GRAFTING MACROPRUDENTIAL POLICIES IN A MACROECONOMIC FRAMEWORK
CHOICE OF OPTIMAL INSTRUMENTS AND INTERACTION WITH MONETARY POLICY

VERY PRELIMINARY. THIS VERSION, MARCH 5, 2010

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Abstract

We use a dynamic general equilibrium model of the euro area featuring a banking sector to answer the following questions: (*i*) within a standard macroeconomic framework, how should macroprudential objectives be modeled? *(ii)* How should macroprudential tools/rules be designed? *(iii)* What would be the interaction between macroprudential policy and monetary policy? An active management of macroprudential instruments has indeed the potential to reduce macroeconomic volatility and to usefully cooperate with monetary policy. The order of magnitude of the benefits does not appear to be large, though. However, once macroprudential policy is introduced, there is the risk that, in the absence of a strong coordination mechanism between macroprudential and monetary authorities, a coordination failure could bring about suboptimal results.

Keywords: Capital requirements; Macroprudential policy; Monetary policy; Banks; DSGE model.

JEL *codes*: E44; E58; E61.

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1. Introduction

The debate on macroprudential policies ignited by the financial crisis is currently under full swing. In its essence, this debate revolves around the idea that policymakers in the various realms – mainly monetary policymakers and financial system supervisors/regulators, but also standard setters such as the two main accounting bodies worldwide – have heretofore overlooked some important aspects of the macroeconomy, and need to change their attitude. Arguably, the task of the new macroprudential policy should be to strengthen the resilience of the financial system in case of crisis, and reduce the likelihood of crises. To address the problem of overlap of this objectives with those of the (micro)prudential regulator, reference is typically made to an externality, systemic risk. The argument is that systemic risk has not been properly been taken into account (or overlooked altogether) by regulators, first and foremost the (micro)prudential supervisor, but also the monetary policymaker.[1] In this respect, a key intuition refers to the so-called fallacy of composition emphasized by several commentators (see e.g. Brunnermeier *et al.*, 2009): risk exposures that can be negligible for any individual institution, which the financial regulator may well overlook or deem safe at the micro level, can have disastrous consequences on overall financial stability if highly correlated in the cross section.

Thus far, the debate has produced a consensus on a few specific issues. In particular, academics and policy-makers agree on the potential benefits of policies that increase the degree of capitalization of financial intermediaries and reduce the pro-cyclicality of the financial system induced by risk-based capital rules, such as the Basle II Accord (G20, 2009; FSB, 2009).[2] Several proposals have been advanced to reduce pro-cyclicality via mechanisms which build up capital buffers in periods of buoyant growth, to be used in downturns. Although these proposals differ in various (important) technical respects, their common idea is that bank capital should be adjusted in a countercyclical fashion.

However, no agreement has yet been reached on the practical implementation of macroprudential policy. The concept remains ambiguous, and there is neither a common framework nor a consensus on the indicators and instruments to be used. Even as far as the objectives of macroprudential policy are concerned, going beyond principles is proving somewhat elusive. To start understanding and modeling the problem of the new policy one

1 The argument is that risk-based capital regulation typically focuses to individual banks, and therefore may neglect the macro impact of banks reacting in unison to a shock (Brunnermeier *et al.* 2009).

2 Other measures currently being discussed include harmonising the definition of eligible capital and improving its quality and complementing Basel II rules with non-risk based limits to leverage.

needs to pin down proxies and measures of systemic risk and financial instability, which the macroprudential action should aim at containing. But systemic risk can manifest itself in a variety of ways, and escapes measurement. This situation stands in sharp contrast with the state of affairs for macroeconomic and monetary policy analysis, where there arguably is a broad consensus on the set of analytical tools, indicators and models (Woodford, 2003).

The current state of the debate prompts the following considerations. First, policies aiming at reducing the pro-cyclicality of the financial system are in potential conflict with other policies that also aim at moderating business cycle fluctuations. The closer link is with monetary policy, as these macroprudential tools mainly operate through variables (e.g. bank loans) that play a key role in the transmission mechanism of monetary policy.

Second, the above mentioned proposals are generally analyzed on a piecemeal, hands-on basis. So far, the policy debate has taken place in the absence of a consistent framework which would allow a more structured approach to the issue of regulatory reform in general and macroprudential policy in particular. Moreover, the proposals pursue the twofold objective of increasing the resilience of the financial system and of mitigating its pro-cyclicality, at times without clearly distinguishing between these two objectives.

Moving from these considerations, the present paper attempts to graft macroprudential policies into a standard macroeconomic framework. We believe that a comprehensive framework should address the following fundamental questions: (*i*) within a standard macroeconomic framework, how should macroprudential objectives be modeled? Is it necessary to amend such standard framework in order to introduce a meaningful role for macroprudential policy? *(ii)* How should such macroprudential tools/rules be designed? For example, should bank capital requirements be set in reaction to GDP growth, credit growth, equity growth, or a combination of these variables? Are countercyclical rules based on bank capital to be preferred to others based, say, on loan-to-value ratios? *(iii)* How would macroprudential policy interact with monetary policy? More specifically, could macroprudential policy virtuously co-operate with monetary policy to help the central bank achieve her goals? Could there be virtuous interactions between the two policies, or is there a risk of conflict?

To address these questions we cast the regulator problem within a macroeconomic model. Specifically, we build on the DSGE model developed by Gerali *et al*. (2009), which features a simplified banking sector with capital, capturing the basic elements of banks' balance sheets: on the assets side there are loans to firms and households while on the liabilities side there are deposits held by households and capital.

We amend this model in various ways. We introduce heterogeneity in the creditworthiness of the various economic operators in a reduced form *ad hoc* way. We also introduce risk-sensitive capital requirements and quantify the extent to which they induce excessive lending and excessive output growth in booms, and vice-versa in downturns. We address the difficult issue of designing a set of objectives for the macroprudential regulator, and assume that she tries to achieve them using her own policy instrument - a capital requirement rule, or a loan-to-value rule. We assess the effectiveness of these rules on the basis of the model. Finally, we study the interaction between the macroprudential policy and monetary policy.

In a first set of exercises we let monetary policy follow the Taylor rule and assume that the macroprudential authority chooses the parameters of a simple rule which links capital requirements (or alternatively the loan-to-value ratio) to various economic indicators, such as output growth. The parameters of this rule are obtained from the minimization of an *ad hoc* objective function of the macroprudential regulator, which we discuss at length in the paper. To study the interaction between macroprudential policy and monetary policy, in a second set of exercises we introduce a standard loss function for the central bank, and let the central bank optimally choose the parameters of the Taylor rule, which have heretofore been held fixed. We then analyze two games. In the first, which we call the cooperative game, the two authorities are assumed to jointly simultaneously set the parameters of the Taylor rule and the capital requirements rule so as to minimize a weighted average of their two objective functions. In the second game, each authority minimizes it own objective function taking the action of the other authority as given, and the game is iterated until a Nash equilibrium is achieved. We cross-check the results from these equilibria, and contrast them with the baseline case of an optimal simple Taylor rule under no macroprudential policy (time invariant capital requirements).

The paper makes two main contributions to the existing literature. First, the potential role of macroprudential policy is studied in the context of a macroeconomic model, which allows us to examine its general equilibrium effects. The DSGE model employed throughout the paper belongs to a new class, which explicitly features a (simplified) financial sector and a meaningful interaction between the latter and the real economy. It is worth recalling that the financial sector was entirely absent in DSGE models of the previous generation. The financial accelerator mechanism of Bernanke, Gertler and Gilchrist (1999) has been only recently re-considered in standard medium scale DSGE models (see for example Gilchrist *et al.*, 2009).[3] Second, we try to integrate this simplified but rigorous framework with a discussion of some of the key policy proposals at the centre of the current debate. This approach stands in sharp contrast, on the one hand, with existing literature on financial stability issues, typically based on reduced-form, partial equilibrium models; on the other hand, with the theoretical macroeconomic literature, typically not concerned with the practical implementation of policy proposals.

Very few papers have analyzed the interrelationship between monetary policy and macroprudential policy. Angeloni and Faia (2009) present a calibrated DSGE model featuring a competitive banking system and the possibility of bank runs, in which monetary policy is allowed to react to asset prices or leverage (besides inflation and output), and capital requirements can be pro- or counter-cyclical. They find that the optimal policy combination includes mildly anti-cyclical capital ratios and a monetary policy rule that reacts to inflation and asset prices or leverage. Kannan, Rabanal and Scott (2009) present a DSGE model focusing on house prices. They also find that a stronger monetary reaction to signs of overheating or of a credit or asset price bubble could help counter accelerator-type mechanisms; in addition, using a macroprudential instrument designed specifically to dampen credit market cycles would also be useful.

1) The macroeconomic framework

Until recently, the financial sector was largely overlooked in macroeconomic modelling. Seminal contributions, starting from Bernanke, Gertler and Gilchrist (1999), have started to fill the gap by introducing credit and collateral requirements in quantitative general equilibrium models. More recently, financial intermediaries in general and banks in particular have begun to appear in macro models (Christiano, Motto and Rostagno, 2007 and Goodfriend and McCallum, 2007). These models, however, emphasize mainly the demand side of credit. The credit spread that arises in equilibrium (the external finance premium) is a function of the riskiness of the entrepreneurs' investment projects and/or his net wealth. Banks, operating under perfect competition, simply accommodate the changing conditions from the demand side.

[3] One possible reason why the empirical literature, in particular, has typically not considered this mechanism is that it does not significantly amplify the effects of monetary policy shocks.

Gerali *et al*. (2010) instead build on the idea that conditions from the supply side of the credit markets are key to shape business cycle dynamics. Starting from a standard model, featuring credit frictions and borrowing constraints as in Iacoviello (2005) and a set of real and nominal frictions as in Christiano *et al*. (2005) or Smets and Wouters (2003), they add a stylized banking sector with three distinctive features. First, banks enjoy some degree of market power when setting rates on loans to households and firms. Second, the rates chosen by these monopolistically competitive banks are adjusted only infrequently, i.e. they are sticky. Third, banks accumulate capital (out of retained profits), as they try to maintain their capital-to-asset ratio as close as possible to an (exogenously given) optimal level. This optimal level might derive to banks because of a mandatory capital requirement (like those explicitly set forth in the Basel Accords) or, in a deeper structural model, might be the equilibrium outcome from balancing the cost of funding with the benefits of having more "skin in the game" to mitigate typical agency problems in credit markets. The model is estimated with Bayesian methods using data for the euro area over the period 1998-2009.

Banks make optimal decisions subject to a balance sheet identity, which forces assets (loans) to be equal to deposits plus capital. Hence, factors affecting bank capital impact on the capital to assets ratio, forcing banks to modify leverage. Thus, the model captures the basic mechanism described by Adrian and Shin (2008), which has arguably had a major role during the current crisis.

In this paper we modify the model by Gerali *et al.* (2010) to study the role of capital regulation. More specifically, we model credit risk heterogeneity across categories of borrowers in a reduced form *ad hoc* way and introduce risk sensitive capital requirements. We then show how banks' optimal lending decisions, and hence the macro environment, are affected by different regulations. We refer the interested reader to the original paper for a more thorough description of the basic features of the model.

2.1 Main features of the model

The model describes an economy populated by entrepreneurs, households and banks. Households consume, work and accumulate housing wealth, while entrepreneurs produce consumption and investment goods using capital and labour supplied by households.

There are two types of households who differ in their degree of impatience, i.e. in the discount factor they apply to the stream of future utility. This heterogeneity gives rise to borrowing and lending in equilibrium. Two types of one-period financial instruments, supplied by banks, are available to agents: saving assets (deposits) and loans. Borrowers face a collateral constraint, tied to the value of collateral holdings: the stock of housing in the case of households, physical capital for entrepreneurs.

The banking sector operates in a regime of monopolistic competition: banks set interest rates on deposits and loans as to maximize profits. The balance sheet is simplified but captures the basic elements of banks' activity. On the assets side are loans to firms and households. On the liabilities side are deposits held by households and capital. Banks face a quadratic cost of deviating from an "optimal" capital to assets ratio ν.[4]

(1) $$\kappa_b \left(\frac{K_{b,t}}{L_t} - \nu \right)^2 K_{b,t}$$

where $K_{b,t}$ is bank capital, L_t are total loans and κ_b is a parameter measuring the cost of deviating from ν. The latter can be thought of as a minimum capital ratio established by the regulator, plus a discretionary buffer. When the capital ratio falls below ν, costs increase and are transferred by banks onto loan rates:

(2) $$R_t^i = R_t - \kappa_b \left(\frac{K_{b,t}}{L_t} - \nu \right) \left(\frac{K_{b,t}}{L_t} \right)^2 + markup_t, \qquad i=H, F$$

where R_t is the monetary policy rate and the term "*markup*" captures the effects of monopolistic power of banks on interest rate setting.[5] Equation (2) highlights the role of bank capital in determining loan supply conditions. On the one hand the bank would like to extend as many loans as possible, increasing leverage and thus profits per unit of capital. On the other hand, when leverage increases, the capital-to-asset ratio falls below ν and banks pay a cost, which they transfer on the interest rates paid by borrowers. This, in turn, may reduce credit demand and hence bank profits. The optimal choice for banks is to choose a level of loans (and thus of leverage) such that the marginal cost of reducing the

[4] The adjustment cost adopted in equation (1) is quadratic, and hence symmetric. An alternative, more realistic version should be asymmetric – the cost of falling below a regulatory minimum is arguably higher than the cost of excess capital. However, the first order approximation of the model which we use throughout the current version of the paper would make such alternative adjustment cost immaterial for the results. In future research we plan to introduce an asymmetric adjustment cost (see Fahr and Smets, 2008 for an application of to downward nominal wage rigidities) and look at a higher order approximation of the model.

[5] In practice, a dynamic version of equation (2), in which bank rates are sticky, is employed in the model (see Gerali *et al.,* 2010). It is assumed that banks, at any point in time, can obtain financing from a lending facility at the central bank at a rate equal to the policy rate R_t. A no-arbitrage condition between borrowing from the central bank and from households by issuing deposits implies that in equilibrium a dynamic version of eq. (2) must hold.

capital-to-asset ratio exactly equals the spread between R_t^i and R_t. The presence of stickiness in bank rates implies that the costs related to the bank capital position are transferred gradually to the interest rate on loans to households and firms. Bank capital is accumulated out of retained profits Π_b, according to the following equation:

(3) $$K_{b,t} = (1-\delta_b)K_{b,t-1} + \Pi_{b,t-1}$$

where the term $\delta_b K_{b,t-1}$ measures the cost associated with managing bank capital and conducting the overall banking intermediation activity.

Firms and households face a borrowing constraint. For households, it takes the following form:

(4) $$(1+r_t^{b,H})b_t^H \leq m_t^H E_t[q_{t+1}h_{t+1}\pi_{t+1}]$$

where q is the price of housing, h the stock of existing homes, b^h the amount of borrowing, r^{bH} the interest rate on loans and π the inflation rate. The parameter m^H measures the loan-to-value (LTV) ratio for mortgages. The LTV ratio can be interpreted as the proportional cost of collateral repossession for banks given default. At a macro-level, the value of m^H determines the amount of credit that banks make available to households, for a given (discounted) value of their housing stock. In Gerali *et al*. (2010) m^H is modelled as an exogenous stochastic process, whose innovations can be loosely interpreted as credit-supply shocks.

Monetary policy is modelled via a Taylor rule with the following specification:

(5) $$R_t = (1-\rho_R)\overline{R} + (1-\rho_R)[\chi_\pi(\pi_t - \overline{\pi}) + \chi_y(y_t - y_{t-1})] + \rho_R R_{t-1} \quad .$$

The estimated values of the parameters of (5) are: $\rho_R = 0.77$, $\chi_\pi = 2.01$, $\chi_y = 0.35$. The other model parameters are reported in Gerali *et al*. (2010).

2.2 Key changes to the analytical framework

Following Angelini *et al.* (2009), we introduce a few changes in the basic framework of Gerali *et al*. (2009), to adapt it to our purposes.[6] Specifically, we assume that

6 In Angelini *et al.* (2009) the objective was to analyze the Basel I vs. Basel II frameworks, focusing on whether the introduction of time-varying risk weights in the latter significantly added to the financial

loans to firms and to households are characterized by different degrees of riskiness captured, in a reduced form, by weights, w_t^F and w_t^H, which we use to compute a measure of risk-weighted assets.[7] The capital adjustment cost (1) is modified as follows:

$$\kappa_b\left(\frac{K_{b,t}}{w_t^F L_t^F + w_t^H L_t^H} - v\right)^2 K_{b,t}\,, \tag{6}$$

where total loans L_t have been replaced by the sum of risk-weighted loans to firms (L_t^F) and households (L_t^H). Note that setting $w_t^F = w_t^H = 1$ expression (6) simulates the Basel I regime for loans to the private sector, whereas allowing the weights to vary over time captures the essence of the risk-sensitive Basel 2 mechanism. Under the latter mechanism, the inputs of the capital function can change through the cycle, reflecting either the rating issued by rating agencies or banks' own internal risk assessment models (the so-called internal ratings based, or IRB, approach). Under this second interpretation, we model the weights so as to roughly mimic their real-world setting by banks. We assume simple laws of motion of the form:

$$w_t^i = (1-\rho_i)\overline{w}^i + (1-\rho_i)\chi_i(y_t - y_{t-4}) + \rho_i w_{t-1}^i \qquad i = F, H \tag{7}$$

where the lagged term w_{t-1}^i models the inertia in the adjustment and the parameter χ_i (<0) measures the sensitivity of the weights to cyclical conditions, measured as the year-on-year growth rate of output.[8] The parameters of (7) have been estimated in Angelini et *al.* (2009).

Equations (7) capture the fact that risk tends to be countercyclical: low in good times and high and increasing in bad times. It also captures the incentive for banks to load on risk pro-cyclically: in good times the risk weights decline, driving the capital/assets ratio above

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system pro-cyclicality. Aguiar and Drumond (2009) also study the additional pro-cyclicality introduced by Basel II relative to Basel I, using a DSGE model similar to ours. They find that the amplification of monetary policy shocks induced by capital requirement becomes stronger under Basel II regulation.

7 The model does not feature defaults, as they are ruled out as equilibrium outcomes (see Kiyotaki and Moore, 1997, and Iacoviello, 2005). However, the device we adopt mimics well the effect of capital requirements based on risk weighted assets.

8 Appropriate choices for the parameters in equation (6) also allow us to study the system dynamics under the two main rating systems allowed by the regulation: "point in time" (PIT) vs. "through the cycle" (TTC). In a nutshell, to assess borrowers' creditworthiness under Basel II, banks can either use ratings supplied by external rating agencies, or produce their own internal ratings. Regardless of the source, ratings can be attained via either a PIT or a TTC approach. PIT ratings represent an assessment of the borrower's ability to discharge his obligations over a relatively short horizon (e.g. a year), and so can vary considerably over the cycle. The TTC approach focuses on a longer horizon, abstracting in principle from current cyclical conditions. TTC ratings are therefore inherently more stable than PIT ratings, although their predictive power for default rates is lower. See Angelini *et al.* (2009).

the target ν; banks react by expanding loans to maintain unchanged the capital asset ratio. The second important change in the analytical framework concerns the parameter ν. In Gerali *et al.* (2010) this parameter is fixed at the steady state value. This is in keeping with both Basel I and II, and with the idea that banks like to keep voluntary capital buffers constant at low values. However, a natural extension is to consider a time-varying ν. Within our framework, this represents the most straightforward way to assess the effect of countercyclical capital requirements. In the exercises that follow we use the equation:

(8) $$\nu_t = (1-\rho_\nu)\bar{\nu} + (1-\rho_\nu)\chi_\nu X_t + \rho_\nu \nu_{t-1}$$

where the parameter $\bar{\nu}$ measures the steady state level of ν_t. In (8), we assume that ν_t adjusts to the year-on-year growth of a key macroeconomic variable X_t – we experiment with output growth, loans growth – with a sensitivity equal to the parameter χ_ν. The aim is to run a horse race among these variables, checking which one helps improving the stabilization properties of the capital requirements rule (8). Assuming a positive χ_ν amounts to imposing a countercyclical regulatory policy: capital requirements increase in good times (banks hold more capital for given amount of loans) and vice-versa.

A second macroprudential instrument with which we experiment is the loan-to-value (LTV) ratio. For some exercises, we assume that the policymaker can set a time varying LTV ratio on households' home purchases in a countercyclical fashion, so at to attain her goals. In this case, we model the LTV ratio as follows:

(9) $$m_t^H = (1-\rho_m)\bar{m}^H + (1-\rho_m)\chi_m X_t + \rho_m m_{t-1}^H$$

where $\bar{m}^H$ denotes the steady state value of m^H.[9]

Note that adding (8) or (9) to the model affects the cyclical pattern of the main variables but not their steady state levels, and is therefore neutral in this sense. The reason is that the steady state of the model is affected only by the values of $\bar{\nu}$ or $\bar{m}^H$ and not by the dynamics of the respective variables, which are influenced by the sensitivity of capital requirements (LTV ratio) to X_t. Therefore, in what follows we focus on the effects of adopting (8) or (9) on the dynamics of the economy.

In this context, $\bar{\nu}$ has a twofold interpretation: as a capital requirement and as a buffer voluntarily held by banks. This interpretation carries over to ν_t and to equation (8): the

[9] In Gerali *et al.* (2010) $\bar{m}^H$ is set at 0.7, in line with evidence for mortgages in the main euro area countries (0.7 in Germany and Spain, 0.75 in France and 0.5 in Italy). The LTV ratio for firms is set at 0.35.

regulator might decide to implement a countercyclical capital requirements policy; alternatively, banks might voluntarily choose to hold countercyclical capital buffers. In what follows we look at these two interpretations, in the order.

Finally, we need to model the behaviour of the macroprudential regulator and of the central bank. For the latter, we follow the standard practice of assuming that she tries to stabilize inflation and GDP growth; she chooses the parameters of a simple Taylor-type reaction function (4) so as to minimize the loss function (*cb* stands for central bank):

$$L^{cb} = \sigma_{\pi}^2 + k_y \sigma_y^2 + k_r \sigma_{\Delta r}^2 \qquad k_y \geq 0, k_r \geq 0 \quad . \tag{10}$$

In (10), the variances σ^2 are the asymptotic (unconditional) variances of the key macroeconomic variables (inflation, output growth) and of the (changes in the) policy instruments (the monetary policy rate). The *k*s are the weights which characterize the policymaker's preferences over these variables. A positive k_r is warranted by the need to keep movements in the policy rate "reasonable" (it is well-known that if policy instruments can be moved at no cost, optimal policies will tend to generate very large, counterfactual, volatility of the policy rate). These parameters can be either arbitrarily chosen or derived from a second order approximation of households' utility. There have been attempts to estimate these parameters in the context of small scale models (e.g. Dennis, 2004 and Lippi and Neri, 2007). In what follows we experiment with a grid of values for these parameters. This should yield a sense of the results as well as a measure of their robustness.

The key difficulty we face next is: how to model macroprudential policy objectives in general, and within the context of a standard macro model in particular? There are two problems in addressing this question. The first is that both micro and macroprudential policies have only one objective, financial stability. In the current debate, this "final" objective is divided into two intermediate objectives: individual institutions risks, to be controlled by traditional microprudential supervision, and systemic risk, to be addressed by macroprudential policies. While useful in principle, this distinction becomes rapidly blurred in practice, as systemic risk is extremely hard to define, let alone to measure. Over time, it has manifested itself in a variety of ways and environments, from the traditional banking and currency crises to the more recent cases involving non banks and the breakdown of entire market segments. The second problem is that these difficulties in defining a clearcut objective for the macroprudential regulator are compounded by the stylized nature of most macroeconomic models (including ours), in which there is no counterpart to systemic risk.

With these caveats, we assume that the macroprudential regulator is interested in stabilizing the loans/GDP ratio and GDP growth around their steady state values. While clearly ad hoc, this formulation moves from a recent definition of the goals of macroprudential policy, which should ensure "*the stable provision of financial intermediation services to the wider economy, [avoiding] the boom and bust cycle in the supply of credit* ..." (Bank of England, 2009).

Therefore, we assume that the macroprudential regulator chooses the parameters of equations (8) or (9) so as to minimize the loss function (*mp* stands for macroprudential):

(11) $$L^{mp} = \sigma^2_{l/y} + k_{y,mp}\sigma^2_Y + k_{mi}\sigma^2_{mi} \quad .$$

In (11), the variances σ^2 are analogous to those in (10); $\sigma_{mi}{}^2$ is variance of the (change in the) macroprudential instrument (the capital requirement in (8) or the loan-to-value ratio in (9)). The *k*s are the weights which characterize the policymaker's preferences over these variables. As above, a positive k_v is warranted by the need to keep movements in the instrument itself within reasonable bounds. In the set of exercises presented below, we first choose the optimal macroprudential policy for given monetary policy. Next, we assume that both are jointly chosen optimally by the same policymaker, sidestepping the important normative issue of whether responsibility for the two policies should be assigned to the same institution or to separate ones. Under this assumption, the policymaker minimizes the sum of the two loss functions (10) and (11) [10]:

(12) $$L = L^{cb} + L^{mp} \,.$$

In the sections that follow we perform several exercises. In particular, we look at a solution in which a single policymaker chooses optimal values of the policy parameters in equations (5)-(8) or (5)-(9) so as to minimize (12):

$$(\rho_R^{c*}, \chi_\pi^{c*}, \chi_y^{c*}; \rho_j^{c*}, \chi_j^{c*}) = \arg\min L(\rho_R, \chi_\pi, \chi_y; \rho_j, \chi_j)$$

subject to the constraint given by the dynamic model. We call this a cooperative equilibrium, denoted by the *c* superscripts.[11] We compare this equilibrium with a Nash equilibrium solution, defined as a tuple $(\rho_R^{N*}, \chi_\pi^{N*}, \chi_y^{N*}; \rho_j^{N*}, \chi_j^{N*})$ such that:

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[10] This is a special case of the more general formulation $L = \alpha L^{cb} + (1 - \alpha) L^{mp}$, in which the weight α modelling the relative bargaining power of the two policymakers has been set to 0.5. Varying α between zero and one would allow to vary this bargaining power and to analyze its impact on our results, an issue which we do not deal with in the current draft.

[11] In its most general definition, a cooperative game is one in which the interests of the two policy-makers are neither completely opposed nor completely coincident. The cooperative equilibrium can be thought of

$$(\rho_R^{c*}, \chi_\pi^{c*}, \chi_y^{c*}) = \arg\min L^{cb}(\rho_R, \chi_\pi, \chi_y; \rho_j^{N*}, \chi_j^{N*})$$
$$(\rho_j^{N*}, \chi_j^{N*}) = \arg\min L^{mp}(\rho_R^{N*}, \chi_\pi^{N*}, \chi_y^{N*}; \rho_j, \chi_j)$$

subject, again, to the constraint given by the dynamic model. In practice, the strategy chosen by each authority is optimal given the strategy chosen by the other policymaker. We compute the Nash equilibrium iteratively. In all the equilibria agents in the economy are assumed to be passive players, who take the actions of the policy-makers as given and do not anticipate them. Our analysis is close to Petit (1989) who studies the interaction between monetary and fiscal policies in a dynamic model of the Italian economy.

3) Is there a role for macroprudential policies?

In the current policy debate several proposals to reduce the pro-cyclicality induced by Basel II have been advanced. In short, they can be grouped under the following headings: (*i*) smoothing the inputs of the capital function (for instance, banks could be required to mitigate the cyclicality of their PIT estimates of the PDs, or to move to TTC estimation methods); (*ii*) adjusting the capital function (for instance, some parameters such as the confidence level or the asset correlations could be appropriately changed over the cycle); (*iii*) smoothing the output of the capital function (i.e., allow capital requirements to move in an autoregressive or countercyclical fashion); (*iv*) adopting countercyclical capital buffers; (*v*) adopting countercyclical provisions.

For the purposes of this section, it is enough to remark that the model with which we work does not allow us to distinguish among these proposals, as it makes no distinction between capital and loss provisions, say. However, it does allow us to assess their macroeconomic effects if one is willing to overlook the (important) technical differences among these suggestions, and concentrate instead on their common denominator: the idea that capital (or provisions) should be adjusted in a countercyclical fashion.

In this section we interpret equation (8) as a simple capital requirement reaction function, where the parameter $\overline{\nu}$ measures the steady state level of capital requirements ν_t, χ_ν>0 measures its sensitivity to the business cycle, and ρ_ν its inertia. A similar set of exercises is replicated using (9), which models an active countercyclical LTV ratio policy management. The issue is: is there room for an active management of countercyclical capital requirements? At first sight, the answer seems to be no, within our model as well as

as a situation in which the two authorities agree on a joint set of actions, which in our case are given by the two feedback rules (5) and (8).

in general: the Taylor rule which closes the model is the natural countercyclical tool, and it would seem that any new instrument with such target should at best be collinear with monetary policy, and at worst conflict with it (e.g. if the responsibility of the new instrument were assigned to another authority and co-ordination between the two authorities were limited). Section 5 deals with these potential conflicts.

Several arguments may run counter this a priori. First, current DSGE models typically feature several frictions. In our case, some are related to the presence of nominal rigidities (prices and wages) and others to the presence of borrowing constraints on households and firms. Woodford (2003) shows that in a simple economy with one friction, optimal monetary policy is capable of restoring the first best allocation. However, Erceg, Henderson and Levin (2000) show that in an economy with staggered wage and price setting, strict inflation targeting can induce substantial welfare costs. This result suggests that when more than one friction is present, policymakers may want to resort to multiple instruments to maximize society's welfare. Second, the study of optimal monetary policy in the context of models with financial frictions is very recent. Cúrdia and Woodford (2009) find that in a simple new Keynesian model with time-varying credit (arising because of financial frictions) the optimal target criterion (i.e. the optimal monetary policy) remains exactly the same as in the basic New Keynesian model, that is the central bank should seek to stabilize a weighted average of inflation and output gap.

With specific regard to the model used in this paper, recall the channels through which the two policies affect the economy. Monetary policy affects the economy via two channels: the cost of borrowing for firms and households, as shown in equation (2) and the return on households' deposits. Through the first channel the central bank affects consumption of borrowing households and investment by firms Through the second channel she influences saving and consumption choices of the households who hold deposits and do not borrow from banks. Macroprudential policy directly affects the costs related to banks' capital position, which enters the model via equation (2). However, it has no direct effect on the deposit rate. This is the reason why, from a technical viewpoint, the two policies are not collinear within our model.

Altogether, there are reasons to believe that the introduction of an additional instrument might well yield an improvement relative to the results attainable when only monetary policy is available.

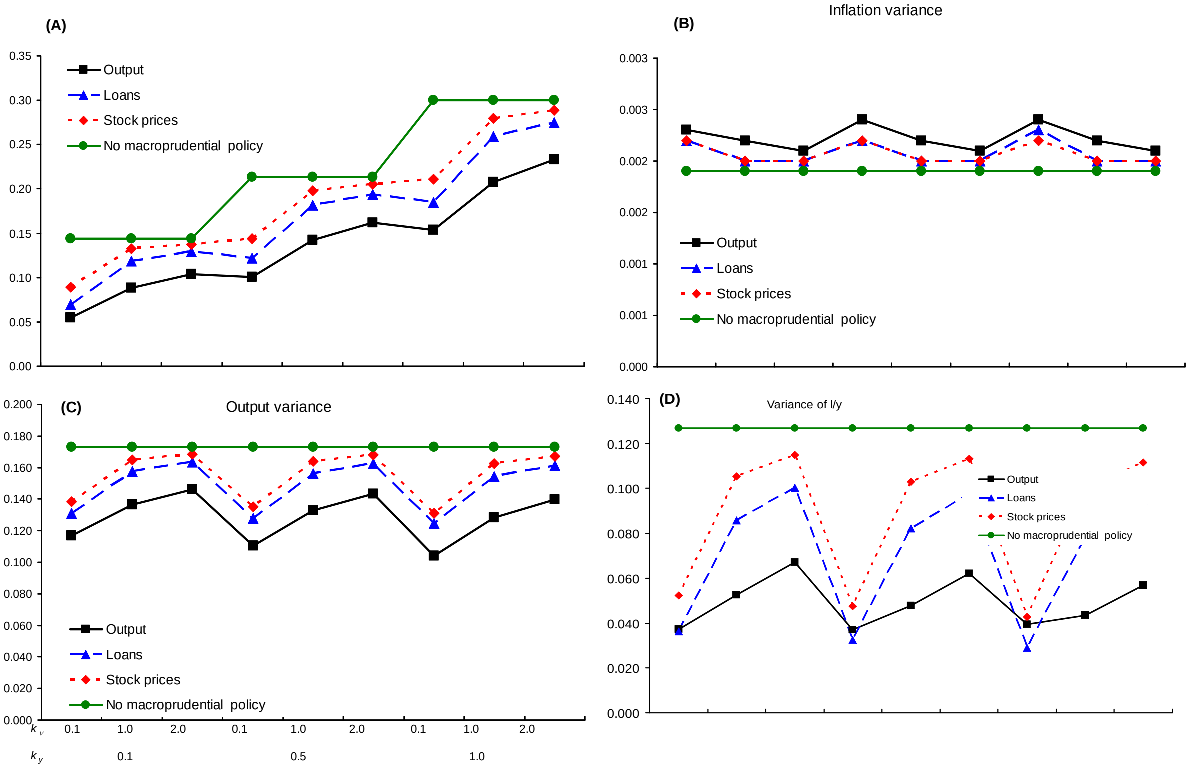
4. Macroprudential policies for given monetary policy

In this section we perform the following exercises. First, we fix the parameters of the Taylor rule at their estimated values and the macroprudential instruments at their steady state values ($\nu_t = \overline{\nu}$, $m_t = \overline{m}$) and compute the unconditional variances of the key macro variables. Next, we assume that a macroprudential authority operates in the economy, choosing the parameters of her reaction function (8) or (9) so as to minimize her loss function (10). We compute the new values of the unconditional variances under this framework, and compare them with those obtained with the model in which macroprudential policy is not implemented. The idea is to gauge how the key macroeconomic and macroprudential objectives are affected by an active management of macroprudential policy. As mentioned above, we experiment with various version of (8) and (9), assuming that the macroprudential authority reacts to output growth, or alternatively to loans growth or equity prices growth. In section 4.1 we run these exercises under the assumption that the economy is hit by technology shocks. In the next subsections the analysis is replicate under a credit crunch shock (a shock which destroys a certain fraction of banks capital).

4.1 Macroprudential policies under a technology shock

We assume that the macroprudential policymaker takes monetary policy (the calibrated Taylor rule) as given, and chooses the parameters of the capital requirement reaction function so as to minimize (10). The key results are reported in figures 1 and 2, obtained with reaction functions (8) and (9), in the order. Consider panel (A) of figure 1. The solid line corresponds to the results obtained by simulating the model under the calibrated Taylor rule and assuming that no active macroprudential policy is run. Each point of the line represents the value of the loss function for a particular configuration of the preference parameters k_j (reported in the legend under the horizontal axis of panel C). The other three lines are obtained with an active capital requirement policy (8), assuming that the policymaker reacts, one at the time, to loans growth, output growth, and stock prices returns. Panels (B) through (D), obtained via the same exercise, report the corresponding values for three key components of the loss function, the variances of output, of inflation and of the loan/output ratio.

Fig. 1 - Values of the objective variables under a technology shock
Macroprudential instrument: capital requirement rule (8)

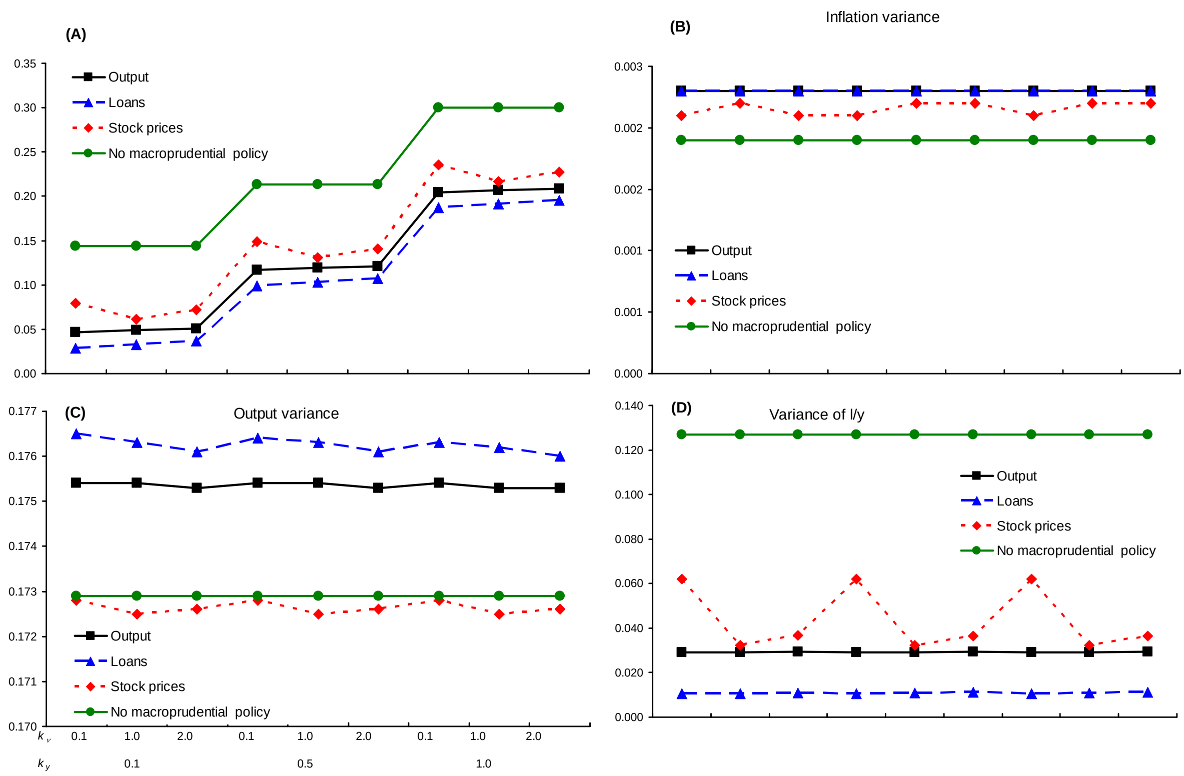


Several results emerge from panel (A) of the figure. First, adding an active macroprudential policy to the system unambiguously improves the loss function (the solid line always lies above the lines obtained under active capital requirements policy). Second, the improvement is always maximum when the weight assigned to the instrument variability in the loss function is minimum. This confirms the existence, in this context, of the typical trade-off between instrument variability and effectiveness. Third, the best results are obtained when the macroprudential policymaker reacts to output growth. Next comes the policy function based on loans, whereas the one based on stock returns is the worst of the three. Fourth, the benefits of an active macroprudential policy tend to increase with the weight assigned by the policymaker to output stabilization.

A look at panel (B) through (D) of figure 1 reveals that the improvement in the overall loss function brought about by the macroprudential policy reflects a corresponding improvement (reduction) in the variability of output and of the loans/output ratio, obtained at the cost of a deterioration in inflation variability. This result is robust across the entire grid of policymaker's preferences. It is hardly surprising, considering that in these exercises the macroprudential authority is not concerned, by assumption, about inflation. If assessed in percentage terms, these effects are sizeable, even overlooking the extreme cases obtained with low values of k_v. For instance, over the range of preference parameters considered, and relative to the baseline model without macroprudential policy, an active management of (8) achieves a reduction in output variance ranging from a minimum of about 18 percent (for the preference combination $k_{l/y}$=2.0, k_y=0.1), and a maximum of 67 percent (for the preference combination $k_{l/y}$=0.1, k_y=1.0).

Next, the above exercise is replicated under the assumption that the macroprudential policymaker adopts the alternative policy (9), focusing on an active management of the LTV ratio. The results are in figure 2. The scales of the vertical axes have been kept as in figure 1 for ease of comparison. Note that the overall value of the loss function is not comparable with that of figure 1, since the policy instrument differs (the variance of the capital requirement and of the LTV ratio feature in the loss functions underlying figures 1 and 2, in the order). However, the variances of the target variables can be compared across the two figures (see more on this in section 4.3). The figure suggests that the LTV ratio also seems to be an effective macroprudential tool. Like in figure 1, the ordering of the various rules remains consistent across the various combinations of the preference parameters.

Fig. 2 - Values of the objective variables under a technology shock
Macroprudential instrument: loan-to-value ratio rule (9)

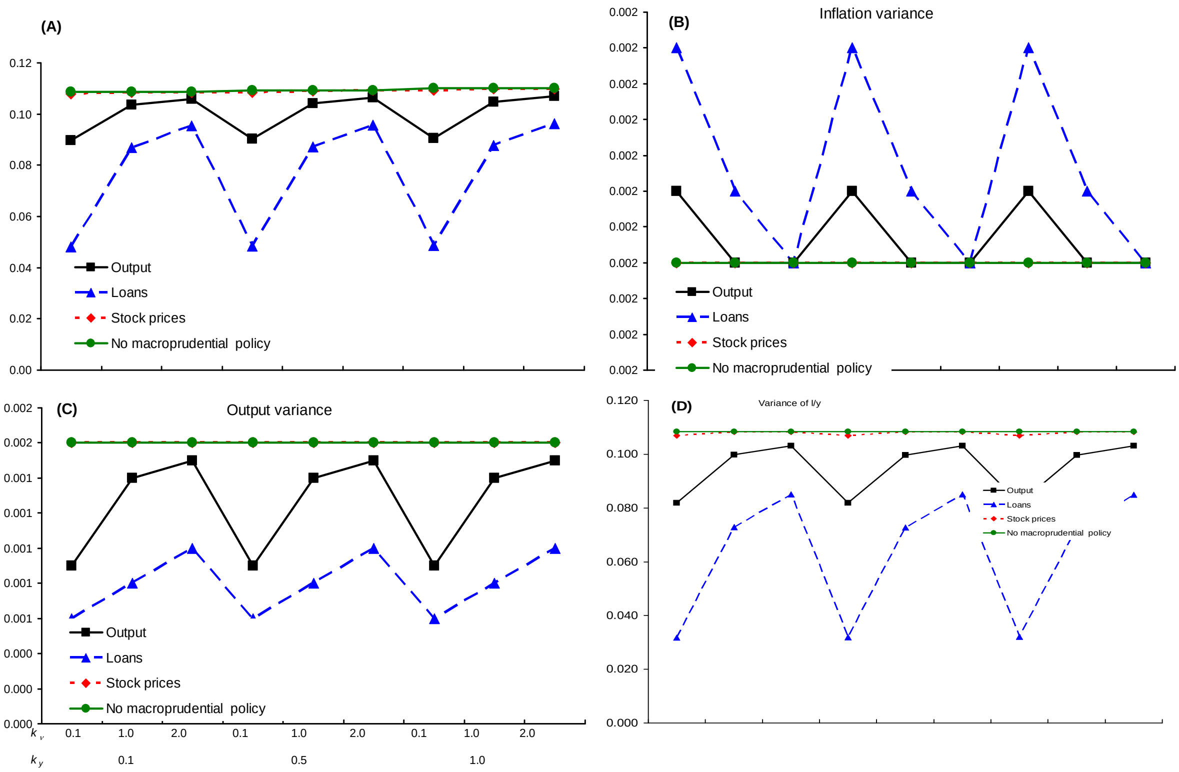


The main differences relative to the exercise conducted with rule (8) are the following. First, the rule that yields the largest reduction in the overall loss is the one based on loans, followed by the rule reacting to output and finally by the one based on stock prices. Second, now stabilization of the loans/output ratio comes at the expense of both higher output and inflation variability. This is due to the fact that the macroeconomic effect in this case takes place only through households' attitude towards debt for home purchase, whereas rule (8) affects both the households and the firms sector.[12] Third, all the rules yield a better stabilization of the loans/output ratio, relative to what can be attained with the capital requirement rule. Fourth, while the rule based on stock prices is not the best in terms of overall loss reduction, its performance is better than the ones based on output or loans if measured in terms of inflation and output variability.

4.2 Macroprudential policies under a credit crunch shock

Figures 3 and 4 replicate the exercises in section 4.1 under the hypothesis that the economy is hit by a credit crunch shock, which destroys bank capital.

Fig. 3 - Values of the objective variables under a credit crunch shock
Macroprudential instrument: capital requirement rule (7)

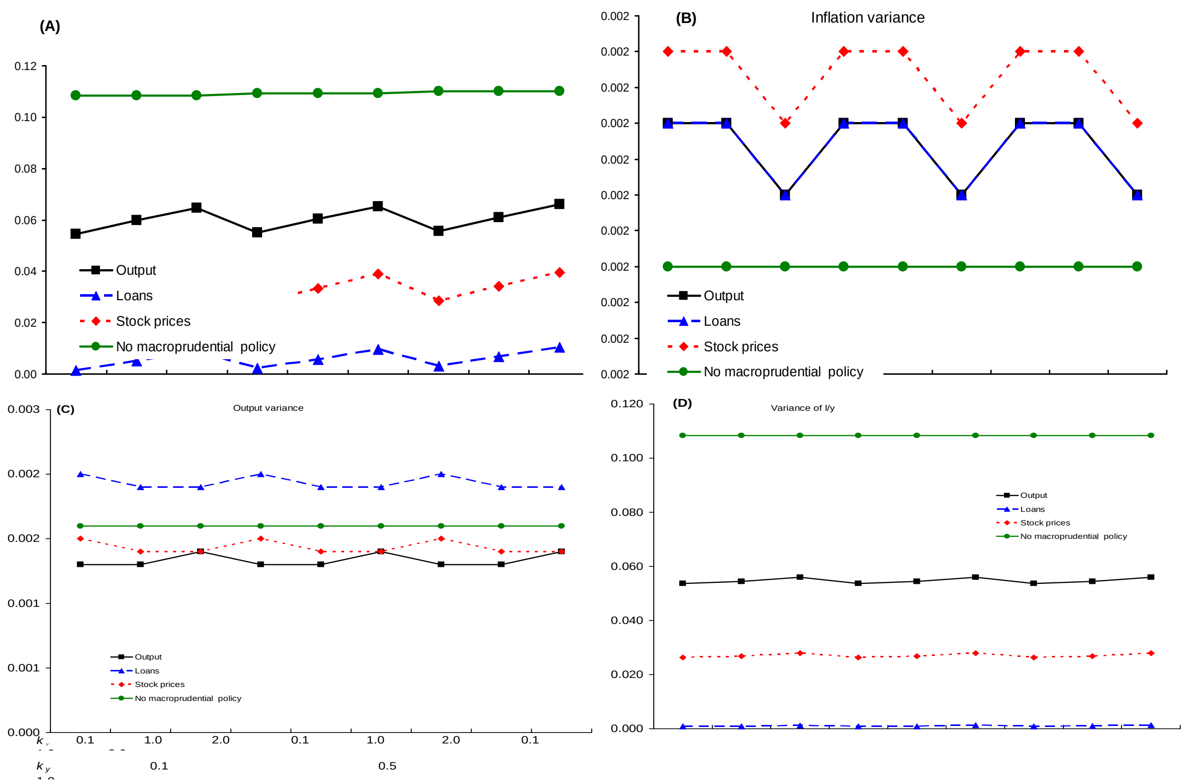


In this case, the values of the loss and of its components are not comparable to those in figures 1 and 2, as the effect of the two shocks on the economy have a clearly a very different magnitude. However, the figures allow ranking the various alternative versions of

12 In a set of unreported exercises we also tried to model a policy of active management of LTV ratios for firms. The results appear unstable.

the macroprudential policies (8) and (9). As shown in figure 3, panel A, some of the results attained via the adoption of the capital requirements reaction function (8) are similar to those in Figure 1. In this case as well, an active macroprudential policy unambiguously improves the loss function; as before, the improvement is inversely related to the dislike for the variability of the instrument. The main differences are as follows. First, in this case the best results are obtained when the macroprudential policymaker reacts to loans growth. Next comes the policy function based on output, whereas the one based on stock returns does not manage to improve upon the baseline situation of no discretion. Second, the benefits of an active macroprudential policy do not increase with the weight assigned by the policymaker to output stabilization.

Fig. 4 - Values of the objective variables under a credit crunch shock
Macroprudential instrument: loan-to-value ratio rule (9)



As under a technology shock, the improvement in the overall loss function reflects a corresponding improvement (reduction) in the variability of output and of the loans/output ratio, at the cost of an increase in inflation variability across the entire grid of preferences.

In figure 4 the exercise is replicated under the alternative management of the LTV ratio for households (equation 9). In this case as well, the best overall results are obtained with the rule reacting to loans growth. This rule is particularly effective at driving down the variance of the loans to output ratio: panel B shows that the reduction in the overall loss comes entirely from this component; the variances of output and inflation increase relative to the baseline case of no macroprudential policy.

4.3 Comparison of LTV and capital requirement policies

The effectiveness of the two instruments available to the macroprudential policymaker cannot be gauged via a direct comparison of the loss functions under the two rules, since the variance of the instruments enters the loss function themselves, making a direct comparison meaningless. By contrast, the volatilities of the target variables remain comparable across the two cases, although with a caveat.[13] Comparison of the volatilities of output and the ratio of loans to output highlights the following. An active management of capital requirements is more effective than managing the LTV on loans to households in reducing the volatility of economic activity, under both a technology shock and a credit crunch shock. This conclusion holds regardless of whether output or loans enter the policy rule described by eq. 8. By contrast, the LTV policy appears to be more effective in reducing the variability of the loans-to-output ratio, assumed to be one of the targets of the macroprudential action. One possible explanation for this result is that while a macroprudential policy based on management of the LTV ratio affects mainly the household sector, adjusting the minimum capital requirement affects both the household and the firm sector through the effects of the capital position of banks on interest rates on loans (see eq. 2 in Section 2). The fact that the LTV policy is relatively more effective in stabilizing the loans-to-output ratio suggests that, in our model, macroprudential policies face a trade-off between stabilisation of economic activity and financial stability. Finally, it is worth noting that the variance of inflation and the policy rate increase regardless of whether the capital requirement rule or the LTV rule is used by the macroprudental policymaker, compared to the case in which macroprudential policy is not implemented. While fairly obvious, given that neither variance appear in (11), this result suggests that, once the monetary policy is chosen optimally, it might conflict with the macroprudential policy. This potential interaction between the two policies is analyzed in the next Section.

[13] According to (11), the policymaker trades off the volatility of the instrument with that of the other target variables. Since the instruments differ, their volatilities are also likely different, and this may affect the position along the trade-off that the policymaker is going to choose. Furthermore, while the weights of the two instruments in the loss function have been kept unchanged, it is not obvious that a given increase in the variance of capital requirements, or of the loan to value ratio, should imply the same cost.

5. Interaction between macroprudential and monetary policies

5.1 The game setup

So far we have worked under the assumption that the parameters of the monetary policy rule (5) are fixed at the values estimated by Gerali *et al.*, (2010). Obviously, these parameter values need not be optimal in the sense of minimizing the loss function which the monetary policy-maker is assumed to be minimizing in the present context, or in a situation in which she needs to interact with an authority in charge of preserving financial stability.

Indeed, as argued above, one of the crucial issues of the current debate about the establishment of a macroprudential authority concerns its interaction with the central bank. In this Section we explore this interaction. More specifically, we perform the two exercises discussed at the end of Section 2. First, we assume that only one policymaker with two instruments (the policy rate and capital requirements) operates in the economy, with the objective of stabilizing the variances of inflation, output, the loans to output ratio, and of the changes in the instruments. In other words, he minimizes the loss function (12). This can be interpreted as the case in which the central bank is assigned macroprudential responsibilities. The equilibrium that characterized the interaction of the two authorities in this case is a cooperative one. Second, we assume that the monetary and the macroprudential policymakers interact a la Nash. In this case each one tries to minimize its own loss function: the central bank minimizes (10), taking the policy rule (8) of the macroprudential authority as given, whereas the latter minimizes (11), taking the monetary policy rule (5) as given. We then compare the outcomes of the two exercises along different dimensions and study the implications for the transmission of business cycle shocks. As the strategic interaction between the two policymakers makes the solution of the model more cumbersome, we fix the preference parameters of the two authorities. Specifically, we set k_y=0.5, k_r=0.1 in (10), and $k_{y,mp}$=0.5, k_v=0.1 in (11). In the current draft we only consider a technology shock. To find the combination of parameters that minimize the loss function in the cooperative case we randomly selected 50 different tuples of initial conditions for the parameters of the two policy rules (5) and (8), in order to find a global minimum.[14] We detect some dependence of the optimized parameters on initial conditions, suggesting that the loss (12) is characterized by several local minima. To compute the Nash equilibria of

[14] Specifically, we fix ρ_R and ρ_v at 0.99, given that all the rules for the macroprudential authority in Section are characterized by a large degree of inertia, and draw initial values for χ_π, χ_y and χ_v from uniform distributions. The ranges used for each parameter are, in the order, [1.7, 3.0], [0.0, 1.0] and [-5.0, 5.0].

the game we perturbed the global minimum tuple $(\rho_R^{c*}, \chi_\pi^{c*}, \chi_y^{c*}; \rho_j^{c*}, \chi_j^{c*})$ of the cooperative game with random normal draws 50 times and for each of them we solved the optimization problems of the two policy makers sequentially, until convergence was achieved.

5.2 Main results

The main features of the different equilibria are illustrated in Table 1 below.

Table 1 – Games between the monetary policy and the macroprudential authority: Key features of the cooperative and Nash equilibria

	Cooperative equilibrium (a)	Nash equilibrium Type 1 (b)	Nash equilibrium Type 2 (c)	Monetary policy only (no macroprudential policy) (d)
Parameters of the policy rules				
Monetary policy (5)				
ρ_R	0.9988	0.9990	0.9990	0.9990
χ_π	2.0127	1.7093	1.7805	1.7090
χ_y	0.9573	61.5092	49.0951	1.0107
Macroprudential (8)				
ρ_v	0.9990	0.9859	0.9990	0
χ_v	1.9779	-3.7726	0.7009	0
Values of loss functions and volatilities of key variables				
Joint loss (12) [(1)]	0.12037	0.12347 (2.6)	0.12577 (4.5)	-
Monetary policy (10)	0.05562	0.05882 (5.7)	0.05390 (-16.8)	0.05972 (7.4)
Macroprudential (11)	0.06474	0.06465 (-0.1)	0.07188 (29.2)	
Volatilities [(2)]				
σ_π	0.48	0.50 (5.7)	0.51 (7.7)	0.48 (-0.2)
σ_y	3.27	3.23 (-1.2)	3.10 (-5.0)	3.39 (3.8)
$\sigma_{L/y}$	1.05	1.05 (0.1)	1.54 (47.0)	-
$\sigma_{\Delta r}$	0.13	2.16 (1618)	1.78 (1318)	0.09 (-24.5)
$\sigma_{\Delta v}$	0.66	1.29 (95.2)	0.24 (-62.9)	-

Notes: (1) For the cooperative equilibrium, value of (12); for the Nash equilibrium, sum of the values of (10) and (11). For the last column, value of (10). - (2) Standard deviations in percentage points. Figures in brackets denote the percentage change with respect to the cooperative case.

Let us first consider the coefficients of the optimized monetary policy and macroprudential policy rules. Both rules are extremely inertial in all the cases. The autoregressive parameters ρ hit the boundary, which we set at 0.999 in order to avoid numerical problems in the computation of the asymptotic variances. This result depends on the features of the estimated model.[15] The optimized value of ρ_R compares with a value of 0.77 in the monetary policy rule estimated in Gerali *et al.* (2010).

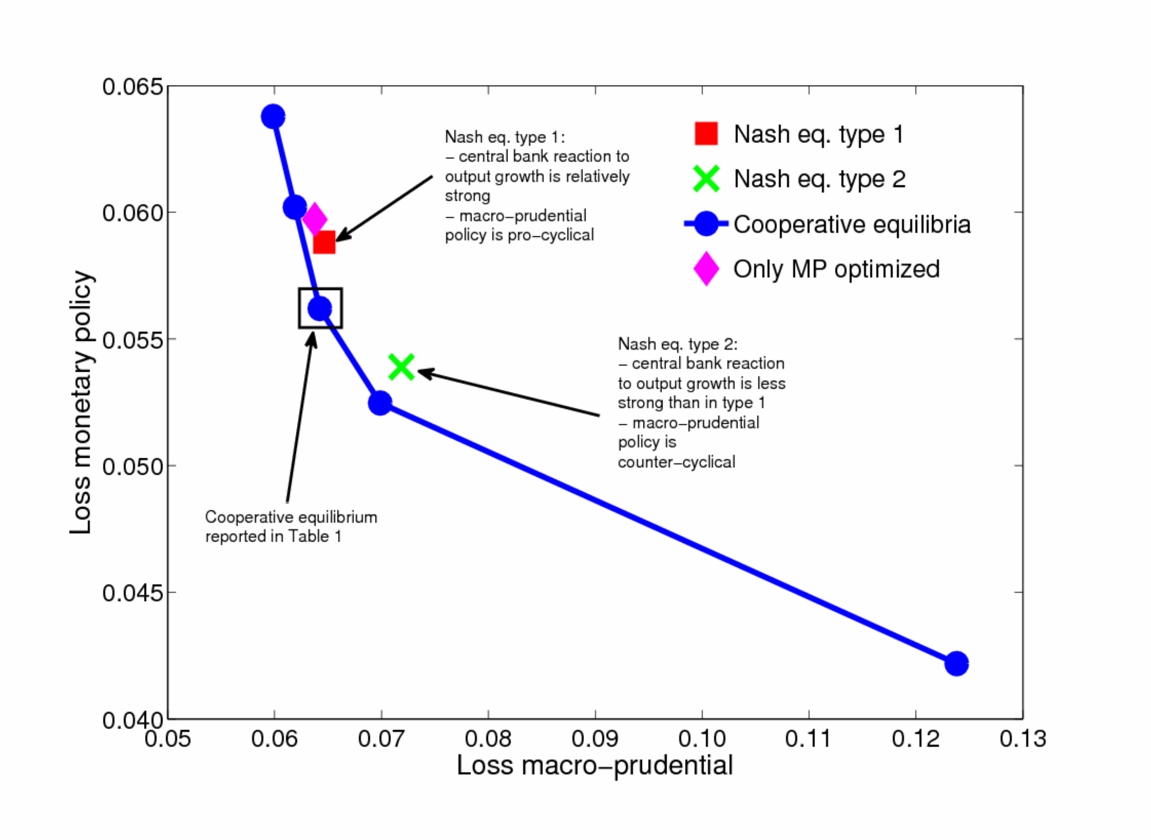
In the cooperative game the values for the monetary policy responses to inflation and output growth are, respectively, 2.01 and 0.96. While the former coefficient is close to the value estimated by Gerali *et al.* (2010), the response to output growth is much larger (0.96 compared to 0.35). The optimized policy rule for the macroprudential authority suggests that in response to positive output growth, capital requirements are tightened (the coefficient χ_v is 1.98).

Two equilibria of the non-cooperative game were found. Figure 5 plots the values of the losses of the two policymakers in the different equilibria. Nash equilibrium of type 1 is characterized by a relatively low value of the macroprudential policymaker's loss function, whereas the central bank is relatively worse off. In the Nash equilibria of type 2, in the lower right corner of the figure, the opposite is true. Table 1 reports key statistics for a representative equilibrium in each cluster. They mainly differ in terms of the cyclicality of the macroprudential policy rule and of the aggressiveness of monetary policy to output growth. In particular, type 1 equilibrium is characterized by a *pro-cyclical* macroprudential authority, that lowers capital requirements when output growth increases (χ_v is equal to -4); the central bank "makes up" for this behaviour by implementing a very strong countercyclical response to output (χ_y around 66). In type 2 equilibrium, the macroprudential policy turns counter-cyclical (χ_v increases to 0.7); correspondingly, the countercyclical response of the central bank to output becomes less aggressive (χ_y falls to 49). Clearly, the values of the parameters of (5) and (8) used as initial conditions for the search determine which of the two types of Nash equilibrium the system is going to end up selecting. Figure 5 plots the set of cooperative equilibria and the two Nash equilibria reported in Table 1. The blue curve representing the cooperative equilibria is obtained by minimizing a loss function which is a linear combination of the loss functions of the two authorities, with weights that add up to 1. More specifically the weight attached to the loss

15 In particular, technology shocks are very persistent (the autoregressive coefficient in the related process is 0.93), and have very persistent effects on real variables because of the set of real and nominal frictions incorporated in the model.

function of the macroprudential policymaker is α (1- α is the weight attached to the loss of the central bank) where α = {0.1, 0.3, 0.5, 0.7, 0.9}.[16] Figure 5 shows that the macroprudential authority is relatively better off when it can implement a pro-cyclical policy compared to the outcome in the cooperative equilibrium reported in Table 1. Figure 5 and Table 1 show that the Nash equilibrium of type 2 constitutes a threat point for the monetary authority, as the central bank can threaten to follow this non-cooperative strategy if the macroprudential authority does not agree to cooperate. Symmetrically, the Nash equilibrium of type 1 represents threat point for the macroprudential authority.

Figure 5 – Trade-off between the loss of the central bank and the loss of the macroprudential authority



The loss achieved in the cooperative case, reported in figure 5 as a square, is equal to 0.12037; the monetary policy component is equal to 0.05562 while the one related to the macroprudential is 0.06474. In Nash equilibrium of type 1 reported in table 1, the sum of the two components is equal to 0.12347, 2.6 percentage points higher than the minimum achieved in the cooperative game. In the other Nash equilibrium (type 2), the sum of the losses is 0.12577, 4.5 percentage points larger than the one in the cooperative case. In both

[16] We follow Petit (1989) in constructing the Pareto-optimal frontier. The cooperative equilibrium reported in Table 1 is achieved by setting α at 0.5. It is easy to show that in this case the following holds: $2L=L^{cb} + L^{mp}$; the minimization of this loss function yields exactly the same values for the policy rules reported in Table 1.

Nash equilibria, the sum of the individual losses is larger than the loss achieved in the cooperative game. However, this need not hold for each individual policymaker: the figure clearly shows that the macroprudential policymaker is worse off in the cooperative equilibrium, relative to Nash equilibria of type 2.

The fairly similar overall values of the loss functions in the three equilibria – cooperative and the two Nash – hide substantial heterogeneity among their key components. Specifically, no significant changes can be detected in the volatilities of the key macroeconomic variables, i.e. inflation and output. However, relative to the cooperative equilibrium, the variability of the policy rate increases between 14 and 18 times, depending of the type of Nash equilibrium considered, while the variability of the capital requirement can either increase (by a factor of 6) or decrease (by a factor of 2). This suggests that the Nash solution may generate substantial coordination problems. The coefficients in the policy rules confirm this view: in the Nash equilibrium the reaction of the central bank to output (the parameter χ_y) increases disproportionately, from 1 to 49 or 63 depending on whether the macroprudential policymaker acts in a countercyclical or pro-cyclically way. This is indeed, *prima facie* evidence of a conflict between the two instruments.

Turning to the volatilities of the target variables, Table 1 suggests the following. The volatility of the policy rate increases significantly between the cooperative and the non-cooperative cases independently of the type of Nash equilibrium considered.[17] Concerning the variability of capital requirements, the two non-cooperative equilibria differ significantly as in one case (type 1) it almost doubles while it falls by a factor of 4 in the other equilibrium (type 2). Concerning the macroeconomic variables, the volatility of inflation is smaller in the cooperative case compared with both Nash equilibria. The volatility of output instead is lower in the Nash equilibrium of type 2 compared to the cooperative case while it is only marginally higher in the type 1. Finally, it is evident from Table 1 that stabilisation of output comes at the cost of increasing the volatility of the loans to output ratio in the case of the Nash equilibrium of type 2. This result stems from the fact that the decrease in the covariance between loans and output more than offsets the decline in the volatility of the two variables (compared with the cooperative equilibrium).[18]

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[17] The variability of the policy instruments depends to large extent on the weights in the loss function. In our experiments these weights are equal to 0.1 for both instruments.

[18] Recall that the variance of a ratio of two random variables is given by the sum of the variance minus twice the covariance between the two.

The last column of Table 1 reports key statistics for one last exercise. Here we represent the standard case: no macroprudential policymaker is active in the economy, and the central bank optimally chooses the parameters of the Taylor rule (5) to minimize its loss function (10). In this case, the relevant comparison is with the cooperative scenario in column (a), which rules out the potential problems of coordination failure and policy conflict characterizing the Nash outcomes which we have discussed above. Relative to the cooperative equilibrium, output volatility increases somewhat; inflation volatility remains the same, interest rate volatility declines. Surprisingly, the variance of the loans to output ratio turns out to be lower in column (d) than in any of the previous columns. Taken at face value, these results suggest that the main advantage of introducing a countercyclical capital requirements policy go to the monetary policymaker: her loss deteriorates by about 7 percent relative to the cooperative case, whereas the loss of the macroprudential authority improves slightly.

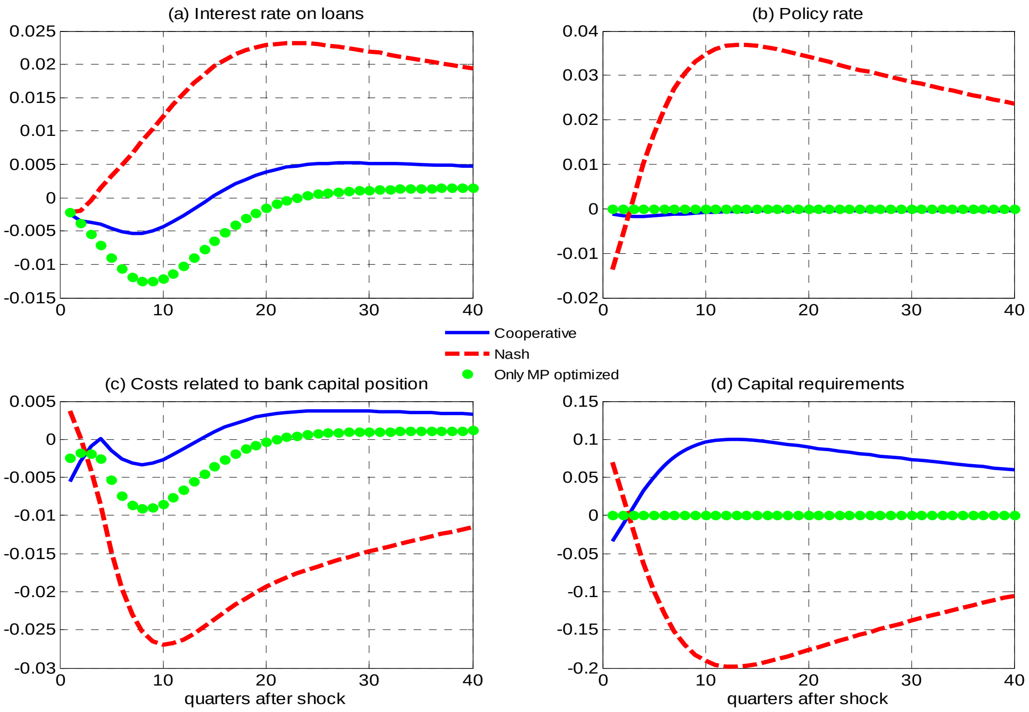
5.3 Understanding the interaction between monetary and macroprudential policies

Comparison of the cooperative and Nash equilibria has highlighted the potential for conflict between the central bank and the macroprudential supervisor, in the absence of close co-ordination. This conflict may result in larger volatility of the policy instruments and may also give rise, depending on the type of policy implemented by the macroprudential policymaker, to an increase in the volatility of output and inflation and also in that of the loans to output ratio. To get a feel for the features of the model that give rise to this result, in this section we analyze the impulse responses to a technology shock.

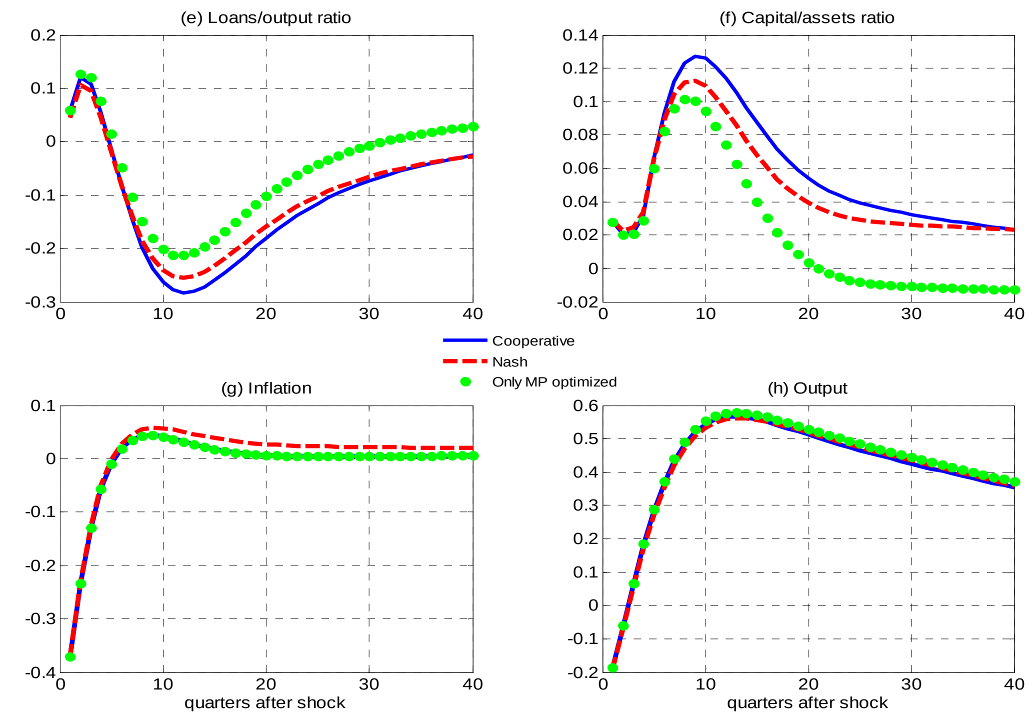
Recall that from the discussion in section 3 that the two policies interact through their effects on the interest rates on loans, in equation (2). To understand this interaction it is useful to look at the response of the interest rate on loans, and of the two components that determine this rate, i.e. the policy rate and the cost of adjusting the capital-to-assets ratio (the term in brackets in equation 2). We omit a discussion of the response of the deposit rate since it reflects that of the policy rate practically one-to-one. Figure 6 below reports the impulse responses to a positive technology shock. We consider three equilibria: the cooperative case, the Nash – type 1 case, in which the conflict between the two policies is more evident, and the monetary policy only case, from column (d) of table 1.

Figure 6 - Impulse responses to a technology shock in the various equilibria

(*A*)



(*B*)



Consider first the reaction of the lending rate, in panel (a). shows that while in all the cases banks react by reducing the cost of borrowing in response to the economic expansion induced by the technology shock, in the Nash equilibrium the initial positive impulse is immediately reversed and the cost of external finance records a strong increase. This behaviour of the interest rate on loans results from two opposite forces, which partially offset each other. On the one hand the central bank, after an initial cut, immediately raises the policy rate (panel b), while on the other the costs related to the capital position of the bank fall after an initial increase (panel c). The net effect is the increase seen in panel (a). The fall is persistent in the Nash equilibrium case, while it is more short-lived in the cooperative case and when there is no macroprudential policy in place. The reason why costs related to the capital position initially increase and then fall persistently in the non-cooperative game is that macroprudential policy adjust capital requirements v (see panel d) in order to compensate the change in the policy rate by the central bank and therefore reduce the volatility of the loans-to-output ratio (panel e), the main target for her policy (see expression 11). In a situation in which the capital-assets ratio tends to increase above the steady state (reflecting an increase in the real value of bank equity after the fall in inflation; panel f), a decline in capital requirements opens up a positive gap between the two therefore reducing the costs related to capital position and supporting loans to the private sector. Indeed, the ratio of loans to output falls by less compared to the cooperative case.

In the cooperative case, the macroprudential authority implements a counter-cyclical policy by raising capital requirements above the steady state level (9 per cent). In this case, the difference between the capital/assets ratio and the regulatory requirements is smaller compared with the Nash equilibrium case and therefore the costs related to the capital position respond less to the technology shock.

Finally the two bottom panels in figure 6 show that despite the differences in the behaviour of the policymakers between the cooperative and the non-cooperative cases, the dynamics of output and inflation are almost identical.

6. Concluding remarks

The exercises performed in this paper are somewhat mechanic, but they represent an attempt at organizing the discussion on macroprudential issues, focusing on the right questions, and providing tentative answers. In what follows we try to cast the main results emerging from our analysis in terms of the questions which we put down in the introduction.

Within a standard macroeconomic framework it is very difficult to devise a satisfactory way of modeling macroprudential objectives. This is partly due to the stylized nature of modern macro models, including ours. Nevertheless, we believe that the key difficulty will likely survive possible future modeling improvements, however desirable. Such difficulty lies in the fact that systemic risk, arguably the objective of macroprudential policy, is extremely hard to define and measure, having the potential to emerge in many different forms from a variety of sources – different markets, financial intermediaries, financial products –and to mutate over time. In our view, these difficulties warrant the conclusion that, in abstract, systemic risk defies modeling, and that it can only be captured in limited, ad-hoc ways. Based on this premise, we assume the macroprudential authority to be concerned about the amplitude of output fluctuations, and about excessive growth of financial activity, as captured by the loans/output ratio. Hence, we write her loss function as a weighted sum of the variances of these two variables. While clearly *ad-hoc*, this formulation captures some of the essential features which, based on the current state of the debate, should play a role in a macroprudential authority's objective function. In the exercises performed in the paper we assume that the macroprudential authority optimally chooses the parameters of a simple policy rule to minimize this objective function.

Concerning the macroprudential tools, the situation is definitely more satisfactory. As we mentioned in the introduction, there is a broad consensus on the need to reduce financial system procyclicality, to be achieved via some amendment to the regulation. Countercyclical management of capital requirements is the most popular proposal – indeed, it features in the consultation document released by the Basel Committee in December. Countercyclical management of the loan-to-value ratio is also often proposed, and has been used in the past by financial supervisors. Therefore, in a first set of exercises we let monetary policy obey the Taylor rule, and assume that the macroprudential authority chooses simple rules which link capital requirements or the loan-to-value ratio to various economic indicators: the growth of output, of loans, of equity prices. The results suggest that, by and large, macroprudential policies have the power to stabilize the dynamics of the economy. In reaction to a technology shock, the best results are obtained when the macroprudential policymaker links capital requirements to output growth. Inferior results are obtained by linking capital requirements, in the order, to the dynamics of loans or stock returns. In all cases, an active macroprudential policy attains a reduction in the variability of output and of the loans/output ratio, at the cost of deterioration in inflation variability. This is hardly surprising, considering that the macroprudential authority is not concerned, by assumption, about inflation. If assessed in percentage terms relative to the baseline model without macroprudential policy, these effects tend to be sizeable: an active countercyclical management of capital requirements achieves a reduction in output variance ranging from a minimum of about 18 percent to a maximum of 67 percent. The improvement in the loss function is always maximum when the weight assigned to the instrument variability in the loss function is minimum. This confirms the existence, in this context, of the typical trade-off between instrument variability and effectiveness.

The LTV ratio also seems to be an effective macroprudential instrument. Relative to the case in which the macroprudential authority uses capital requirements as a tool, the main differences are the following. First, the rule that yields the largest reduction in the overall loss is the one based on loans, followed by the rule reacting to output and finally by the one based on stock prices. Second, now stabilization of the loans/output ratio comes at the expense of both higher output and inflation variability.

These exercises were replicated under a credit crunch shock, modelled as a reduction in banks' capital. The main difference relative to the results illustrated thus far is that the best results are now obtained when the macroprudential policymaker reacts to loans growth.

A direct comparison of the loss functions attained under the capital requirement rule and the LTV rule is not feasible, since the variances of the instruments enter the loss function themselves. By contrast, the volatilities of the target variables remain comparable across the two cases, although with a caveat. A comparison between the capital requirement and the LTV rules suggests that the former is more effective in reducing the volatility of output, under both a technology shock and a credit crunch shock. By contrast, the LTV rule appears to be more effective in reducing the variability of the loans/output ratio.

These exercises were replicated under a credit crunch shock, modelled as a reduction in banks' capital. The main difference relative to the results illustrated thus far is that the best results are now obtained when the macroprudential policymaker reacts to loans growth.

While these results should not be taken at face value, they hold over a relatively broad parameterization of the macroprudential policymaker's preferences (various configurations of the weights with which the variances of output and of the loans/output ratio enter the loss function). That there is no single optimal instrument is likely to be a robust result, as optimality likely depends on the nature of the shock considered.

Finally, we address the interaction between macroprudential policy and monetary policy. The key issue here is: could macroprudential policy co-operate with monetary policy, achieving a further inward shift of the output-inflation volatility trade-off? Or, would it be redundant? Or, in a worst-case scenario, could it conflict with it? To address these questions we introduce a standard loss function for the central bank, whose arguments are inflation and output volatility, and two analyze two types of games: a cooperative game, in which the two authorities simultaneously minimize a weighted average of their two objective functions; and a Nash game, in which each authority minimizes her loss.

The key although preliminary results (we only analyze the technology shock case, and do not check for robustness across alternative combinations of the policymakers' preference parameters) are the following. First, in the cooperative equilibrium the macroprudential policy rule acts countercyclically, raising the capital requirements in reaction to positive output growth. Relative to the monetary-policy-only scenario, output volatility is reduced, inflation volatility is unaffected; overall, the benefits of introducing the additional policy appear to be relatively modest. Second, if we let the two authorities optimize their own objective function independently, two types of Nash equilibria emerge. In the first type the central bank is better off relative to the macroprudential authority, in the second type the opposite holds true. If assessed in terms of the properties of the key macroeconomic variables, the differences between these two equilibria are relatively modest. By contrast, they differ substantially in terms of the behaviour of the policy instruments. In one equilibrium, qualitatively similar to the cooperative one, the behaviour of the macroprudential policymaker is countercyclical. In the other equilibrium the coefficient of the capital requirements rule becomes procyclical; correspondingly, the monetary policy rule becomes strongly countercyclical; the variability of the policy instruments increases substantially. Overall, these results suggest that the Nash solution might generate substantial coordination problems. The preliminary answer to the question raised above seems to be that an active management of macroprudential policy has indeed the potential to usefully cooperate with monetary policy; at the same time, the order of magnitude of the related benefits does not appear to be large; furthermore, there appears to be the risk that, in the absence of a strong coordination mechanism between the two authorities, a coordination failure could bring about suboptimal results.

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