volatility with higher weights on macroeconomic variables (output growth, inflation, real exchange rate depreciation), grouping: both macroeconomic and financial system variables (Table 8, panel b); and macroeconomic variables and interest rates only (Table 8, panel c). In both cases, capital requirements that vary with the output gap show the lowest volatility. This suggests, perhaps naturally, that a CAR that changes with an indicator of the business cycle is more apt to do better when the main concern is macroeconomic performance.

Next, we compute aggregate volatility with higher weights on financial system variables (interest rates, credit), once again grouping macroeconomic and financial system variables (Table 8, panel d), and macroeconomic and interest rates only (Table 8, panel e). In panel d, CAR as a function of interest rates spread delivers lower volatility in two cases, whereas in two others a better perfomance is found for capita requirements that change with the output gap, or even the "exogenous" CAR, In panel e, "exogenous" capital requirements are associated to lower volatility. Thus, when more weight is put on financial system indicators' performance, there appears to be a role for macroprudential policy based on interest rate spreads.

Table 8: *Loss Functions of alternative models*

Variables Considered in Loss Function	*Model 1* Baseline	*Model 2* Exogenous CAR	*Model 3* Endogenous CAR (y)	*Model 4* Endogenous CAR (cred)	*Model 5* Endogenous CAR (spread)
a) Equal weights $\left(\omega = \frac{1}{n}\right)$					
g^y, π	0.00661	0.00318	**0.00312**	0.00323	0.00324
g^y, i^{act}	0.00355	**0.00251**	0.00254	0.00255	0.00252
g^y, π, i^{act}	0.00666	0.00319	**0.00314**	0.00324	0.00325
$g^y, \pi, i^{act}, e^{tri}$	0.00688	0.00323	**0.00317**	0.00328	0.00329
g^y, π, i, i^{act}	0.00710	0.00355	**0.00352**	0.00362	0.00361
g^y, π, i, CAR	0.00679	**0.00355**	0.00379	0.00377	0.00555
$g^y, \pi, i, e^{tri}, CR^H$	0.03250	0.02564	**0.02563**	0.02577	0.02560
$g^y, \pi, i, e^{tri}, CR^F$	0.06607	0.04305	0.04302	**0.04318**	0.04291
$g^y, \pi, i, e^{tri}, CR^F, CAR$		**0.04319**	0.04342	0.04347	0.04500
$g^y, \pi, i^{act}, e^{tri}, CR^H$	0.03250	0.02564	0.02563	0.02577	**0.02560**
$g^y, \pi, i^{act}, e^{tri}, CR^F$	0.06607	0.04305	0.04302	0.04318	**0.04291**
b) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \omega^{e^{tri}} = \frac{4}{15}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{1}{15}$					
$g^y, \pi, i, e^{tri}, CR^H$	0.00532	0.00298	**0.00297**	0.00301	0.00300
$g^y, \pi, i, e^{tri}, CR^F$	0.00756	0.00415	**0.00414**	0.00418	0.00416
$g^y, \pi, i, e^{tri}, i^{act,H}$	0.00425	0.00175	**0.00173**	0.00177	0.00176
$g^y, \pi, i, e^{tri}, i^{act,F}$	0.00425	0.00175	**0.00174**	0.00178	0.00177
c) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \frac{5}{12}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{1}{12}$					
$g^y, \pi, , i, i^{act,H}$	0.00280	0.00136	**0.00133**	0.00138	0.00138
$g^y, \pi, i, i^{act,F}$	0.00280	0.00136	**0.00133**	0.00138	0.00138
d) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \frac{2}{15}$ and $\omega^{e^{tri}} = \frac{1}{15}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{5}{15}$					
$g^y, \pi, i, e^{tri}, CR^H$	0.00701	0.00696	**0.00695**	0.00698	0.00695
$g^y, \pi, i, e^{tri}, CR^F$	0.01821	0.01281	0.01280	0.01283	**0.01276**
$g^y, \pi, i, e^{tri}, i^{act,H}$	0.00167	0.00081	0.00082	0.00083	**0.00081**
$g^y, \pi, i, e^{tri}, i^{act,F}$	0.00166	**0.00076**	0.00077	0.00078	0.00077
e) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \frac{1}{12}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{5}{12}$					
$g^y, \pi, i, i^{act,H}$	0.00075	**0.00042**	0.00043	0.00043	0.00043
$g^y, \pi, i, i^{act,F}$	0.00075	**0.00042**	0.00043	0.00043	0.00043

In general, results suggest that for the 2003-2011 period, the interaction of monetary and foreign exchange policy (interest rate rules plus foreign exchange intervention) and macroprudential policy (capital requirements) generated lower volatility of key macroeconomic and financial variables than if no macroprudential policy would have been implemented. As shown above, for a considerable set of macroeconomic and financial system variables, we find lower volatility associated to the implementation of capital adequacy ratio rules under different definitions. When measures of aggregate volatility are computed, capital requirements that are modelled as functions of macroeconomic or financial system variables (the credit gap, output growth or spread) generally outperform an "exogenous" formulation of the capital adequacy rations.

What do we make of these findings? First and foremost, measures that contain risk in the financial system also have an influence on macroeconomic performance—evidence for the relevance of macroprudential policy design. Just as the managed floating regime has been found to be optimal for the Argentine economy in a large scale DSGE model (Escudé, 2009) and to deliver lower observed variability of macroeconomic variables than alternative regimes in a fully estimated model (Aguirre and Grosman, 2010), an enhanced policy package that includes regulation of the financial system further contributes to lowering the volatility of certain variables.

Furthermore, there appears to be some "division of labour" among CAR formulations: when macroprudential regulation is a function of cyclical indicators (the output gap), it appears to be more helpful to dampen macroeconomic fluctuations; but when it is based on financial system indicators or even "exogenous", it may more directly help reduce financial system volatility.

Finally, it is worth pointing out that capital requirements that do not depend directly on macroeconomic or financial system variables yield lower volatility than when no such policy is in place. Rationalizing lower aggregate variability of the exogenous CAR rule is at least twofold. On the one hand, in an economy with a relatively small financial system, where credit barely reaches 15% of GDP by the end of the sample period, there does not appear to be a clear advantage of putting in place a rule that links capital requirements to some indicator of the state of the real economy or of the financial system at large. We hypothesize that this may have to do with a more significant influence from the real economy to the financial system than otherwise—something that calls for further work to be properly established. This is also consistent with the model of Angeloni and Faia (2013), who find that banking sector risk is more stable under a "fixed" capital regime. On the other hand, we cannot rule out that, since the CAR rule actually in place during the estimation period[14] is more similar to that of model 2 (exogenous) than to a function of macroeconomic or aggregate financial system variables, this may imply a generally better fit to data (in this case, through lower variance) when compared to rules that were actually not in place. However, a measure of comparative fit like logarithmic data densities suggests that the model with CAR as a function of credit would be the one of choice (Table 9). Of course, we may advance further by computing optimal policy and comparing it with what is reported; even within the limits of a small structural model, this could shed some more light on the interplay of monetary, foreign exchange and macroprudential policy.

[14] Capital ratios in the Argentine financial system are a functions of the risk of the different type of assets held by financial institutions. See BCRA (2014) for details.

Table 9

Log data densities of alternative models

Model	Log data density
Baseline	1207.69
Exogenous CAR	1316.30
Endogenous CAR (y)	1318.77
Endogenous CAR (cred)	**1324.89**
Endogenous CAR (spread)	1301.44

6 Concluding Remarks

Based on our previous work (Aguirre and Blanco, 2013), we estimated a small macroeconomic model of the Argentine economy, augmented—in its baseline version—to include explicit depiction of the credit market, active rates and interest rate spread; and an enriched description of monetary policy, with sterilized intervention in the foreign exchange market. In this paper, we present a somewhat more detailed specification of the financial sector, distinguishing credit by type (commercial or consumption) and making non performing loans endogenous. Compared to current analyses of the interaction of monetary and macroprudential policy, we provide a framework that explicitly allows for the interaction of foreign exchange intervention, interest rate policy and macroprudential policy—something that, to our knowledge, is only dealt with by Escudé (2014) for the case of capital controls. This feature is particularly relevant in emerging market economies, where foreign exchange intervention is frequently implemented, but rarely included in macroeconomic models, and even less in those that extend the framework to include financial stability issues.

Bayesian estimation techniques allow us to incorporate our prior knowledge of the workings of this economy during the estimation period (2003-2011). Looking at impulse-response functions of the estimated model, we gain an intuitive understanding of the model's dynamics—whether they conform to hypotheses regarding the response of macroeconomic (activity, prices, exchange rates) and financial (money, credit) variables to different shocks. Higher lending rates are associated to higher spread, lower credit and output growth; in turn, higher output implies lower interest rate spread and higher credit. Impacts from the credit market to the rest of the economy should be further investigated to see whether a hypothesis of "financial cycles" (Borio,2012) may apply during the estimation period. Likewise, the financial system (in this highly aggregate representation) is affected by macroeconomic shocks: in particular, credit behaves in a procyclical way (in line, for instance, with evidence by Bebczuk et al, 2011). Assessing the impact of changes in international financial conditions is also part of further work to be done.

In Aguirre and Blanco (2013) we looked at forecast performance, showing our estimated model predicts quarterly output growth, annual interest rates and quarterly foreign exchange rate depreciation with significantly higher accuracy than: a conventional "three equation plus UIP" macroeconomic model; and a model with sterilized intervention (but no "financial block)—this was evaluated for 1-, 2- and 4-step out-of-sample forecasts, and using RMSE and MAE forecast evaluation criteria. We also looked at whether macroprudential policy helped macroeconomic performance in any meaningful way during the estimation period. Here we advance further in this kind of evaluation, considering the aggregate volatility of macroeconomic and financial system variables.

Just as previous results show that macroeconomic volatility is reduced when foreign exchange intervention is implemented in addition to interest rate rules (Escudé, 2009; Aguirre and Grosman, 2010), we find that capital requirements may affect not only solvency or liquidity conditions, but also macroeconomic variables at large; over and above their strictly prudential role, they contribute to desirable cyclical macroeconomic property—smoothing output, price, interest rate and credit volatility over the business cycle. This is found when comparing fully estimated models with alternative capital adequacy rules during the 2003-2011 period. These results suggest that the interaction of monetary policy, foreign exchange intervention and prudential tools is, an a way, synergic; they enhance the findings of Agenor and Pereira da Silva (2013), who point out that for the sake of macroeconomic and financial stability, monetary and macroprudential policy are largely complementary; and illustrate the conclusion of Cecchetti and Kohler (2014), for whom the linkages between monetary policy and macroprudential tools open the way for the improvement of both macroeconomic and financial system performance. Our findings extend such notions in a possible sequence of availability of tools: from interest rates to foreign exchange intervention and capital requirements, more tools at the disposal of a central bank may help reduce volatility.

Thus, the discussion may not be so much between interest rate and macroprudential measures as complements or substitutes; instead, the question is whether counting on a larger set of tools helps the central bank achieve more desirable outcomes in terms of policymakers' preferences or objectives. Here, our findings are in line with the literature developed so far, which appears to point toward a positive answer—qualified, of course, by the different analytical settings and actual experiences on which each study has been developed. Even within the limitations of small structural models for simulation exercises, in our assessment results suggest a likely role for regulation of the financial system in dampening macroeconomic fluctuations in a developing economy like Argentina.

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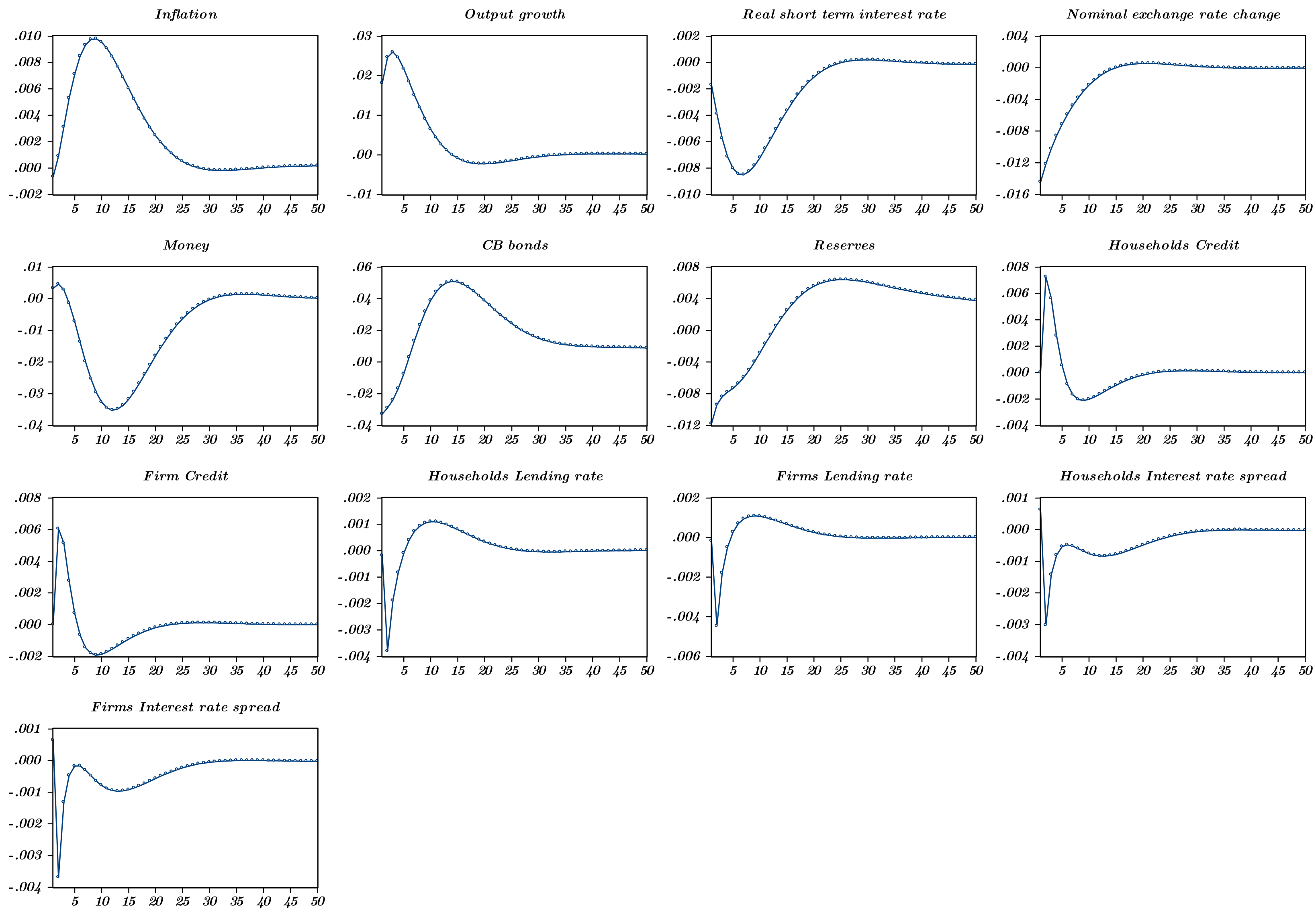
Annex 1. Description of variables and data sources

Table A.1

Variable	Description	Source
g^y	GDP growth seasonally adjusted, 1993 base year series	National accounts (INDEC)
π	Inflation, change in consumer price index and in composite index (wages and wholesale prices)	INDEC
i	Domestic passive interest rate - fixed term deposits in AR pesos, 30-59 day maturity	Central Bank of Argentina
π^*	Foreign inflation,changes in: average main commercial partners US, Brazil and Euro-zone CPI	FRED and Bloomberg
i^*	Foreign interest rate - USD Libor, 3 months	Bloomberg
δ	Bilateral exchange rate depreciation (US dollar, AR pesos)	Bloomberg
m	Money: currency in circulation in AR peso million as a percentage of GDP	Central Bank of Argentina
res	International reserves: in USD millions as a percentage of GDP	Central Bank of Argentina
sf	Fiscal surplus: revenues minus spending (primary)	Ministry of Economy
$e^{US,R}$	nominal exchange rate US dollar, BR real	Bloomberg
$e^{US,E}$	nominal exchange rate US dollar, euro	Bloomberg
CR	Credit: Ratio of non financial private sector credit (Households and Firms) to GDP	Central Bank of Argentina
CR^H	Household Credit: Pledge lending, Personal loans, Private securities and Accrued resources on loans in domestic and foreign currency (as a ratio to GDP)	Central Bank of Argentina
CR^F	Firm Credit: Overdrafts and Discounts loans in domestic and foreign currency (as a ratio to GDP)	Central Bank of Argentina
i^{act}	Interest rates on loans granted to the non-financial private sector - avg. $i^{act,H}$ and $i^{act,F}$	Central Bank of Argentina
$i^{act,H}$	Interest rates on Pledge lending, Personal loans, Private securities and Accrued resources on loans granted to the non-financial private sector	Central Bank of Argentina
$i^{act,F}$	Interest rates on Overdrafts and Discounts loans granted to the non-financial private sector	Central Bank of Argentina
$Delinq$	Non performing loans as a percentage of non-financial private sector credit	Central Bank of Argentina
CAR	Tier 1 capital compliance / Risk weighted assets (financial system)	Central Bank of Argentina

Annex 2. Accumulated responses to 1 s.d. shock to the IS curve



Annex 3. Parameter estimates of alternative models

Table A.2. *Models 2-5: Posterior means*

	No CAR	Exogenous CAR	Endogenous CAR *output gap*	Endogenous CAR *credit gap*	Endogenous CAR *credit spread*
α_1	0.264	0.215	0.184	0.206	0.243
α_3	0.078	0.032	0.035	0.009	0.063
α_4	0.065	0.141	0.071	0.073	0.075
β_1	0.526	0.323	0.445	0.356	0.353
β_2	0.397	0.459	0.383	0.493	0.346
β_3	0.136	0.217	0.156	0.172	0.150
β_4	0.109	0.158	0.145	0.265	0.164
β_5	0.113	0.166	0.128	0.110	0.206
β_6	0.123	0.260	0.311	0.268	0.374
ρ_1	0.937	0.962	0.962	0.968	0.960
ρ_2	0.741	0.709	0.813	0.516	0.370
ρ_3	0.320	0.364	0.307	0.315	0.223
ρ_4	0.972	0.962	0.968	0.984	0.971
ρ_5	0.711	0.905	0.912	0.928	0.851
ρ_6	0.658	0.220	0.363	0.253	0.166
γ_1	0.573	0.626	0.616	0.898	0.556
γ_2	0.021	0.013	0.009	0.039	0.033
γ_3	0.025	0.024	0.030	0.019	0.028
γ_4	0.083	0.077	0.088	0.130	0.111
γ_5	0.007	0.005	0.008	0.003	0.008
ω_1	5.911	5.595	5.948	6.196	5.698
ω_2	0.008	0.010	0.010	0.007	0.010
ω_3	0.178	0.240	0.100	0.148	0.098
η_1	1.203	0.952	0.988	1.002	0.960
η_2	0.553	0.692	0.621	0.765	0.618
η_3	0.031	0.027	0.028	0.029	0.024
η_4	0.665	0.738	0.744	0.478	0.662
κ_1	0.982	0.976	0.978	0.987	0.973
κ_2	0.138	0.128	0.065	0.106	0.071
A_1^H	0.401	0.377	0.437	0.335	0.399
A_2^H	0.066	0.098	0.058	0.114	0.117
A_3^H	0.379	0.414	0.464	0.446	0.455
B_1^H	0.069	0.099	0.093	0.103	0.079
B_2^H	0.169	0.254	0.201	0.187	0.212
B_3^H	0.228	0.239	0.127	0.243	0.168
B_4^H		0.145	0.230	0.153	0.144
ρ_1^{DH}	0.810	0.819	0.783	0.797	0.812
ρ_2^{DH}	0.472	0.374	0.304	0.339	0.396
A_1^F	0.333	0.385	0.366	0.388	0.325
A_2^F	0.110	0.099	0.059	0.211	0.029
A_3^F	0.410	0.459	0.553	0.377	0.440

Table (Cont.) *Models 2-5: Posterior means*

	No CAR	Exogenous CAR	Endogenous CAR *output gap*	Endogenous CAR *credit gap*	Endogenous CAR *credit spread*
B_1^F	0.018	0.023	0.028	0.031	0.023
B_2^F	0.230	0.244	0.279	0.225	0.220
B_3^F	0.215	0.261	0.162	0.273	0.272
B_4^F		0.134	0.281	0.317	0.186
ρ_1^{DF}	0.912	0.907	0.898	0.890	0.912
ρ_2^{DF}	0.455	0.473	0.316	0.459	0.416
ψ_0		0.011	0.010	0.015	0.011
ψ_1		0.378	0.704	0.587	0.295
ψ_2			0.155	0.025	0.154
ψ_3					0.753

Annex 4. Evaluation of alternative macroprudential rules using estimated models

We present an alternative way of assessing macroprudential policy implemented as different capital adequacy rules. We estimate each model, from 2 to 5, completely, instead of just using the estimated coefficients of model 2 and changing the parameters of equation (31), as shown in section 5.1. Estimated coefficients of models 2-5 are shown in Table A.2. We compute standard deviations of macroeconomic and financial variables under each estimated model, plus model 1. We do the exercise for: inflation, output growth, local short term interest rates, the real trilateral (trade-weighted) exchange rate, money growth, international reserves, credit (total and by line), lending interest rates (average and by credit line), non performing loans (by credit line) and capital requirements. The comparison in Table A3 suggests the lowest volatility during the estimation period under an endogenous capital requirement (output gap, model 3) for the following variables: international reserves, average, consumption and commercial lending interest rates, and consumption non-performing loans. In turn, capital requirements as a function of interest rate spreads (model 5) deliver lower growth, deposit interest rate, money growth and commercial non-performing loans than alternative policies. When capital adequacy is implemented based on the credit-to-GDP gap (model 4), it shows the lowest variability for inflation, real exchange rate depreciation and capital requirements. An "exogenous" CAR (model 2) delivers the lowest standard deviations of average and commercial credit. Finally, using no capital requirements but monetary and foreign exchange policy (model 1) is associated to the lowest variability of consumption credit.

In addition, as in section 5.1, we also compute ad-hoc loss functions, aggregating volatility of selected variables associated to each type of macroprudential policy (table A.4). When all variables are given equal weight (panel a), CAR as a function of interest rate spread is linked to the lowest volatility when output growth, inflation and interest rates are included; if, however, we consider a larger set of variables in the loss functions, (with the exchange rate and credit market variables), then an "exogenous" CAR formulation yields lower volatility. The latter rule also delivers lower volatility than the alternatives when both macroeconomic (including the exchange rate) and financial system variables are considered; this applies to both higher weights on macroeconomic variables (panel b) and on financial variables (panel c). However, when only growth, inflation and interest rates are arguments of the loss function, we find that the lowest volatility is obtained in three of four specifications under a CAR that depends on interes rate spread.

Compared to the results of section 5.1, aggregate volatility here is more frequently associated to an "exogenous" rule; this seem, to some extent, driven by the inclusion of the the exchange rate and of credit. That a rule that is not a function of cyclical conditions yields a better result may have to do with the fact that it was such type of rule that was in place during the estimation period; or with the relatively low impact of shocks from the financial system to the macroeconomy than otherwise (see the discussion in section 5.1). In any case, this alternative evaluation suggests the robustness of the finding that implementation of some type of macroprudential policy is beneficial in terms of macroeconomic volatility reduction.

Table A.3 : *Observed and estimated standard deviations of selected variables*

	Model 1	Model 2	Model 3	Model 4	Model 5
	Baseline	Exogenous CAR	Endogenous CAR (y)	Endogenous CAR (cred)	Endogenous CAR (spread)
π	0.058	0.031	0.033	0.029	0.037
i	0.013	0.012	0.013	0.020	0.011
g^y	0.057	0.047	0.059	0.061	0.042
e^{tri}	0.096	0.057	0.073	0.045	0.073
m	0.220	0.184	0.193	0.151	0.134
res	0.550	0.507	0.503	0.661	0.608
CR	0.262	0.239	0.252	0.277	0.252
CR^H	0.128	0.137	0.144	0.141	0.137
CR^F	0.224	0.191	0.196	0.232	0.208
i^{act}	0.017	0.016	0.013	0.020	0.017
$i^{act,H}$	0.018	0.019	0.014	0.021	0.018
$i^{act,F}$	0.018	0.015	0.015	0.021	0.018
$Delinq^H$	0.115	0.076	0.069	0.082	0.069
$Delinq^F$	0.197	0.157	0.129	0.176	0.128
CAR		0.015	0.032	0.013	0.035

Table A.4: *Loss Functions of alternative models*

Variables Considered in Loss Function	*Model 1* Baseline	*Model 2* Exogenous CAR	*Model 3* Endogenous CAR (y)	*Model 4* Endogenous CAR (cred)	*Model 5* Endogenous CAR (spread)
a) Equal weights $\left(\omega = \frac{1}{n}\right)$					
g^y, π	0.0066	0.0032	0.0045	0.0046	**0.0031**
g^y, i^{act}	0.0036	0.0025	0.0036	0.0042	**0.0020**
g^y, π, i^{act}	0.0069	0.0035	0.0047	0.0050	**0.0034**
$g^y, \pi, i^{act}, e^{tri}$	0.0161	**0.0068**	0.0100	0.0071	0.0087
g^y, π, i, i^{act}	0.0071	0.0036	0.0049	0.0055	**0.0035**
g^y, π, i, CAR	0.0068	**0.0036**	0.0057	0.0052	0.0044
$g^y, \pi, i, e^{tri}, CR^H$	0.0324	**0.0254**	0.0308	0.0270	0.0273
$g^y, \pi, i, e^{tri}, CR^F$	0.0659	**0.0430**	0.0483	0.0609	0.0518
$g^y, \pi, i, e^{tri}, CR^F, CAR$		**0.0432**	0.0493	0.0611	0.0531
$g^y, \pi, i^{act}, e^{tri}, CR^H$	0.0325	**0.0256**	0.0308	0.0270	0.0276
$g^y, \pi, i^{act}, e^{tri}, CR^F$	0.0661	**0.0431**	0.0483	0.0609	0.0520
b) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \omega^{e^{tri}} = \frac{4}{15}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{1}{15}$					
$g^y, \pi, i, e^{tri}, CR^H$	0.0053	**0.0030**	0.0040	0.0031	0.0035
$g^y, \pi, i, e^{tri}, CR^F$	0.0076	**0.0042**	0.0052	0.0054	0.0051
$g^y, \pi, i, e^{tri}, i^{act,H}$	0.0043	**0.0018**	0.0026	0.0018	0.0023
$g^y, \pi, i, e^{tri}, i^{act,F}$	0.0042	**0.0017**	0.0026	0.0018	0.0023
c) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \frac{5}{12}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{1}{12}$					
$g^y, \pi, , i, i^{act,H}$	0.0028	0.0014	0.0019	0.0020	**0.0013**
$g^y, \pi, i, i^{act,F}$	0.0028	0.0014	0.0019	0.0020	**0.0013**
d) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \frac{2}{15}$ and $\omega^{e^{tri}} = \frac{1}{15}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{5}{15}$					
$g^y, \pi, i, e^{tri}, CR^H$	0.0070	**0.0070**	0.0080	0.0075	0.0071
$g^y, \pi, i, e^{tri}, CR^F$	0.0182	**0.0128**	0.0138	0.0188	0.0153
$g^y, \pi, i, e^{tri}, i^{act,H}$	0.0017	**0.0008**	0.0011	0.0010	0.0009
$g^y, \pi, i, e^{tri}, i^{act,F}$	0.0017	**0.0008**	0.0011	0.0010	0.0009
e) Weights: Macro variables $\omega^{g^y} = \omega^{\pi} = \frac{1}{12}$; *Financial variables* $\omega^{i} = \omega^{i^{act,H}} = \omega^{i^{act,F}} = \frac{5}{12}$					
$g^y, \pi, i, i^{act,H}$	0.0008	0.0005	0.0005	0.0007	**0.0004**
$g^y, \pi, i, i^{act,F}$	0.0008	**0.0004**	0.0005	0.0007	0.0004