Monetary and macroprudential policy mix: An institution-design approach*

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Abstract

In this paper, we investigate an implementable design for macroprudential policy in an open economy model with nominal rigidities and financial frictions. We look for transparent and accountable objectives that guide the macroprudential authority, and that promote consumers' welfare given aggregate shocks. We evaluate three mutually exclusive mandates: credit growth, output growth, and credit spreads. Given an objective, the macroprudential authority then choose its policy rule to minimize its loss function. We find that the output growth mandate is welfare superior to the other two candidates in closed and open economy settings, although the welfare gains are small.

Keywords: Welfare costs, Financial Frictions, Macroprudential Policy Design
JEL Classification: E44, E52, E59

1 Introduction

The costs of the global financial crisis has brought a heated debate on the design of macroprudential policy. This discussion transpires in a world in which the operational objectives for the monetary authority to attain price stability are well established (e.g., adopt an explicit or implicit inflation target, or limit the volatility of consumer prices). In contrast, similar operational objectives are ambiguous on the discussion of an optimal design for macroprudential policy (see Angelini, Neri and Panetta, 2014). It is understood that a fine macroprudential policy should address a regulatory gap on the supervision and control of systemic risk in financial markets, such as it limits the risk of financial disruptions that affect the functioning of the economy as a whole (see FSB, IMF and BIS, 2011). Consequently, some economies have built new institutions to host a macroprudential

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authority, while others have enlarged the mandate of their central banks.[1] However, there is not yet a consensus about the operational objectives that a macroprudential authority should follow to insulate the real economy from financial instability.

In the debate, we can characterize two kinds of macroprudential policies: those that are preventive (e.g., banks stress tests, re-balance of risk-weighted assets), and those that can be adjusted over time (see International Monetary Fund, 2011). Concerning preventive policies, researchers on banking regulation has studied mechanisms that discourage excessive risk taking behavior by financial intermediators. Regarding dynamic policies, the literature has recently focused on reaction functions for macroprudential instruments (e.g., bank capital requirement, loan-to-value ratios), and on the interaction between these macroprudential rules and monetary policy.[2] For instance, Beau et al. (2012) identify circumstances in which monetary and macroprudential policies may enter in conflict to attain both price stability and low credit volatility.[3] Similarly, Angelini et al. (2014) study the interaction between these policies assuming coordination and no coordination games, and find that macroprudential policy helps to moderate aggregate fluctuations in face of financial shocks.[4] In any case, the success of a macroprudential rule should be measured to the extent it helps consumers to attain a higher welfare. So a natural objective for the macroprudential authority is to maximize welfare, and then choose a policy rule compatible with the objective.[5] However, this solution is not quite useful in practice because welfare is not observable, and it cannot work as an operational, or transparent, objective for a macroprudential authority.

In this paper, we intend to fill this gap by asking which operational objectives, compatible with welfare maximization, should the macroprudential authority follow to set a dynamic response of its instruments in face of aggregate shocks. Since we are looking for a policy design that is implementable on actual economies, we focus on objectives that are clear, feasible, and accountable. We thus ask whether the authority should focus on the stabilisation of indicators of the credit

[1] On 2010, the European Union created the *European Systemic Risk Board*, and the United States established the *Financial Stability Oversight Council*. In the same vein, the Bank of England incorporated an independent *Financial Policy Committee* in 2013.

[2] See Angelini et al. (2014), Beau, Clerc and Mojon (2012), De Paoli and Paustian (2013), Kannan, Rabanal and Alasdair (2012), Quint and Rabanal (2014), among others

[3] A potential conflict may appear because the two policies influence interest rates, credit, and asset prices, and so they can mutually affect their transmission mechanisms. Using an estimated DSGE model for the Euro Area with financial frictions, Beau et al. (2012) suggest that episodes of conflict are rare, and hence a macroprudential rule display a limited or a stabilizing effect on inflation, provided that the rule effective offsets the transmission of financial shocks to the real economy.

[4] These results echo the findings of Kannan et al. (2012), who using a DSGE model with housing and a financial accelerator, show that a macroprudential policy rule provide helps to stabilize the economy after financial shocks. However, if the shock affecting the economy is a productivity shock using macroprudential policy to counter the expansion of credit would decrease welfare.

[5] This is the approach taken by Quint and Rabanal (2014), who estimate a DSGE model for the Euro Area and find optimal simple rules for their macroprudential instrument.

market, or real activity, or a combination of them, in order to promote a higher welfare on average, given the stochastic environment of the economy. From the normative perspective, the first best solution is to adopt Ramsey rules for the policy instruments that maximize welfare. However, the Ramsey approach is model dependent and quite vulnerable to omissions (see Williams, 2003). And even if welfare would be observable, Ramsey policies are too complex to explain to the public. In contrast, a quantifiable objective with a simple policy rule would facilitate and guide the actions of the macroprudential authority. We are looking thus for transparent policies that enhances accountability and which sets policy in a systematic way, easy to understand to the public.[6]

We proceed as follows. We expand an open economy *á la* Adolfson, Lasen, Lind and Villani (2007) with the banking intermediation structure of Gerali, Neri, Sessa and Signoretti (2010). The model economy thus features nominal rigidities, incomplete real exchange rate pass-through, a banking sector with stochastic bank capital, sluggish lending and deposit rates, and collateral constraints on borrowing, as in Iacoviello (2005).[7] The monetary authority chooses the parameters of its policy rate reaction function to minimize the discounted losses derived from deviations of inflation from its target.[8] In a first stage, we assume the central bank is the incumbent authority and sets its policy under a scenario with no macroprudential policy rule. Then, taking the incumbent's policy as given, the macroprudential authority picks the parameters of its policy rule to minimize the loss function associated with its objective. We evaluate the outcomes of three rival and mutually exclusive macroprudential objectives: credit growth, output growth, and a target credit spread. Then, we assess which one of them is associated with the highest welfare.[9] Finally, we check whether the monetary authority has any incentive to choose different parameters given the newly set macroprudential rule. We perform this exercise for both the closed and open economies. Our interest is to screen the welfare gains that a dynamic macroprudential rule may bring about in the two economies. So far, we have focused on the bank capital requirement ratio as the macroprudential instrument, but we intend to include a rule for the loan-to-value ratio in future versions.

Our results, yet incomplete and preliminary, are the following. First, the welfare gains associated with adding a dynamic rule for the bank capital requirement are small in both the open economy and the closed economy. This is the case even if one considers full coordination between policies, where a benevolent social planner sets optimal simple rules for the central bank and the macroprudential authority to maximize welfare. Second, the macroprudential authority performs best

[6] We are also aware that there might be coordination problems between the monetary and the macroprudential authorities leading to suboptimal outcomes, and our approach will take this possibility into account.

[7] The model specifics are displayed on Section 2.

[8] The loss function of the central bank contains only an inflation motive, but we intend to consider also a measure of activity and lagged interest rate for the next version of the paper.

[9] It should be noted that, given the complexity of the model economy, none of the loss functions considered here correspond to the welfare function. The differences are intentional, as we are looking for implementable policies with clear objectives.

to improve welfare if it focus on output growth, and not any of the two other measures of the credit market. This result should be taken with caution, because the welfare gains from using a dynamic macroprudential rule are not large. And third, in the open economy, the three candidate objectives for the macroprudential authority proposed herein are not welfare enhancing, which calls for alternative candidate objectives than those proposed for the closed economy. It should be noted that a battery of exercises is still pending, and the present findings reflect the state of our work.

The broad objective of macroprudential policy is to reduce the risks and costs of systemic crisis (see Galati and Moessner, 2013; BIS, 2010). The specific objectives are twofold: to limit the excessive lending to the private sector and to reduce the cyclical behavior of the economy,(Angelini, Neri and Panetta, 2012). In this paper, we consider three possible objectives for the macroprudential policy, but there can be others. In terms of macroprudential instruments, Galati and Moessner (2013) highlight capital requirements, loan-to-value ratios, and loan loss provisions. The approach we take in this paper closely follows the one in Angelini et al. (2012) and Angelini et al. (2014), who use the DSGE model developed by Gerali et al. (2010) to analyze the strategic interaction between monetary policy and macroprudential authorities. They consider a case of cooperation, where the same policymaker minimizes a the loss function of a common objective function, and a non-cooperative case in which each authority minimize its own objective, taking the other policy as given. The authors suggest that macroprudential policy generates modest benefits for macroeconomic stability (not only price stability as in the case of Beau et al. (2012)) when the economy is driven mainly by supply shocks. The benefits become large when financial shocks are important drivers of macroeconomic fluctuations. Moreover, in both scenarios, policy coordination is preferable since it provides more stability in the policy instruments. Our work differs from that of Angelini et al., because we focus on the design of an implementable policy and set a horse race among different objectives. In contrast, Angelini et al. fix the macroprudential objective and focus on the benefits of cooperation. De Paoli and Paustian (2013) also study the way in which monetary and macro prudential authorities should coordinate in order to minimize the social costs of macroeconomic fluctuations, and find that introducing a macroprudential tool improves welfare regardless the type of shock driving economic fluctuations. De Paoli and Paustian consider a simpler framework, without a banking sector, in which the authorities loss function coincides with the utility-based welfare criterion. However, this correspondence is no so simple when one considers more complex models, as the one used in central banks and that are fitted to the data. In contrast with their work, we aim at policy objectives that can be clearly implemented.

This is still a work in progress. Regarding the model, in the near future we plan to add two features. First, we want to introduce a borrowing constraint when the entrepreneurs borrow from abroad. Second, we intend to add a very stylized foreign economy to be able to study shocks from abroad. With respect to the policy analysis, there are different aspects that we want to further look at. Firstly, we are interested on looking at different instruments for the macroprudential policy, in particular the loan-to-value ratio of the entrepreneurs. We believe that this policy is more transparent to implement than a capital-to-asset ratio. Secondly, we need to add the deviations from the output growth in the loss function of the central bank and study different combinations for the macroprudential authority. Thirdly, we have to study the consumption equivalent behavior for a broader set of macroprudential parameters and a smaller set for the Taylor rule ones. Fourth, we are interested on looking at an augmented Taylor rule, i.e. the central bank has financial stability on its mandate. Lastly, we have to estimate the model for Mexican data to have more accurate results of the policy implications.

2 Model

We build on the work of Gerali et al. (2010) and extend their model to an open economy à la Adolfson et al. (2007) and Christiano, Trabandt and Walentin (2011).The model results in a small open economy with financial frictions. The economy is populated by a continuum of two types of agents: (patient) households and (impatient) entrepreneurs. Households consume, supply labor to intermediate goods producers, and make deposits to domestic banks. Entrepreneurs derive utility from consumption and in order to finance it, they rent capital to domestic intermediate goods producers, and take loans from domestic and foreign banks. Although entrepreneurs are constrained on how much they can borrow from domestic banks, they are not constrained on borrowing from foreign banks.

Domestic intermediate firms choose capital and labor to maximize profits in a competitive environment. There are domestic, importing, and exporting firms. They all produce differentiated goods and set prices à la Calvo (1983). As in the previous literature, the introduction of nominal rigidities in the importing and exporting sectors allow for short-run incomplete exchange rate pass-through to both import and export prices. There are three final goods: consumption, investment, and exports. The first two, consumption and investment goods, are produced by combining domestic and imported goods. Households and capital good producers combine the two goods to generate the basket.

Capital goods producers buy the capital goods undepreciated from entrepreneurs, as well as a domestic and imported final goods (that the combine to generate the investment basket), to transform it into new capital. They face investment adjustment costs à la Christiano, Eichenbaum and Evans (2005).

The economy also features a banking system which intermediates resources between households and entrepreneurs. Financial intermediaries receive the deposits made by households. The funds are captured by the deposit branch of the bank. They receive the differentiated deposits, aggregate them and sale them to the wholesale bank. The wholesale bank combines retained earnings, or bank capital, with the deposits and makes loans to the loan branch of the bank. Then, the loan branch differentiates them at no cost and sells them to entrepreneurs. The wholesale bank operates in a competitive setup while the retailers (deposit and loan branch) are monopolistic competitive. These branches set up the interest rates so as to maximize profits. Moreover, there are quadratic costs for adjusting retail rates, prompting sticky interest rates.

Below we describe the main characteristics of the model. In Appendix **??** we derive all the equations with more detail.

2.1 Households

Households are indexed by i, where $i \in [0,1]$. Each household chooses consumption, $c_t^P(i)$, labor, $l_t(i)$, and domestic deposits, $d_t(i)$, in order to maximize its discounted lifetime utility. Consumption is a bundle of imported and domestic final goods. The household i's optimization problem reads

$$\max_{c_t^P(i),l_t(i),d_t(i)} E_t \sum_{t=0}^{\infty} \beta_P^t \Big\{ \epsilon_t^z \left(1-h^P\right) \frac{\left[c_t^P(i) - h^P c_{t-1}^P\right]^{1-\sigma_c}}{1-\sigma_c} - \epsilon_t^l \frac{\left[l_t(i)\right]^{1+\phi}}{1+\phi} \Big\}, \tag{1}$$

subject to a sequence of budget constraints in real terms

$$c_t^P(i) + d_t(i) \leq w_t l_t(i) + \frac{1+r_{t-1}^d}{\pi_t} d_{t-1}(i) + \Pi_t^P(i) \ \forall t,$$

where w_t is the real wage, r_t^d is the nominal interest rate associated with domestic deposits, and π is the domestic rate of inflation. Patient households own the retailers firms in the economy and the banks, therefore they use their dividends, $\Pi_t^P(i)$, labor income, $w_t l_t(i)$, and the return on deposits made last period to pay for consumption and new deposits.

Notice that we assume external habits on consumption, where h^P denotes the degree of habit persistence. ϵ_z and ϵ_l are preference exogenous shocks processes for consumption and labor, respectively. The intertemporal elasticity of substitution of consumption goods is σ_c, while the inverse of the Frisch elasticity of labor supply is ϕ.

The first order conditions of the model are standard and we derive them in Appendix **??**.

Maximization of the consumption bundle Households consume domestic and imported final goods, so aggregate consumption is given by a constant elasticity of substitution index of domestic and imported goods. To obtain the demands for each good, households solve the problem given by:

$$\max_{c_{H,t}^P, c_{F,t}^P} \left[\nu_c^{\frac{1}{\eta_c}} \left(c_{H,t}^P\right)^{\frac{\eta_c-1}{\eta_c}} + (1-\nu_c)^{\frac{1}{\eta_c}} \left(c_{F,t}^P\right)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c-1}}$$

$$\text{s.t.} \qquad P_t^c c_t^P = P_t c_{H,t}^P + P_t^{f,c} c_{F,t}^P.$$

The demands for each of the goods result in

$$c_{H,t}^P = \left(\frac{P_t}{P_t^c}\right)^{-\eta_c} \nu_c c_t^P \quad \text{and} \quad c_{F,t}^P = \left(\frac{P_t^{f,c}}{P_t^c}\right)^{-\eta_c} (1-\nu_c)\, c_t^P.$$

2.2 Entrepreneurs

Entrepreneurs receive utility only from consumption, $c_t^E(i)$. The discount factor, β_E, is lower than the discount factor for patient households, β_P, so in the neighborhood of the steady state entrepreneurs are net borrowers. They buy capital k_t from capital good producer and rent it to domestic intermediate good producers. Also, entrepreneurs demand loans to finance their expenditures. The loans can be domestic, b_t, or from abroad, f_t. The problem of the entrepreneur i is to

$$\max_{c_t^E(i),k_t(i),f_t(i),u_t(i)} E_t \sum_{t=0}^{\infty} \beta_E^t \frac{\left[c_t^E(i) - h^E c_{t-1}^E\right]^{1-\sigma_E}}{1-\sigma_E}. \tag{2}$$

They face three constraints. The first one is their budget constraint

$$c_t^E(i) + \frac{1+r_{t-1}^b}{\pi_t} b_{t-1}(i) + \frac{1+r_{t-1}^f}{\pi_t^*} q_t f_{t-1}(i) + q_t^k k_t(i) + \psi\left[u_t(i)\right] k_{t-1}(i) =$$
$$r_t^k u_t\left(i\right) k_{t-1}\left(i\right) + b_t(i) + q_t f_t(i) + q_t^k (1-\delta) k_{t-1}(i),$$

where with new loans and the return on capital lent last period they have to buy final goods to consume, pay the loans that they took last period, buy new capital, and pay for the capital utilization rate. The real exchange rate is q_t and is equal to $\frac{e_t P_t^*}{P_t}$.

The second and third constraints are the borrowing constraints. Entrepreneurs borrow from domestic banks up to certain level of their stock of capital, this level is the loan-to-value ratio given by m,

$$(1+r_t^b) b_t(i) \leq m E_t \left[q_{t+1}^k \pi_{t+1} (1-\delta) k_t(i)\right]. \tag{3}$$

Entrepreneurs might or might not be constrained on borrowing from abroad. If they are, they face the following restriction

$$(1+r_t^f) q_t f_t(i) \leq m^* E_t \left[q_{t+1}^k \pi_{t+1} (1-\delta) k_t(i)\right],$$

that is equivalent to Equation (3), with $m^* \neq m$. The constrains are modeled as in Iacoviello and Neri (2010) and Iacoviello (2004), and bind in the neighborhood of the steady state. We first assume a model where entrepreneurs are not restricted on how much they can borrow from abroad, and they we include this constraint.

Following Schmitt-Grohé and Uribe (2005), the capital utilization is

$$\psi[u_t(i)] \quad = \quad \psi_1(u_t - 1) + \frac{\psi_2}{2}(u_t - 1)^2.$$

We assume that the interest rate that entrepreneurs pay for foreign loans, r_t^f, is the exogenous foreign interest rate, r^*, times a risk premium faced by the small economy, that depends on the real foreign debt level to GDP, as in Schmitt-Grohé and Uribe (2003),

$$r_t^f \quad = \quad r^* \exp\left[\varrho\left(\frac{f_t}{gdp_t} - \frac{f^*}{gdp}\right)\right] \epsilon_{\phi,t},$$

where $\epsilon_{\phi,t}$ is an exogenous shock.

2.3 Loan and Deposit Demand

To model market power in the banking sector, we assume a Dixit-Stiglitz aggregator for the retail credit and deposit markets. The deposits bought by households and the loans bought by entrepreneurs are a composite constant elasticity of substitution basket of slightly differentiated product, supplied by a branch of a bank j. The elasticity terms are ϵ_t^d (< -1) and ϵ_t^b (> 1), respectively. We assume that these terms are stochastic, there is an exogenous component in the credit market spreads. These innovations can be understood as innovations to bank spreads independent of monetary policy.

Entrepreneur i demands $\bar{b}_t(i)$ of real loans that is derived from a minimization problem of the CES Dixit-Stiglitz bundle aggregator. The demand for loans results in

$$b_t(j) = b_t \left[\frac{r_t^b(j)}{r_t^b}\right]^{-\epsilon_t^b},$$

where $r_t^b \equiv \left\{\int_0^1 \left[r_t^b(j)\right]^{1-\epsilon_t^b} dj\right\}^{\frac{1}{1-\epsilon_t^b}}$.

The demand for deposits of household i is defined in a similar way, and after solving the optimization problem yields

$$d_t(j) = d_t \left[\frac{r_t^d(j)}{r_t^d}\right]^{-\epsilon_t^d}$$

with $r_t^d \equiv \left\{\int_0^1 \left[r_t^d(j)\right]^{1-\epsilon_t^d} dj\right\}^{\frac{1}{1-\epsilon_t^d}}$.

2.4 Producers

As explained above, there are different types of producers. There are two final goods producers: capital producers and final goods producers. Then, there are four type of retailers: domestic, consumption importing, investment importing, and exporting.

2.4.1 Capital good producers

Capital good are produced by firms operating in a competitive market. They sell capital at price $q_t^k \equiv Q_t^k/P_t$, where P_t is the price of the final good. Each period, capital producers use undepreciated capital, $(1-\delta)k_{t-1}$, from entrepreneurs and an amount i_t of the final good as inputs for the production of capital. Also, capital producers incur in adjustment costs. Then, the capita good producer problem is given by:

$$\max_{i_t} E_t \sum_{t=0}^{\infty} (\beta_E)^t \frac{\lambda_t^E}{\lambda_0^E} \Big(q_t^k \left(k_t - (1-\delta)k_{t-1}\right) - p_t^i i_t\Big)$$

$$\text{s.t.} \quad k_t = (1-\delta)k_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{i_t \epsilon_t^{qk}}{i_{t-1}} - 1\right)^2\right] i_t \tag{4}$$

where $p_t^i \equiv \frac{P_t^i}{P_t}$, and is the price of the investment bundle. The first order condition is

$$(q_t^k - p_t^i) + q_t^k \left[-\frac{\kappa_i}{2} \left(\frac{i_t \epsilon_t^{qk}}{i_{t-1}} - 1 \right)^2 \right] - q_t^k \frac{i_t}{i_{t-1}} \epsilon_t^{qk} \kappa_i \left(\frac{i_t \epsilon_t^{qk}}{i_{t-1}} - 1 \right)$$
$$+ \beta_E E_t \frac{\lambda_{t+1}^E}{\lambda_0^E} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} \right)^2 \epsilon_{t+1}^{qk} \left(\frac{i_{t+1} \epsilon_{t+1}^{qk}}{i_t} - 1 \right) = 0.$$

Investment is a bundle of domestic and imported final goods. The problem is solved next.

Cost minimization of investment bundle Aggregate investment is assumed to be a CES index of imported and domestic final goods. Then, the capital goods producers face the next problem in order to obtain the demands for each investment good:

$$\max_{i_{H,t}, i_{F,t}} \left[\nu_i^{\frac{1}{\eta_i}} (i_{H,t})^{\frac{\eta_i - 1}{\eta_i}} + (1 - \nu_i)^{\frac{1}{\eta_i}} (i_{F,t})^{\frac{\eta_i - 1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i - 1}}$$
$$\text{s.t.} \qquad P_t^i i_t = P_t i_{H,t} + P_t^{f,i} i_{F,t}$$

The solution of the optimization problem yields

$$i_{H,t} = \left(\frac{P_t}{P_t^i} \right)^{-\eta_i} \nu_i i_t \quad \text{and} \quad i_{F,t} = \left(\frac{P_t^{f,i}}{P_t^i} \right)^{-\eta_i} (1 - \nu_i) \, i_t.$$

2.4.2 Domestic final good producers

Domestic final good producers buy the differentiated intermediate goods, aggregate them in a homogeneous good by a CES Dixit-Stiglitz technology and sell it at price P_t. The problem for the final good producer is given by:

$$\max_{y_t(j_H)} P_t y_t - \int_0^1 P_t (j_H) \, y_t (j_H) \, dj_H$$
$$\text{s.t.} \;\; y_t = \left[\int_0^1 y_t(j_H)^{\frac{\eta_H - 1}{\eta_H}} dj_H \right]^{\frac{\eta_H}{\eta_H - 1}}.$$

The final good firm takes its output price, P_t, and its input prices $P_t(j_H)$ as given. Profit maximization leads to the following demand for intermediate goods:

$$y_t(j_H) = \left(\frac{P_t(j_H)}{P_t} \right)^{-\eta_H} y_t.$$

Also, we the price of the final good is defined by

$$P_t = \left[\int_0^1 P_t (j_H)^{1 - \eta_H} dj_H \right]^{\frac{1}{1 - \eta_H}}.$$

2.4.3 Domestic intermediate producers

The domestic intermediate goods producers operate in a monopolistic competitive environment. They rent capital goods from entrepreneurs at a rate r_t^k and hire labor from the households at a wage w_t to produce a differentiated good $y_t(j_H)$. The domestic intermediate goods producers have a production function of the form

$$y_t(j_H) = a_t \left[\tilde{k}_t(j_H)\right]^{\alpha} [l_t(j_H)]^{1-\alpha} - \phi,$$

where $\tilde{k}_t = k_{t-1}u_t$ denote capital services.

Cost minimization Domestic intermediate producers minimize their cost of producing a given $\bar{y}_t = \bar{y}$ solving the following problem

$$\min_{l_t, k_t} w_t l_t + r_t^k \tilde{k}_t + mc_t \left[\bar{y} - a_t \tilde{k}_t^{\alpha} l_t^{1-\alpha} + \phi\right],$$

with the rental rate of capital services as r_t^k..From the minimization problem we learn the marginal cost for the intermediate good producer is

$$mc_t = \frac{1}{a_t}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}. \tag{5}$$

Price setting Intermediate good producers differentiate their product j_H and then they sell to the final good producer of y_t. They set prices à la Calvo. In each period, a fraction $(1-\theta_H)$ of intermediate good producers change their price. The rest can only partially adjust the prices following an updating rule, of the form

$$\begin{aligned} P_t(j_H) &= P_{t-1}(j_H)\bar{\pi}^{1-\zeta_H}\pi_{t-1}^{\zeta_H} \\ P_t(j_H) &= P_{t-1}^{new}(j_H)\tilde{\pi}_{t-1,t}, \end{aligned} \tag{6}$$

where

$$\tilde{\pi}_{t,t+\tau} = \begin{cases} \bar{\pi}^{1-\zeta_H}\pi_{t+\tau-1}^{\zeta_H}\tilde{\pi}_{t,t+\tau-1} & \tau > 0 \\ 1 & \tau = 0 \end{cases}$$

Those that re-optimize chose the price according to the following problem

$$\begin{aligned} &\max_{P_t^{new}} E_t \sum_{\tau=0}^{\infty} (\beta_P\theta_H)^{\tau} \frac{\lambda_{t+\tau}^P}{\lambda_t^P}\left\{\frac{\tilde{\pi}_{t,t+\tau}P_t^{new}}{P_{t+\tau}} y_{t+\tau}(j_H) - mc_{t+\tau}\left[y_{t+\tau}(j_H) + \phi\right]\right\} \\ &\text{s.t.} \quad y_{t+\tau}(j_H) = \left(\frac{\tilde{\pi}_{t,t+\tau}P_t^{new}}{P_{t+\tau}}\right)^{-\eta_H} y_{t+\tau}. \end{aligned}$$

2.4.4 Importing good firms

There are two different types of importing firms. One that turns the imported product, a homogeneous good in the world market, into a differentiated consumption good, and another that turns it into a differentiated investment good. The generic problem for the final imported s good, where $s \in \{c, i\}$, i.e. for consumption and investment goods, is

$$\max P_t^{f,s} s_{F,t} - \int_0^1 P_t^{f,s}(j_F)\, s_{F,t}(j_F)\, dj_F$$
$$\text{s.t.} \quad s_{F,t} = \left[\int_0^1 s_{F,t}(j_F)^{\frac{\eta_{F,s}-1}{\eta_{F,s}}} dj_F\right]^{\frac{\eta_{F,s}}{\eta_{F,s}-1}}.$$

The demand for intermediate goods reads

$$s_{F,t}(j_F) = \left(\frac{P_t^{f,s}(j_F)}{P_t^{f,s}}\right)^{-\eta_{F,s}} s_{F,t}$$

and the aggregate price index is:

$$P_t^{f,s} = \left[\int_0^1 P_t^{f,s}(j_F)^{1-\eta_{F,s}} dj_F\right]^{\frac{1}{1-\eta_{F,s}}}$$

Importing firms purchase a homogeneous good from abroad, they differentiate and they sell the goods to consumers and investors. The nominal marginal cost that they face is $e_t P_t^*$, and the real marginal cost in terms of domestic final goods is $q_t = \frac{e_t P_t^*}{P_t}$. To allow for incomplete exchange rate pass-through in the price of imported goods, we assume that import prices are sticky in the local currency by following a Calvo rule setup. The updating rule is $P_t^{f,s}(j_F) = P_t^{f,s,new} \tilde{\pi}_{t,t+\tau}^{f,s}$, where

$$\tilde{\pi}_{t,t+\tau}^{f,s} = \begin{cases} \left(\bar{\pi}^{f,s}\right)^{1-\zeta_F} \left(\pi_{t+\tau-1}^{f,s}\right)^{\zeta_F} \tilde{\pi}_{t,t+\tau-1}^{f,s} & \tau > 0 \\ 1 & \tau = 0 \end{cases}.$$

The generic problem for the importing s sector, where $s \in \{c, i\}$, i.e. for consumption and investment goods, is

$$\max_{P_t^{f,s,new}} E_t \sum_{\tau=0}^{\infty} (\beta_P \theta_{F,s})^\tau \frac{\lambda_{t+\tau}^P}{\lambda_t^P} \left\{ \frac{P_t^{f,s,new} \tilde{\pi}_{t,t+\tau}^{f,s}}{P_{t+\tau}} s_{F,t+\tau}(j_F) - q_{t+\tau}\left[s_{F,t+\tau}(j_F) + \phi_{F,j}\right] \right\}$$
$$\text{s.t.} \quad s_{F,t+\tau}(j_F) = \left(\frac{\tilde{\pi}_{t,t+\tau}^{f,s} P_t^{f,s,new}}{P_{t+\tau}^{f,s}}\right)^{-\eta_{F,s}} s_{F,t+\tau}.$$

2.4.5 Exporting good firms

The demand for total exports demand comes from the problem of the foreign economy and is

$$y_{H,t}^* = \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\eta^*} y_t^*,$$

where $P^*_{H,t}$ is the general price index of exports in terms of foreign currency (local market pricing), $y^*_{H,t}$ is the final exporting good, which is produced by a competitive firm using the technology

$$y^*_{H,t} = \left[\int_0^1 y^*_{H,t}(j^*_H)^{\frac{\eta^*_H-1}{\eta^*_H}} dj^*_H\right]^{\frac{\eta^*_H}{\eta^*_H-1}}.$$

The input specific demands for the the intermediate exporting goods are

$$y^*_{H,t}(j^*_H) = \left(\frac{P^*_{H,t}(j^*_H)}{P^*_{H,t}}\right)^{-\eta^*_H} y^*_{H,t},$$

and the general price index of exports is

$$P^*_{H,t} = \left[\int_0^1 P^*_{H,t}(j^*_H)^{1-\eta^*_H} dj^*_H\right]^{\frac{1}{1-\eta^*_H}}.$$

The intermediate exporters set prices following the Calvo sticky-price setup. With probability $1-\theta^*_H$ they can re-optimize their price, while with probability θ^*_H they cannot. The updating rule is $P^*_{H,t+\tau}(j^*_H) = P^{*,new}_{H,t}\tilde{\pi}^*_{H,t,t+\tau}$, where

$$\tilde{\pi}^*_{H,t,t+\tau} = \begin{cases} (\bar{\pi}^*)^{1-\zeta^*}\left(\pi^*_{t-1}\right)^{\zeta^*}\tilde{\pi}^*_{H,t,t+\tau-1} & \tau > 0 \\ 1 & \tau = 0 \end{cases}.$$

They solve the following problem set in foreign currency terms

$$\max_{p^{*,new}_{H,t}(j^*_H)} E_t \sum_{\tau=0}^{\infty} (\beta_P \theta^*_H)^\tau \frac{\lambda^P_{t+\tau}}{\lambda^P_t}\left\{\frac{P^{*,new}_{H,t}\tilde{\pi}^*_{H,t,t+\tau}}{P^*_{t+\tau}} y^*_{H,t+\tau}(j^*_H) - \frac{P_{t+\tau}}{e_{t+\tau}}\frac{1}{P^*_{t+\tau}}\left[y^*_{H,t+\tau}(j^*_H) + \phi^*_H\right]\right\},$$

$$\text{s.t. } y^*_{H,t+\tau}(j^*_H) = \left(\frac{P^{*,new}_{H,t}\tilde{\pi}^*_{H,t,t+\tau}}{P^*_{H,t+\tau}}\right)^{-\eta^*_H} y^*_{H,t+\tau}.$$

2.5 Financial sector

The model incorporates a banking sector where banks interact in a monopolistically competitive environment. This allows interest rate spreads between the monetary policy and the interest rates that households and entrepreneurs face. Furthermore, in order to capture an incomplete short-run pass-through from movements in the monetary policy interest rate to the other interest rates in the economy we assume sluggish interest rates.

Banks make loans with deposits and net worth, or bank capital. Bank capital builds on retained earnings and they are almost fixed in the short run. Banks have a target level of bank capital. When they deviate from it, they face quadratic costs; this is the capital-to-asset ratio and is also going to be used as a macroprudential policy instrument. When the capital-to-asset ratio is lower than the target, banks can give out more loans. This prompts a positive feedback loop in the real economy.

In this setup we also study shocks coming from the supply side of credit. There are shocks to the loan-to-value ratios of the borrowing constraints, that can be understood as exogenous decrease in loan availability. And there are shocks to the demand elasticities for loans and deposits; this can generate an exogenous increase in loan and deposit rates independently of the economic conditions and the monetary policy interest rate.

We think of a representative bank as having three units: two retail branches and one wholesale unit. The loan retail branch gives out differentiated loans to entrepreneurs. The second retail branch is the deposit unit and receives differentiated deposits. The retailers branches set rates in a monopolistically competitive environment. The wholesale branch manages the capital position of the bank.

2.5.1 Wholesale branch

The wholesale branch operates under perfect competition. With net worth, or bank capital K_t^b, and wholesale deposits, D_t, they issue loans to the retailer loan branch, B_t. The wholesale branch manages the capital position of the bank, and there is a cost when moving the capital position. The bank faces a quadratic cost when the capital-to-asset ratio deviates from the target value, ν_b.

The balance sheet of the bank in real terms is

$$K_t^b + D_t = B_t. \tag{7}$$

And the net worth is accumulated out of retained earnings

$$\pi_t K_t^b = (1 - \delta^b) K_{t-1}^b + j_{t-1}^b, \tag{8}$$

where the profits of all the branches are captured in j^b, and δ^b measures the costs of managing the bank capital.

The problem of the wholesale branch is to maximize the discounted sum of real cash flows by choosing loans and deposits subject to the balance sheet constraint:

$$\begin{aligned} \max_{B_t, D_t} E_t \sum_{t=0}^{\infty} \Lambda_{0,t}^P \Big[& (1 + R_t^b) B_t - B_{t+1}\pi_{t+1} + D_{t+1}\pi_{t+1} - (1 + R_t^d) D_t \\ & + \left(K_{t+1}^b \pi_{t+1} - K_t^b \right) - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - \nu_b \right)^2 K_t^b \Big] \\ & s.t. \quad Equation(7), \end{aligned}$$

where R_t^b and R_t^d are the net wholesale loan and deposit rate, respectively, and the bank takes them as given. Combining the first order conditions we learn about the spread between wholesale rates on loans and on deposits,

$$R_t^b - r_t = -\kappa_{Kb} \left(\frac{K_t^b}{B_t} \right)^2 \left(\frac{K_t^b}{B_t} - \nu_b \right). \tag{9}$$

where we have replaced R_t^d with r_t because, as in the previous literature we assume that banks have access to unlimited finance from the central banks lending facility at policy rate r_t. The left hand side of the last equation is the marginal benefit from increasing lending, while the right hand side is the marginal cost of increasing lending, i.e. the cost of deviating for the capital-to-asset ratio target.

2.5.2 Retail banking

The loan and the deposit branch are the monopolistically competitors of the units of the representative bank.

Loan Branch The loan branch of the bank receives wholesale real loans $B_t(j)$, by paying R_t^b as interest rate, differentiates them at no cost and sells them to entrepreneurs applying a markup. We assume that retailers face a quadratic cost when moving the interest rate over time. The problem of the retail loan branch is to maximize their profits subject to the demand of loans by entrepreneurs:

$$\begin{aligned}
&\max_{r_t^b(j)} \; E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t^b(j) b_t(j) - R_t^b B_t(j) - \frac{\kappa_{kb}}{2} \left(\frac{r_t^b(j)}{r_{t-1}^b(j)} - 1 \right)^2 r_t^b b_t \right] \\
&s.t. \quad Equation(4) \\
&and \quad B_t(j) = b_t(j).
\end{aligned}$$

The first order condition, after imposing a symmetric equilibrium ($r_t^b = r_t^b(j)$), yields

$$\begin{aligned}
&\left[(1 - \epsilon_t^b) + \epsilon_t^b \frac{R_t^b}{r_t^b} \right] - \kappa_{kb} \left(\frac{r_t^b}{r_{t-1}^b} - 1 \right) \frac{r_t^b}{r_{t-1}^b} \\
&+ E_t \beta^P \kappa_{kb} \left[\frac{\lambda_{t+1}^P}{\lambda_t^P} \left(\frac{r_{t+1}^b}{r_t^b} \right)^2 \frac{b_{t+1}}{b_t} \left(\frac{r_{t+1}^b}{r_t^b} - 1 \right) \right] = 0. \qquad (10)
\end{aligned}$$

The last equation shows how the interest rate on loans to entrepreneurs is set as a function of shocks to the markups and the wholesale rate. Note that the discount factor of all the three branches of the bank corresponds to the one from the households; this is the case because households own the banks.

Deposit Branch The retail deposit branch receives funds from households at r_t^j interest rate, differentiate them at no cost and resells them to wholesale banks at the policy interest rate, r_t. As the loan branch, when the deposit branch moves the interest rate over time, they face a quadratic cost. The problem of the deposit branch is to choose the interest rate that maximize the profits subject to the demand of deposits

$$\begin{aligned}
&\max_{r_t^d(j)} \; E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t d_t(j) - r_t^d(j) d_t(j) - \frac{\kappa_{kd}}{2} \left(\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1 \right)^2 r_t^d d_t \right] \\
&s.t. \quad Equation(4) \\
&and \quad D_t(j) = d_t(j).
\end{aligned}$$

Arranging the first order condition and assuming symmetry, $r_t^d = r_t^d(j)$, results in

$$-\epsilon_t^d \frac{r_t}{r_t^d} - (1 - \epsilon_t^d) - \kappa_{kd} \frac{r_t^d}{r_{t-1}^d} \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right) + \kappa_{kd} \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P} \left(\frac{r_{t+1}^d}{r_t^d} \right)^2 \left(\frac{r_{t+1}^d}{r_t^d} - 1 \right) \frac{d_{t+1}}{d_t} \right] = 0$$

Bank Profits The profits of a representative bank come from the three units that it has. Without taking into account intragroup transactions, the profits are the difference between the total loans and deposits from the retailers branches and the total adjustment costs. The adjustment costs correspond to the sum of each of the three branches adjustment costs.

$$j_t^b = r_t^b b_t - r_t^d d_t - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{B_t} - \nu_b \right)^2 K_t^b - \frac{\kappa_{kb}}{2} \left(\frac{r_t^b}{r_{t-1}^b} - 1 \right)^2 r_t^b b_t - \frac{\kappa_{kd}}{2} \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right)^2 r_t^d d_t.$$

2.6 Monetary policy

Monetary policy is standard. The central bank sets the interest rate r_t that depends on the steady state policy rate, the past rate, and the deviation of the inflation with respect to its target and the evolution over time of the output. Also, there is a white noise shock to the policy rate, ϵ_t^r.

$$(1 + r_t) = (1 + r)^{1-\phi_r} (1 + r_{t-1})^{\phi_r} \left(\frac{\pi_t}{\pi} \right)^{\phi_\pi (1-\phi_r)} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_y (1-\phi_r)} \epsilon_t^r. \tag{11}$$

2.7 Macroprudential policy

We use the capital-to-asset target in the wholesale branch of the bank, ν_b, in Equation (9) as the macroprudential instrument. The rule that follow the instrument is similar to the one for the interest rate,

$$\nu_{b,t} = \nu_b^{1-\phi_\nu} \nu_{b,t-1}^{\phi_\nu} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_{\nu,y} (1-\phi_\nu)} \left(\frac{b_t}{b_{t-1}} \right)^{\phi_{\nu,b} (1-\phi_\nu)} \epsilon_t^\nu. \tag{12}$$

The variables to which $\nu_{b,t}$ responds to can be extended to other measures of financial stability, like banking leverage or credit spread. But for now, we restrict our attention to this particular policy rule. There is also a white noise shock to the macroprudential instrument, ϵ_t^ν.

2.8 Market clearing

For intermediate final goods, the production ready to use taking into account price dispersion, Δ_t is

$$y_t = \frac{a_t \tilde{k}_t^{\alpha} l_t^{1-\alpha} - \phi}{\Delta_t}.$$

From the demand side, the production from the above equation is used for

$$y_t = \left(c_{H,t}^P + c_{F,t}^P\right) + c_t^E + \left(i_{H,t} + i_{F,t}\right) + g_t + \left(y_{H,t}^* - c_{F,t}^P - i_{F,t}\right).$$

For total imports, we know that they are, in terms of domestic currency:

$$e_t P_t^* Y_{F,t} \equiv e_t P_t^* C_{F,t}^P + e_t P_t^* I_{F,t} \tag{13}$$

If we write total imports in terms of domestic goods, and taking into account their respective price dispersion, $\Delta_t^{f,c}$ and $\Delta_t^{f,i}$,

$$\begin{aligned} q_t Y_{F,t} &= q_t C_{F,t}^P + q_t I_{F,t} \\ q_t Y_{F,t} &= q_t \Delta_t^{f,c} c_{F,t}^P + q_t \Delta_t^{f,i} i_{F,t}. \end{aligned}$$

Finally, for the exporting sector, we have that total exports are

$$Y_{H,t}^* = \Delta_{H,t}^* y_{H,t}^*. \tag{14}$$

The current account, in real terms becomes

$$f_t q_t = \left(\frac{1 + r_{t-1}^f}{\pi_t^*}\right) f_{t-1} q_t + q_t p_{H,t}^* Y_{H,t}^* - q_t Y_{F,t}.$$

2.9 Welfare and consumption equivalent measures

We introduce welfare in the model to compare the costs of the different policies presented in next section. Welfare is defined as in Schmitt-Grohé and Uribe (2007),

$$V_t = V_t^P + V_t^E,$$

where

$$\begin{aligned} V_t^P &= E_t \left\{ \sum_{j=0}^{\infty} \left(\beta^P\right)^j U^P \left(c_{t+j}^P, l_{t+j}\right) \right\}, \text{ and} \\ V_t^E &= E_t \left\{ \sum_{j=0}^{\infty} \left(\beta^E\right)^j U^E \left(c_{t+j}^E\right) \right\}. \end{aligned}$$

Notice that each consumer type has a different welfare function with their own stochastic discount factor. Recursively, these functions, can be rewritten as

$$V_t^P = U^P\left(c_t^P, l_t\right) + \beta^P V_{t+1}^P \text{ and } V_t^E = U^E\left(c_t^E\right) + \beta^E V_{t+1}^E, \tag{15}$$

where the utility functions are defined in Equation (1) and (2), respectively. Aggregate welfare is thus the sum of the welfare of households and entrepreneurs.

Let $\varrho_k \in \Phi$ denote a set k of policy rules derived from the universe of implementable policies Φ. Thus, the stochastic steady state conditional on policy set ϱ_k is given by

$$V_{ss}\left(\varrho_k\right) = V_{ss}^P\left(\varrho_k\right) + V_{ss}^E\left(\varrho_k\right).$$

where $V_{ss}^{\zeta}\left(\varrho_k\right) = E\left\{V_t^{\zeta}\right\}$ is the unconditional expectation of agent ζ's welfare, for $\zeta \in \{P, E\}$. Following Schmitt-Grohé and Uribe (2007), we measure welfare costs associated with policy set ϱ_k as a percetage ω^{ζ} of a reference level of consumption. In particular, ω^{ζ} represents a consumption cost that makes agent ζ indifferent between the reference environment and the induced by policy set ϱ_k. For households, ω^P is given by

$$V_{ss}^P\left(\varrho_k\right) = V^P\left(\left(1-\omega^P\right)c_{ref}^P, l_{ref}\right),$$

where the subindex ref denotes variable levels at the reference steady state. Solving for ω^P yields[10]

$$\omega^P = 1 - \exp\left\{\left(1-\beta^P\right)\left[V_{ss}^P\left(\varrho_k\right) - V^P\left(c_{ref}^P, l_{ref}\right)\right]\right\}.$$

Our reference for welfare is the one achieved by a benevolent social planner that sets optimally the coefficients of the simple rules for the nominal interest rate and the capital requirement, under a stochastic environment.

3 Results

3.1 Calibration

We calibrate our model using the estimated results of Gerali et al. (2010) for the banking sector, and the results of previous estimations for Mexico done in the BIS Joint Project 2015, the previous work of Adame, Carrillo, Roldán and Zerecero (2014), and data from INEGI for some steady state ratios and the parameters of the Calvo price setting of the different sectors. We display the calibrated parameters in Tables 1 and 2. We plan to estimate the model for Mexican data.

The discount factor on patient households is higher than the one for entrepreneurs, in the neighborhood of the steady state, households lend and entrepreneurs borrow. The value of β_P matches a 2.29% points annual interest rate on deposits, slightly lower than the one for Mexico, 2.72% points. The difference between the two discount factors delivers an annual credit spread of

[10] See the technical appendix for details.

Parameter	Description	Value	Source
β_P	Patient households' discount factor	0.9943	Gerali et al. (2010)
β_E	Entrepreneurs' discount factor	0.9750	Iacoviello (2005)
ϕ	Inverse of the Frisch elasticity	1.0000	Gerali et al. (2010)
α	Capital share in the production function	0.2500	Gerali et al. (2010)
δ	Depreciation rate of physical capital	0.0250	Gerali et al. (2010)
m	Entrepreneurs' loan-to-value ratio	0.3500	Gerali et al. (2010)
ν_b	Target capital-to-loans ratio	0.0900	Gerali et al. (2010)
ε^d	$\frac{\varepsilon^d}{\varepsilon^d-1}$ Markdown on deposit rate	-1.4602	Gerali et al. (2010)
ε^b	$\frac{\varepsilon^b}{\varepsilon^b-1}$ Markup on rate on loans	2.9328	Gerali et al. (2010)
δ^b	Cost for managing the bank's capital position	0.1049	Calibrated for the SS
Ψ_1	Adjustment cost for capacity utilization	0.0428	Calibrated for the SS
$\frac{\text{exports}}{\text{gdp}}$	Value of exports over gdp	0.2000	Calibrated for the SS

Tab. 1. Calibration

7.96% points, way above the value for Mexico, 3.37% points. The entrepreneurÂ´s discount factor corresponds to the value in Iacoviello (2005) for impatient households.

The parameters in the production side of the economy, α, and the capital depreciation, δ, are set to 0.25 and 0.025, respectively. The loan-to-value ratio for entrepreneurs is set to 0.35, as in Gerali et al. (2010); this value is lower than the usually calibrated for impatient households, 0.85 in Iacoviello and Neri (2010), or 0.7 in Calza, Monacelli and Stracca (2013), but goes in line with the estimated value for Canada found by Christensen, Corrigan, Mendicino and Nishiyama (2007) of 0.35. The capital utilization adjustment cost matches the steady state level of the return on capital. The cost for managing the capital position of the bank assures that the target capital-to-loan ratio is satisfied. Finally, the ratio of exports to GDP is set to calibrate the open economy.

The parameters on the home bias on consumption and investment bundles match the data for Mexico from INEGI; there is a higher home bias on consumption than investment goods. The elasticity of substitution between domestic and imported goods on the CES aggregators are estimated on the BIS Joint Project. The rest of the parameters correspond to the Calvo price setting scheme. The elasticity of substitution of the aggregators are all set up to 6 following a wide literature that set up the price markups in 1.2. The indexation parameters are estimated in Adame et al. (2014) for Mexico while the Calvo probability of adjustment costs comes from the estimation of the BIS Joint Project.

The shock parameters, the adjustment costs on the financial sector, and the parameters on the Taylor rule are the median values of the estimation in Gerali et al. (2010).

Parameter	Description	Value	Source
η_c	Elasticity of subst., consumption	1.5000	BIS Joint Project 2015
ν_c	Home bias on consumption	0.9495	INEGI
η_i	Elasticity of subst.,investment	1.8360	BIS Joint Project 2015
ν_i	Home bias on investment	0.8540	INEGI
η_H	Elasticity of subst., domestic	6.0000	
ζ_H	Indexation, domestic	0.2860	Adame et al. (2014)
θ_H	Calvo, domestic	0.5000	
$\eta_{F,c}$	Elasticity of subst., imported consumption	6.0000	
$\zeta_{f,c}$	Indexation, imported consumption	0.6480	Adame et al. (2014)
$\theta_{F,c}$	Calvo, imported consumption	0.8140	BIS Joint Project 2015
$\eta_{F,i}$	Elasticity of subst., imported investment	6.0000	
$\zeta_{f,i}$	Indexation, imported investment	0.3160	Adame et al. (2014)
$\theta_{F,i}$	Calvo, imported investment	0.5560	BIS Joint Project 2015
η_H^*	Elasticity of subst., exports	6.0000	
ζ^*	Indexation, exports	0.5200	Adame et al. (2014)
θ_H^*	Calvo, exports	0.5800	Adame et al. (2014)

Tab. 2. Calibration. Calvo price setting parameters.

3.2 Impulse Response Functions

First, we study the first order approximation of the model by looking at the impulse response functions. Our benchmark economy is the banking model of Gerali et al. (2010) without impatient households and without housing demand. We compare this closed economy framework with the small open economy, opened à la Adolfson et al. (2007) with domestic banks. We look at three different shocks: an i.i.d. monetary policy, a bank capital, and a credit spread shock.

In Figure 1 we plot the reaction of a small set of variables to an increase in the policy rate. The red dashed line is the closed economy model, while the blue solid line is the open economy. Both economies show a similar reaction to the monetary policy shock. The increase in the policy rate prompts a fall in output, consumption, and investment. Because of a decrease in the demand side, prices fall. The increase in the policy rate drives a fall on the interest rate spread on impact, but an increase after 2 periods. This increase in the spread and the borrowing interest rate is anticipated by the entrepreneurs and they demand less loans. Banks accumulate capital because households have an incentive to make more deposits and entrepreneurs to demand less loans.

In the open economy, net exports fall and so does the exchange rate that appreciates for the small economy. Entrepreneurs can borrow from abroad, to an increase in the domestic interest rate and an appreciation of the domestic currency, the net foreign asset position deteriorates for the small economy. Entrepreneurs borrow more from abroad, but this drives the interest rate on foreign debt up. After certain periods, it is expensive to borrow from abroad and entrepreneurs borrow less.

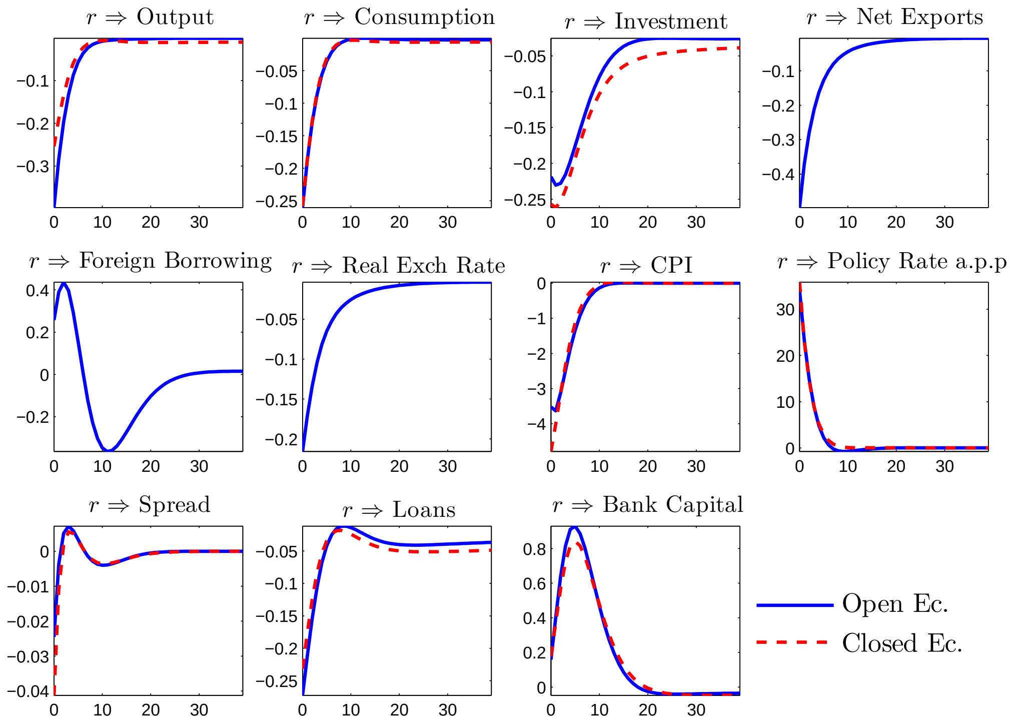

Fig. 1. Impulse Responses to a Monetary Policy Shock
y axis: percentage deviation from steady state; x axis: quarters

We report the simulation of the models to a bank capital shock in Figure 3. As in Gerali et al. (2010) this is an unexpected destruction of bank capital and we know that the very simplified model is not able to address the mechanism behind the initiation of the 2009 financial crisis. The bank capital shock is an unexpected contraction on the bank capital accumulation equation, Equation (8). The reduction on the retained earnings of the banks prompts an increase in loan rates to compensate the composition of the balance sheet. The increase in rates and in the spread drives loans down. Entrepreneurs lend less capital, investment falls and so does output.

In the open economy, an increase in the loan rate induces entrepreneurs to borrow more from abroad, the new inflows to the economy drag a depreciation of the real exchange rate and an increase in the net exports. The open economy shows a smoother reaction to the shock than the closed economy due to the availability of foreign borrowing.

The last shock that we study is one to the credit spread between the interest rate faced by the banks retailer branch and the one faced by the entrepreneurs. This is an exogenous innovation to the markup on loans to entrepreneurs and is reflected in Equation (10). When the markup increases the retail interest rate on loans adjust too and dampens the loans to entrepreneurs. The decrease in financial intermediation reduces investment, output, and consumption. The policy rate adjusts to attenuate the contraction on the real economy.

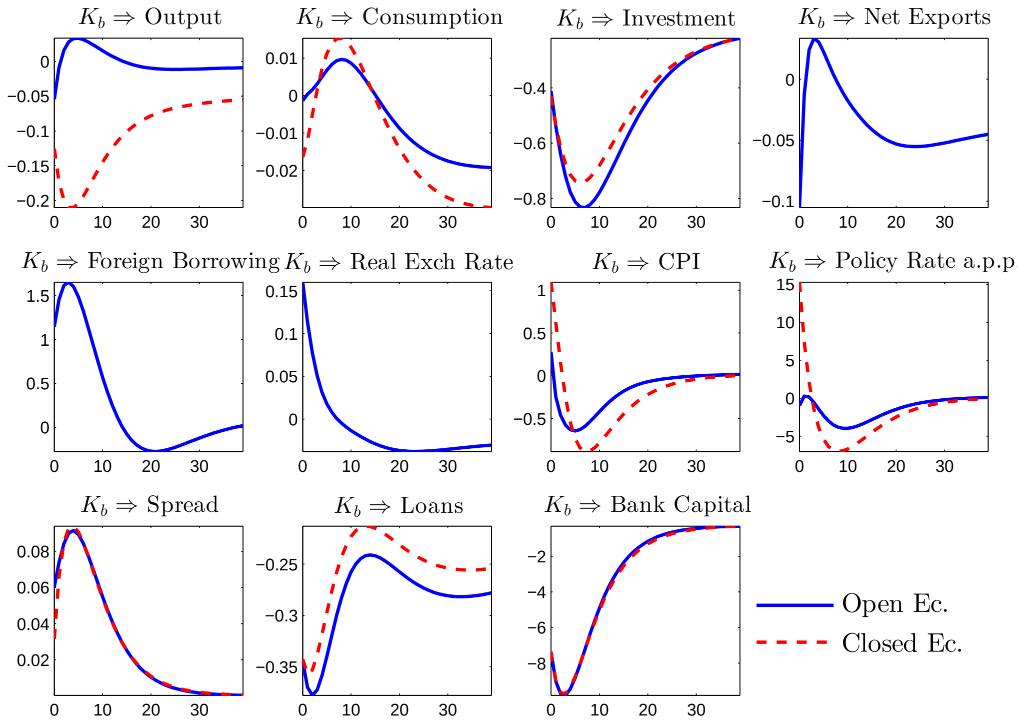

Fig. 2. Impulse Responses to a Bank Capital Shock
y axis: percentage deviation from steady state; x axis: quarters

When the economy can borrow from abroad, the increase in the retail interest rate pushes foreign loans up together with a depreciation of the domestic currency. As in the previous shock, the open sector dampens the response of the economy to the shocks.

3.3 Macroprudential Policy Design and Welfare Costs

This section evaluates the welfare costs of households[11] associated to different arrangements on the objectives and conduction of macroprudential policy. Our aim is to give a macroprudential authority an objective that is implementable, transparent, and accountable, and which will guide the dynamic reaction of the macroprudential instrument (in this case, the bank capital requirement ratio). In particular, we ask the macroprudential authority to choose the coefficients of the capital requirement rule to minimize the loss function associated to its objective. We propose and evaluate the outcomes of three rival objectives, and we assess which one of them is associated with the highest welfare. We assume that the macroprudential authority can only focus on one objective at the time, and thus the rival objectives are also mutually exclusive. Our candidate objectives are to minimize either the volatility of output growth, or either that of credit growth, or either that of

[11] We restrict our attention to household welfare because the consumption of entrepreneurs is small in the economy.

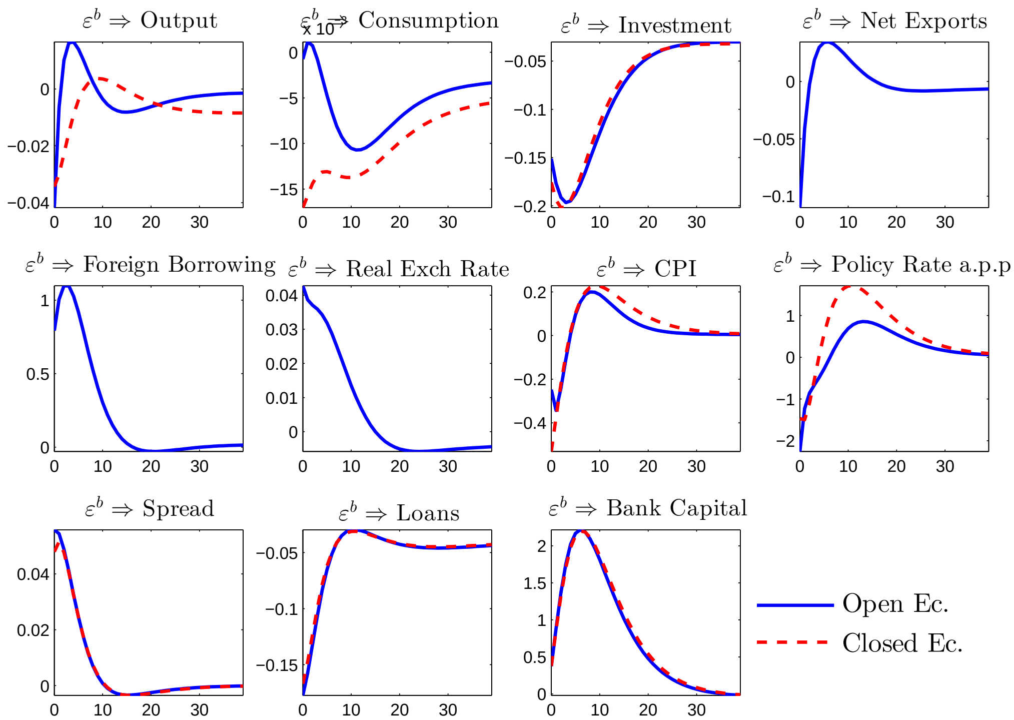

Fig. 3. Impulse Responses to a Credit Spread Shock
y axis: percentage deviation from steady state; x axis: quarters

the credit spread. Thus, the macroprudential authority solves only one of the following problems:

$$\min_{\phi_v,\phi_{v,y},\phi_{v,b}} L_{\Delta y}, \text{ or } \min_{\phi_v,\phi_{v,y},\phi_{v,b}} L_{\Delta b}, \text{ or } \min_{\phi_v,\phi_{v,y},\phi_{v,b}} L_{\Delta (r_e - r)},$$

where $L_{\Delta \upsilon} = E\left\{\sum_{i=0}^{\infty} \left(\beta^P\right)^i (\Delta \upsilon_{t+i})^2\right\}$ for $\upsilon \in \{y, b, (r_e - r)\}$. Each one of these objectives will be associated with a set of coefficients (ϕ_v, $\phi_{v,y}$, and $\phi_{v,b}$) and a stochastic steady state level for welfare ($V_{ss}^P(\varrho_{\Delta \upsilon})$). Notice that the objectives are set at the unconditional expectation of the loss function, and thus the decisions on ϕ_v, $\phi_{v,y}$, and $\phi_{v,b}$ are not subject to change with each period, unless the stochastic structure of the economy changes too.

To discipline the exercise, we set the following environment. First, we assume that there is no macroprudential policy in place ($\phi_v = \phi_{v,y} = \phi_{v,b} = 0$,) and let the central bank to choose the coefficients of its policy rule that minimize a loss function coherent with its objective. For simplicity, we assume that the central bank aims at minimizing the deviations of inflation from its target, and that it must smooth the policy rate while taking decisions (we constraint $\phi_r = .75$).[12]

[12] In our analysis we find that monetary rules with a high degree of policy inertia attain higher levels of welfare. This result echoes Williams (2003), who finds that efficient simple monetary policy rules that respond to inflation, output, and lagged interest rate perform nearly as well as fully optimal rules that respond to all variables in the model. In addition, the observation that central banks tend to smooth their policy rate in actual economies is widespread. Therefore, without loss of generality, we assume that the interest-rate smoothness coefficient is arbitrarily large.

The central bank thus solves the problem

$$\min_{\{\phi_\pi,\phi_y\}|_{\phi_r=.75}} L_\pi,$$
$$\text{where } L_\pi = E\left\{\sum_{i=0}^{\infty}\left(\beta^P\right)^i\left(\pi_{t+i}-\bar{\pi}\right)^2\right\}.$$

In a second stage, after the central bank has fixed its policy rule, the macroprudential authority chooses its own reaction function coefficients following one of the three above proposed mandates. Finally, we compute the welfare losses associated to each mandate, and screen the best macroprudential objective conditional on the incumbent monetary policy rule.

As a benchmark of the best implementable policies, we find the set of coefficients that are consistent to those that a social planner would choose to maximize welfare (instead of those that minimize the ad hoc loss functions of the central bank and the macroprudential authority in isolation). We call this set the Optimal Simple Rules (OSR) solution and characterize it by $\phi^{osr}=\left\{\phi_r^{osr},\phi_\pi^{osr},\phi_y^{osr},\phi_\nu^{osr},\phi_{\nu,y}^{osr},\phi_{\nu,b}^{osr}\right\}$, and a welfare level for households of $V_{osr}^P=V_{ss}^P\left(\phi^{osr}\right)$.[13] We therefore compare the welfare costs obtained with different sets of coefficients in terms of the consumption level c_{osr}^P associated with V_{osr}^P. It is worth mentioning that we are explicitly assuming that both economic authorities do not observe social welfare, and this is the reason why they have to resort to objectives that are implementable, transparent and accountable.

Finally, we are interested in evaluating the welfare costs of the different macroprudential objectives when the economy is closed and when the economy is open. To anticipate the results of our welfare evaluation, Figures 4 and 5 display the welfare costs associated to different values of selected policy coefficients for the closed and open economies, respectively. To compute these numbers, we set a grid of parameters of more than 100,000 combinations of the 6 policy parameters, and for each combination we obtained the stochastic steady state of the models up to a second-order approximation.

In Figure 4, right panel, we observe that, given all other coefficients constant,[14] the welfare cost are minimized when the central bank reacts vigorously to inflation deviations, and moderately to output growth. In turn, in the same figure, left panel, a lower welfare cost is achieved when the macroprudential authority reacts strongly to credit growth and is muted in face of output growth. Notice as well that the variations in the households welfare are more sensitive to movements in the monetary policy coefficients than to changes in the reaction of macroprudential policy.

[13] By definition, the first best that a social planner can do to maximize welfare is to find the Ramsey rules for the policy instruments r_t and $\nu_{b,t}$. There are two drawbacks with this solution. First, the Ramsey rules are not likely to be implemented given their complexity, so we prefer to have as benchmark a maximum welfare level that may be achieved by implementable rules, even if this solution is suboptimal. The second issue is more technical. Since we are solving a second-order approximation of the model, we ignore how the stochastic terms associated with this solution may affect the Ramsey policies. In future drafts of this paper, we intend to explore this subject in further detail.

[14] In the figures, we fix the levels of all other parameters not shown in the picture at the values contained in ϕ^{osr}.

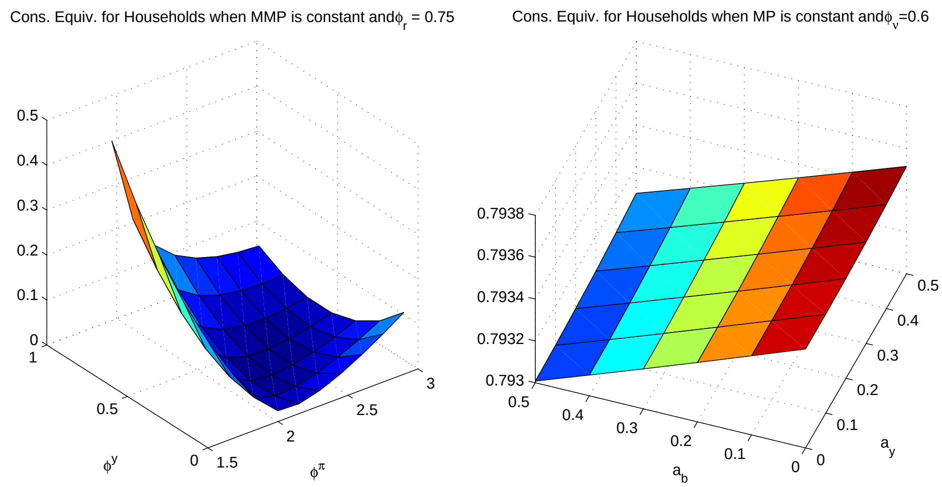

Fig. 4. Closed Economy, welfare levels for different parameters

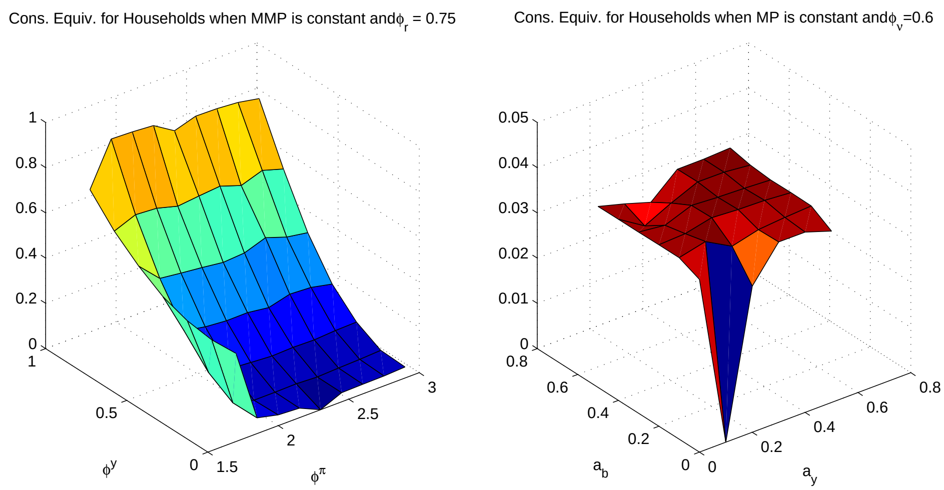

Fig. 5. Open Economy, welfare levels for different parameters

Figure 5 shows the best combination of policy parameters for the open economy. For the monetary policy, the minimum welfare losses are obtained with a similar combination of parameters than those of the closed economy. In contrast, for macroprudential policy the best parameter combination points to a moderate reaction to output growth and no reaction to credit growth. Also, welfare seems now more sensitive to the macroprudential parameters than in the closed economy case. We will come back to the intuitions of these results later on.

3.4 Closed economy

Table 3 shows the welfare costs in the closed economy case for the different combination of parameters explained above. In the first row, we present the OSR solution of the social planner. Since this is our benchmark welfare level, the costs in consumption-equivalent terms are zero by definition. In the same row, we observe that the best implementable policy set considers active reactions in both the nominal interest rate and the bank capital requirement ratio. In the optimal simple monetary rule, the central bank reacts to deviations of inflation and output growth, while in the optimal simple macroprudential rule, the capital requirement ratio displays smoothness and a strong reaction to credit growth ($a_b = 0.5$ was the maximum value of this parameter in the grid), but not so for output growth. As a counterfactual, the second row of the table display the OSR combination of parameters for the monetary rule, assuming that no dynamic macroprudential rule is in place (so $\nu_{b,t} = \nu_b$). Two interesting findings result from the counterfactual: first, the monetary parameters are the same as before; and second, the welfare costs are greater than zero, but only marginally. These observations imply that the contribution to welfare of a dynamic bank capital requirement rule is quite small in the closed economy case.

Table 3. Welfare costs comparison: closed economy.

Case	Welfare cost (× 100)	ρ_r	ϕ_π	ϕ_y	ρ_{ν^b}	a_y	a_b
Welfare-based Optimal Simple Rules (OSR)	-	0.75	2.30	0.30	0.60	0.00	0.50
Welfare-based OSR, without Macropru.	0.001	0.75	2.30	0.30	-	-	-
CB, π objective, without Macropru.	0.139	0.75	2.90	0.00	-	-	-
Macropru., Δy objective, cond. on CB	0.137	0.75	2.90	0.00	0.75	0.50	0.50
Macropru., Δb objective, cond. on CB	0.139	0.75	2.90	0.00	0.00	0.00	0.00
Macropru., $\Delta(r_b - r)$ objective, cond. on CB	0.139	0.75	2.90	0.00	0.00	0.00	0.00
CB, π objective, cond. on optimal Macropru.	0.137	0.75	2.90	0.00	0.75	0.50	0.50

Note : This table shows the welfare costs, in terms of consumption units of the Welfare-based OSR steady state, for different values of the coefficients in the monetary rule (ρ_r, ϕ_π, ϕ_y), and the macroprudential rule (ρ_ν, a_y, a_b)

The third row of Table 3 displays the case in which the central bank fixes its reaction function coefficients in order to minimize the discounted losses from the deviations of inflation away from its target. We observe that under this objective, the welfare costs increase substantially with respect to the OSR case, and that now the central bank reacts strongly to inflation deviations but not at all to output growth (2.9 is precisely the highest point in the grid for a_π). Taking as given the central bank policy of row 3, in rows 4 to 6 of the table we show the welfare costs obtained when the macroprudential authority chooses coefficients to minimize the losses corresponding to the three rival mandates. Notably, we observe that given the incumbent monetary policy rule, the macroprudential authority decides an active rule only when the objective is to minimize the volatility of output growth. This objective also achieves the lower welfare costs conditional on the incumbent's monetary rule, and it is thus the best objective that the macroprudential authority may follow out of the other 2 candidates. Nevertheless, the table also shows that the welfare gains

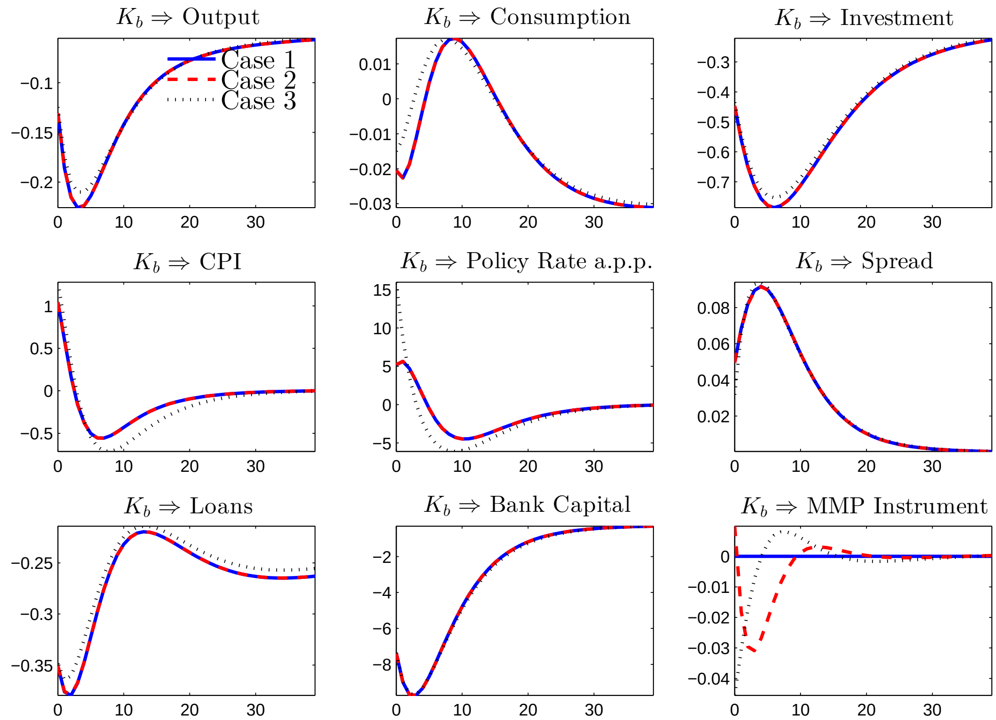

Fig. 6. Closed Economy, bank capital shock with active policy rules

from having an active and dynamic rule for the capital requirement ratio are quite small.

Finally, in the last row of Table 3 we consider a second stage in the game between the central bank and the macroprudential authority in setting rules to attain their objectives. In particular, we ask whether the central bank would have incentives to change its policy coefficients, given that the macroprudential authority has chosen to minimise the volatility of output growth. Not surprisingly, the central bank chooses exactly the same rule parameters as in the case of no active macroprudential policy, in row 3. The reason is again that the added value of a dynamic bank capital requirement rule is quite small.

This conclusion is confirmed in Figure 6, that shows the impulse responses of endogenous variables to an exogenous negative shock in bank capital. The blue plain line, labeled case 1, depicts the variables responses conditional on the coefficients of row 3 of Table 3, i.e., when there is an active monetary rule in place and no an active macroprudential rule. The red dashed line, labeled case 2, adds the macroprudential rule that results from minimizing output growth volatility (row 4 in Table 3). Except for the macroprudential instrument itself, the differences with respect to case 1 are completely negligible, and thus the welfare losses are almost the same as before. For completeness, Figure 6 also shows the impulse responses conditional to the OSR solution, represented by the black dotted line, labeled case 3. In such case, we observe differences with respect to the previous 2 cases, but overall these differences are small.

3.4.1 Open economy

Table 4 presents the welfare costs analysis for the open economy, which is similar to the closed economy one. Row 1 shows again the social planner's OSR solution that maximize welfare. In this case, monetary policy reacts similarly as before to inflation deviations, but it is muted to output growth. For macroprudential policy, the policy rule changes importantly as it places importance to output growth, instead to credit growth as in the closed economy case. In the second row, we again show the counterfactual OSR solution when no macroprudential policy is in place, and the social planner set the monetary rule parameters to maximize welfare. In this case, the optimal central bank rule reacts also to output growth, while the absence of a dynamic macroprudential rule causes welfare costs that are significantly higher than in the closed economy case.

Table 4. Welfare costs comparison: open economy.

Case	Welfare cost (× 100)	ρ_r	ϕ_π	ϕ_y	ρ_{ν^b}	a_y	a_b
Welfare-based Optimal Simple Rules (OSR)	-	0.75	2.30	0.00	0.60	0.10	0.00
Welfare-based OSR, without Macropru.	0.033	0.75	2.30	0.15	-	-	-
CB, π objective, without Macropru.	0.698	0.75	1.70	0.90	-	-	-
Macropru., Δy objective, cond. on CB	0.710	0.75	1.70	0.90	0.00	0.50	0.20
Macropru., Δb objective, cond. on CB	0.790	0.75	1.70	0.90	0.75	0.10	0.50
Macropru., $\Delta(r_b - r)$ objective, cond. on CB	0.720	0.75	1.70	0.90	0.00	0.50	0.00
CB, π objective, cond. on optimal Macropru.	0.710	0.75	1.70	0.90	0.00	0.50	0.20

Note : This table shows the welfare costs, in terms of consumption units of the Welfare-based OSR steady state, for different values of the coefficients in the monetary rule (ρ_r, ϕ_π, ϕ_y), and the macroprudential rule (ρ_ν, a_y, a_b)

In row 3, Table 4 shows the central bank parameter choices in the absence of a dynamic macroprudential policy rule. Interestingly, in this case we observe that the central bank moderates its reaction to inflation, and places more importance to output growth. These choices are in sharp contrast with their counterparts in the closed economy scenario. At the same time, the welfare costs are substantially higher in the open economy case.

Row 4 to 6 display again the welfare costs and parameter choices of the macroprudential authority under the assumption that the monetary rule is set as in row 3. Surprisingly, for these particular candidate objectives, a dynamic macroprudential policy rule is always welfare detrimental. The lower loss is nevertheless obtained when the macroprudential objective is set to minimize output growth volatility, which is consistent with the closed economy case. Finally, row 7 shows that the central bank has no incentive to change its policy rule once the macroprudential policy has set its relative best objective out of the three candidates, namely output growth.

The results of row 4 to 6 contrasts with the OSR solution, which finds that a moderate response of the capital requirement ratio is indeed welfare enhancing. This seemingly contradiction can be

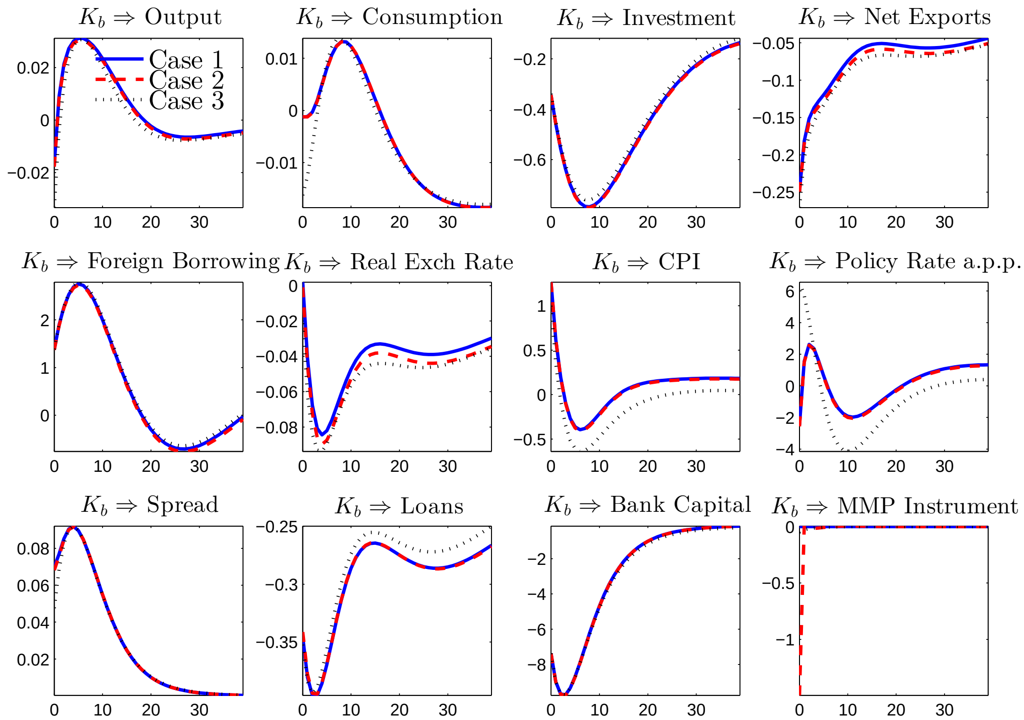

Fig. 7. Open Economy, bank capital shock with active policy rules

explained by two reasons. First, the candidate objectives considered in this exercise, although implementable, are far away from the welfare-based criterion, which we assume is not observable. We therefore should look for an objective that lies relatively closer to the social planner's objective. Second, the game's settings, with the central bank as the incumbent and assuming no cooperation between authorities, determines the outcome of the game. Assuming a cooperation between authorities might lead to an outcome closer to the OSR solution.

Figure 7 shows a comparison between impulse responses resulting from the same cases than in the close economy case, with the difference that the parameters corresponds to those shown in Table 4. Case 1 assumes that only the monetary rule is active; case 2 adds the rule from the best macroprudential objective; and case 3 presents the OSR solution. For the open economy case, we observe that the differences between cases is larger than for the closed economy, notably for the policy rate, and the real exchange rate. However, similar conclusions as for the closed economy case apply for the open economy.

4 Conclusion

TBC

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