ISSN 2704-7407

UNIVERSITÀ CATTOLICA DEL SACRO CUORE
Dipartimento di Economia e Finanza

Working Paper Series

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Working Paper n. 110

September 2021

UNIVERSITÀ
CATTOLICA
del Sacro Cuore

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Monetary and macroprudential policy:

The multiplier effects of cooperation

Federico Bassi* **, Andrea Boitani**

Abstract

A BMW model is augmented with a credit market affected by banks' balance sheet and used to assess the dynamic performance of an economy in the face of demand and financial shocks under different assumptions about the interactions between monetary and macroprudential policy. We show that the regulatory bank's capital requirement has a multiplier effect that interferes with monetary policy, thus influencing the credit market and the output gap, and this multiplier effect varies according to the institutional arrangements in which macroprudential and monetary policies are embedded. In particular, we find that cooperation between monetary policy and macroprudential policy delivers the best overall stabilization outcomes in the face of both negative demand and bank equity shocks, if such shocks are not highly persistent. As shock persistence increases, non-cooperation or a simple leaning against the wind monetary policy outperform cooperation. However, adding countercyclical capital buffers in the macroprudential toolkit reinstates the original ranking of institutional arrangements with cooperation dominating overall.

JEL code: E44, E52, E58, E61, G21, G28

Keywords: Financial Frictions, Monetary Policy, Macroprudential Policy, Policy Coordination

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When considering the connections between financial stability, price stability, and full employment, the discussion often focuses on the potential for conflicts among these objectives. Such situations are important, since it is only when conflicts arise that policymakers need to weigh the tradeoffs among multiple objectives. But it is important to note that, in many ways, the pursuit of financial stability is complementary to the goals of price stability and full employment.

Janet Yellen, 2014

1. Introduction

Achieving and maintaining financial stability is now considered crucial for achieving and maintaining overall macroeconomic stability. The outbreak of the financial crisis after 2007 reminded us that financial factors and banks behaviour may amplify economic fluctuations and even trigger deep and long-lasting recessions. Consequently, new macroprudential policy tools have been forged to mitigate the risks spreading from the financial and banking systems to the real economy. Promoting aggregate financial stability – by assigning additional mandates to monetary policy and/or by setting up a regulatory authority with the explicit mandate of targeting some key financial variable or banking ratio – has become an objective in its own i.e., to be distinguished from the standard focus on micro-stability, i.e. on the viability and good health of individual financial intermediaries.

Macroprudential policy interacts with monetary policy in several ways. Hence, the actual institutional framework in which the two policies are embedded does affect the outcome of the interplay between macroprudential and monetary policy. Such an interplay is generally studied by means of DSGE modelling, by augmenting a standard New Keynesian model with different financial frictions (Cozzi et al, 2021 is a recent example) or making use of full-fledged agent-based models (Popoyan et al, 2017; 2020). However, most of the relevant results can be obtained in a simple BMW framework (Bofinger et al, 2007), which represents a static approximation of a more general New Keynesian DSGE model (Bofinger et al, 2004). The 3-equations BMW model has to be extended to deal with financial frictions and different scenarios for macroprudential policy. Absent financial frictions (as in a Modigliani-Miller world), macroprudential policy is not needed as likely disruptions of individual financial intermediaries never impinge upon the stability of macroeconomic variables.

There are many channels through which financial frictions may affect the business cycle (see IMF, 2013 and Nier & Kang, 2016 for early surveys, Popoyan, 2020 for a recent one). We follow Bernanke & Blinder (1988) and Woodford (2010) in focussing on the role played by lenders (banks) balance sheet, summarised by the loan-to-equity ratio, in determining the supply of credit and – through the spread between the (real) interest rate on loans and the (real) interest rate on bonds (assumed to be equal to the policy rate) – in influencing the output gap, thereby competing with the monetary policy. We also assume that the output gap affects the time evolution of banks' equity, as an increase (decrease) in the output gap leads to lower (higher) defaults on credit and hence higher (lower) banks' profit margins and retained profits. Therefore, monetary policy affects financial stability by influencing the equity base and the supply of credit by banks, thereby competing with macroprudential policy. By so doing, we are able to simulate the impact of either financial or macroeconomic shocks under different institutional arrangements which represent different interplays of monetary and macroprudential policies. We find that our macroprudential tool (the regulatory loan-to-equity ratio) has a multiplier effect that interferes with monetary policy, and such a multiplier effect varies according to the institutional arrangement in which macroprudential and monetary policies are embedded. That is, different combinations of macroprudential and monetary policies may have different impacts on the length and strength of business fluctuations and financial markets stability.

We shall compare the dynamic response of either demand or equity shocks under four distinct institutional arrangements.[1] As a *baseline* institutional setting, we assume that the macroprudential policy maker sets the regulatory loan-to-equity ratio as constant at its equilibrium level, while the central bank receives a standard dual mandate that consists of minimizing the output gap and the inflation gap. In the second institutional setting, the central bank receives an additional financial mandate. Hence, the monetary policy mandate implies setting the interest rate as to minimize the output gap, the inflation gap, and the *credit gap*, which is the gap between the current loan-to-GDP ratio and the macroprudential target loan-to-GDP ratio, thereby reflecting a l*eaning against the wind* approach (Filardo et al, 2016; Gambacorta & Signoretti, 2014). We then introduce a macroprudential authority that oversees stabilizing the credit gap, by either cooperating or non-cooperating with the central bank, reflecting institutional arrangements similar, respectively, to the UK or the US: while the Bank of England is fully responsible of the macroprudential policy, the Federal Reserve participates to the Financial Stability Oversight Council but has no leading role (Angelini et al, 2012; De

[1] For the sake of brevity, we shall leave out supply shocks as the results for this kind of shocks are not really surprising and have little multiplier effects. However, those results are available from the authors upon request.

Paoli & Paustian, 2017; Gelain & Ilbas, 2017) [2]. Hence, in the third "non cooperative" setting, the macroprudential authority minimizes both the credit gap and the output gap, while the central bank aims at minimizing the output gap and the inflation gap. Non-cooperation arises from the simultaneous co-existence of a common objective (the output gap) and two independent objectives (the inflation gap and the credit gap), leading to a conflict over the output gap. In the fourth "cooperative" setting, we assume a common mandate for both authorities that consists of minimizing a joint loss function based on output, inflation, and credit volatility. Hence, cooperation consists of internalizing the *financial externalities* of monetary policy and the *inflation externalities* of macroprudential policy. Nevertheless, while Angelini et al (2012), De Paoli & Paustian (2017) and Gelain & Ilbas (2017) take the policy mandates as given and estimate the optimal parameters of predefined policy rules, we follow Poutineau & Vermandel (2015) and explicitly derive the optimal monetary and macroprudential rules under both non-cooperation and cooperation (Poutineau and Vermandel, 2015, however, only consider the cooperative case)[3].

The main results of the paper can be summarized as follows. We confirm the superiority of introducing a specific macroprudential tool to address financial instability, relative to a "monetary policy alone" world (Adrian et al, 2020; Angelini et al, 2012; De Paoli & Paustian, 2017; Martinez-Miera & Repullo, 2019; Poutineau & Vermandel, 2015). Moreover, cooperation between monetary policy and macroprudential policy delivers the best global stabilization outcomes in the face of both negative demand and (bank) equity shocks, thereby confirming the results of Angelini et al (2012), De Paoli & Paustian (2017) and Gelain & Ilbas (2017). Indeed, in a *cooperative* institutional arrangement, credit volatility is effectively tackled, without negative consequences on output and inflation stability. Contrary to Angelini et al (2012), we do not find any side effect on interest rate volatility, thereby reinforcing the relative benefits of cooperation over non-cooperation. The reason behind this superior performance is that, under cooperation, the multiplier moves pro-cyclically (when the output gap increases after the monetary policy reaction, the multiplier increases as well), thereby making monetary policy more effective. Whilst it is counter-cyclical (when the output gap increases after the monetary policy reaction the multiplier shrinks) under non-cooperation and

[2]Aikman et al (2019) for an evaluation of how well-equipped actual US and UK financial regulators are "to prevent – or materially dampen – a rerun the last [2007-08] financial crisis".
[3] See Appendix A.2 for the algebraic proofs.

a-cyclical by construction in the baseline and the *leaning against the wind* settings, where the macroprudential tool is muted.

The pro-cyclicality of the multiplier, however, turns out to be destabilizing as shocks become increasingly persistent, reverting the efficiency ranking between the cooperative and non-cooperative scenarios: when shocks are persistent, a cooperative macroprudential policy jeopardizes the increased monetary policy effectiveness by amplifying the (unexpected) adverse shocks through larger multipliers, thereby increasing global volatility. In such a situation, a simple *leaning against the wind* monetary policy might be even preferable to an active macroprudential policy (either cooperative or non-cooperative) in terms of output, inflation and credit stability, with almost negligible costs in terms of interest rate volatility relatively to the other scenarios, especially when an equity shock hits the economy. This result contrasts with Poutineau & Vermandel (2015), since they do not consider equity shocks and the divine coincidence holds in their model, such that the persistence of demand shocks is irrelevant to the output gap. *Leaning against the wind* would also outperform the standard dual mandate monetary policy, in line with Filardo et al (2016) and Gambacorta & Signoretti (2014). The original ranking is reinstated as soon as counter-cyclical capital buffers are added to the discretionary loan-to-equity regulation in the macroprudential toolkit, thereby minimizing the effects of persistent unexpected shocks on bank's equity.

Sensitivity analysis shows that results are robust to changes in the specification of the objective functions. Namely, we find that by increasing the relative weight of financial stability (hence, by decreasing the relative weight of output gap stabilization for the macroprudential authority), the negative consequences of non-cooperation are substantially lower, as in De Paoli & Paustian (2017) and Gelain & Ilbas (2017). This is because the macroprudential authority underscores the side effects on output gap produced by the monetary policy relatively to the side effects on financial stability produced by its reaction. Instead, by increasing the relative weight of inflation stabilization (hence, by decreasing the relative weight of output gap stabilization for the Central Bank), the costs of non-coordination increase faster, because of the stronger side effects on output gaps produced by the hawkish monetary policy. Hence, while a hawkish central bank would be better off by coordinating with the macroprudential authority in order to make the latter internalize the inflation costs of macroprudential policy, the macroprudential authority might offset the costs of non-coordination by paying a larger attention to credit stability relatively to output stability.

The paper is organized as follows. In section 2, we introduce the model and discuss the relevant variables and policy tools. Section 3 shows the solution of the model in the four above-mentioned institutional arrangements, whilst we leave the algebraic proofs to appendix A.2. In section 4, we examine the dynamic reactions to negative demand and equity shocks in the four institutional settings and provide a sensitivity analysis showing the effects of changing policy preference parameters and shocks' persistence. We also introduce a second instrument in the macroprudential toolkit to analyze possible interaction effects. Section 5 concludes.

2. The model

We move from a standard BMW framework (Bofinger et al. 2007). The model features an IS function to which financial frictions are added (*à la* Bernanke & Blinder, 1988), that give rise to a financial accelerator, a simple Phillips curve with adaptive expectations, a credit market, a monetary policy rule and a macroprudential rule, for which we do not provide explicit micro foundations. The reason is that we aim to concentrate on the stylized properties of a simple model to isolate the *multiplier effect* of policy cooperation, which is hard to find in log-linearized full-fledged models. Moreover, our simple model is still comparable with the reduced form of larger DSGE models (De Paoli & Paustian, 2017; Adrian et al, 2020), such that further extensions of this work might provide micro foundations for this *toy model*.

2.1. The IS equation

We assume financial hierarchy. That is, there is a wedge between the cost of funds raised externally and the opportunity cost of internal funds. In a nutshell, firms are operating in a non-Modigliani-Miller world. In a Modigliani-Miller world (MM hereafter) the way firms gather resources for investment financing has no influence on resource allocation and on macroeconomic performance. Self-financing out of retained profits, bonds issue, banks loans or shares issue are perfect substitutes. Hence the cost of a "capital unit" is equal irrespective of how financial resources are gathered. The standard monetary policy transmission mechanism implicitly assumes a MM world. The reason why there is just one interest rate in the IS-LM model or in the IS-AS-MPR model is that in these models no distinction is made between bank loans and bond financing. Thus, we introduce an IS function under financial hierarchy:

$$\hat{y}_t = g - \varphi(r_t + \kappa \hat{r}_{L,t}) + \eta_{D,t} \qquad (1)$$

Whereby $\hat{y}_t$ is the output gap, g is the autonomous component of demand, φ and κ are positive coefficients, r_t is the real interest rate on securities and $\hat{r}_{L,t}$ is the spread between the real interest rate on loans, $r_{L,t}$, and the real interest rate on securities.[4] $\eta_{D,t}$ captures the unobservable demand shocks. The natural interest rate, r_N, is thus equal to $\frac{g}{\varphi}$ [5].

2.2. The Phillips curve

Although recent empirical works find evidence of anchored inflation expectations (Blanchard, 2016; Ball & Mazumder, 2019), we refer to a Phillips curve with adaptive expectations:

$$\pi_t = \pi_{t-1} + \gamma \hat{y}_t + \eta_{S,t} \tag{2}$$

whereby π_t represents the current rate of inflation, γ is a positive coefficient and $\eta_{S,t}$ captures the unobservable supply shocks. The assumption of adaptive expectations, as opposed to anchored expectations, is justified by the hypothesis that large and/or persistent shocks might de-anchor inflation expectations (Williams, 2006; Turner et al, 2019), such that a persistent Phillips curve can better capture the long run effects of persistent shocks. Furthermore, we tested an alternative Phillips curve with partially anchored expectations and the qualitative results did not change for positive and non-negligible degrees of persistence[6].

2.3. The credit market

Following Bernanke & Blinder (1988), we model a simplified credit market in which the demand for loans (relative to GDP) depends on the spread between the interest rate on loans and the interest rate on bonds: if the interest rate on loans raises above (falls below) the interest rate on bonds, agents substitute loans (bonds) with bonds (loans):

$$v_t = v^* - \chi \hat{r}_{L,t} \tag{3}$$

Whereby v_t is the demand for credit as a share of GDP (*loan-to-GDP* ratio), v^* is the *loan-to-GDP* ratio that prevails if the spread $\hat{r}_{L,t}$ is null, and χ is a positive coefficient. On the other hand, the supply of credit depends on banks' equity given the regulatory *loan-to-equity* ratio:

$$v_t = \frac{L_t}{E_t} e_t = \omega_t e_t \tag{4}$$

[4] $\hat{r}_{L,t}$ is more precisely, the difference between the current and the equilibrium spread between the real interest rate on loans and the real interest rate on securities. As we assume, for simplicity a zero equilibrium spread, the definition of $\hat{r}_{L,t}$ in the text applies.

[5] Without financial hierarchy the IS equation (1) reduces to the standard IS found in the BMW model and the natural interest rate is still equal to $r_N = g/\varphi$.

[6] Results are available from the authors upon request.

Whereby L_t is the total supply of loans, E_t is the bank's equity, e_t is bank's equity relative to GDP and ω_t the regulatory *loan-to-equity* ratio (the inverse of the capital ratio). Therefore, the equilibrium between demand and supply of loans (relative to GDP) determines the spread:

$$\hat{r}_{L,t} = \frac{1}{\chi} \left(v^* - \omega_t e_t\right) \tag{5}$$

With no financial hierarchy, $\hat{r}_{L,t} = 0$; hence $v_t = v^*$. That is, banks' leverage and equity do not affect the IS curve and have no macroeconomic impact. In this case, macroprudential policy plays no role. This might explain why it is ignored in standard macro-models.

2.4. Bank's equity

Here, we follow the assumption that banks can expand their equity only by retaining profits (Angelini et al, 2012). Because an increase in the output gap leads to lower defaults on credit and therefore higher profit margins for the bank, we assume that bank's equity relative to GDP is a positive function of the output gap. Moreover, because we assume that equity does not adjust instantaneously to the new profit conditions, such that the effects of shocks can persist, the ratio of bank's equity to GDP follows the persistent linear process:

$$e_t = \overbrace{e^* + \rho(e_{t-1} - e^*)}^{\equiv \varepsilon_{t-1}} + \sigma\hat{y}_t + \eta_{e,t} = \varepsilon_{t-1} + \sigma\hat{y}_t + \eta_{e,t} \tag{6}$$

Whereby e^* is the equilibrium level of the bank's *equity-to-GDP* ratio, ρ and σ are positive coefficients and $\eta_{e,t}$ captures unobservable equity shocks.By substituting (6) in (4), we rewrite the *loan-to-GDP* ratio as:

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t + \eta_{e,t}) \tag{7}$$

Hence, while the macroprudential authority directly affects the supply of loans through ω_t, the Central Bank indirectly affects the supply of loans through $\hat{y}_t$. Finally, by substituting (3) and (7) into (1), we obtain the equilibrium IS:

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\left\{g^* - \varphi r_t + \Theta\omega_t\left(\varepsilon_{t-1} + \eta_{e,t}\right) + \eta_{D,t}\right\} \tag{8}$$

With $\Theta \equiv \frac{\varphi\kappa}{\chi}$ and $g^* \equiv (g - \Theta v^*)$.

As it appears clearly in (8), the fiscal multiplier is endogenous to the regulatory loan-to-equity ratio ω_t, suggesting that the macroprudential policy has a *multiplier effect* that might interfere with the monetary policy. Therefore, coordination between the two authorities becomes key to avoid excess volatility of policy tools, which might lead in turn to sub-optimal equilibria and adverse scenarios (i.e., the zero-lower bound). The core equations of the model are thus:

$$\begin{cases} \hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\left[g^* - \varphi r_t + \Theta\omega_t\left(\varepsilon_{t-1} + \eta_{e,t}\right) + \eta_{D,t}\right] \\ \pi_t = \pi_{t-1} + \gamma\hat{y}_t + \eta_{S,t} \\ v_t = \omega_t\left(\varepsilon_{t-1} + \sigma\hat{y}_t + \eta_{e,t}\right) \end{cases} \qquad (9)$$

For a matter of simplicity, we will hereafter refer simply to *credit* and *equity* for *credit-to-GDP* and *equity-to-GDP*.

3. Model solutions in different institutional arrangements

In this section, we show how to solve the model in the four above mentioned institutional settings, under the assumption that stochastic shocks cannot be directly observed by neither the Central Bank nor the macroprudential Authority (when active), who can only observe *ex-post* the consequences on output, inflation and credit. This assumption is crucial to rule out the *divine coincidence* and test the effects of demand shocks, which would otherwise be fully neutralized by the Central Bank if they were observable, as in Poutineau & Vermandel (2015). In the *baseline* and *leaning against the wind* settings, the macroprudential tool (the regulatory loan-to-equity ratio) is set at its equilibrium level, as if macroprudential policy were invariant. Consequently, in these two scenarios the multiplier in the IS equation is constant. As the macroprudential authority is given either a dual (financial and output stability) or triple (financial, output and inflation stability) mandate, the multiplier in the IS equation is no longer constant because the macroprudential tool becomes endogenous, as it will be shown in sections 3.3 and 3.4.

3.1. Constant Macroprudential Regulation (CMPR)

In the first setting, the macroprudential authority sets the regulatory loan-to-equity ratio at the constant, equilibrium level $\omega^* = v^*/e^*$, while the central bank sets the interest rate so to minimize a standard loss function based on output and inflation volatility, under the constraints (9) and (2):

$$\min_{r_t}\left\{\hat{y}_t^{\ 2} + \zeta(\hat{\pi}_t)^2\right\} \qquad (10)$$

s.t.

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t$$

By substituting the constraints into the loss function and minimizing w.r.t r_t, we obtain the rule:

$$r_t = \frac{1}{\varphi}\left\{g^* + \Theta\omega_t\varepsilon_{t-1} + \frac{\Gamma}{\Phi}\hat{\pi}_{t-1}\right\} \tag{11}$$

With $\Gamma = \frac{\zeta\gamma}{(1+\zeta\gamma^2)}$, $\Phi = \frac{1}{(1-\Theta\sigma\omega_t)}$ and $\omega_t = \omega^*$.

3.2. Leaning against the wind (LAW)

In the second setting, the macroprudential authority still sets the regulatory loan-to-equity ratio at the constant, equilibrium level $\omega^* = \frac{v^*}{e^*}$, while the central bank receives a third mandate that consists of minimizing credit volatility, beyond output and inflation, under the constraints (2), (7) and (9), and under the assumption that stochastic shocks cannot be observed:

$$\min_{r_t}\left\{\hat{y}_t^{\,2} + \zeta(\hat{\pi}_t)^2 + \xi(\hat{v}_t)^2\right\} \tag{12}$$

s.t.

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t$$

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t)$$

By substituting the constraints into the loss function and minimizing w.r.t r_t, we obtain the rule:

$$r_t = \frac{1}{\psi\varphi}\left\{g' + \Xi\omega_t\varepsilon_{t-1} + \frac{\varsigma\Gamma}{\Phi}\hat{\pi}_{t-1}\right\} \tag{13}$$

With $\varsigma = (1 + \zeta\gamma^2)$, $\psi = [\varsigma + \xi\sigma^2\omega_t^{\,2}]$, $\Xi = (\xi\sigma\omega_t + \varsigma\Theta)$, $g' = (\psi g - \Xi v^*)$ and $\omega_t = \omega^*$.

3.3. Independent Macroprudential Policy (IMPP)

In the third setting, we introduce an independent macroprudential authority to complement the Central Bank dual mandate. While there is a large literature on monetary policy mandates, there are still few theoretical and empirical contributions on which are (or should be) the macroprudential mandates. We thus follow closely the existing literature (Angelini et al, 2012; De Paoli & Paustian, 2017; Gelain & Ilbas, 2017) and assume that the macroprudential authority seeks to stabilize the *credit gap* (the gap between the loan-to-GDP ratio and its equilibrium value) – hence, the spread – and the output gap, which is a direct source of credit expansion through equation (7). The rationale is that while the Central Bank is formally in charge of ensuring monetary stability, the macroprudential authority is in charge of ensuring the financial stability, although both authorities are interested in ensuring the stability of output to prevent, respectively, inflationary or financial tensions. Therefore, given the assumption that equity shocks are unobservable, the independent macroprudential authority minimizes a dual mandate loss function given the constraints (7) and (9),

$$\min_{\omega_t}\{\hat{y}_t{}^2 + \xi(\hat{v}_t)^2\} \tag{14}$$

s.t.

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\}$$

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t)$$

By substituting the constraints into the loss function and minimizing w.r.t. ω_t, we thus obtain the macroprudential policy rule:

$$\omega_t = \frac{\xi v^* - \Theta(g^* - \varphi r_t)}{[(\Theta^2+\xi)\varepsilon_{t-1} + \xi\sigma(g-\varphi r_t)]} \tag{15}$$

From equation (15), it is apparent that ω_t is not constant. In this institutional arrangement, the monetary policy rule is the same of the baseline setting, except that the regulatory loan-to-equity ratio is no longer constant at the equilibrium value. Therefore, to derive the reduced form optimal monetary and macroprudential policy rules under the non-cooperative setting, we simply solve the subsystem (12) and (15), and obtain the solutions:

$$\begin{cases} r_t = \frac{\xi g + (\Theta^2+\xi)\Gamma\hat{\pi}_{t-1}}{\xi\varphi} \\ \omega_t = \frac{(\xi v^* + \Theta\Gamma\hat{\pi}_{t-1})}{\xi(\varepsilon_{t-1} - \sigma\Gamma\hat{\pi}_{t-1})} \end{cases} \tag{16}$$

3.4. Lend a hand (LAH)

In the fourth setting, we assume that both authorities *lend a hand* to each other by internalizing the externalities produced by their own policy rule, thereby minimizing a joint loss function based on output, inflation, and credit volatility (Angelini et al, 2012; De Paoli & Paustian, 2017; Gelain & Ilbas, 2017; Poutineau & Vermandel, 2015), given the constraints (2), (7) and (9):

$$\min_{r_t\,;\,\omega_t}\{\hat{y}_t{}^2 + \zeta(\hat{\pi}_t)^2 + \xi(\hat{v}_t)^2\} \tag{17}$$

s.t.

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t$$

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t)$$

By substituting the constraints into the loss function and minimizing w.r.t. r_t, we obtain the *LAW* monetary rule (although the regulatory loan-to-equity ratio is no longer constant):

$$r_t = \frac{1}{\psi\varphi}\left\{g' + \Xi\omega_t\varepsilon_{t-1} + \frac{\varsigma\Gamma}{\Phi}\hat{\pi}_{t-1}\right\}$$

With $\varsigma = (1 + \zeta\gamma^2)$, $\psi = [\varsigma + \xi\sigma^2{\omega_t}^2]$, $\Xi = (\xi\sigma\omega_t + \varsigma\Theta)$ and $g' = (\psi g - \Xi v^*)$.

Then, by minimizing (16) w.r.t. ω_t, and substituting the constraints into the minimized loss function, we obtain the *cooperative* macroprudential policy rule:

$$\omega_t = \frac{(\xi v^* - \Theta\zeta\gamma\hat{\pi}_{t-1}) - \Theta\varsigma(g^* - \varphi r_t)}{(\xi\varepsilon_{t-1} + \xi\sigma(g - \varphi r_t) + \Theta^2\Lambda)} \tag{18}$$

With $\varsigma = (1 + \zeta\gamma^2)$ and $\Lambda = (\varsigma\varepsilon_{t-1} - \sigma\zeta\gamma\hat{\pi}_{t-1})$

Therefore, to derive the optimal monetary and macroprudential policy rules under the cooperative equilibrium, we solve the subsystem (14) and (19) to obtain the solutions:

$$\begin{cases} \omega_t = \frac{\varsigma v^*}{\Lambda} \\ r_t = \frac{1}{\varphi}(g + \Gamma\hat{\pi}_{t-1}) \end{cases} \tag{19}$$

4. Results

In order to concentrate specifically on the multiplier effect, we neglect supply shocks (that are already largely explored in the literature) and only simulate negative demand and equity shocks, by assuming that the system is initially at the steady state and comparing the four institutional arrangements[7]. The shocks take the form:

$$\eta_t = \delta\eta_{t-1} + {\eta^e}_t \tag{20}$$

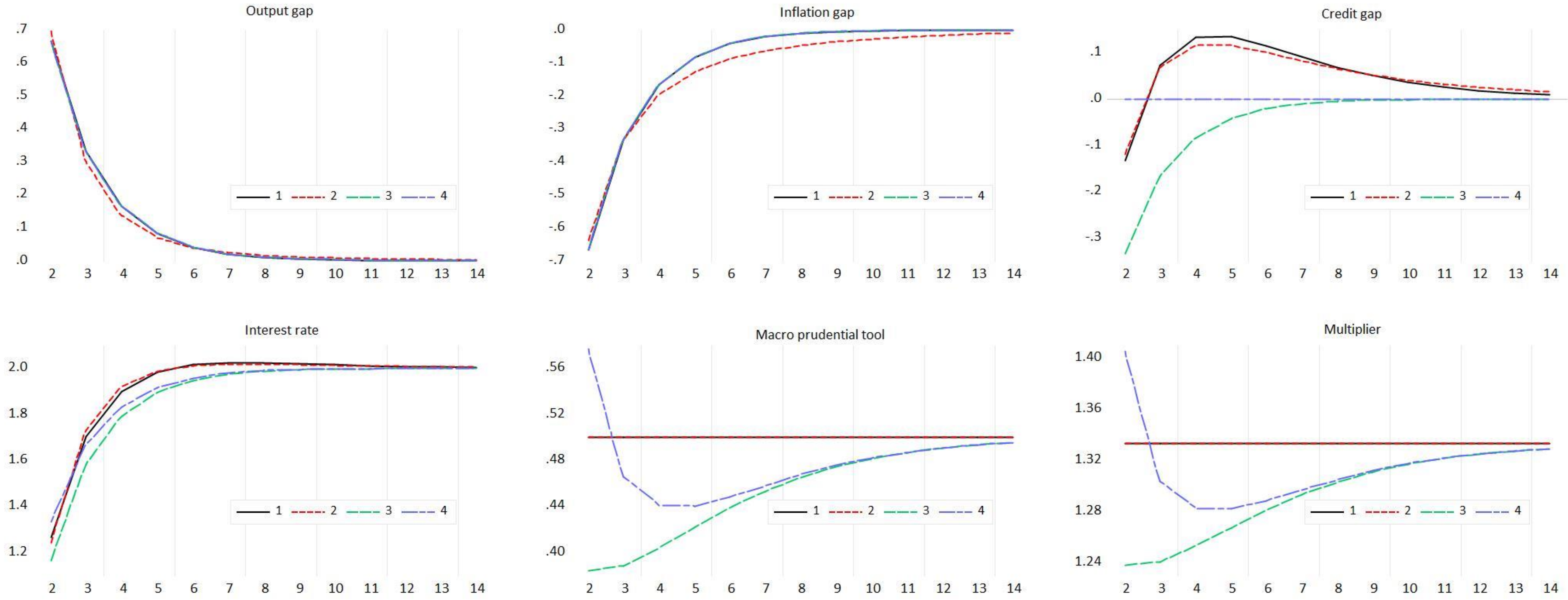
With $\delta < 1$ and ${\eta^e}_t = \begin{cases} 1 & iff \quad t = 1 \\ 0 & otherwise \end{cases}$

4.1. Demand shock

We start by simulating a negative, non-persistent ($\delta = 0$) 1% demand shock that leads, by the end of period 1, to a decrease in the output gap, the rate of inflation and the credit gap. This unexpected shock will thus imply, as of period 2, a policy reaction by the two authorities, according to the policy scenario in place.

[7] The calibration of the model does not follow any empirical reference, as we do not aim to replicate specifically a set of stylized fact, but we rather prefer to concentrate on the qualitative results of the model. Appendix A.1 reports the baseline parameters.

Figure 1. Demand shock



CMPP

The central bank reacts in period 2 by decreasing the interest rate to tackle the persistent effects of the shock on current inflation, such that the output gap becomes positive. Nevertheless, the inflation gap and the credit gap remain both negative because the persistence effects of past inflation and past equity more than compensate the policy-induced increase in the output gap. Then, the system returns gradually to the steady state, although the credit gap temporary overshoots the equilibrium level, given the lower persistence with respect to inflation (ρ <1).

LAW

The *leaning against the wind* setting does not provide any substantial improvement with respect to the baseline (Table 1, first column). Moreover, the volatility of the interest rate is relatively similar in both scenarios. The reason is that reducing credit volatility would require a more aggressive monetary policy leading to raising output volatility.

IMPP

In the third setting – whereby the macroprudential authority oversees output and credit using the regulatory loan-to-equity ratio, while the central bank returns to the baseline dual mandate – the output gap and the inflation gap coincide with the baseline scenario. Nevertheless, the credit gap and the interest rate are much more volatile with respect to the baseline and the LAW scenarios (Table 1, first column). For instance, in period 2, after observing the negative demand shock of period 1, the central bank cuts the interest rate to generate a positive output gap and avoid strong persistence effects on inflation, thereby accepting a larger volatility of output to minimize the volatility of inflation. Nevertheless, the macroprudential authority – which does not care of inflation but does care of output stability – reacts by decreasing the regulatory loan-to-equity ratio to reduce the positive output gap at the cost of a slightly larger volatility of the credit gap, thereby creating a conflict with the central bank. This conflict lasts until the macroprudential authority stops lowering the regulatory loan-to-equity ratio because the costs of the additional credit volatility offset the benefits of the additional output stability, and it has two main implications.

First, the volatility of both policy tools increases without producing any substantial effect on output and inflation stability, since the dual mandate of the central bank allows the central bank to set both the output gap and the inflation gap at the desired level as long as the interest rate is under control. Second, the loan-to-GDP ratio shrinks downwards in period 2, reaching a negative peak, thereby amplifying the effect of the demand shock on financial stability. As a result, credit volatility increases despite the introduction of a new authority – the macroprudential authority – that has the explicit mandate of minimizing it, using an additional tool. Hence, a monetary policy that *leans against the wind* is preferable to an independent macroprudential policy.

LAH

In the fourth setting, the central bank *leans against the wind* and the macroprudential authority *lends a hand* to the central bank to stabilize inflation. Although this cooperative joint mandate has no effects on output and inflation stability with respect to the IMPP setting, the credit gap goes to zero and the interest rate has the lowest volatility relatively to all scenarios. The reason is that the macroprudential authority accepts a larger output gap and refrains from lowering the regulatory loan-to-equity ratio after internalizing its costs in terms of inflation. Therefore, the policy conflict that emerged under non-cooperation fully disappears.

Cooperation between the two authorities has therefore two major implications. The first implication is that credit volatility fully disappears without additional costs in terms of output and inflation. The second implication is that the volatility of the interest rate also shrinks, suggesting an increased efficiency of monetary policy. This increased efficiency relies on the pro-cyclicality of the multiplier: the multiplier increases together with the output gap as the macroprudential authority raises the regulatory loan-to-equity ratio (instead of lowering it, as in the non-cooperative mandate), thereby increasing monetary policy effectiveness. This pro-cyclicality, however, becomes counterproductive when unexpected shocks persist (section 3.3).

4.1.1. Sensitivity analysis

To get deeper insights on the causalities of the model, we test how results change when we modify the authorities' preferences for credit and inflation stability (respectively, ξ and ζ) and the persistence degree of shocks (δ).

Preference for credit and inflation stability

We first focus on changes in the preference for credit stability (ξ). Not surprisingly, the CMPP and the LAH settings do not change. For instance, in the first setting, the central bank does not care about credit stability and there is no macroprudential policy. In the *LAH* setting, the macroprudential authority is already able to neutralize completely the credit gap one period after the shock, irrespective of the degree of preference for credit stability.

Table 1. Standard deviations as a function of the preference for credit and inflation stability

		ξ						ζ					
		1	**1,2**	**1,4**	**1,6**	**1,8**	**2**	**1**	**1,2**	**1,4**	**1,6**	**1,8**	**2**
σ^{y}	**1**	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,817	0,856	0,889	0,918	0,943
	2	0,776	0,778	0,779	0,781	0,782	0,784	0,776	0,819	0,856	0,887	0,914	0,938
	3	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,817	0,856	0,889	0,918	0,943
	4	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,817	0,856	0,889	0,918	0,943
σ^{π}	**1**	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,680	0,611	0,556	0,510	0,471
	2	0,769	0,771	0,773	0,775	0,778	0,781	0,769	0,684	0,618	0,564	0,519	0,482
	3	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,680	0,611	0,556	0,510	0,471
	4	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,681	0,611	0,556	0,510	0,471
σ^{ν}	**1**	0,303	0,303	0,303	0,303	0,303	0,303	0,303	0,288	0,277	0,269	0,263	0,259
	2	0,272	0,267	0,262	0,257	0,252	0,248	0,272	0,262	0,256	0,251	0,247	0,245
	3	0,385	0,321	0,275	0,241	0,214	0,193	0,385	0,408	0,428	0,444	0,459	0,471
	4	0	0	0	0	0	0	0	0	0	0	0	0
σ^{r}	**1**	0,799	0,799	0,799	0,799	0,799	0,799	0,799	0,834	0,864	0,89	0,912	0,931
	2	0,806	0,808	0,810	0,811	0,813	0,814	0,806	0,839	0,866	0,89	0,911	0,929
	3	0,962	0,930	0,907	0,890	0,877	0,866	0,962	1,021	1,070	1,111	1,147	1,179
	4	0,770	0,770	0,770	0,770	0,770	0,770	0,770	0,817	0,856	0,889	0,918	0,943
σ^{ω}	**1**	/	/	/	/	/	/	/	/	/	/	/	/
	2	/	/	/	/	/	/	/	/	/	/	/	/
	3	0,223	0,197	0,180	0,169	0,161	0,155	0,252	0,262	0,273	0,283	0,293	0,303
	4	0,145	0,145	0,145	0,145	0,145	0,145	0,164	0,159	0,154	0,151	0,149	0,147

In the LAW setting, an increase in the relative preference for credit stability implies a slight worsening of both the output gap and the inflation gap, compensated by a larger improvement in credit stability. Nevertheless, this comes at the cost of a larger volatility of the interest rate. The reason is intuitive: a larger preference for credit stability requires a more aggressive monetary policy in the aftermath of the negative unexpected shock, thereby increasing output volatility. Moreover, because inflation is more persistent than equity (ρ <1), stabilizing credit requires accepting a more persistent inflation gap.

In the IMPP setting, however, an increase in preference for credit stability has undoubtedly a desirable effect on both credit and policy tools volatility, suggesting a spontaneous convergence towards the cooperative result. The reason is that the larger preference for credit stability increases the costs of the conflict for the macroprudential authority: by lowering the regulatory loan-to-equity ratio to offset the positive output gap produced by the expansionary monetary policy, the output gap would gain stability although credit volatility would increase as a side effect. This reduces the anti-cyclicality of the multiplier and makes monetary policy more effective. However, the interest rate remains highly (although less) volatile.

By varying the preference for inflation stability (ζ), we confirm our interpretation of the policy conflict between the monetary and the macroprudential authority. In the IMPP setting, the increase in the central bank's preference for inflation stability leads the central bank to a more aggressive monetary policy that raises output volatility. The macroprudential authority will thus react to the larger output volatility by reducing the regulatory loan-to-equity ratio to reduce the output gap. This leads in turn the central bank to cut even further the interest rate in order to increase the output gap and achieve the desired output-inflation trade-off. Consequently, the final cost of the lower inflation volatility is a larger output, interest rate and loan-to-equity volatility. Moreover, credit volatility increases instead of decreasing, in contrast with the other institutional arrangements, thereby confirming that a non-cooperative macroprudential policy is self-defeating in presence of a demand shock and an inflation-averse central bank.

The cooperative setting, in turns, confirms its success. With respect to the IMPP setting, the volatility of the interest rate increases at the same pace (interest rate volatility with $\zeta = 2$ is about 1.22 times larger than with $\zeta = 1$, in both scenarios), although the volatility of the regulatory loan-to-equity ratio decreases in the LAH setting. For instance, the macroprudential authority internalizes the larger preference for inflation, thereby avoiding a policy conflict, without compromising the full stabilization of credit. Nevertheless, the volatility of the interest rate becomes larger with respect to IMPP and LAW, as the internalized increased preference for inflation stability leads the macroprudential authority to accept a stronger monetary policy.

Persistence of shocks

We finally test the effect of shocks' persistence by varying δ from 0 to 1.

Table 2. Standard deviations as a function of shock's persistence (δ)

δ		***0***	***.2***	***.4***	***.6***	***.8***	***1***
σ^y	**1**	*0,770*	*0,646*	*0,582*	*0,582*	*0,646*	*0,770*
	2	*0,776*	*0,633*	*0,545*	*0,524*	*0,587*	*0,769*
	3	*0,770*	*0,651*	*0,580*	*0,557*	*0,577*	*0,612*
	4	*0,770*	*0,644*	*0,593*	*0,618*	*0,706*	*0,817*
σ^π	**1**	*0,770*	*1,114*	*1,567*	*2,258*	*3,685*	*11,340*
	2	*0,769*	*1,115*	*1,586*	*2,309*	*3,871*	*12,259*
	3	*0,770*	*1,089*	*1,505*	*2,126*	*3,356*	*9,390*
	4	*0,770*	*1,130*	*1,597*	*2,293*	*3,669*	*10,427*
σ^v	**1**	*0,303*	*0,416*	*0,560*	*0,745*	*0,998*	*1,403*
	2	*0,272*	*0,382*	*0,525*	*0,710*	*0,974*	*1,451*
	3	*0,385*	*0,517*	*0,689*	*0,937*	*1,397*	*3,161*
	4	*0*	*0,164*	*0,343*	*0,564*	*0,907*	*2,018*
σ^r	**1**	*0,799*	*0,881*	*1,013*	*1,239*	*1,727*	*4,501*
	2	*0,806*	*0,881*	*1,006*	*1,224*	*1,706*	*4,482*
	3	*0,962*	*1,076*	*1,257*	*1,568*	*2,257*	*5,772*
	4	*0,770*	*0,874*	*1,040*	*1,326*	*1,952*	*5,120*
σ^ω	**1**	/	/	/	/	/	/
	2	/	/	/	/	/	/
	3	*0,223*	*0,262*	*0,322*	*0,423*	*0,641*	*1,429*
	4	*0,145*	*0,164*	*0,194*	*0,246*	*0,357*	*0,698*

In the CMPP setting, an increase in the degree of persistence of unexpected demand shocks leads simultaneously to a decrease in output gap's volatility and an increase in inflation volatility, because the persistent negative shocks offset the positive output gap set by the central bank to lean down the deflation curve. The volatility of the interest rate also increases as a response to the unexpected negative demand shocks. Nevertheless, as soon as the degree of persistence becomes larger than 0.5, output volatility starts to increase by alternating positive and negative output gaps.

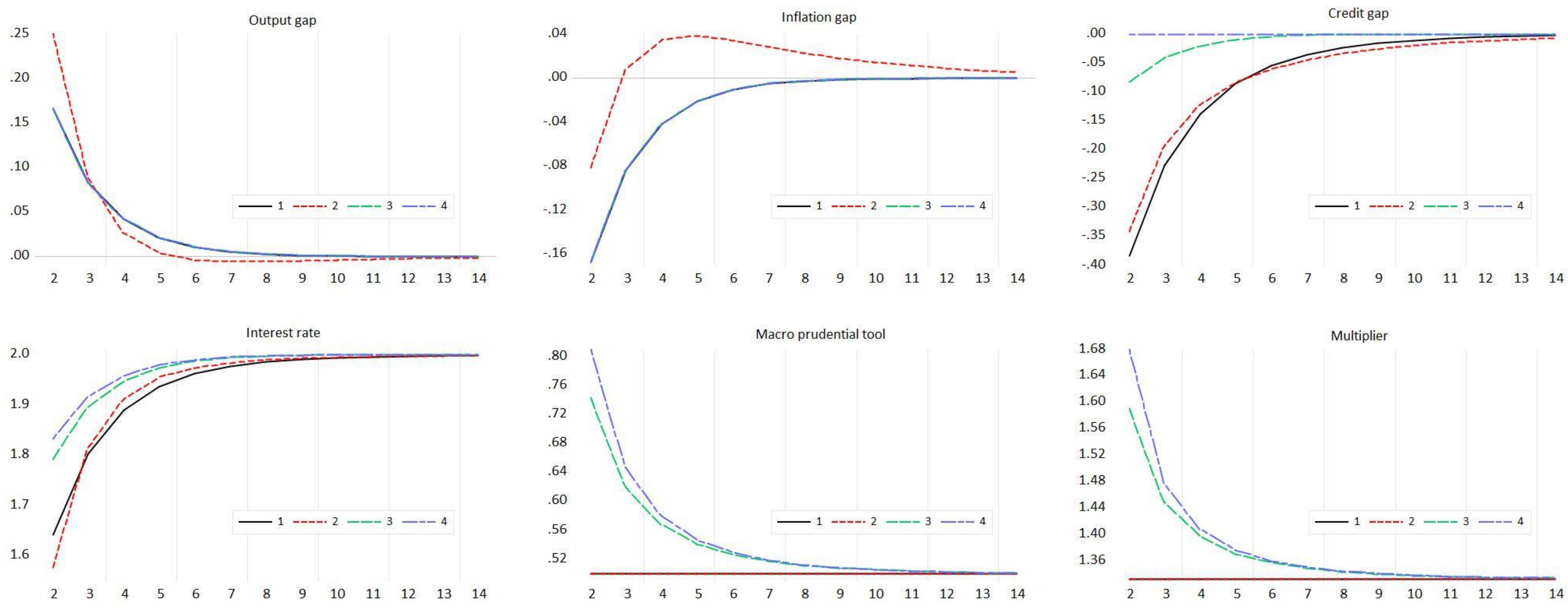
If the central bank *leans against the wind*, inflation and credit volatility increase faster than in the CMPP setting, because of the unexpected demand shocks that reduce output volatility even further. Interest rate's volatility also increases although slightly less than in the CMPP setting.

Most interestingly, however, shocks' persistence affects the relative preference of cooperation over non-cooperation. As the degree of persistence increases, the volatility of output and inflation gaps in LAH increases above the volatility of output and inflation gaps in IMPP. Moreover, although the LAH setting allows stabilizing credit more efficiently than the IMPP one, the gap between the two decreases as the degree of shocks' persistence increases. The reason of this reversal relies in the pro-cyclical multiplier effect of cooperation. The cooperative macroprudential authority increases the regulatory loan-to-equity ratio such that the multiplier becomes pro-cyclical, in order to make monetary policy more effective. Nevertheless, by doing so, the macroprudential authority amplifies the potential negative effects of unexpected new shocks. Therefore, if unexpected shocks are sufficiently persistent, the amplification of the negative shocks jeopardizes the increased monetary policy effectiveness. Vice versa, the countercyclical non-cooperative use of the multiplier allows offsetting more efficiently the unexpected sequence of shocks. Nevertheless, the effects of the conflict between the two authorities on the volatility of the policy tools remains: the IMPP setting produces the largest volatility of policy tools and credit gap for all degrees of persistence.

4.2. Equity shock

We then simulate a non-persistent ($\delta = 0$) 1% negative shock to bank's equity relative to GDP (for example, an unexpected fall in assets' price) that leads, by the end of period 1, to a negative credit gap, a negative output gap (through the effect on the spread) and a negative inflation gap. This unexpected shock will thus imply, as of period 2, a policy reaction aimed at avoiding a real and financial recession.

Figure 3. Equity shock



CMPP

In the CMPP setting, the central bank observes the effects of the negative shock on the output gap and the inflation gap, and lowers the interest rate in order to create a positive output gap that brings gradually inflation back to the target, by minimizing the policy-induced volatility of the output gap. The negative equity shock is thus comparable to a negative demand shock from the perspective of a standard dual mandate monetary policy.

LAW

In the LAW scenario, the central bank choses between reducing the output gap or the credit gap: for instance, a more aggressive monetary policy would reduce credit instability by increasing output instability. Since a more aggressive monetary policy is also beneficial to inflation stability, we observe a larger output gap and a larger volatility of the interest rate, compensated by a lower credit gap and a lower inflation rate with respect to the CMPP setting.

IMPP

By introducing an independent macroprudential policy to a dual mandate monetary policy, the credit gap rapidly falls, suggesting that a countercyclical macroprudential policy is more effective than a triple mandate monetary policy to stabilize both output and credit, at the cost of a larger inflation gap. Moreover, the volatility of the interest rate shrinks, suggesting that the monetary policy is more effective after introducing a macroprudential policy. This larger policy effectiveness relies on the milder conflict between the monetary and the macroprudential authorities, thereby leading to a pro-cyclical multiplier. For instance, if we compare the negative financial shock with the negative demand shock, we can observe that the *multiplier gap* is positive in the case of a financial shock, while it was negative in the case of the demand shock. The reason is that the risk of a large financial crisis after the negative equity shock is such that both the monetary and the macroprudential authority accept to increase output volatility in order to reach, respectively, inflation and credit stability.

LAH

Cooperation, however, still proves to be the most efficient institutional arrangement. For instance, while output and inflation volatility do not change, the macroprudential authority is able to neutralize fully the credit gap. Moreover, interest rate volatility falls even further, suggesting an improved monetary policy efficiency. For instance, in the cooperative setting, the pro-cyclical use of the regulatory loan-to-equity ratio is stronger than in the IMPP setting, such that the multiplier increases even further, by making monetary policy more effective.

4.2.1. Sensitivity analysis

Preference for credit and inflation stability

We first focus on the impact of the preference for credit stability (ξ) in the four settings. As the preference for credit stability increases, we have no effects in CMPP and LAH: in the first setting, credit stability is not an issue for the central bank; in the fourth setting, the two authorities are always able to neutralize completely credit volatility.

Table 3. Standard deviations as a function of the preference for credit and inflation stability

		ξ						ζ					
		1	**1,2**	**1,4**	**1,6**	**1,8**	**2**	**1**	**1,2**	**1,4**	**1,6**	**1,8**	**2**
σ^y	**1**	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,204*	*0,214*	*0,222*	*0,229*	*0,236*
	2	*0,269*	*0,283*	*0,296*	*0,310*	*0,322*	*0,334*	*0,269*	*0,273*	*0,277*	*0,281*	*0,283*	*0,286*
	3	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,204*	*0,214*	*0,222*	*0,229*	*0,236*
	4	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,204*	*0,214*	*0,222*	*0,229*	*0,236*
σ^π	**1**	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,170*	*0,153*	*0,139*	*0,128*	*0,118*
	2	*0,113*	*0,122*	*0,137*	*0,157*	*0,178*	*0,201*	*0,113*	*0,102*	*0,093*	*0,086*	*0,079*	*0,074*
	3	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,170*	*0,153*	*0,139*	*0,128*	*0,118*
	4	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,170*	*0,153*	*0,139*	*0,128*	*0,118*
σ^v	**1**	*0,480*	*0,480*	*0,480*	*0,480*	*0,480*	*0,480*	*0,480*	*0,472*	*0,466*	*0,461*	*0,457*	*0,453*
	2	*0,429*	*0,421*	*0,413*	*0,405*	*0,398*	*0,391*	*0,429*	*0,428*	*0,427*	*0,426*	*0,426*	*0,425*
	3	*0,096*	*0,080*	*0,069*	*0,060*	*0,054*	*0,048*	*0,096*	*0,102*	*0,107*	*0,111*	*0,115*	*0,118*
	4	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
σ^r	**1**	*0,431*	*0,431*	*0,431*	*0,431*	*0,431*	*0,431*	*0,431*	*0,437*	*0,442*	*0,447*	*0,451*	*0,454*
	2	*0,473*	*0,481*	*0,489*	*0,497*	*0,504*	*0,512*	*0,473*	*0,476*	*0,477*	*0,479*	*0,481*	*0,482*
	3	*0,241*	*0,233*	*0,227*	*0,223*	*0,219*	*0,217*	*0,247*	*0,255*	*0,267*	*0,278*	*0,287*	*0,295*
	4	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,193*	*0,204*	*0,214*	*0,222*	*0,229*	*0,236*
σ^ω	**1**	/	/	/	/	/	/	/	/	/	/	/	/
	2	/	/	/	/	/	/	/	/	/	/	/	/
	3	*0,285*	*0,297*	*0,306*	*0,312*	*0,317*	*0,321*	*0,285*	*0,271*	*0,261*	*0,252*	*0,246*	*0,240*
	4	*0,358*	*0,358*	*0,358*	*0,358*	*0,358*	*0,358*	*0,358*	*0,349*	*0,340*	*0,334*	*0,328*	*0,324*

Nevertheless, the introduction of an independent macroprudential authority largely dominates over a central bank that *leans against the wind*. For instance, in the LAW setting, the increasing preference for credit stability allows to reduce slightly the credit gap, at the cost of a larger output gap, inflation gap and interest rate volatility. In the IMPP scenario, output and inflation volatility are not affected by the increased preference for credit stability, despite credit volatility falls even faster than in LAW. Moreover, interest rate volatility decreases because of the spontaneous cooperation between the two independent authorities: as the preference for credit stability increases, the macroprudential authority is willing to accept a larger output gap volatility and increases the regulatory loan-to-equity ratio, thereby increasing monetary policy effectiveness. Consequently, the central bank can reduce the volatility of the interest rate with no major consequences on the output gap.

We then focus on the impact of the preference for inflation stability (ζ). Interestingly, as the preference for inflation stability increases, the conflict between the two independent authorities re-emerge. Namely, the central bank wants a larger output volatility to stabilize inflation and reduces the interest rate, thereby pushing the macroprudential authority to decrease the *loan-to-equity ratio* to neutralize the expansionary monetary policy. Consequently, the volatility of the interest rate increases while the volatility of the regulatory loan-to-equity ratio decreases (recall that the regulatory *loan-to-equity gap* is positive, therefore the increase in preference for inflation stability pushes the *loan-to-equity gap* downwards). The credit gap also increases as the macroprudential authority accepts a larger credit volatility to reach a larger output stability.

In the LAH scenario, on the other hand, credit volatility is always zero for any degree of preference for inflation stability. Nevertheless, because the macroprudential authority internalizes the preference for inflation stability, it will accept the increased output gap and will not lower the regulatory loan-to-equity ratio as much as in the IMPP setting (the volatility of the regulatory loan-to-equity ratio decreases but less than in the IMPP setting).

Shocks' persistence

We finally test the effect of varying the degree of persistence of unexpected shocks.

Table 9. Standard deviations as a function of shocks' persistence (δ)

δ		**0**	**.2**	**.4**	**.6**	**.8**	**1**
σ^y	**1**	*0,193*	*0,161*	*0,146*	*0,146*	*0,161*	*0,193*
	2	*0,269*	*0,231*	*0,203*	*0,180*	*0,159*	*0,113*
	3	*0,193*	*0,160*	*0,198*	*0,289*	*0,515*	*7,673*
	4	*0,193*	*0,165*	*0,228*	*0,363*	*0,939*	/
σ^π	**1**	*0,193*	*0,278*	*0,392*	*0,565*	*0,921*	*2,835*
	2	*0,113*	*0,176*	*0,253*	*0,352*	*0,505*	*1,118*
	3	*0,193*	*0,343*	*0,544*	*0,889*	*1,794*	*18,544*
	4	*0,193*	*0,365*	*0,601*	*1,045*	*2,701*	/
σ^v	**1**	*0,480*	*0,667*	*0,924*	*1,332*	*2,208*	*6,892*
	2	*0,429*	*0,609*	*0,856*	*1,250*	*2,110*	*6,714*
	3	*0,096*	*0,343*	*0,645*	*1,121*	*2,307*	*19,125*
	4	*0*	*0,277*	*0,595*	*1,115*	*2,991*	/
σ^r	**1**	*0,431*	*0,492*	*0,591*	*0,766*	*1,173*	*3,392*
	2	*0,473*	*0,529*	*0,622*	*0,790*	*1,185*	*3,400*
	3	*0,241*	*0,299*	*0,399*	*0,594*	*1,141*	*6,590*
	4	*0,193*	*0,247*	*0,344*	*0,548*	*1,361*	/
σ^ω	**1**	/	/	/	/	/	/
	2	/	/	/	/	/	/
	3	*0,285*	*0,321*	*0,389*	*0,520*	*0,817*	*2,556*
	4	*0,358*	*0,411*	*0,513*	*0,719*	*1,291*	/

In CMPP, as the degree of persistence of the equity shock increases, credit volatility directly raises, while the output gap initially decreases: the bank whishes a strong positive output gap to offset the negative equity shock, but the unexpected negative shocks reduce it. Consequently, also the interest rate and the inflation volatility increase because of the unrealized output-inflation trade-off and the consequent downwards adjustments of the interest rate. Beyond $\delta = 0.5$, however, also the output gap starts increasing because the unexpected persistent shocks are such that the desired positive output gap turns into an undesired negative output gap, thereby increasing the volatility of output around potential output.

In LAW, the output gap keeps decreasing as unexpected shocks become more persistent, such that the inflation rate and the credit gap both keep increasing. The volatility of the interest rate also increases. Moreover, as the degree of persistence of unexpected shocks increases, the credit-augmented monetary policy starts dominating over the dual mandate policy: beyond $\delta = 0.8$, output, inflation and credit volatility are lower in LAW than in CMPP, despite a comparable volatility of the interest rate.

The introduction of an independent macroprudential authority, with highly persistent shocks, proves inefficient: the involuntary cooperation produced by the negative equity shock leads the macroprudential authority to raise the regulatory loan-to-equity ratio (hence, the multiplier), making the monetary policy more effective but simultaneously amplifying the effect of the unexpected shocks. Consequently, the overall volatility of output, inflation and interest rate raises, suggesting a lower resilience to shocks: for high degrees of persistence, the interest rate hits the *zero-lower bound*, and output, inflation and credit volatilities explode.

In such a context, a cooperative macroprudential policy would perform even worse, as the multiplier increases further, thereby anticipating the *zero lower bound*'s constraint. For instance, the *LAH* setting is still effective below $\delta = 0.6$, in terms of lower credit and interest rate volatility (at the cost of a higher output and inflation volatility). Nevertheless, beyond $\delta = 0.8$, it provides very poor results in all respects (with $\delta = 1$, the regulatory loan-to-equity ratio reaches unreasonably high values that make the multiplier negative!).

4.3. Tackling persistence: countercyclical capital buffers

Sections 4.1 and 4.2 point to the main conclusion that cooperation between monetary and macroprudential policies is effective to reduce credit volatility, by simultaneously lowering interest rate volatility, which represents a cost and a source of instability in the nearby of the zero-lower bound, and that this cooperation is even more effective in presence of demand shocks. For instance, a cooperative macroprudential policy implies a pro-cyclical fiscal multiplier that increases monetary policy effectiveness. Consequently, with low degrees of shock's persistence, the pro-cyclicality of the multiplier plays a stabilizing role. Nevertheless, as shocks become highly persistent, and the monetary and macroprudential authorities cannot predict the sequence of unexpected shocks, the pro-cyclicality of the multiplier can become counterproductive as it amplifies the adverse effects of the unexpected shocks. This contradiction applies more generally to macroprudential policy, independently of the degree of formal cooperation between monetary and macroprudential policies, when the economy is hit by equity shocks. For instance, also in absence of a formal cooperative setting, equity shocks lead to a spontaneous cooperation between macroprudential and monetary policy that produces pro-cyclicality in the multiplier. Therefore, this suggests that a central bank endowed with a triple mandate – output, inflation and credit stability – represents a preferable alternative if both authorities fear highly persistent unexpected shocks.

In this section, we explore the robustness of this result by combining two different types of macroprudential policy: the macroprudential rule analyzed in the previous sections and the introduction – or strengthening – of counter-cyclical capital buffers, which we can identify, at first approximation, in the parameter σ. For instance, this parameter captures the sensitivity of equity to bank's profits, which we assumed positively correlated with the output gap. Therefore, as σ increases, bank's equity is more sensitive to changes in output gap. Conversely, as σ decreases, bank's equity is less sensitive to output gap variations. Lower values of σ might thus reflect the regulatory accumulation of counter-cyclical buffers that reduce the amount of equity the bank can use to support the supply of credit. We thus test the effects of introducing capital buffers in presence of persistent shocks ($\delta = 0.5$), starting with a negative demand shock.

As shown in table 10, when bank's equity is highly sensitive to output gap fluctuations ($\sigma = 2$), output, inflation and credit become highly unstable, whatever the institutional arrangement, but particularly in the LAH setting. However, the introduction of an independent macroprudential policy helps to stabilize credit more efficiently with respect to all other scenarios, despite a larger cost in terms of interest rate volatility. This superiority of non-cooperation vanishes as σ diminishes: if we consider the extreme case σ=0, we can observe that the credit gap is equal to zero in all scenarios except the third one. This suggests that an independent macroprudential policy acting with an independent monetary policy can lead to a policy-induced credit crisis (if σ=0, the demand shock has no direct effects on equity) that raises credit and policy tools' volatility.

Table 10. Standard deviations as a function of capital buffers (σ)

σ		2	1.6	1.2	1	.8	.4	0
σ^y	**1**	*0,861*	*0,717*	*0,615*	*0,574*	*0,538*	*0,478*	*0,430*
	2	*0,661*	*0,591*	*0,545*	*0,525*	*0,507*	*0,471*	*0,430*
	3	*0,866*	*0,707*	*0,602*	*0,563*	*0,529*	*0,473*	*0,430*
	4	*2,761*	*0,910*	*0,660*	*0,597*	*0,549*	*0,480*	*0,430*
σ^π	**1**	*2,802*	*2,335*	*2,002*	*1,868*	*1,751*	*1,557*	*1,401*
	2	*3,040*	*2,448*	*2,048*	*1,895*	*1,766*	*1,559*	*1,401*
	3	*2,457*	*2,121*	*1,878*	*1,778*	*1,687*	*1,531*	*1,401*
	4	*5,622*	*2,618*	*2,070*	*1,903*	*1,768*	*1,559*	*1,401*
σ^ν	**1**	*1,938*	*1,292*	*0,831*	*0,646*	*0,485*	*0,215*	*0*
	2	*1,632*	*1,141*	*0,768*	*0,610*	*0,466*	*0,213*	*0*
	3	*1,458*	*1,129*	*0,896*	*0,799*	*0,712*	*0,559*	*0,430*
	4	*5,418*	*1,256*	*0,614*	*0,445*	*0,318*	*0,133*	*0*
σ^r	**1**	*1,687*	*1,390*	*1,187*	*1,109*	*1,043*	*0,938*	*0,861*
	2	*1,644*	*1,366*	*1,173*	*1,099*	*1,036*	*0,936*	*0,861*
	3	*1,980*	*1,686*	*1,475*	*1,389*	*1,313*	*1,183*	*1,076*
	4	*2,984*	*1,552*	*1,258*	*1,162*	*1,083*	*0,957*	*0,861*
σ^ω	**1**	/	/	/	/	/	/	/
	2	/	/	/	/	/	/	/
	3	*0,599*	*0,495*	*0,406*	*0,365*	*0,328*	*0,263*	*0,215*
	4	*0,788*	*0,413*	*0,272*	*0,216*	*0,166*	*0,078*	*0*

Therefore, an independent macroprudential policy outperforms a cooperative macroprudential policy at high levels of σ, because the adverse effects of the policy conflict between the two authorities are still preferable to the adverse effects of a pro-cyclical multiplier in the case of cooperation. Nevertheless, strengthening capital buffers helps significantly to stabilize the economy in all institutional arrangements, and particularly in the LAH setting: output and interest rate volatility fall faster in LAH than in all other settings (while inflation falls slower because of the smaller output volatility). Also, the volatility of the regulatory loan-to-equity ratio decreases significantly if compared to the IMPP setting, suggesting that the combination of capital buffers and a cooperative macroprudential rule can successfully stabilize the credit gap, performing better than all other settings, with low costs in terms of output and interest rate volatility. Therefore, a cooperative macroprudential rule, combined with counter-cyclical capital buffers, provides a successful solution to credit stability also in presence of reasonably high degrees of persistence of unexpected demand shocks.

The equity shock confirms the results obtained with a demand shock: for high levels of σ, the LAH setting leads to strong instability in all respects (when σ=2, the multiplier becomes negative in both the IMPP and the LAH settings). Nevertheless, as σ diminishes, the combination of capital buffers and a cooperative macroprudential rule allows stabilizing the credit gap by simultaneously reducing output and inflation costs. Moreover, the volatility of the interest rate shrinks faster in the LAH setting, thereby reducing the costs of monetary policy.

Therefore, we can confirm that a cooperative macroprudential rule, combined with counter-cyclical capital buffers, provides a successful solution to credit stability also in the presence of reasonably high degrees of persistence of unexpected demand shocks.

Table 11. Standard deviations as a function of capital buffers (σ)

σ		2	1.6	1.2	1	.8	.4	0
σ^y	1	0,215	0,179	0,154	0,143	0,135	0,120	0,108
	2	0,267	0,238	0,208	0,191	0,173	0,137	0,108
	3	/	0,429	0,277	0,236	0,206	0,166	0,139
	4	/	0,717	0,348	0,282	0,238	0,182	0,149
σ^π	1	0,701	0,584	0,500	0,467	0,438	0,389	0,350
	2	0,407	0,348	0,312	0,298	0,289	0,297	0,350
	3	/	1,034	0,770	0,687	0,621	0,523	0,452
	4	/	1,556	0,907	0,777	0,685	0,559	0,475
σ^ν	1	1,253	1,168	1,117	1,010	1,086	1,066	1,052
	2	1,026	1,005	1,015	1,025	1,036	1,052	1,052
	3	/	1,336	0,960	0,847	0,758	0,629	0,539
	4	/	1,810	0,969	0,808	0,696	0,549	0,455
σ^r	1	0,775	0,717	0,679	0,664	0,652	0,632	0,617
	2	0,771	0,730	0,704	0,692	0,680	0,652	0,617
	3	/	0,697	0,530	0,477	0,435	0,370	0,323
	4	/	0,806	0,488	0,423	0,376	0,312	0,268
σ^ω	1	/	/	/	/	/	/	/
	2	/	/	/	/	/	/	/
	3	/	0,398	0,425	0,443	0,462	0,497	0,529
	4	/	0,666	0,598	0,596	0,600	0,614	0,630

5. Conclusions

Before the 2007-08 financial crisis there was a widespread consensus that policy makers should only focus on inflation and output stability (with a higher weight attached to inflation), whilst no attention should be paid to financial variables, to be monitored and regulated only in so far as to ensure the stability of individual financial institutions. The fall-out of the financial crisis has magnified the interplay between financial factors and aggregate demand in amplifying macroeconomic fluctuations. This opened the way for economic modelers and policy makers to contrive new regulatory frameworks aimed at preventing aggregate financial imbalances. Macroprudential rules and institutions were consequently evaluated by means of different macro-models. In this paper, we set up a standard BMW model augmented (*à la* Bernanke & Blinder, 1988) to account for financial frictions and give scope to macroprudential regulation and its interplay with monetary policy.

We simulated the impact of either financial or macroeconomic shocks under four different institutional arrangements which represent different possible interplays of monetary and macroprudential policies. Our macroprudential variable (the regulatory loan-to-equity ratio) has a multiplier effect that interferes with monetary policy, thus influencing the credit market and the output gap. Such a multiplier effect varies according to the institutional arrangement in which macroprudential and monetary policies are embedded. That is, different combinations of macroprudential and monetary policies may have different impacts on the length and strength of business fluctuations and financial markets stability.

Our model supports the viewof the literature that introducing a specific macroprudential tool to address financial instability leads to better results relative to a monetary policy-only world. Cooperation between monetary policy and macroprudential policy delivers the best global stabilization outcomes in the face of both negative demand and (bank) equity shocks. Indeed, in a *cooperative* institutional arrangement, credit volatility is effectively tackled, without negative consequences on output and inflation stability. Moreover, we do not find any side effect on interest rate volatility, thereby reinforcing the relative benefits of cooperation over non-cooperation. The reason behind this superior performance is that, under cooperation, the multiplier moves pro-cyclically, thereby making monetary policy more effective. Whilst it is counter-cyclical under non-cooperation and a-cyclical by construction in the baseline and the *leaning against the wind* settings, where the macroprudential tool is muted. The pro-cyclicality of the multiplier, however, turns out to be destabilizing as shocks become increasingly persistent, reverting the efficiency ranking between the cooperative and non-cooperative scenarios. In such a situation, a simple *leaning against the wind* monetary policy might be even preferable to an active macroprudential policy (under both cooperative and non-cooperative arrangements) in terms of output, inflation, and credit stability, with almost negligible costs in terms of interest rate volatility relatively to the other scenarios, especially when an equity shock hits the economy. *Leaning against the wind* would also outperform the standard dual mandate monetary policy. The original ranking is reinstated as soon as counter-cyclical capital buffers are added to leverage regulation in the macroprudential toolkit, thereby minimizing the effects of persistent unexpected shocks on bank's equity. Sensitivity analysis shows that results are robust to changes in the specification of the objective functions. Namely, we find that by increasing the relative weight of financial stability (hence, by decreasing the relative weight of output gap stabilization), the negative consequences of non-cooperation are substantially lower. This is because the macroprudential authority underscores the side effects on output gap produced by the monetary policy relatively to the side effects on financial stability produced by its reaction. Instead, by increasing the relative weight of inflation stabilization, the costs of non-coordination increase faster, because of the stronger side effects on output gaps produced by the hawkish monetary policy. Hence, while a hawkish central bank would be better off by coordinating with the macroprudential authority in order to make the latter internalize the inflation costs of macroprudential policy, the macroprudential authority might offset the costs of non-coordination by paying a larger attention to credit stability relatively to output stability.

As in the literature that inspired this paper, the results we find are conditional on the modelling framework (especially on the financial side) and the assumptions made about the loss functions of the policy makers. In the cost-benefit analysis of our modelling choice, we attached higher weight to tractability than to the search for *ad hoc* microfoundations, and we privileged a qualitative to a quantitative approach as it came down to calibrate the model. The consequences of the zero-lower-bound on the nominal interest rate are not explicitly examined in the paper, and the endogenous build-up of systemic risk and the consequent burst of financial bubbles is also ruled out. Finally, we avoid any distinction between good loans and bad loans to define and measure the degree of financial instability. All these concerns are matter for future research.

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Appendix A.1. Baseline parameters

Parameter	*Description*	*Value*
g	*Autonomous demand*	*2*
ϕ	*Output gap sensitivity to changes of the interest rates*	*1*
κ	*Sensitivity of the output gap to changes of the spread*	*0,5*
γ	*Sensitivity of the inflation gap to changes of the output gap*	*1*
v^*	*Equilibrium loan-to-value ratio*	*1*
χ	*Sensitivity of credit demand to changes of the spread*	*1*
e^*	*Bank's equilibrium equity*	*2*
ρ	*Degree of persistence of the current equity gap to past equity gap*	*0.7*
σ	*Sensitivity of the equity gap to changes of the output gap*	*1*
ζ	*Preference for inflation stability*	*1*
ξ	*Preference for credit stability*	*1*
δ	*Degree of persistence of unexpected shocks*	*0*

Appendix A.2. Proofs

Constant Macroprudential Policy (CMPP)

The central bank minimizes a standard dual mandate loss function

$$L^{CB} = \hat{y}_t{}^2 + \zeta(\hat{\pi}_t)^2 \quad \text{(A1)}$$

with $\hat{\pi}_t \equiv \pi_t - \pi^*$

Subject to the constraints represented by the IS and the Phillips curve:

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\} \quad \text{(A2)}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t \quad \text{(A3)}$$

We set $\frac{1}{(1-\Theta\sigma\omega_t)} = \Phi$ and derive (A1) with respect to r_t

$$\frac{\vartheta L^{CB}}{\vartheta r_t} = -\hat{y}_t - \zeta\hat{\pi}_t\gamma = 0 \quad \text{(A4)}$$

We replace (A2) and (A3) into (A4) :

$$-[\Phi g^* - \Phi\varphi r_t + \Phi\Theta\omega^*{}_t\varepsilon_{t-1}][1 + \zeta\gamma^2] - \zeta\gamma\hat{\pi}_{t-1} = 0$$

We finally set $\frac{\zeta\gamma}{(1+\zeta\gamma^2)} = \Gamma$ and, recalling that $\omega_t = \omega_t^*$ in the baseline, we get:

$$\boldsymbol{r_t = \frac{1}{\varphi}\left\{g^* + \Theta\omega^*{}_t\varepsilon_{t-1} + \frac{\Gamma}{\Phi}\hat{\pi}_{t-1}\right\}} \quad \textbf{(A5)}$$

Leaning Against the Wind (LAW)

The central bank minimizes a triple mandate loss function

$$L^{CB} = \hat{y}_t{}^2 + \zeta\hat{\pi}_t{}^2 + \xi\hat{v}_t{}^2 \quad \text{(A6)}$$

Given the constraints represented by the IS, the Phillips curve and the credit function:

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\} \quad \text{(A2)}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t \quad \text{(A3)}$$

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t) \quad \text{(A7)}$$

We derive (A6) with respect to r_t and, because the macroprudential tool is constant, we get:

$$\hat{y}_t + \zeta\gamma\hat{\pi}_t + \xi\sigma\omega_t\hat{v}_t = 0 \quad \text{(A8)}$$

We finally replace the constraints (A2), (A3) and (A7) into (A8) and simplify to get:

$$(g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1})(1 + \zeta\gamma^2) + \left(\varepsilon_{t-1} + \sigma(g^* - \varphi r_t)\right)\xi\sigma\omega_t{}^2 + (1 - \Theta\sigma\omega_t)\zeta\gamma\hat{\pi}_{t-1} - (1 - \Theta\sigma\omega_t)\xi\sigma v^*\omega_t = 0$$

By isolating r_t, and recalling that $g^* \equiv (g - \Theta v^*)$:

$[1 + \zeta\gamma^2 + \xi\sigma^2{\omega_t}^2]\varphi r_t = \xi\sigma\big({\omega_t}^2\varepsilon_{t-1} + \sigma{\omega_t}^2(g - \Theta v^*)\big) + \xi\sigma^2 v^*\Theta{\omega_t}^2 + (1 + \zeta\gamma^2)\Theta\varepsilon_{t-1}\omega_t - \zeta\gamma\hat{\pi}_{t-1}\Theta\sigma\omega_t - \xi\sigma v^*\omega_t + (1 + \zeta\gamma^2)(g - \Theta v^*) + \zeta\gamma\hat{\pi}_{t-1}$

We set $\varsigma = (1 + \zeta\gamma^2)$, $\psi = [\varsigma\ + \xi\sigma^2{\omega_t}^2]$ and $\Xi = (\xi\sigma\omega_t + \varsigma\Theta)$, and rewrite:

$\psi\varphi r_t = \Xi\omega_t\varepsilon_{t-1} + \psi g - \Xi v^* + \zeta\gamma(1 - \Theta\sigma\omega_t)\hat{\pi}_{t-1}$

Recall that $\frac{1}{(1-\Theta\sigma\omega_t)} = \Phi$ and $\frac{\zeta\gamma}{(1+\zeta\gamma^2)} = \Gamma$. Therefore:

$$\boldsymbol{r_t = \frac{1}{\psi\varphi}\left\{g' + \Xi\omega_t\varepsilon_{t-1} + \frac{\varsigma\Gamma}{\Phi}\hat{\pi}_{t-1}\right\}} \quad \textbf{(A9)}$$

With $g' = (\psi g - \Xi v^*)$.

Independent Macroprudential Policy (IMPP)

The central bank minimizes a standard dual mandate loss function

$$L^{CB} = {\hat{y}_t}^2 + \zeta(\hat{\pi}_t)^2 \quad \text{(A1)}$$

The macroprudential authority minimizes the dual mandate loss function:

$$L^{MP} = {\hat{y}_t}^2 + \xi{\hat{v}_t}^2 \quad \text{(A10)}$$

Both authorities face the same constraints:

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\} \quad \text{(A2)}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t \quad \text{(A3)}$$

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t) \quad \text{(A7)}$$

The optimal monetary policy rule is the same from the baseline scenario, although the macroprudential tool is no longer equal to the equilibrium value ω^*. For instance, the lack of cooperation between the two authorities implies that each authority minimizes its loss function by taking the instrument of the other authority as given.

$$\boldsymbol{r_t = \frac{1}{\varphi}\left\{g^* + \Theta\omega_t\varepsilon_{t-1} + \frac{\Gamma}{\Phi}\hat{\pi}_{t-1}\right\}} \quad \textbf{(A11)}$$

We instead obtain the optimal macroprudential rule by minimizing (A10) with respect to ω_t and, after simplifying, we obtain:

$$\frac{\varepsilon_{t-1}+\sigma(g^*-\varphi r_t)}{(1-\Theta\sigma\omega_t)^2}\{\Theta\hat{y}_t + \xi\hat{v}_t\} = 0$$

We thus have two first order conditions. The first one is:

$$\varepsilon_{t-1} + \sigma(g^* - \varphi r_t) = 0$$

Which leads to the monetary policy rule:

$r_t = \frac{1}{\varphi}\left[\frac{\varepsilon_{t-1}}{\sigma} + g^*\right]$

Nevertheless, recalling that $g^* \equiv (g - \Theta v^*)$, if we set the equilibrium conditions $r_t = r_n = \frac{g}{\varphi}$, ${\omega^*}_t = \frac{v^*}{e^*}$ and $\varepsilon_{t-1} = e^*$, we obtain:

${\omega^*}_t = \frac{1}{\sigma\Theta}$

Hence, the first rule implies that, at the equilibrium, the macroprudential tool must be equal to $(\sigma\Theta)^{-1}$, which is clearly implausible, since the denominator of the multiplier would be 0. Therefore, we reject this condition and retain only the second first order condition:

$$\{\Theta\hat{y}_t + \xi\hat{v}_t\} = 0 \quad \text{(A12)}$$

We thus replace (A2) and (A7) in (A12) and, after simplifying, we obtain:

$$[\Theta(g^* - \varphi r_t) - \xi v^*] + [(\Theta^2 + \xi)\varepsilon_{t-1} + \xi\sigma(g^* + \Theta v^* - \varphi r_t)]\omega_t = 0$$

Which leads to:

$$\boldsymbol{\omega_t = \frac{\xi v^* - \Theta(g^* - \varphi r_t)}{[(\Theta^2 + \xi)\varepsilon_{t-1} + \xi\sigma(g^* + \Theta v^* - \varphi r_t)]}} \quad \textbf{(A13)}$$

To obtain the reduced form optimal policy rules we thus solve the subsystem:

$$\begin{cases} r_t = \frac{1}{\varphi}\left\{g^* + \Theta\omega_t\varepsilon_{t-1} + \frac{\Gamma}{\Phi}\hat{\pi}_{t-1}\right\} \\ \omega_t = \frac{\xi v^* - \Theta(g^* - \varphi r_t)}{[(\Theta^2 + \xi)\varepsilon_{t-1} + \xi\sigma(g^* + \Theta v^* - \varphi r_t)]} \end{cases}$$

We first replace r_t in ω_t and, after simplifying, we obtain:

$$\omega_t = \frac{\xi v^* + \Theta[\Gamma\hat{\pi}_{t-1} + \Theta(\varepsilon_{t-1} - \sigma\Gamma\hat{\pi}_{t-1})\omega_t]}{[\Theta^2\varepsilon_{t-1} + \xi(\sigma\Theta v^* + \varepsilon_{t-1} - \sigma\Gamma\hat{\pi}_{t-1}) - \xi\sigma\Theta(\varepsilon_{t-1} - \sigma\Gamma\hat{\pi}_{t-1})\omega_t]}$$

We set $(\varepsilon_{t-1} - \sigma\Gamma\hat{\pi}_{t-1}) = \Psi$ and rewrite:

$$\omega_t = \frac{\xi v^* + \Theta[\Gamma\hat{\pi}_{t-1} + \Theta\Psi\omega_t]}{[\Theta^2\varepsilon_{t-1} + \xi(\sigma\Theta v^* + \Psi) - \xi\sigma\Theta\Psi\omega_t]}$$

We further develop and by setting $\Omega = (\xi v^* + \Theta\Gamma\hat{\pi}_{t-1})$ we obtain:

$$-\xi\sigma\Theta\Psi{\omega_t}^2 + (\Theta\sigma\Omega + \xi\Psi)\omega_t - \Omega = 0$$

We thus have a quadratic equation of the type

$$A{\omega_t}^2 + B\omega_t + C = 0$$

with:

$$A = -\xi\sigma\Theta\Psi, B = (\Theta\sigma\Omega + \xi\Psi)\ e\ C = -\Omega$$

Whose solutions are:

$$\omega_{t,1} = \frac{-(\Theta\sigma\Omega+\xi\Psi)+(\Theta\sigma\Omega-\xi\Psi)}{-2\xi\sigma\Theta\Psi} = \frac{-2\xi\Psi}{-2\xi\sigma\Theta\Psi} = \frac{1}{\sigma\Theta}$$

$$\omega_{t,2} = \frac{-(\Theta\sigma\Omega+\xi\Psi)-(\Theta\sigma\Omega-\xi\Psi)}{-2\xi\sigma\Theta\Psi} = \frac{-2\Theta\sigma\Omega}{-2\xi\sigma\Theta\Psi} = \frac{\Omega}{\xi\Psi}$$

Again, the first solution is implausible since it violates the necessary condition $\omega_t \neq (\sigma\Theta)^{-1}$, which ensures that the denominator of the multiplier is different from zero. Therefore, the reduced form optimal macroprudential rule is equal to:

$$\boldsymbol{\omega_t = \frac{\Omega}{\xi\Psi} = \frac{(\xi v^* + \Theta\Gamma\hat{\pi}_{t-1})}{\xi(\varepsilon_{t-1} - \sigma\Gamma\hat{\pi}_{t-1})}} \quad \textbf{(A14)}$$

By replacing (A14) into (A11), and after simplifying, we obtain the reduced form optimal monetary policy rule:

$$\boldsymbol{r_t = \frac{\xi g + (\Theta^2 + \xi)\Gamma\hat{\pi}_{t-1}}{\xi\varphi}} \quad \textbf{(A15)}$$

Lend A Hand (LAH)

Both authorities minimize the joint loss function:

$$L^{CB} = L^{MP} = \hat{y}_t{}^2 + \zeta\hat{\pi}_t{}^2 + \xi\hat{v}_t{}^2 \quad \text{(A6)}$$

facing the same constraints:

$$\hat{y}_t = \frac{1}{(1-\Theta\sigma\omega_t)}\{g^* - \varphi r_t + \Theta\omega_t\varepsilon_{t-1}\} \quad \text{(A2)}$$

$$\pi_t = \pi_{t-1} + \gamma\hat{y}_t \quad \text{(A3)}$$

$$v_t = \omega_t(\varepsilon_{t-1} + \sigma\hat{y}_t) \quad \text{(A7)}$$

The central bank minimizes (A6) with respect to r_t:

$$\frac{\vartheta L}{\vartheta \hat{r}_t} = \hat{y}_t + \zeta\gamma\hat{\pi}_t + \xi\sigma\omega_t\hat{v}_t = 0 \quad \text{(A16)}$$

We now replace the constraints (A2), (A3) and (A7) into (A16) and, after simplifying, we obtain:

$$[1 + \zeta\gamma^2 + \xi\sigma^2\omega_t{}^2]\varphi r_t = \xi\sigma[\varepsilon_{t-1} + \sigma(g^* + \Theta v^*)]\omega_t{}^2 + \left[\Theta\left((1+\zeta\gamma^2)\varepsilon_{t-1} - \sigma\zeta\gamma\hat{\pi}_{t-1}\right) - \xi\sigma v^*\right]\omega_t + (1+\zeta\gamma^2)g^* + \zeta\gamma\hat{\pi}_{t-1}$$

We set $\Lambda = \left((1+\zeta\gamma^2)\varepsilon_{t-1} - \sigma\zeta\gamma\hat{\pi}_{t-1}\right)$ and, recalling $\varsigma = (1+\zeta\gamma^2)$, we obtain the optimal monetary policy rule:

$$\boldsymbol{r_t = \frac{1}{[\varsigma + \xi\sigma^2\omega_t{}^2]\varphi}\{\xi\sigma[\varepsilon_{t-1} + \sigma(g^* + \Theta v^*)]\omega_t{}^2 + [\Theta\Lambda - \xi\sigma v^*]\omega_t + [\varsigma g^* + \zeta\gamma\hat{\pi}_{t-1}]\}} \quad \textbf{(A17)}$$

The macroprudential authority minimizes the joint loss function (A6) with respect to ω_t

$\frac{\vartheta L}{\vartheta \omega_t} = \frac{(\sigma[g^* - \varphi r_t] + \varepsilon_{t-1})}{(1 - \Theta\sigma\omega_t)^2} (\Theta \hat{y}_t + \Theta\zeta\gamma\hat{\pi}_t + \xi\hat{v}_t) = 0$

As we did in the IMPP scenario, we reject the first first order condition $(\sigma[g^* - \varphi r_t] + \varepsilon_{t-1}) = 0$, which leads to an implausible equilibrium with ${\omega^*}_t = \frac{1}{\sigma\Theta}$, and concentrate on the second first order condition:

$$(\Theta \hat{y}_t + \Theta\zeta\gamma\hat{\pi}_t + \xi\hat{v}_t) = 0 \qquad \text{(A18)}$$

We thus replace the constraints (A2), (A3) and (A7) and, after simplifying, we obtain:

$$\left(\xi\varepsilon_{t-1} + \xi\sigma(g^* - \varphi r_t + \Theta v^*) + \Theta^2\left((1+\zeta\gamma^2)\varepsilon_{t-1} - \sigma\zeta\gamma\hat{\pi}_{t-1}\right)\right)\omega_t + \Theta(1+\zeta\gamma^2)(g^* - \varphi r_t) - (\xi v^* - \Theta\zeta\gamma\hat{\pi}_{t-1}) = 0$$

Recalling that $\Lambda = \left((1+\zeta\gamma^2)\varepsilon_{t-1} - \sigma\zeta\gamma\hat{\pi}_{t-1}\right)$ and $\varsigma = (1+\zeta\gamma^2)$, we obtain:

$$\boldsymbol{\omega_t = \frac{(\xi v^* - \Theta\zeta\gamma\hat{\pi}_{t-1}) - \Theta\varsigma(g^* - \varphi r_t)}{(\xi\varepsilon_{t-1} + \xi\sigma(g^* - \varphi r_t + \Theta v^*) + \Theta^2\Lambda)}} \qquad \textbf{(A19)}$$

To obtain the reduced form optimal policy rules we thus solve the subsystem:

$$\begin{cases} r_t = \frac{1}{[\varsigma + \xi\sigma^2{\omega_t}^2]\varphi}\{\xi\sigma[\varepsilon_{t-1} + \sigma(g^* + \Theta v^*)]{\omega_t}^2 + [\Theta\Lambda - \xi\sigma v^*]\omega_t + [\varsigma g^* + \zeta\gamma\hat{\pi}_{t-1}]\} \\ \omega_t = \frac{(\xi v^* - \Theta\zeta\gamma\hat{\pi}_{t-1}) - \Theta\varsigma(g^* - \varphi r_t)}{(\xi\varepsilon_{t-1} + \xi\sigma(g^* - \varphi r_t + \Theta v^*) + \Theta^2\Lambda)} \end{cases}$$

We first substitute r_t in ω_t and, after simplifying, we obtain:

$$\omega_t = \frac{\xi\sigma\left[(\xi + \varsigma\Theta^2)\sigma v^* + \Theta\Lambda\right]{\omega_t}^2 + \Theta\varsigma[\Theta\Lambda - \xi\sigma v^*]\omega_t + [\varsigma\xi v^*]}{[\xi\sigma^2\Theta^2\Lambda]{\omega_t}^2 + \xi\sigma[\xi\sigma v^* - \Theta\Lambda]\omega_t + [\varsigma\xi\sigma\Theta v^* + (\xi + \varsigma\Theta^2)\Lambda]}$$

We then develop and obtain

$$[\sigma^2\Theta^2\Lambda]{\omega_t}^3 - \sigma\Theta[2\Lambda + \varsigma\sigma\Theta v^*]{\omega_t}^2 + [2\varsigma\sigma\Theta v^* + \Lambda]\omega_t - [\varsigma v^*] = 0$$

Which we can rewrite as

$$A{\omega_t}^3 + B{\omega_t}^2 + C\omega_t + D = 0$$

with

$$A = \sigma^2\Theta^2\Lambda, B = -\sigma\Theta(2\Lambda + \varsigma\sigma\Theta v^*), C = (2\varsigma\sigma\Theta v^* + \Lambda)\ e\ D = -\varsigma v^*$$

We thus have a cubic equation, which we solve using the Cardano's method. Hence, the solution of this cubic equation is

$$\omega_t = \frac{t - B}{3A}$$

with

$$t = \sqrt[3]{-\frac{q}{2} - \sqrt[2]{\frac{q^2}{4} + \frac{p^3}{27}}} + \sqrt[3]{-\frac{q}{2} + \sqrt[2]{\frac{q^2}{4} + \frac{p^3}{27}}}$$

$$p = 9AC - 3B^2$$

$q = 27A^2D - 9ABC + 2B^3$

Let first compute *p* and, after simplifying, we obtain:

$$\boldsymbol{p = -3[\sigma\Theta(\Lambda - \varsigma\sigma\Theta v^*)]^2}$$

We then compute q and, after simplifying, we obtain:

$$\boldsymbol{q = 2[\sigma\Theta(\Lambda - \varsigma\sigma\Theta v^*)]^3}$$

We thus compute *t* and, after simplifying, we obtain:

$$t = \left\{-\sqrt[3]{[\sigma\Theta(\Lambda - \varsigma\sigma\Theta v^*)]^3} - \sqrt[3]{[\sigma\Theta(\Lambda - \varsigma\sigma\Theta v^*)]^3}\right\}$$

Hence, the three intermediate solutions are

$$\boldsymbol{t_1 = -2\sigma\Theta(\Lambda - \varsigma\sigma\Theta v^*)}$$

and:

$$\boldsymbol{t_2 = t_3 = \sigma\Theta(\Lambda - \varsigma\sigma\Theta v^*)}$$

Because $\omega_t = \frac{t-B}{3A}$, the three final solutions are:

$$\omega_1 = \frac{\varsigma v^*}{\Lambda}$$

And

$$\omega_{2,3} = \frac{1}{\sigma\Theta}$$

Again, we find that the second and third solution are implausible, since they violate the condition $\omega_t \neq (\sigma\Theta)^{-1}$, which ensures that the denominator of the multiplier is different from zero. Therefore, we reject the second and third solution and only retain the first solution as our reduced form optimal macroprudential policy:

$$\boldsymbol{\omega_1 = \frac{\varsigma v^*}{\Lambda}} \qquad \textbf{(A20)}$$

We thus replace (A20) into (A17) to obtain the reduced form optimal monetary policy:

$$\boldsymbol{r_t = \frac{1}{\varphi}(g + \Gamma\hat{\pi}_{t-1})} \qquad \textbf{(A21)}$$

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