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Institutional Mandates for Macroeconomic and Financial Stability

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Institutional Mandates for Macroeconomic and Financial Stability

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Abstract

The performance of alternative institutional policy mandates for achieving macroeconomic and financial stability is studied in a model with financial frictions. Based on different level of coordination, these mandates involve goal-integrated, goal-distinct, and common-goal mandates for the monetary authority and the financial regulator. In the first case, featuring full coordination, both monetary and macroprudential policies are set optimally, but in the last two cases, featuring no or partial coordination, monetary policy only is set optimally whereas macroprudential policy is implemented through a simple, credit-based reserve requirement rule. The model is parameterized and used to simulate responses to a financial shock. The analysis shows that the benefit of using the required reserve ratio is substantial only under the goal-integrated mandate. In addition, it is optimal to delegate the financial stability goal solely to the monetary authority when the financial regulator is only equipped with a credit-based reserve rule. The key reason for these findings is that only coordination *via* the integrated mandate can fully internalize the policy spillovers which adversely affect economic stability.

JEL Classification Numbers: E31, E44, E52.

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1 Introduction

The global financial crisis prompted a far-reaching debate on the role of monetary and macroprudential policies in achieving macroeconomic and financial stability. Key issues in that context have been the extent to which central banks, in addition to pursuing a price stability objective, should also respond to financial imbalances—in the form of a significant and sustained deviation of asset prices from their longer-term trends, an unsustainable expansion of credit, or excessive interest rate spreads—and how best to combine monetary policy and macroprudential regulation, given that both policies influence the transmission process of the other. The business cycle effects of macroprudential policy may influence price developments and monetary policy decisions, and in turn changes in monetary policy motivated solely by price stability may affect systemic financial risks. Indeed, the tension between price stability and financial stability has been exacerbated in recent years by exceptionally accommodative monetary policy; in many countries, interest rates have been kept at very low levels in order to stimulate aggregate demand and avoid deflation. In some cases, this has occurred even as sustained credit growth and asset price pressures have raised concerns about the build-up of financial vulnerabilities.[1]

A number of contributions have attempted to examine these questions in formal dynamic stochastic general equilibrium (DSGE) models with financial frictions and an explicit account of financial regulation. Some of them have focused on the trade-offs that may arise when monetary policy rules are augmented to lean directly against the build-up of financial imbalances, whereas others have zeroed in on the case where standard Taylor-type monetary policy rules are complemented by countercyclical macroprudential rules designed to achieve financial stability. These contributions include, among others, Faia and Monacelli (2007), Akram and Eitrheim (2008), Christensen et al. (2011), Gelain et al. (2012), Agénor et al. (2013), Angelini et al. (2014), Gambacorta and Signoretti (2014), Rubio and Carrasco-Gallego (2014, 2016), Agénor and

[1]Some observers have argued that the tension between price stability and financial stability also reflects in part the different policy horizons over which central banks can aim to achieve stability goals. Price stability typically focuses on inflation developments over a short horizon, usually two years or so. By contrast, financial stability risks often develop over a longer horizon, because financial booms and busts tend to last longer than traditional business cycles.

Zilberman (2015), Benes and Kumhoff (2015), Bailliu et al. (2015), Levine and Lima (2015), Collard et al. (2016), Silvo (2016), De Paoli and Paustian (2017), and Gelain and Ilbas (2017). Collard et al. (2016) and De Paoli and Paustian (2017) for instance study policy coordination and optimal interactions between instruments in a setting that involves separate prudential and monetary authorities with potentially different objectives. Christensen et al. (2011), Agénor et al. (2013), Angelini et al. (2014), and Rubio and Carrasco-Gallego (2016) focus more specifically on the interaction between monetary policy and countercyclical capital buffers—along the lines proposed by the Basel III Accord, see Basel Committee on Banking Supervision (2011)—whereas Rubio and Carrasco-Gallego (2014) examined the interplay between monetary policy and loan-to-value ratios. A common finding of the literature is that, in the presence of financial shocks, countercyclical capital requirements may yield significant gains in terms of macroeconomic stabilization, regardless of the way monetary and capital requirements policies interact. In addition, some also found that when monetary policy "leans against the wind," significant gains can be achieved in terms of either reduced macroeconomic and financial volatility or higher social welfare.

At the same time, other contributions have argued—based on Tinbergen's *effective assignment principle*, or what Stein (2013) has referred to more broadly as the *decoupling philosophy*—that monetary policy should remain squarely focused on macroeconomic stability whereas macroprudential policy should focus solely on financial stability. For Svensson (2016*a*) for instance, monetary policy should (almost) never be used to contain threats to financial stability and so should not have a financial stability goal; moreover, monetary policy and macroprudential policies should be conducted by separate entities and need not be coordinated.[2] A higher policy rate, in particular, may have benefits in terms of lower real debt growth and a lower probability of a financial crisis, but it may have costs in terms of higher unemployment and lower inflation, which may increase the cost of a crisis when the economy is weaker. However,

[2] A similar view is taken by the International Monetary Fund (2015) and Ajello et al. (2016). An often cited example as to why monetary policy should not be used as the primary tool for achieving financial stability is the Riksbank's attempt to use monetary policy to choke off pressures on house prices and rapid increases in household debt in Sweden during the period 2010-11, when the policy rate was raised from 0.25 percent to 2 percent in the span of a few months. Svensson (2016*b*) argued that it ultimately generated below-target inflation, higher unemployment, and even higher real debt.

this policy assignment may be suboptimal if the ability of macroprudential regulation to mitigate credit growth is not well established or if the regulatory structure is fragmented—thereby impeding the effective operation of macroprudential tools.[3] In addition, observers have argued that some of the assumptions underlying this line of analysis—that the policy response does not affect the cost of financial crises, that crises occur with a given frequency and that they do not result in permanent output losses—tend to underestimate the costs of crises and limit the potential benefits of a "leaning-against-the-wind" policy (Bank for International Settlements (2016, Chapter 4) and Gourio et al. (2016)). The empirical evidence suggests indeed that recessions that coincide with financial crises often result in permanent output losses and persistently lower growth rates thereafter (see Claessens et al. (2011) and Claessens and Kose (2014)). Put differently, the costs and benefits of leaning against the wind need to be assessed over the course of full financial cycles—rather than focusing only on the occurrence of full-blown financial crises—and the impact of past policy decisions on today's and tomorrow's financial outcomes need to be accounted for. In addition, incorporating the role of asset prices, credit, and bank risk-taking may significantly alter the cost-benefit analysis of the use of monetary policy (Adrian and Liang (2016)). A fair assessment therefore is that the debate on whether monetary policy should be used to achieve a financial stability objective, in the context of either separate or joint mandates with macroprudential regulation, remains largely unsettled.

The purpose of this paper is to contribute to this debate by examining the performance of alternative institutional policy mandates in terms of achieving macroeconomic and financial stability (or, for short, economic stability). To do so it uses a model with banking and financial frictions to analyze how monetary and macroprudential policies interact to shape macroeconomic outcomes and mitigate financial volatility. We focus on reserve requirements as a macroprudential tool—an instrument that has been used extensively in middle-income countries in recent years, not only as a substitute

[3]Even though recent empirical studies suggest that sector-specific macroprudential tools have proved effective in terms of mitigating financial risks (especially in terms of mitigating pressure on house prices), the evidence is either less compelling or quasi inexistent when it comes to some of the countercyclical tools introduced under the new Basel arrangement (such as countercyclical capital buffers or the net funding ratio) and other tools such as so-called dynamic provisions. See Akinci and Olmstead-Rumsey (2015), Bruno et al. (2015), and Cerutti et al. (2015) for instance.

to monetary policy (often during episodes of large capital flows) but also as a tool to mitigate credit growth and manage financial risks.[4] Although reserve requirements are set at either zero or very low levels in high-income countries, they have been made part of Basel III's liquidity coverage ratio (LCR).[5] Thus, although in our framework reserves held at the central bank earn no interest—unlike some of the highly liquid assets that banks are allowed to hold to comply with the LCR under the Basel Accord—our analysis can also be viewed more broadly as a relevant contribution for understanding the macroeconomic and financial effects of liquidity requirements. Moreover, there has been some discussion recently on whether in advanced economies reserve requirements should not only be increased permanently but also used—as we discuss in this paper—as a countercyclical rule to mitigate excessive credit growth. Stein (2012) and Kashyap and Stein (2012) for instance argued that, by implementing a comprehensive but flexible reserve requirement system, central banks may be able to effectively tax the negative systemic externality associated with credit booms. In addition, and in contrast to increases in capital requirements, which often require giving banks significant lead time to comply in order to avoid a credit crunch, reserve requirements are under the direct control of the monetary or prudential authority and can be adjusted quickly. They are also difficult to evade, at least in the short run.

In effect, in our framework the required reserve ratio—often presented, from a public finance perspective, as a tax on financial intermediation—is conceptually similar to the macroprudential tax rate on bank loans considered for instance by Levine and Lima (2015) and De Paoli and Paustian (2017), and the lump-sum levy on bank capital considered by Gelain and Ilbas (2017), except that here its impact on lending operates indirectly (as explained later), through market and policy interest rates.[6] Interestingly, recent evidence (see Cerutti et al. (2017)) suggests that reserve requirements

[4]See Agénor et al. (2015) and Agénor and Pereira da Silva (2016) for a detailed discussion of the evidence for these countries.

[5]See Basel Committee on Banking Supervision (2013). Historically, reserve requirements played a significant role in many of today's high-income countries; see for instance O'Brien (2007) and Gray for a review of the characteristics of reserve requirement systems in these countries in the past decade and Elliot et al. (2013) for a discussion of the experience of the United States over the period 1948-80.

[6]In addition, it is worth noting that Bianchi (2011) showed that, for a generic bank balance sheet, capital and reserve requirements have similar effects and may therefore be thought of *ex ante* (although not *ex post*) as substitutes from a macroprudential perspective.

have indeed been used countercyclically in advanced economies, albeit with significant heterogeneity between countries.

To investigate how best the combination of policy interest rates and reserve requirements could contribute to macroeconomic and financial stability, we analyze three alternative institutional arrangements featuring different levels of coordination between the monetary authority and the financial regulator. The first arrangement is the *goal-integrated mandate*, whereby the monetary authority and the financial regulator aim to achieve jointly macroeconomic and financial stability by minimizing a common policy loss function. They have access to the same information set but they differ in that each entity can manipulate only one instrument—the base policy rate for the monetary authority and the required reserve ratio for to the financial regulator. They are thus *operationally* independent, but fully coordinated. The second arrangement, the *goal-distinct mandate*, is such that the macroeconomic stability goal is delegated only to the monetary authority, which sets the base policy rate accordingly, and the financial stability goal only to the financial regulator, who sets the reserve requirement ratio on the basis of a simple implementable rule based solely on the behavior of credit—a variable that has often been associated with financial crises in both developed and developing countries (see Schularick and Taylor (2012), Agénor and Montiel (2015, Chapter 15), Aikman et al. (2015), and Gertler and Hofman (2016)). Thus, in a sense, credit becomes an *operational target* for financial stability. This mandate features no coordination and captures the fact that, in practice, separate institutions are often made responsible for achieving narrower goals on the grounds of accountability; it implies therefore that spillover effects between authorities are not internalized by either one of them. The third arrangement, the *common-goal mandate*, is such that the financial stability goal is given to both the monetary authority and to an independent and separate financial regulator. Yet, the central bank is allowed to set the policy rate only (by minimizing its loss function) to achieve both macroeconomic and financial stability—thereby internalizing spillover effects—whereas the financial authority sets the required reserve ratio as it does under the second mandate, that is, using a simple credit-based implementable rule. This last mandate features partial coordination in the sense that the monetary authority and the financial regulator share one of the two goals.

Under all of these mandates, macroeconomic stability is defined in terms of the volatility of output and inflation, whereas financial stability—as in Angeloni et al. (2014), Agénor and Zilberman (2015), and Laureys et al. (2016) for instance—is defined in terms of the volatility of the credit-to-output ratio. To compare how the economy performs in terms of macroeconomic and financial stability under the three mandates, we define a policy loss function in terms of the unconditional variances of the macroeconomic, financial, and instrument variables.[7]

A comparison of the alternative mandates reveals that the benefit of using the required reserve ratio are substantial under the goal-integrated mandate while is negligible or changes in a cost under the other mandates. These findings suggest that the required reserve ratio should be used along with the policy interest rate only under coordination, when institutions share common goals and information sets, and follow rules that optimally account for the behavior of the economy as a whole, as in the goal-integrated mandate defined earlier. Such a combination suggests therefore that coordination at some levels does matter. Yet, coordination does not mean that one institution can (or should) interfere with the other: both are independent at the operational level. In fact, under this regime, each entity is assigned an optimal rule for its own instrument that reacts to the state of the economy. Thus, neither institution can affect how the other institution sets its instrument. The main contribution of this paper lies therefore in showing that reserve requirements should be relied upon as an instrument to promote economic stability if and only if their use is coordinated with the policy rate.

The fundamental reason for these results is the extent to which spillover effects can be internalized under the alternative regimes. When macroprudential policy is implemented through a credit-based reserve requirement rule (as is the case under the goal-distinct and common-goal mandates), the policy has some efficacy at stabilizing

[7] Our policy loss function is not explicitly micro-founded and consequently the policy mandates do not coincide with the Ramsey policy. However, the macroeconomic stability objectives are consistent with the practice of central banks operating a flexible inflation targeting regime; see Svensson (2010, Section 3) and Adolfson et al. (2011, p. 1288) for instance. In addition, the corresponding loss function may represent a parsimonious approximation to social welfare; see Laureys et al. (2016) and Debortoli et al. (2017) in particular.

credit and investment in response to a financial shock. It therefore contributes to promoting financial stability, as measured by the volatility of the credit-to-output ratio. However, because changes in the required reserve ratio operate through changes in bank pricing decisions, this stability gain occurs at the cost of increased volatility of market interest rates, which translates (through intertemporal effects) into more volatility in aggregate demand. In turn, this mitigates the benefits of lower volatility in investment on the volatility of output and prices. These conflicting effects cannot be internalized by a financial regulator following a narrow rule—even when, as is the case under the common-goal mandate, monetary policy does not generate spillovers and accounts for the rule followed by the financial regulator. By contrast, under a goal-integrated mandate, the required reserve ratio reacts not only to fluctuations in the credit-to-output ratio but also to output and price volatility. Thus, under a broader mandate, involving coordination *via* common goals yet operational independence, macroprudential regulation can be more effective in promoting both macroeconomic and financial stability.

The remainder of the paper proceeds as follows. Section 2 presents the model, which is based in part on the model with monopoly banking and credit market imperfections of Agénor et al. (2013) but with two important differences. First, it introduces a penalty rate in the cost of borrowing from the central bank to account for imperfect substitutability between funding sources for commercial banks (deposits and central bank liquidity), thereby creating a role for changes in reserve requirements as a countercyclical policy. Second, it assumes the optimization of a standard loss function under commitment in a timeless perspective to set the refinance rate—simultaneously with the required reserve ratio under the integrated mandate.[8] This is in contrast to several existing studies, in which standard and augmented Taylor rules are directly specified. The equilibrium solution of the model and some key features of its steady state are discussed in Sections 3 and 4, whereas a parameterization is presented in Section 5. The performance of alternative mandates in response to a financial shock (an increase

[8]This approach is adopted by some infation targeting central banks as discussed for the Norges Bank by Holmsen et al. (2008) and, from a theoretical perspective, Svensson (2010).

in the risk of default) is studied in Section 6.[9] Section 7 provides some robustness analysis. The last section offers some concluding remarks and discusses some possible extensions.

2 The Model

We consider a closed economy with nine categories of agents: a representative final good-producing (FGP) firm, a continuum of capital good (CG) producers with unit mass, employment agencies, a continuum of intermediate good-producing (IGP) firms indexed by $j \in [0,1]$, a continuum of households indexed by $h \in [0,1]$, a continuum of commercial banks indexed by $i \in [0,1]$, the government, a monetary authority, and a financial authority.

The representative FGP firm aggregates imperfectly substitutable intermediate goods into a final good, which is sold in a perfectly competitive market. CG producers buy the final good for investment and produce new capital. Each IGP firm produces an intermediate good using capital rented from a CG producer and homogenous labor provided by the employment agencies. Competitive employment agencies combine specialized labor supplied by households into a homogenous labor input.

For simplicity, each household is matched to an IG producer, a CG producer, and a commercial bank, and receives profits from all of them. They consume the final good, supply deposits to commercial banks, and supply specialized labor to employment agencies. Commercial banks supply credit to CG producers to purchase the final good. The supply of loans is perfectly elastic at the prevailing lending rate. Loans are paid off at the end of the period. Liquidity demanded by commercial banks is supplied by the monetary authority which, along with a financial regulator, is in charge of macroeconomic and financial stability. We consider later on alternatives scenarios with respect to the goals, the instruments, and the operating procedures that society bestows upon these authorities.

[9] We focus on a financial shock only, given the large consensus in the recent literature that macroprudential regulation provides limited benefits in response to real shocks.

2.1 Final Good-Producing Firm

The representative final good producer uses a continuum of imperfectly substitutable intermediate goods Y_{jt}, indexed by $j \in [0, 1]$, to produce the final good Y_t. The production technology for combining intermediate goods to produce the final good is given by:

$$Y_t = \left\{ \int_0^1 Y_{jt}^{(\theta-1)/\theta} dj \right\}^{\theta/(\theta-1)}, \tag{1}$$

where $\theta > 1$ represents the elasticity of substitution.

Given the prices of intermediate goods P_{jt} and the price of the final good P_t, the final good-producing firm chooses the quantities of intermediate goods to maximize its profits. The profit maximization problem of the final good producer is given by:

$$\max_{Y_{jt}} P_t \left\{ \int_0^1 Y_{jt}^{(\theta-1)/\theta} dj \right\}^{\theta/(\theta-1)} - \int_0^1 P_{jt} Y_{jt} dj.$$

The first-order condition with respect to Y_{jt} gives the demand for each intermediate good j:

$$Y_{jt} = (\frac{P_{jt}}{P_t})^{-\theta} Y_t. \tag{2}$$

Substituting (2) in (1) yields the final good price:

$$P_t = (\left\{ \int_0^1 P_{jt}^{1-\theta} dj \right\}^{1/(1-\theta)}. \tag{3}$$

The final good Y_t is used for private and government consumption as well as investment by the CG producer.

2.2 Capital Good Producers

All the capital used in the economy is owned by CG producers, who employ a linear production function to produce capital goods. At the beginning of each period, the representative CG producer purchases I_t of the final good. Payments for these goods must be made in advance and the CG producer borrows $L_t^F = P_t I_t$ from commercial banks. In real terms,

$$l_t^F = I_t. \tag{4}$$

Loans are repaid at the end of the period. The total cost of buying an amount I_t of the final good is $(1+i_{t-1}^L)P_tI_t$, where i_t^L is the lending rate.

The representative CG producer combines undepreciated capital from the previous period with investment to produce new capital goods and rents it to a randomly matched IGP firm at the rate r_t^K. The stock of capital goods at $t+1$, K_{t+1}, is thus given by:

$$K_{t+1} = I_t + (1-\delta_K)K_t - \frac{\Theta_K}{2}(\frac{K_{t+1}}{K_t} - 1)^2 K_t, \tag{5}$$

where $\delta_K \in (0,1)$ is the depreciation rate and $\Theta_K > 0$ measures the magnitude of adjustment costs.

The CG producer chooses the amount of capital that maximizes the value of the discounted stream of end-of-period dividend payments to the household:

$$\max_{K_{t+1}} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \Lambda_{t+s} (\frac{J_{t+s}^K}{P_{t+s}}), \tag{6}$$

where $\mathbb{E}_t$ is the expectation operator conditional on the information available at t and

$$J_t^K = r_t^K P_t K_t - q_t(1+i_{t-1}^L)P_t I_t - (1-q_t)\,\kappa P_t K_t,$$

is nominal profits and $q_t \in (0,1)$ the repayment probability of IGP firms (assumed identical across them), given by[10]

$$q_t = (\frac{\kappa K_{t-1}}{l_{t-1}^F})^{\phi_1}(\frac{Y_{t-1}}{Y})^{\phi_2}\xi_t^{-\phi_3}, \tag{7}$$

where $\kappa = \int_0^1 \kappa^i di$ and $\kappa^i \in (0,1)$ is the fraction of the capital stock pledged as collateral to each bank i, and $\phi_1, \phi_2, \phi_3 > 0$. The term ξ_t is a financial shock, which follows an $AR(1)$ process of the form

$$\xi_t = \xi_{t-1}^{\rho_\xi} \exp(\varepsilon_t), \tag{8}$$

where $\rho_\xi \in (0,1)$ and $\varepsilon_t \sim \mathbf{N}(0, \sigma_\varepsilon)$. Thus, the repayment probability depends on the lagged effective collateral-loan value and on lagged cyclical output, where Y is the steady-state value of Y_t.

[10] Agénor and Pereira da Silva (2014) formally derive a relationship similar to (7) by relating bank monitoring effort and borrowers' incentives to repay their loans, and by assuming that monitoring costs are countercyclical.

Maximizing (6) subject to (5), yields the first-order condition[11]

$$\mathbb{E}_t r^K_{t+1} = q_t(1+i^L_{t-1})\mathbb{E}_t \left\{ \left[1+\Theta_K(\frac{K_{t+1}}{K_t}-1) \right] (\frac{1+i^B_t}{1+\pi_{t+1}}) \right\} \tag{9}$$

$$+\mathbb{E}_t \left\{ (1-q_{t+1})\,\kappa - q_{t+1}(1+i^L_t) \left\{ 1-\delta_K+\frac{\Theta_K}{2}[(\frac{K_{t+2}}{K_{t+1}})^2-1] \right\} \right\}.$$

The amount borrowed by the representative CG producer is a Dixit-Stiglitz basket of differentiated loans, each supplied by a bank i, with a constant elasticity of substitution $\zeta^L > 1$:

$$l^F_t = [\int_0^1 (l^{i,F}_t)^{(\zeta^L-1)/\zeta} di]^{\zeta^L/(\zeta^L-1)}.$$

The demand for type-i loan, l^i_t, is thus given by the downward-sloping curve

$$l^{i,F}_t = (\frac{1+i^{L,i}_t}{1+i^L_t})^{-\zeta^L} l^F_t, \tag{10}$$

where $i^{L,i}_t$ is the rate on the loan extended by bank i and $i^L_t = [\int_0^1 (1+i^{L,i}_t)^{1-\zeta^L} di]^{1/(1-\zeta^L)} - 1$ the aggregate loan rate.

2.3 Intermediate Good-Producing Firms

Each IGP firm, indexed by $j \in [0,1]$, produces a separate good which is sold on a monopolistically competitive market. To produce these goods, each firm rents capital at the price r^K_t from a randomly matched CG producer, and combines it with an homogenous labor input bought at the real wage $\omega_t = W_t/P_t$.

The technology faced by IGP firms is given by the Cobb-Douglas production function:

$$Y_{jt} = H_t K^\alpha_{jt} N^{1-\alpha}_{jt}, \tag{11}$$

where H_t is the identical level of total factor productivity, N_{jt} is the representative household's supply of labor hours to firm j, K_{jt} the amount of capital rented by the firm, and $\alpha \in (0,1)$ the elasticity of output with respect to capital. The productivity shock follows an AR(1) process of the form

$$H_t = H^{\rho_H}_{t-1} \exp(\varepsilon_{H,t}),$$

[11]Equation (9) boils down to the standard arbitrage condition $\mathbb{E}_t r^K_{t+1} \simeq i^B_t - \mathbb{E}_t \pi_{t+1} + \delta_K$ in the absence of borrowing and adjustment costs.

where $\rho_H \in (0,1)$, and $\varepsilon_{\xi,t} \sim \mathbf{N}(0,\sigma_\xi)$.

IGP firms solve a two-stage problem. In the first stage, given input prices and technology, firms determine their capital and labor inputs in a perfectly competitive market in order to minimize real costs:

$$\min_{N_{jt},K_{jt}} \omega_t N_{jt} + r_t^K K_{jt}, \tag{12}$$

subject to (11). From the first-order conditions with respect to N_{jt} and K_{jt} the common capital-labor ratio is

$$\frac{K_{j,t}}{N_{j,t}} = (\frac{\alpha}{1-\alpha})\frac{\omega_t}{r_t^K}, \tag{13}$$

and the common unit marginal cost is

$$mc_{jt} = \frac{1}{H_t}\frac{\omega_t^{1-\alpha}(r_t^K)^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha}}. \tag{14}$$

In the second stage, each IGP firm chooses the optimal price at random intervals following the standard Calvo staggered price model and have the opportunity to change their prices with probability $1-\zeta_p$, where $\zeta_p \in (0,1)$. Thus, a firm j that is allowed to set its price in period t chooses its new price for the random period starting in t, P_t, to maximize, subject to (2), the expected discounted value of current and future real profits:

$$\max_{P_{jt}} \mathbb{E}_t \sum_{s=0p}^{\infty} \zeta_p^s \frac{\beta^s \Lambda_{t+s}}{\Lambda_t}\left\{(\frac{P_{jt}}{P_{t+s}} - mc_{jt+s})Y_{jt+s}\right\}, \tag{15}$$

where Λ_t is the marginal utility of nominal income. The first-order condition is then

$$\mathbb{E}_t\left\{\sum_{s=0}^{\infty} \zeta_p^s \beta^s \Lambda_{t+s}\tilde{Y}_{t+s}(\tilde{P}_t - \frac{\theta}{\theta-1}mc_{t+s})\right\} = 0,$$

where $\tilde{P}_t$ is the optimally chosen price, which is the same for all IGP firms and $\tilde{Y}_{t+s}$ and mc_{t+s} are, respectively, the demand they face and the marginal cost in $t+s$. IGP firms buy labor from employment agencies.

2.4 Employment Agencies

As in Erceg et al. (2000), a large number of competitive employment agencies combine specialized labor type $N_{h,t}$ supplied by each household into a homogenous labor input according to

$$N_t = [\int_0^1 N_{h,t}^{(\theta_\omega - 1)/\theta_\omega} dh]^{\theta_\omega/(\theta_\omega - 1)}, \tag{16}$$

where $\theta_\omega > 1$ is the constant elasticity of substitution between different types of labor.

Profit maximization by the perfectly competitive employment agencies implies that the demand for each labor type is

$$N_{h,t} = (\frac{W_{h,t}}{W_t})^{-\theta_\omega} N_t, \tag{17}$$

where $W_{h,t}$ is the wage paid by the employment agencies to the supplier of labor of type h and W_t the aggregate wage paid by IGP firms for the composite labor input N_t and is given by

$$W_t = (\int_0^1 W_{h,t}^{1-\theta_\omega} dh)^{1/(1-\theta_\omega)}. \tag{18}$$

2.5 Households

The representative household maximizes utility from consumption, hours worked and the liquidity services provided by monetary assets. His discounted utility is:

$$U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{C_{t+s}^{1-\sigma^{-1}}}{1-\sigma^{-1}} - \frac{N_{i,t+s}^{1+\gamma}}{1+\gamma} + \eta_x \ln x_{t+s} \right\}, \tag{19}$$

where C_t is consumption, $N_{i,t}$ the share of total time endowment (normalized to unity) spent working, x_t a composite index of real monetary assets, $\beta \in (0,1)$ the discount factor, $\sigma > 0$ the intertemporal elasticity of substitution in consumption, $\gamma > 0$ the inverse of the Frisch elasticity of labor supply, and $\eta_x > 0$.

The composite monetary asset is a combination of real cash balances m_t^H and real bank deposits d_t:

$$x_t = (m_t^H)^\nu d_t^{1-\nu}, \tag{20}$$

where $\nu \in (0,1)$.[12]

Nominal wealth at the end of period t, A_t, is given by

$$A_t = M_t^H + D_t + B_t^H, \tag{21}$$

[12] Cash and deposits are both accounted for because the bond rate is solved (as noted later) from the equilibrium condition of the money market.

where $M_t^H = P_t m_t^H$ is nominal cash holdings, $D_t = P_t d_t$ is nominal bank deposits, and $B_t = P_t b_t$ represents holdings of one-period nominal government bonds.

The household enters period t with M_{t-1}^H holdings of cash. It also collects principal plus interest on bank deposits at the rate contracted in $t-1$, $(1+i_{t-1}^D)D_{t-1}$, where i_{t-1}^D is the interest rate on deposits, and principal and interest payments on maturing government bonds, $(1+i_{t-1}^B)B_{t-1}^H$, where i_{t-1}^B is the bond rate at $t-1$.

At the beginning of the period, the household chooses the real levels of cash, deposits, and bonds, and supplies labor to IGP firms, for which it receives factor payment $\omega_t N_t$. It receives the profits made by the matched IG producer, CG producer, and commercial bank, J_t^I, J_t^K, and J_t^B, respectively.[13] It also pays a lump-sum tax, whose real value is T_t.

The household's real budget constraint is thus

$$C_t + m_t^H + d_t + b_t^H = \omega_t N_t - T_t + (\frac{P_{t-1}}{P_t})m_{t-1}^H + (1+i_{t-1}^D)(\frac{P_{t-1}}{P_t})d_{t-1} \tag{22}$$

$$+(1+i_{t-1}^B)(\frac{P_{t-1}}{P_t})b_{t-1}^H + \frac{J_t^I}{P_t} + \frac{J_t^B}{P_t}.$$

Maximizing the utility function (19), with respect to C_t, b_t^H, m_t^H, and d_t, subject to (20)-(22), and taking i_t^D, i_t^B, P_t, and T_t as given, yields the following first-order conditions:

$$C_t^{-1/\sigma} = \Lambda_t P_t, \tag{23}$$

$$\mathbb{E}_t(\frac{C_{t+1}^{1/\sigma}}{C_t^{1/\sigma}}) = \beta \mathbb{E}_t(\frac{1+i_t^B}{1+\pi_{t+1}}), \tag{24}$$

$$m_t^H = \frac{\eta_x \nu C_t^{1/\sigma}(1+i_t^B)}{i_t^B}, \tag{25}$$

$$d_t = \frac{\eta_x (1-\nu) C_t^{1/\sigma}(1+i_t^B)}{i_t^B - i_t^D}, \tag{26}$$

where Λ_t is the marginal utility of income and $1+\pi_{t+1} = P_{t+1}/P_t$ the gross inflation rate.

Equation (24) is the Euler equation, (25) defines the demand for real cash balances (which is positively related to consumption and negative to the opportunity cost

[13] The FGP firm makes zero profits in equilibrium.

of holding money) and (26) defines the real supply of household deposits (which is positively related to consumption and the deposit rate).

As in Erceg et al. (2000), in each period a constant fraction $\zeta_w \in (0,1)$ of workers cannot reoptimize their wage and follow a simple indexation rule:

$$W_{h,t} = (1+\pi_{t-1})\, W_{h,t-1},$$

whereas the remaining fraction chooses the optimal wage by maximizing

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \zeta_w^s \beta^s \left[-\frac{N_{h,t+s}^{1+\gamma}}{1+\gamma} + \Lambda_{t+s} W_{h,t} N_{h,t+s} \right] \right\},$$

subject to the labor demand function (17). The wage-setting equation for workers renegotiating their salary is given by the following first-order condition:

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \zeta_w^s \beta^s \Lambda_{t+s} N_{t+s} \left[\tilde{W}_t \Pi_{t,t+s}^w - \frac{\theta_\omega}{\theta_\omega - 1} \frac{\tilde{N}_{t+s}^{\gamma}}{\Lambda_{t+s}} \right] \right\} = 0, \tag{27}$$

where

$$\Pi_{t,t+s}^w = \begin{cases} 1 & \text{for } s = 0 \\ \prod_{k=1}^{s} (P_{t+k}/P_{t+k-1}) & \text{for } s = 1, 2, ... \end{cases}$$

and wages evolve as

$$W_t = \left[(1-\zeta_w)\, \tilde{W}_t^{\theta_\omega - 1} + \zeta_w \left(\pi_{t-1} W_{t-1} \right)^{\theta_\omega - 1} \right]^{\frac{1}{\theta_\omega - 1}}. \tag{28}$$

2.6 Commercial Banks

Banks collect differentiated deposits from households and extend (as discussed earlier) differentiated loans to the representative CG producer, in an environment of monopolistic competition. Assets of commercial bank $i \in [0,1]$ at the beginning of period t consist of loans, $l_t^{i,F}$, and reserve holdings, R_t^i, whereas its liabilities consist of household deposits, d_t^i, and loans from the central bank, $l_t^{i,B}$. Bank i's balance sheet is thus:

$$l_t^{i,F} + R_t^i = d_t^i + l_t^{i,B}. \tag{29}$$

Reserves held at the central bank do not pay interest. They are determined by:

$$R_t^i = \mu_t d_t^i, \tag{30}$$

where $\mu_t \in (0,1)$ is the required reserve ratio. As discussed next, according to the specific mandate in place μ_t is set by a financial regulator either optimally, while taking into account the rest of the economy, or by a simple implementable rule.

The supply of deposits by households is a basket of differentiated deposits, with a constant elasticity of substitution $\zeta^D > 1$, each supplied to a bank i:

$$d_t = [\int_0^1 (d_t^i)^{(1+\zeta^D)/\zeta^D} di]^{\zeta^D/(1+\zeta^D)}.$$

The supply of type-i deposit, d_t^i, is thus given by the upward-sloping curve

$$d_t^i = (\frac{1+i_t^{i,D}}{1+i_t^D})^{\zeta^D} d_t, \tag{31}$$

where $1+i_t^{i,D}$ is the deposit rate offered by bank i and $1+i_t^D = [\int_0^1 (1+i_t^{i,D})^{1+\zeta^D} di]^{1/(1+\zeta^D)}$ the aggregate deposit rate.

We assume that commercial bank i (central bank) lends in t to the CG producer (commercial bank i) at $t-1$ interest rates. Thus, using (29), bank i's optimization problem can be written as

$$\max_{\left\{1+i_{t+s}^{i,L},\, 1+i_{t+s}^{i,D}\right\}_{s=0}^{\infty}} \mathbb{E}_t \sum_{s=t}^{\infty} \beta^s \Lambda_s \left\{ q_s \left(1+i_{s-1}^{i,L}\right) l_s^{i,F} + (1-q_s)\,\kappa^i K_s + \mu_s d_s^i \right. \tag{32}$$
$$\left. - \left(1+i_s^{i,D}\right) d_s^i - \left(1+i_{s-1}^C\right)\left[l_s^{i,F} - (1-\mu_s)\, d_s^i\right] \right\},$$

where i_t^C is the cost of central bank liquidity (hereafter the refinance rate), which is taken as given by bank i. The term $q_t(1+i_{t-1}^{i,L})l_t^{i,F}$, represents repayment on loans if there is no default, which occurs with average probability q_t. The term $(1-q_t)\kappa^i K_t$ represents what bank i earns in case of default (which occurs with probability $1-q_t$), that is, under limited liability, the "effective" value of collateral pledged by the borrower, κK_t.[14] The term $\mu_t d_t^i$ represents the reserve requirements held at the central bank and returned to bank i at the end of the period (prior to its closure). The terms $(1+i_t^{i,D})d_t^i$ and $(1+i_{t-1}^C)[l_t^{i,F}-(1-\mu_t)d_t^i]$ represent repayment of deposits and borrowing from the central bank (principal and interest) by bank i.

[14] Note that although revenues depend on whether the borrower repays or not, payments of principal and interest to households and the central bank are *not* contingent on shocks occurring during period t and beyond, and on firms defaulting or not.

Maximizing (32) with respect to gross interest rates $R_t^{i,L} = 1+i_t^{i,L}$ and $R_t^{i,D} = 1+i_t^{i,D}$ subject to (10) and (31) yields the first-order conditions

$$\mathbb{E}_t q_{t+1}(\frac{R_t^{i,L}}{R_t^L})^{-\zeta^L} l_t^F - \mathbb{E}_t q_{t+1} R_t^{i,L} \zeta^L (\frac{R_t^{i,L}}{R_t^L})^{-\zeta^L - 1}(\frac{l_t^F}{R_t^L})$$

$$+(1+i_t^C)\zeta^L(\frac{R_t^{i,L}}{R_t^L})^{-\zeta^L-1}(\frac{l_t^F}{R_t^L}) = 0,$$

$$-(\frac{R_t^{i,D}}{R_t^D})^{\zeta^D} d_t - [R_t^{i,D} - \mu_t - (1-\mu_t)(1+i_{t-1}^C)]\zeta^D(\frac{R_t^{i,D}}{R_t^D})^{\zeta^D-1}(\frac{d_t}{R_t^D}) = 0,$$

which imply that, in a symmetric equilibrium,

$$1 + i_t^L = (\frac{\zeta^L}{\zeta^L - 1})(\frac{1+i_t^C}{\mathbb{E}_t q_{t+1}}), \tag{33}$$

$$1 + i_t^D = \frac{\zeta^D}{1+\zeta^D}[\mu_t + \left(1 + i_{t-1}^C\right)(1-\mu_t)]. \tag{34}$$

2.7 Monetary and Financial Authorities

The balance sheet of the monetary authority comprises government bonds, B_t^C, and loans to commercial banks, L_t^B, on the asset side, whereas its liabilities consist of reserves, R_t, and currency supplied to household and firms, M_t^S:

$$B_t^C + L_t^B = R_t + M_t^S. \tag{35}$$

The cost of central bank liquidity is increasing in the base policy rate, i_t^R, and in a penalty rate which depends on the ratio of commercial bank borrowing to required reserves:

$$1 + i_t^C = (1 + i_t^R)[1 + \tau(\frac{l_t^B}{\mu_t d_t})], \tag{36}$$

where $\tau \geq 0$ is the penalty rate scale coefficient. Thus, the central bank imposes a premium that increases with the amount borrowed, scaled by the bank's required reserves, which represent implicit collateral, as argued for instance in Agénor and Jia (2015) and Barnea et al. (2015).[15] This specification captures in a simple manner

[15] Note that here collateral determines not the *amount* that can be borrowed from the central bank but rather the *cost* at which such borrowing occurs.

imperfect substitutability between funding sources for commercial banks—a necessary condition for reserve requirements to be effective as a countercyclical instrument.[16]

The monetary authority sterilizes liquidity injections by a percentage factor $\kappa_F \in (0,1)$:

$$\frac{B_t^C}{B_{t-1}^C} = -\left(\frac{L_t^B}{L_{t-1}^B}\right)^{\kappa_F} \tag{37}$$

Income received by the monetary authority from bond holdings and lending to commercial banks are subsequently transferred to the government at the end of each period.

In this economy, goals, instruments and operating procedure of the monetary and financial authorities depend on the specific policy mandate that they are conferred to by society. We consider three alternative arrangements. Under each arrangement, policymakers have access to their own instrument and set its value according to a specific rule.

Under the first arrangement, the *goal-integrated* mandate, the monetary authority and the financial regulator share common macroeconomic and financial stability goals, have access to the same information set, and adopt a forecast targeting operating procedure. They differ, however, in that each entity can manipulate only one instrument. Formally, the two entities jointly minimize a policy loss function in terms of two instruments, the base policy rate, i_t^R, and the required reserve ratio, μ_t, while taking into account the behavior of the private sector. The operating procedure consists of forecast targeting.

Formally, the central bank solves the following problem:

$$\min_{\left\{i_{t+s}^R, \mu_{t+s}\right\}_{s=0}^{\infty}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \delta^s \left[f_{ms} \left(\hat{\pi}_{p,t+s}^2 + \lambda_y \hat{y}_{t+s}^2 \right) + (1 - f_{ms}) \left(\hat{l}_{t+s}^F - \hat{y}_{t+s} \right)^2 \right.\right. \tag{38}$$
$$\left.\left. + \lambda_{i^R} \left(\hat{\imath}_{t+s}^R - \hat{\imath}_{t+s-1}^R \right)^2 + \lambda_\mu \left(\hat{\mu}_{t+s} - \hat{\mu}_{t+s-1} \right)^2 \right] \right\},$$

subject to the first-order conditions of the private sector. In (38) the hat symbol over a variable denotes the log-deviation of that variable from its steady-state value, and

[16] Had we introduced heterogeneity among banks and an (imperfectly competitive) interbank market, an alternative interpretation of (36), would be to define i_t^C as the money market rate and view the penalty rate as reflecting the premium that banks charge each other in response to the "stigma effect" associated with borrowing from the central bank. See Ennis and Weinberg (2013) for a discussion.

macroeconomic stability is defined in terms of the volatility of cyclical output and inflation, whereas financial stability is defined in terms of the volatility of the credit-to-output ratio. All λ coefficients are positive and $f_{ms} \in (0, 1)$ and $1 - f_{ms}$ capture the weights given to macroeconomic and financial stability, respectively

Promoting a stable financial system is largely a matter of avoiding events that have a low probability of occurring but which may entail major economic costs when they do occur. The variable used here helps to capture indirectly these concerns. Finally, to mitigate excessive fluctuations in policy variables—which would not be consistent with how central banks and financial regulators normally adjust their instruments—changes in the base policy rate and the required reserve ratio are also penalized in the loss function.

Solving problem (38) leads to two optimal rules, one for the base policy rate and the other for the required reserve ratio. These rules are respectively attributed to the monetary authority and to the financial regulator. Because each authority is given a different instrument and optimal rule, they are *operationally independent*. Put differently, neither of the two authorities can affect the optimal rule of the other as they both stem from the policy loss function bestowed upon them by society. Nor can either one affect the setting of the instrument that the other authority controls, as each one has its own instrument. At the same time, because they share the same targets and information set, the monetary and financial authorities are not *goal independent*.[17]

It is worth noting that the optimal rules devolved to the different entities share two features: a) each instrument reacts optimally to all the available information; and b) each instrument is set optimally given the choice of the other instrument. These features identify the optimal rules as two best reaction functions that are given to two operationally-independent entities. Hence, these optimal rules are naturally interpreted as two strategies which, along with the outcome in terms of macroeconomic and financial stability, determine a Nash equilibrium between the monetary authority

[17]This scenario captures to some extent the actual behavior of the ECB and the FED, where both a monetary authority and a financial regulator coexist within each institution. In the case of the FED for instance, some members belong to the board of both authorities. In the policy mandate discussed here, there is some coordination at the higher level of goals, information, and operating procedures, while there is independence at the lower level of rules to manipulate policy instruments.

and the financial regulator.

Under the second arrangement, the *goal-distinct* mandate, the financial stability goal only is delegated to an independent financial regulator who sets the reserve requirement ratio according to the following simple implementable rule:

$$\frac{1+\mu_t}{1+\mu} = (\frac{1+\mu_{t-1}}{1+\mu})^{\chi_1}(\frac{l_t^F/Y_t}{l^F/Y})^{(1-\chi_1)\chi_2}, \tag{39}$$

which relates μ_t to changes in the credit-to-output ratio. This specification is consistent with the evidence, alluded to earlier, showing that excessive credit expansion is a key predictor of financial crises.

At the same time, the monetary authority now sets the base policy rate i_t^R to achieve only macroeconomic stability. In this case, the problem for the monetary authority is to minimize a restricted loss function

$$\min_{\left\{i_{t+s}^R\right\}_{s=0}^{\infty}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \delta^s \left[f_{ms} \left(\hat{\pi}_{p,t+s}^2 + \lambda_y \hat{y}_{t+s}^2 \right) + \left(\hat{\imath}_{t+s}^R - \hat{\imath}_{t+s-1}^R \right)^2 \right] \right\}, \tag{40}$$

subject to the first-order conditions of the private sector and the simple implementable rule (39) given to the financial regulator.

Finally, under the third arrangement, the *common-goal* mandate, the financial stability goal is given to both the monetary authority and the independent financial regulator. Yet, the monetary authority is allowed to set the base policy rate to achieve *both* macroeconomic and financial stability by minimizing the loss function

$$\min_{\left\{i_{t+s}^R\right\}_{s=0}^{\infty}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \delta^s \left[f_{ms} \left(\hat{\pi}_{p,t+s}^2 + \lambda_y \hat{y}_{t+s}^2 \right) + (1-f_{ms}) \left(\hat{l}_{t+s}^F - \hat{y}_{t+s} \right)^2 + \lambda_{i^R} \left(\hat{\imath}_{t+s}^R - \hat{\imath}_{t+s-1}^R \right)^2 \right] \right\}, \tag{41}$$

subject to the first-order conditions of the private sector and the simple implementable rule (39), whereas the financial regulator sets the reserve coefficient requirement just as under the second mandate. This mandate is consistent with monetary policy "leaning against the wind," as documented in studies of the impact of financial stability risks on policy interest rates (see for instance Friedrich et al. (2015)) and the idea of *integrated inflation targeting* discussed by Agénor and Pereira da Silva (2013).[18]

[18] A fourth mandate that could be considered is the case where, as in Gelain and Ilbas (2017),

To compare how the economy performs in terms of macroeconomic and financial stability under the three alternatives mandates, it is convenient to define the policy loss function, PL, in terms of the unconditional variances of the macroeconomic and financial variables:[19]

$$PL = f_{ms}(\sigma_{\pi}^2 + \lambda_y \sigma_y^2) + (1 - f_{ms})\sigma_{l^F/y}^2. \tag{42}$$

2.8 Government

The government purchases the final good, collects taxes, and issues bonds, B_t, which are held by the central bank, B_t^C, and households, B_t^H. The government's budget constraint is given by

$$B_t = (1 + i_{t-1}^B)B_{t-1} + P_t(G_t - T_t) - i_t^C L_t^B - i_{t-1}^B B_{t-1}^C, \tag{43}$$

where $B_t = B_t^C + B_t^H$, G_t denotes government spending, T_t represents real lump-sum tax revenues. The terms $i_t^C L_t^B$ and $i_{t-1}^B B_{t-1}^C$ are included in the budget constraint to account for the fact that the income earned by the central bank from lending to commercial banks and holding government bonds, respectively, is transferred to the government.

Government purchases represent a fraction $\psi \in (0, 1)$ of output of the final good. Thus,

$$G_t = \psi Y_t. \tag{44}$$

3 Equilibrium

In a symmetric equilibrium, all IGP firms are identical. Therefore, $K_{jt} = K_t$, $N_{jt} = N_t$, $Y_{jt} = Y_t$, $P_{jt} = P_t$, for all $j \in [0, 1]$.

the financial regulator is also concerned about output stability, with monetary policy retaining sole responsability for price stability. This could affect significantly the monetary policy gains from co-ordination, especially in the presence of a cost channel. However, the broad consensus remains that financial regulation should focus solely on financial stability.

[19] In line with the existing literature, two alternative approaches to studying optimal policy could have been followed. The first would have been to use systematically simple, implementable rules for both the monetary authority and the financial regulator, as for instance in Bailliu et al. (2015) and Levine and Lima (2015). The second approach would have been to solve for the (constrained) Ramsey problem by maximising a utility-based measure of social welfare, as for instance in De Paoli and Paustian (2013), Collard et al. (2016), and Silvo (2016).

The supply of loans by commercial banks and supply of deposits by households are perfectly elastic at the prevailing interest rates; as a result, the markets for loans and deposits always clear. The equilibrium condition of the goods markets is

$$Y_t = C_t + G_t + I_t. \tag{45}$$

Assuming for simplicity that bank loans to the CG producer are only extended in the form of cash, $l_t^F = m_t^F$, the equilibrium condition of the currency market is denoted by

$$m_t^S = m_t^H + l_t^F, \tag{46}$$

which, using (25), can be solved for the bond rate.[20]

4 Steady State

Appendix A contains the steady-state equations, whereas the log-linearized equations are presented in Appendix B. In brief, in the steady state the inflation rate is constant and equal to the inflation target, which is set to zero. The steady-state interest rate on bonds is given by $\tilde{\imath}^B = \beta^{-1} - 1$. The steady-state deposit and lending rates are given by

$$1 + \tilde{\imath}^L = (\frac{\zeta^L}{\zeta^L - 1})\frac{1 + \tilde{\imath}^C}{\tilde{q}},$$

$$1 + \tilde{\imath}^D = \frac{\zeta^D[\tilde{\mu} + (1 + \tilde{\imath}^C)(1 - \tilde{\mu})]}{1 + \zeta^D},$$

where the steady-state values of the repayment probability and the refinance rate are

$$\tilde{q} = (\frac{\kappa\tilde{K}}{\tilde{l}^F})^{\phi_1}, \quad 1 + \tilde{\imath}^C = [1 + \tau(\frac{\tilde{l}^B}{\tilde{\mu}\tilde{d}})](1 + \tilde{\imath}^R).$$

From these equations it is easy to see that $\tilde{\imath}^D < \tilde{\imath}^C$ (deposits are cheaper than central bank borrowing) and, because $\zeta^L > 1$, $\tilde{q}(1 + \tilde{\imath}^L) > 1 + \tilde{\imath}^C$, which ensures that banks have an incentive to borrow from the central bank to fund investment. We must also have $\tilde{\imath}^C = \tilde{\imath}^B$, to ensure that in equilibrium the bank has no incentive to borrow from the central bank to purchase bonds.

[20] We eliminate the equilibrium condition of the bonds market by Walras' Law.

5 Parameterization

Table 1 summarizes our parameter values. Starting with employment agencies and households, we set the elasticity of substitution between different types of labor, θ_ω, to 21, as in Altig et al. (2011). The discount factor, β, is set equal to 0.97 to match a real interest rate of about 3 percent. As in Walsh (2014), the fraction of workers who are not optimizing their wage is equal to 0.75. The inverse of the Frisch elasticity of labor supply is set equal to 3, well within the empirically plausible range. The intertemporal elasticity of substitution, σ, is set at 0.5, in line with the empirical evidence discussed by Braun and Nakajima (2012) for instance. The preference parameter for composite monetary assets, η_x, is set at a low value of 0.09 to capture the fact that monetary assets bring little direct utility (see for instance Christiano et al. (2010) and Christoffel and Schabert (2015)). Furthermore, the share parameter in the index of money holdings, ν, which corresponds to the relative share of cash in narrow money, is set at 0.2 to capture a significantly higher use of deposits.

Regarding production, the elasticity of demand for intermediate goods, θ, is set at 6, implying a steady-state value of the markup rate equal to 20 percent, a fairly standard benchmark (see Ireland (2001), Christiano et al. (2010) and Christoffel and Schabert (2015)). The fraction of firms who are not optimizing their price is set at 0.65, in line with Walsh (2014) and consistent with some previous estimates.[21] This implies an average duration between price optimizations of 3 quarters. The share of capital in output of intermediate goods, α, is set at 0.3, a fairly standard value, and the quarterly rate of depreciation of private capital, δ_K, is set equal to 0.03, corresponding to an annual depreciation rate of 12.6 percent. The adjustment cost for transforming the final good into investment, Θ_K, is set at 10, as in Ireland (2001).

The elasticity of the repayment probability with respect to the collateral-loan ratio is set equal to $\phi_1 = 0.6$, whereas the elasticity of the repayment probability with respect to cyclical output is set at $\phi_2 = 0.22$, and with respect to the financial shock at $\phi_3 = 0.98$. As to the effective collateral-loan ratio, κ, we set it at 0.3. For the parameters characterizing banks, the elasticities of substitution ζ^L and ζ^D are set to

[21] See, among others, Lubik and Schorfheide (2006).

25 and 22.5, respectively, as in Agénor et al. (2015). These values capture therefore a high degree of sensitivity of bank interest rates to changes in the refinance rate and the required reserve ratio.

As for the central bank, the scale coefficient in the penalty rate, τ, is set to 0.9 to generate reasonable departures for the refinance rate from the base policy rate. The steady-state required reserve ratio, μ, is set at 0.05, in line with available data for advanced economies (see Cerutti et al. (2017)). The sterilization factor, κ_F, is set at 0.2, implying therefore that changes in central bank provision of liquidity largely feed into the supply of cash. In the loss function, the weights on inflation and cyclical output stabilization are set to 1 and 0.2, respectively, to reflect greater concern (as documented in practice) with price stability. When either the first or third mandates are at work, the weights on the credit-to-output ratio, $f_{l_{I/y}}$, is set equal to 0.3, under the second mandate instead it is zero. Finally, the share of government spending on goods and services in output, ψ, is set at 0.2, as in Christoffel and Schabert (2015) for instance, and the degree of persistence in the financial shock is set at 0.8.

Before we consider the numerical experiments, it is worth discussing intuitively what happens if the central bank raises the reserve requirement rate. An increase in μ_t lowers initially the deposit rate (as can be inferred from (34)), thereby reducing the supply for deposits by households. All else equal, borrowing from the central bank increases. With perfect substitution between funding sources ($\tau = 0$), the drop in deposits is perfectly offset by an increase in central bank borrowing. By contrast, with $\tau > 0$, and given that from (30), $R_t = \mu_t D_t$, the net effect on required reserves is in general ambiguous (μ_t increases, whereas D_t falls). If the interest elasticity of deposits is sufficiently high, required reserves fall, and given that L_t^B rises as well, so does the ratio $l_t^B/\mu_t d_t$. From (36), borrowing from the central bank becomes more expensive. In turn, the increase in the refinance rate i_t^C tends to raise the deposit rate, which mitigates the initial drop in i_t^D as well as the loan rate. The increase in the loan rate dampens investment, whereas the higher deposit rate induces an increase in household deposits. By implication, even if there is a reduction in the bond rate (a likely outcome) on impact, and an expansion in current consumption (as a result of the intertemporal effect), output may still drop if the fall in investment, induced by the higher loan rate, is sufficiently large. Thus, the policy may indeed be countercyclical, as discussed elsewhere in the literature (see Glocker and Towbin (2012) and Agénor et al. (2015)). At the same time, to the extent that cyclical output and inflation fall, the optimal base policy rate i_t^R may also fall; thus, second-round effects may involve lower deposit and loan rates, which may in turn mitigate the initial contractionary effects.

6 Response to Financial Shock

In what follows we study the performance of alternative policy mandates when the economy is hit by a temporary negative shock to the repayment probability, of the order of one standard deviation. We thus focus on the case where, as a result of (perceived) adverse conditions in the economy, the risk of default of borrowers has increased. This shock could also be viewed as representing a negative disturbance to collateral values.[22]

In order to compare the policy loss under the alternative mandates defined earlier, we need a benchmark. Because we are interested in analyzing how both the policy rate and the required reserve ratio affect economic stability, we define this benchmark in such a way that it features the "minimum" feasible use of these instruments. Specifically, we first computed the policy loss function defined in (42) for each mandate under the assumption that the required reserve ratio is fixed at its steady-state value and the policy rate reacts to the shock just enough for the economy to get back to its initial steady state. Table 2 reports the three values of the policy loss function. We then take as a benchmark the smallest of these values, which turns out to be the one associated with the first mandate where the monetary authority and the financial regulator operate with common goals and the same information set, but are operationally independent.

Tables 3 to 5 report the ratio between the policy loss associated with the mandate under consideration and the benchmark loss when either only one instrument or both

[22] To save space and given our focus on the performance of alternative mandates, we do not provide a full description of the associated impulse response functions. They are consistent with intuition—the shock is contractionary (the lower repayment probability leads to a higher loan rate, which reduces credit and investment) but endogenous policy reaction, which depends on the institutional mandate, mitigates its effects.

instruments are manipulated. Specifically, moving downward across rows increases the intensity in the use of the policy rate, and moving rightward across columns increases the intensity in the use of the required reserve ratio. Furthermore, highlighted ratios correspond to cases in which either the refinance rate, or the required reserve ratio are used too intensively and thus they turn out to hit the zero lower bound. For this reason highlighted values are not admissible. Finally, in each table, the ratio in bold characterizes the minimum per column and row.[23]

6.1 Goal-Integrated Mandate

In this scenario, as noted earlier, the monetary authority and the financial regulator share the same goals of macroeconomic and financial stability, the same information set, and the same operating procedure of forecast targeting. They are given, however, different instruments and optimal policy rules. For this reason, they are independent entities from an operational standpoint.

Table 3 shows a remarkable efficacy of the refinance rate and the required reserve ratio to jointly achieve macroeconomic and financial stability. Furthermore, both instruments exhibit some complementary in their ability to reduce the loss. When both instruments are used intensively, the loss can fall down by up to 83.1 percent of its benchmark value. Table 3 also shows that their efficiency is different. Indeed, when the required reserve ratio is not used (first column), by using the refinance rate only it is possible to reduce the loss to 94.5 percent of its benchmark value. Instead, when the refinance rate is not used (first row), the loss can be reduced to 88.2 percent of its benchmark value. These findings clearly signal that the required reserves ratio plays the major role in reducing the loss under the current mandate.[24]

6.2 Goal-Distinct or Separate Mandates

Under this mandate, as noted earlier, the monetary authority and the financial regulator have different goals, information sets, operating procedures, and instruments.

[23] To ease the readability of the tables, we report only two digits after the decimal point. This explains why some figures in the tables are equal, but only one is in bold.

[24] In Table 3, the policy aggressiveness of each optimal rule is defined as the inverse of the weight in the loss function for smoothing the path of the instrument associated with the policy rule.

Table 4 shows a remarkable worsening in achieving the stability goals with respect to the previous case. Now the lowest achievable loss is almost three times as large as the lowest loss in the previous mandate, specifically it increases to 236.5 percent of its benchmark value.

Interestingly, when there is an independent financial regulator manipulating a simple implementable rule that only reacts to the credit-to-output ratio (first row), then the loss cannot be significantly reduced, in particular it only drops from 316.0 percent to 311.6 percent of its benchmark value. Instead, when the refinance rate is the only instrument and it is optimally manipulated (first column), the loss drops from 316.0 percent to 257.8 percent of its benchmark value. These results suggest that a financial regulator equipped with a simple implementable rule and adjusting the required reserve ratio in countercyclical fashion can contribute in a negligible way to reducing the total loss.

This outcome is in stark contrast with the ones in the previous goal-integrated mandate where the required reserve ratio was more efficient than the refinance rate to achieve macro and financial stability. This finding is also counterintuitive, but before explaining the mechanism at work two further remarks are in order.

First, comparing the first column in Tables 3 and 4 shows that even keeping constant the reserve requirement ratio, the loss would fall from 246.8 percent to 94.5 percent of its benchmark value by simply assigning to the central bank also the financial stability goal. This shows that in presence of two goals, the refinance rate optimally set to achieve both goals delivers more stability than when it is optimally set to achieve only macroeconomic stability. Second, for both instruments, the intensity of their use now exert a non-monotonic impact on the loss. This is in contrast with the previous mandate and casts a doubt on the actual implementability of the current mandate.

To investigate why the goal-integrate mandate provides such different results from the goal-distinct mandate and, in particular, why a financial authority equipped with a simple rule for the required reserve ratio can contribute in a negligible manner to reducing the loss, we examined the two components of the loss: the one associated with financial instability, and the one associated with macroeconomic instability. From the findings reported in Tables 3A-3B and Tables 4A-4B we see that what most determines the loss under both mandates is financial instability. This is in line with the expectations as we are dealing with a financial shock. Under the first mandate, both financial instability (Table 3A) and macroeconomic instability (Table 3B) decrease monotonically in the use of both instruments, although the latter less.[25] Thus, when instruments can be freely assigned to goals as under the first mandate, we do not have that the refinance rate is assigned to macroeconomic stability and the required reserve ratio to financial stability as one could expect. What we have, instead, is that both instruments are assigned to both goals, with the financial stability goal receiving more attention due to the financial nature of the shock. In this case, both instruments are set optimally in a goal-integrated perspective and the forecast targeting operating procedure allows internalizing their spillovers.

The outcome is more varied under the second mandate. Here, similar to the first, financial instability (Table 4A) tends to fall in the use of the required reserve ratio. This signals that the simple implementable rule has some efficacy to achieve financial stability. Yet, in contrast to the first mandate, financial instability increases in the use of the refinance rate. The reason is that the refinance rate now is used by the monetary authority that has a unique goal: macroeconomic stability. And it turns out that maximizing macroeconomic stability disturbs financial stability.[26] Now, when we turn to macroeconomic stability (Table 4B) we find the opposite result. Macroeconomic instability substantially falls with the use of the refinance rate thanks to the optimal rule followed by the monetary authority. But it rises with the use of the required reserve ratio, due to the fact that the financial authority has the unique goal of financial stability and therefore it cannot internalize the spillovers of its policy on macroeconomic stability. This explains why under the second mandate macro and financial stabilization is much worse than under the first mandate.

Summing up, in the presence of a financial shock, the main concern is financial stability. Under the first arrangement (goal-integrated mandate), both instruments can

[25] The loss due to financial instability drops from 0.6061 to 0.4592, (24.24 percent), whereas the loss due to macro instability drops from 0.3939 to 0.3715, (5.69 percent).

[26] Even if the monetary authority minimizes its loss account being taken of the simple implementable rule of the financial authority, it cannot internalize the spillovers of its decisions on financial stability as it does not share the financial stability goal.

be optimally devoted where they are required the most, i.e. to financial stability, but also accounting for macroeconomic stability. Thus, both instruments are manipulated to achieve more financial stability at the cost of less macroeconomic stability. Under the second arrangement (goal-distinct mandate) this is no longer possible: the refinance rate is optimally devoted to macroeconomic stability, while the reserves requirement is devoted to financial stability according to a simple rule. In this case, on the one hand the manipulation of the required reserve ratio reduces the financial instability part of the loss but increases the macro instability part of the loss. On the other, the manipulation of the refinance rate increases the financial instability part of the loss but decreases the macro instability part. As a result, the second arrangement delivers more macroeconomic stability but less financial stability than the previous one.

These institutional arrangements present two polar cases in terms of goals management: goals are either fully integrated or fully distinct. A natural question to ask is then to what extent, if any, the result still holds if at least one of the two institutions can internalize spillovers effect by means of a common goal. We address this question by introducing a third mandate, where financial stability is the common goal.

6.3 Common-Goal Mandate

In this scenario the monetary authority targets macroeconomic and financial stability but with the base policy rate only, whereas the financial authority manipulates the required reserve ratio to achieve financial stability with the simple rule. The results are shown in Table 5.

Comparing these results with those shown in Table 4, a first difference is that the policy loss can be significantly reduced to 111.6 percent of the benchmark from 236.5 percent in Table 4.

A second difference is that now the loss is minimized by preventing the financial regulator from moving the required reserve ratio, and only using intensively the refinance rate, first column. Thus, the utility to have the financial authority targeting financial stability with a simple rule, observed in Table 4 and already almost not significant, is completely lost when the monetary authority targets both macro and financial stability with the refinance rate. Indeed, in this case, the best overall result is achieved when the financial authority does not manipulate its instrument at all.

The reason for this improvement is that the refinance rate now is manipulated to achieve both goals. As a result the spillovers effects generated by the monetary authority in the previous mandate now vanish. This can be clearly seen comparing Tables 5A and 4A. Under the third mandate, the financial instability part of the loss falls in the use of the refinance rate while under the second mandate it increases. Interestingly, Table 5A shows that even if the refinance rate is used to achieve two goals, it allows reducing the financial part of the loss much more than the required reserve ratio manipulated according to the simple implementable rule.

A snapshot on the relation between policy spillovers and economic instability is provided by Table 6. For each mandate, Table 6 reports if increasing the intensity in the use of an instrument increases or decreases the two components of the policy loss. Presence and absence of policy spillovers are highlighted in Red/dark grey and blue/light grey respectively. We can notice that the previous ranking of the institutional arrangements in terms of the policy loss value inversely matches the presence of policy spillovers: zero for the first mandate, one for the third and two for the second.

This analysis of the institutional arrangements therefore implies that, due to policy spillovers, the financial stability goal should not be given to a financial regulator whose sole instrument is a required reserve ratio set on the basis of a simple, credit-based rule. Put differently, unless the policy spillovers are considered, for example with a policy mandate that involves minimizing a common intertemporal loss function (defined in terms of both macroeconomic and financial stability targets), it is better to keep the reserve requirement constant.

The key reason why, in response to a financial shock, combining the policy interest rate and the reserve requirement ratio performs best in promoting macroeconomic and financial stability is that when macroprudential policy is implemented through a narrowly-defined, credit-based reserve requirement rule (as is the case under the goal-distinct and common-goal mandates), the policy has some efficacy at stabilizing credit—and therefore investment, which is financed through bank loans. It therefore contributes to promoting directly financial stability (as measured by the volatility of the credit-to-output ratio) and indirectly output and price stability. However, in the present setting changes in the required reserve ratio operate through changes in bank pricing decisions. Reduced volatility in credit flows and investment occurs at the cost of increased volatility of market interest rates, which translates into more volatility in consumption as a result of intertemporal effects. Increased volatility in consumption mitigates the benefits of lower volatility in investment on the volatility of aggregate demand, output and prices. These conflicting effects cannot be internalized by a financial regulator following a narrow rule—even when, as is the case under the common-goal mandate, the monetary authority can do so through its setting of the policy rate. By contrast, under a goal-integrated mandate, the financial regulator can make the required reserve ratio respond not only to fluctuations in the credit-to-output ratio but also to output and price volatility. Thus, under a broader mandate, involving common goals and full information sharing but operational independence in setting instruments, macroprudential regulation is more effective in terms of promoting both macroeconomic and financial stability.

Our results are therefore consistent, but more nuanced, than those highlighted in existing contributions, such as Angelini et al. (2014), Rubio and Carrasco-Gallego (2014, 2016), Bailliu et al. (2015), and Levine and Lima (2015)—who all assume different forms of standard or augmented Taylor rules and focus on other types of macroprudential instruments—where cooperation between the central bank and the regulator always yields superior outcomes in terms of lower volatility or higher welfare in response to financial shocks. At the same time, we find significantly larger benefits associated with the goal-integrated mandate than those reported in the literature.

7 Robustness Analysis

To test the robustness of the results, we conducted sensitivity analysis focusing on three key aspects of the model. First, we consider an alternative scenario in which the policymakers assign the same relevance to macro and financial stability. Next we investigate the case in which the penalty rate impacts more on the cost of central bank liquidity. Finally, we account for the possibility that the economy is hit by a productivity shock instead of a financial shock.[27]

In the first case, equal weight is assigned to macro and financial stability in the policy loss (42), that is $f_{ms} = 0.5$, while in the previous analysis macroeconomic stability received prominence with $f_{ms} = 0.8$. Under the first mandate, the current results parallel the previous ones in terms of *a*) the efficacy of both instruments to jointly achieve macro and financial stability, *b*) their complentarity, and *c*) the major efficiency of the required reserve ratio at reducing the loss. Moreover, now the efficacy of both instruments to stabilize the economy increases. Also under the second and third mandate the results with the alternative weights in the policy function are qualitiatively the same. What is worth reporting is that when financial stability receives the same attention of macroeconomic stability from the policymakers, then the stabilization performance dramatically worsens with an independent financial regulator manipulating a simple implementable rule. To fix the ideas, we report that under the second mandate the minimum loss reaches 379.4 percent of its benchmark when $f_{ms} = 0.5$, while it was 193.7 percent of its benchmark when $f_{ms} = 0.8$.

In the second case, the analysis is carried out by increasing the scale coefficient τ for the penalty rate so that the latter may impact more than proportionally on the cost of central bank liquidity. The experiment is run setting $\tau = 1.1$ in equation (36). In this case also the analysis corroborates the previous results.

In the final case, we expose the economy to a productivity shock.[28] Although most of the loss now is due to macroeconomic instability, the results are in line with the ones obtained with the financial shock. What seems interesting to highlight is that, also with a productivity shock, the required reserve ratio becomes an inefficient instrument when it is manipulated according to the simple implementable rule (second and third mandate), whereas the major role in the stabilization is played by the refinance rate.

[27] Results for all these experiments are available upon request.

[28] The analysis is run under the benchmark case wich gives prominence to macroeconomic stability, that is, $f_{ms} = 0.8$.

8 Concluding Remarks

Since the Global financial crisis, there has been much discussion about whether monetary policy should "lean against the wind" in response to financial imbalances—in contrast with the "cleaning up after the crash" approach favored by some early observers and the view promoted by others that monetary policy is too blunt an instrument to deal with financial stability concerns. The issue of how best to combine monetary policy and macroprudential regulation to achieve macroeconomic and financial stability has also received much attention from academics and policymakers alike. The purpose of this paper was to study both issues in a dynamic stochastic general equilibrium model with financial frictions and three alternative institutional mandates for policymakers. Based on different levels of coordination between the monetary and the financial authority, these mandates involve goal-integrated (but instrument independent), goal-distinct, and common-goal mandate (partially dependent) arrangements for the monetary authority and the financial regulator. In the first case both monetary and macroprudential policies are set optimally, whereas in the last two cases macroprudential policy is carried out through a simple implementable rule, linking the required reserve ratio and the credit-to-output ratio. Such a rule, and variants of it, has received much attention in the recent literature.

A parameterized version of the model was used to study the performance of these alternative mandates when the economy is hit by a financial shock, taking the form of an increase in the risk of default by bank borrowers. Our analysis showed that it is optimal to use both the policy rate and the required reserve ratio only under the integrated mandate, because it allows policymakers to internalize policy spillovers, specifically the effects of changes in macroprudential and monetary policy instruments on both macroeconomic and financial stability. This combination generates substantial gains in terms of reduced volatility, compared to a benchmark case where the required reserve ratio is fixed at its steady-state value and the policy rate reacts to shocks just enough for the economy to get back to its original steady state. In addition, we also found that it is optimal to delegate the financial stability goal solely to the monetary authority when the financial regulator is only equipped with a credit-based reserve requirement rule. The reason again is that monetary policy can internalize (at least in part) the conflicting effects of changes in the required reserve ratio on credit flows and market interest rates.

These results have useful implications for the ongoing debate about the best way to combine monetary and macroprudential policies to achieve macroeconomic and financial stability, and, in so doing, whether monetary policy should also respond to financial imbalances in addition to pursuing price stability. As noted earlier, a number of middle-income countries (most notably in Asia and Latin America) have used reserve requirements intensively in recent years to manage financial risks and mitigate macroeconomic volatility. For advanced economies, there has been renewed thinking about the countercyclical role that these requirements may play, especially with respect to (excessive) credit growth. Our analysis suggests that while they may help, they may not be sufficient to promote financial stability if monetary policy is constrained to pursue a macroeconomic stability objective only.

Our analysis could be extended to account for the possibility that monetary policy affects the risk-taking incentives of financial intermediaries (as in Christensen et al. (2011) and Collard et al. (2016) for instance) and to consider the case where more than a single macroprudential instrument is available to regulators. Regarding the first extension, our intuition is that the superiority of a mandate that internalizes the policy spillovers would be strengthened. Regarding the second, it is indeed important to determine whether a combination of macroprudential tools (involving not only reserve requirements but also dynamic provisions, restrictions on funding ratios, as well as sectoral tools, such as loan-to-income and debt-to-income ratios) may be more effective under the goal-distinct and common-goal mandates. In fact, there has been very little work focusing on the combination of several macroprudential instruments and monetary policy. Doing so is important because, despite some recent progress, much uncertainty remains regarding the ability of some of these instruments to effectively address financial stability concerns, and the extent to which they complement or offset each other in their impact on banks' incentives to engage in excessive risk taking over the cycle and regulatory arbitrage, their market signaling effects, and so on.

A case in point is countercyclical capital buffers (designed to address *unexpected* losses in bad times) and dynamic provisions (whose goal is to absorb *expected* losses during bad times). In addition, the practical implementation of these instruments has raised serious operational challenges—even in a strong supervisory environment—related not only to the choice of indicators but also because of coordination problems between decision makers.[29] In such circumstances, the bluntness of monetary policy may actually be a major advantage relative to macroprudential regulation. Indeed, it may well be possible that—as predicted by our results—the most effective way to implement a strong macroprudential approach to financial stability is by allowing for greater overlap in the goals of monetary policy and financial regulation.

[29] This relates, in particular, to the use of the gap between the credit-to-GDP ratio and its trend as a guide to trigger countercyclical capital buffers, as recommmended by the Basel III Accord (see Drehman and Tsatsaronis (2014)). However, this ratio is a noisy indicator; it may rise because of a fall in the denominator (GDP) rather than an increase in the numerator (credit). This tends to occur in the early stages of a recession. A mechanical use of the indicator would then produce unintended effects and this militates in favor of using a larger set of indicators, as discussed by Behn et al. (2013). Note that this issue also arises for the simple, credit-based rule discussed earlier.

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Table 1
Benchmark Parameterization

Parameter	Value	Description
θ_w	21	Elasticity of substitution, different types of labor
β	0.97	Discount factor
ζ_w	0.75	Fraction of workers not optimising their wage in given period
γ	3	Inverse of the Frisch elasticity of labor supply
σ	0.5	Elasticity of intertemporal substitution
η_x	0.09	Relative preference for money holdings
ν	0.2	Share parameter in index of money holdings
θ	6.0	Elasticity of demand, intermediate goods
ζ_p	0.65	Fraction of firms not optimizing their price in given period
α	0.3	Share of capital in output, intermediate good
δ_K	0.03	Depreciation rate of capital
Θ_K	10	Adjustment cost parameter, investment
ϕ_1	0.6	Elasticity of repayment probability wrt collateral-loan ratio
ϕ_2	0.22	Elasticity of repayment probability wrt cyclical output
ϕ_3	0.98	Elasticity of repayment probability wrt financial shock
κ	0.3	Effective share of capital pledged as collateral
τ	0.9	Penalty rate scale coefficient
ζ^L	25	Elasticity of substitution, bank loans
ζ^D	22.5	Elasticity of substitution, bank deposits
μ	0.05	Steady-state required reserve ratio
κ_F	0.2	Sterilization factor
f_{ms}	0.8, 0.5	Weight on macro stabilization
λ_y	0.3	Weight on cyclical output stability
ψ	0.2	Share of government spending in output
ρ_ξ	0.8	Degree of persistence, financial shock
ρ_H	0.95	Degree of persistence, productivity shock

Table 2. Value of the policy loss in the three mandates assuming minimum use of the instruments.

Mandates for Monetary Authority and Financial Regulator	Policy Loss Value
1. Goal-integrated: same goals, information set, operating procedure but different instruments.	0.009
2. Goal-distinct: different goals, information set, operating procedure, and instruments.	0.034
3. Common-goal: monetary authority has both goals, financial regulator only financial stability; difference in information set, operating procedure, and instruments.	0.023

Table 3. Total loss ratios under the goal-integrated mandate. Monetary authority and financial regulator optimally target both macro and financial stability.

	Aggressiveness of the optimal rule for the required reserve ratio										
Aggressiveness of the optimal interest rate rule	**0.05**	**0.075**	**0.1**	**0.15**	**0.225**	**0.3**	**0.4**	**0.6**	**0.8**	**1.2**	**1.6**
0.0031	1	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.88	0.87	0.87
0.0063	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.88	0.87	0.87
0.0125	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.88	0.87	0.87
0.0250	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.87	0.87	0.87
0.05	0.98	0.96	0.95	0.93	0.91	0.90	0.89	0.88	0.87	0.87	0.86
0.1	0.97	0.96	0.94	0.92	0.91	0.89	0.88	0.87	0.86	0.86	0.85
0.2	0.95	0.94	0.93	0.91	0.90	0.88	0.87	0.86	0.85	0.85	**0.84**

Table 3A. Financial instability component in total loss ratio under the goal-integrated mandates. Monetary authority and financial regulator optimally target both macro and financial stability.

	Aggressiveness of the optimal rule for the required reserve ratio										
Aggressiveness of the optimal interest rate rule	**0.05**	**0.075**	**0.1**	**0.15**	**0.225**	**0.3**	**0.4**	**0.6**	**0.8**	**1.2**	**1.6**
0.0031	0.62	0.61	0.59	0.57	0.56	0.55	0.54	0.53	0.53	0.52	0.52
0.0063	0.62	0.60	0.59	0.57	0.56	0.55	0.54	0.53	0.53	0.52	0.52
0.0125	0.62	0.60	0.59	0.57	0.56	0.55	0.54	0.53	0.53	0.52	0.52
0.0250	0.62	0.60	0.59	0.57	0.56	0.55	0.54	0.53	0.52	0.52	0.52
0.05	0.61	0.60	0.58	0.57	0.56	0.54	0.54	0.53	0.52	0.52	0.51
0.1	0.60	0.59	0.58	0.56	0.55	0.54	0.53	0.52	0.52	0.51	0.51
0.2	0.59	0.58	0.56	0.55	0.54	0.53	0.52	0.51	0.51	0.50	**0.50**

Table 3B. Macro instability component in total loss ratio under the goal-integrated mandates. Monetary authority and financial regulator optimally target both macro and financial stability.

	Aggressiveness of the optimal rule for the required reserve ratio										
Aggressiveness of the optimal interest rate rule	**0.05**	**0.075**	**0.1**	**0.15**	**0.225**	**0.3**	**0.4**	**0.6**	**0.8**	**1.2**	**1.6**
0.0031	0.37	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34
0.0063	0.37	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34
0.0125	0.37	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34
0.0250	0.37	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34
0.05	0.37	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34
0.1	0.37	0.36	0.36	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34
0.2	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.34	0.34	0.34	**0.34**

Table 4. Total loss ratios under the goal-distinct mandates. Monetary authority optimally targets macro stability while financial authority pursues financial stability via a simple implementable rule.

	Aggressiveness of simple implementable financial stability rule for the required reserve ratio $\chi_2 = 1-\chi_1$								
Aggressiveness of the optimal interest rate rule	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0031	2.81	2.82	2.83	2.83	2.83	2.83	2.83	2.83	2.83
0.0063	2.63	2.63	2.64	2.64	2.63	2.63	2.62	2.62	2.61
0.0125	2.38	2.38	2.38	2.37	2.37	2.36	2.35	2.34	2.33
0.0250	2.14	2.14	2.14	2.14	2.13	2.12	2.10	2.09	2.08
0.05	2.01	2.01	2.01	2.00	2.00	1.99	1.97	1.96	1.95
0.1	1.99	1.99	1.98	1.98	1.97	1.96	1.95	1.94	**1.93**
0.2	2.01	2.01	2.01	2.01	2.00	2.00	1.99	1.98	1.97

Table 4A. Financial instability component in total loss ratios under the goal-distinct mandates. Monetary authority optimally targets macro stability while financial authority pursues financial stability via a simple implementable rule.

	Aggressiveness of simple implementable financial stability rule for the required reserve ratio $\chi_2 = 1-\chi_1$								
Aggressiveness of the optimal interest rate rule	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0031	1.69	1.69	1.68	1.66	1.64	1.62	1.60	1.58	**1.55**
0.0063	1.75	1.75	1.74	1.72	1.71	1.69	1.66	1.64	1.62
0.0125	1.78	1.77	1.77	1.75	1.74	1.72	1.70	1.68	1.66
0.0250	1.80	1.80	1.79	1.78	1.77	1.75	1.74	1.72	1.70
0.05	1.85	1.85	1.84	1.83	1.82	1.81	1.80	1.78	1.77
0.1	1.91	1.91	1.90	1.90	1.89	1.88	1.87	1.86	1.85
0.2	1.97	1.97	1.97	1.96	1.96	1.95	1.94	1.94	1.93

Table 4B. Macro instability component in total loss ratios under the goal-distinct mandates. Monetary authority optimally targets macro stability while financial authority pursues financial stability via a simple implementable rule.

	Aggressiveness of simple implementable financial stability rule for the required reserve ratio $\chi_2 = 1-\chi_1$								
Aggressiveness of the optimal interest rate rule	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0031	1.12	1.13	1.14	1.16	1.18	1.21	1.23	1.25	1.27
0.0063	0.87	0.88	0.89	0.91	0.92	0.94	0.95	0.97	0.99
0.0125	0.59	0.60	0.61	0.61	0.62	0.63	0.64	0.65	0.67
0.0250	0.34	0.34	0.34	0.35	0.35	0.36	0.36	0.37	0.37
0.05	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.18	0.18
0.1	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
0.2	**0.04**	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 5. Total loss ratios under the common-goal mandate. Monetary authority optimally targets both macro and financial stability while financial authority pursues financial stability via a simple implementable rule.

	Aggressiveness of simple implementable financial stability rule for the required reserve ratio $\chi_2 = 1-\chi_1$								
Aggressiveness of the optimal interest rate rule	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0031	2.50	2.51	2.52	2.53	2.54	2.55	2.56	2.56	2.57
0.0063	2.15	2.16	2.17	2.17	2.18	2.18	2.19	2.19	2.20
0.0125	1.78	1.78	1.78	1.79	1.79	1.79	1.80	1.80	1.80
0.0250	1.46	1.46	1.46	1.47	1.47	1.47	1.47	1.47	1.47
0.05	**1.25**	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
0.1	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
0.2	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04

Table 5A. Financial instability component in total loss ratios under the common-goal mandate. Monetary authority optimally targets both macro and financial stability while financial authority pursues financial stability via a simple implementable rule.

	Aggressiveness of simple implementable financial stability rule for the required reserve ratio $\chi_2 = 1-\chi_1$								
Aggressiveness of the optimal interest rate rule	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0031	1.24	1.24	1.23	1.22	1.22	1.20	1.19	1.18	1.17
0.0063	1.13	1.13	1.13	1.12	1.11	1.10	1.09	1.08	1.07
0.0125	1.01	1.01	1.00	1.00	0.99	0.99	0.98	0.97	0.96
0.0250	0.89	0.89	0.89	0.83	0.88	0.88	0.87	0.87	0.86
0.05	0.80	0.80	0.79	0.79	0.79	0.79	0.78	0.78	**0.78**
0.1	0.72	0.72	0.72	0.72	0.72	0.72	0.71	0.71	0.71
0.2	0.66	0.66	0.65	0.65	0.65	0.65	0.65	0.65	0.65

Table 5B. Macro instability component in total loss ratios under the common-goal mandate. Monetary authority optimally targets both macro and financial stability while financial authority pursues financial stability via simple implementable rule.

	Aggressiveness of simple implementable financial stability rule for the required reserve ratio $\chi_2 = 1-\chi_1$								
Aggressiveness of the optimal interest rate rule	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0031	1.26	1.27	1.28	1.30	1.32	1.34	1.36	1.38	1.40
0.0063	1.02	1.02	1.03	1.05	1.06	1.08	1.09	1.10	1.12
0.0125	0.77	0.77	0.78	0.79	0.79	0.80	0.81	0.82	0.83
0.0250	0.56	0.57	0.57	0.58	0.58	0.59	0.59	0.60	0.60
0.05	**0.45**	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.47
0.1	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.41
0.2	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38

Table 6. Relation between policy aggressiveness and macro and financial instability

Mandate	Policy aggressiveness	Policy loss components	
		Macro instability	Financial instability
Goal-integrated	i_R	↓	↓
	μ	↓	↓
Goal-distinct	i_R	↓	↑
	μ	↑	↓
Common-goal	i_R	↓	↓
	μ	↑	↓