When the Central Bank Meets the Financial Authority: Strategic Interactions and Institutional Design*

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Abstract

We investigate the strategic interactions between the central bank and a financial authority in an economy distorted with nominal rigidities and credit frictions, and hit by financial shocks. Using a policy-rule approach, we find that introducing an independent financial instrument increases consumers welfare, versus the alternative of a central bank alone leaning against the financial shocks. Also, we find that when the two policymakers maximize welfare (our ideal case), the Nash equilibrium corresponds to the first best. However, under our implementable case, the policymakers face a conflict in objectives, as the central bank focuses on the stability of prices, while the financial authority on the stability of the credit spread. In such a case, cooperation across institutions is second best, while Nash is third best. However, if the policymakers have the same objectives, cooperation and Nash coincide and are second best.

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1 Introduction

In recent years, there has been a heated debate in academic and policy forums about how to design macroprudential policy, and whether it should be conducted by one or several institutions. For instance, Cúrdia and Woodford (2010), Eichengreen, Prasad and Rajan (2011b), or Smets (2014), among others, have argued that central banks should react to financial stability measures, despite the fact that there might be a separate financial authority. This argument calls to apply the principle of *leaning against the wind*, or a countercyclical monetary policy, to financial headwinds. Against this position, Svensson (2014, 2015) and Yellen (2014) argue in favor of having a different authority addressing financial imbalances, while keeping the central bank focus on price stability. Other authors, such as De Paoli and Paustian (2013), or Angelini, Neri and Panetta (2014) have studied the interaction between monetary and financial authorities, focusing on whether these two authorities should cooperate or not, what goals financial policy should pursue, and what settings are necessary for an optimal-policy arrangement.

In this paper, we add to the discussion by studying how to institutionally design a financial policy, given that there is an incumbent central bank already in office. In particular, we are interested in two issues. First, we ask whether a central bank that leans against financial headwinds by itself is a better choice, in terms of welfare, than introducing a financial authority that has an independent instrument. And second, we analyze the strategic interactions between the central bank and a financial authority, either with an ideal objective or with implementable objectives. Our key contribution is that we characterize the reaction function of each policymaker given the set of all affordable strategies by his counterpart; the latter allows us to picture the trade-offs faced by an authority when the other one chooses a particular shape for its policy rule. Our characterization of the policymakers' best responses is thus very similar to that of Mendoza and Tesar (2005) for tax competition among countries, and it is closely related to Dixit and Lambertini (2003)'s analysis for monetary-fiscal interactions.

We use a New Keynesian general equilibrium model with financial frictions *à la* Bernanke, Gertler and Gilchrist (1999), which is hit by shocks originated in the financial sector. Such shocks perturb the returns of investment projects, and thus increase the riskiness of the economy.[1] We set our policy environment in terms of simple rules.[2] In our baseline scenario, the central bank sets the

[1] Christiano, Motto and Rostagno (2014) argue that these *risk* shocks explain a large proportion of U.S. business cycle fluctuations. Further, in the Appendix we explore other aggregate shocks as well, such as technology or government spending, and show that in those cases there is no role for a countercyclical financial policy.

[2] Given the complexity of the model, we avoid the use of Ramsey-type rules, in order to preserve clarity. See

short-run nominal interest rate in response to inflation deviations; in turn, the financial authority sets a tax/subsidy to the financial intermediary's returns in response to deviations in the credit spread (in the case of *leaning against the wind*, we also allow the central bank to respond to deviations in this variable). As such, the best responses of each policymaker are stated in terms of how aggressive an authority wants its reaction function to be, given the policy rule of the other. We solve the model to a second-order approximation and measure the welfare costs associated to different policy games. First, we explore the policymakers' strategic behavior when welfare is their objective. Then, we move to implementable objectives, such as inflation targeting for the central bank, or a measure of financial stability for the financial authority.

Our results are as follow. First, we show that, when facing financial shocks, consumers are better off when there is an independent financial instrument in addition to the nominal interest rate. In line with previous results (see Cúrdia and Woodford, 2010), we also find that the economy would benefit if the central bank responds to credit-spread deviations when a countercyclical financial policy is absent. However, once we introduce the dynamic financial instrument, the welfare gains are undoubtedly higher. And in fact, the gains of a *leaning against the wind* central bank are negligible when the independent financial authority is active. The reason is that, as the economy faces two sources of inefficient fluctuations, one nominal and one financial, two independent instruments provide more degrees of freedom to face these fluctuations than a single instrument.

Second, for the scenario with implementable targets, we show that when there is a conflict in objectives between the central bank and the financial authority, the Nash equilibrium leads to a third-best solution. In this case, cooperation by the two policymakers yields an equilibrium which is second best with respect to an ideal solution (one in which both policymakers aim to maximize welfare; in such a setting, both the cooperative and the Nash equilibrium coincide with the social planner's solution, i.e. the optimal-simple-rule solution). The conflict in objectives arises because the central bank aims to minimize the variance of inflation, while the financial authority aims to minimize the variance of the credit spread.[3] As the objectives differ, each policymaker tears aggregate demand into different directions, which results in a suboptimal equilibrium. To avoid the exhausting fight involved by conflicting objectives, in a counterfactual exercise we assume both authorities care about the variances of inflation and the credit spread. In such a case, as the objectives are the same, the cooperative and the Nash equilibria coincide, and such a point constitutes a second-best solution with respect to the ideal point.

Section 3 for further details. For a analysis using Ramsey-type rules, see Bodenstein, Guerrieri and LaBriola (2014).

[3]Each authority is also concerned about the variability of its policy instrument.

Our results thus imply that, conditional on our model economy, if monetary and financial policy are conducted by different institutions with different objectives, these institutions should cooperate to achieve a solution as close as possible to the welfare-maximizing solution. However, if objectives are the same, cooperation is not necessary to achieve the second best. Evidently, these results depend on the nature of the implementable objectives pursued. If the policy objectives are close measures of the inefficient distortions in the economy, then cooperation will lead to a socially desired outcome. Otherwise, it will hardly be the case.

Our paper relates with a growing literature that studies monetary and financial policy interactions. Our results thus complement others in the literature. For instance, similar to De Paoli and Paustian (2013), we identify the sources of inefficient allocations in our model economy, and argue that the two policy instruments can be engineered to reduce the welfare costs caused by the inefficient wedges. Also, as De Paoli and Paustian (2013), or Bodenstein *et al.* (2014), we study the strategic behavior of the central bank and financial authority in cooperative and non-cooperative games. However, we focus on solutions under commitment (to a policy rule) and neglect solutions under discretion. Although our analysis is less general than theirs, our approach allows us to study the trade-offs faced by an authority in and outside the equilibrium; in contrast, De Paoli and Paustian and Bodenstein *et al.* show the equilibrium outcomes of their policy games, and not the policy trade-offs that lead to that outcome. Angelini *et al.* (2014) and Quint and Rabanal (2014) also use simple policy rules to study monetary-financial policy interactions. However, the former uses only *ad hoc* loss functions as policy objectives, while the latter uses only welfare. We use both criteria to compare how socially-optimum are popular implementable objectives, such as inflation targeting or credit-spread stability. Finally, our work also relates to a broader literature on policy-makers interactions, such as Dixit and Lambertini (2001), Dixit and Lambertini (2003), Mendoza and Tesar (2005), Blake and Kirsanova (2011), Mendoza, Tesar and Zhang (2014), among many others.

Section 2 introduces the model economy. Section 3 analyzes the case for a central bank that *leans against the wind*. Section 4 explores the strategic behavior of the central bank and the financial authority. The final section concludes.

2 The Model

The model builds on Bernanke *et al.* (1999), BGG hereafter. It consists of six types of agents: a final-good producer, intermediate-good monopolists, a capital producer, a financial intermediary, entrepreneurs, and households. The economy faces two types of inefficient rigidities: one in productions prices, and one in the supply of credit. These two frictions entail inefficiency wedges both at the steady state and at the aggregate dynamics of the economy. To focus attention in the latter, we use appropriate subsidies to remove the steady-state inefficiencies created by monopolistic competition and agency costs in the credit market. In such a context, the central bank and the financial authority use their policies to address the dynamic distortions caused by price dispersion and inefficient fluctuations in the cost of credit. We restrict our attention to simple policy rules, where a policymaker is prone to choose the *aggressivity* of its own rule, taking into account the strategy of the other policymaker. The advantage of this approach is that it allow us to visualize easily the trade-offs between policymakers in a medium-scale model, as the one we display below. It is worth mentioning that our framework, as the great majority of DSGE models with financial frictions, abstracts entirely from systemic risk. As Angelini *et al.* (2014) argue, systemic risk is a quite elusive concept to model in DSGEs. So we limit ourselves to study the aggregate distortions caused by financial frictions, and how a financial policy can be used to decrease such distortions. We thus neglect an analysis of a *macroprudential* policy focused on safeguarding the resilience of the financial sector.

2.1 Households

The economy is inhabited by a continuum of identical households, indexed by $i \in [0, 1]$. A typical household selects a sequence of consumption, $c_{i,t}$, labor supply, $\ell_{i,t}$, and real deposit holdings, $d_{i,t}$, to maximize her discounted lifetime utility. The problem of the representative household is thus

$$\max_{c_{i,t},\ell_{i,t},d_{i,t}} \mathrm{E}_t \left\{ \sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(c_{i,t}, \ell^h_{i,t}\right) \right\}, \text{ with } \mathcal{U}\left(c_{i,t}, \ell^h_{i,t}\right) = \frac{\left[\left(c_{i,t} - hC_{t-1}\right)^{\upsilon} \left(1 - \ell^h_{i,t}\right)^{1-\upsilon}\right]^{1-\sigma} - 1}{1-\sigma} \tag{2.1}$$

subject to the budget constraint

$$c_{i,t} + d_{i,t} \leq w_t \ell^h_{i,t} + \frac{R_{t-1}}{1+\pi_t} d_{i,t-1} - \Upsilon_{i,t} + \mathcal{A}_{i,t} + \mathrm{div}_{i,t} \text{ for all } t, \tag{2.2}$$

where $\beta \in (0, 1)$ is the subjective discount factor; $h \in [0, 1]$ denotes the degree of external habits to aggregate consumption from the previous period, denoted by C_{t-1}; $\sigma > 0$ is the coefficient of relative risk aversion; $\upsilon \in (0, 1)$ is a scale parameter that ensures that labor equals $\frac{1}{3}$ at the non-stochastic steady state; E_t is the expectation operator conditional on the information available in period t; P_t is the price of final goods and $1 + \pi_t = P_t/P_{t-1}$ is the gross inflation rate from period $t-1$ to t; w_t is the real wage rate; R_t is the gross nominal interest rate associated with one-period-maturity nominal deposits, which corresponds to the central bank's policy instrument; finally, $\mathrm{div}_{i,t},\ \Upsilon_{i,t},\ \mathcal{A}_{i,t}$ denote real profits from monopolistic firms, net taxes, and transfers from entrepreneurs, respectively, each stated as a lump sum. The first order conditions of problem (2.1) are standard and we describe them in the Appendix.

2.2 Entrepreneurs

There is a continuum of risk neutral entrepreneurs, indexed by $e \in [0, 1]$. At time t, type-e entrepreneur purchases the stock of capital $k_{e,t}$ at a real price q_t, using her own net worth $n_{e,t}$, and one-period maturity debt $b_{e,t}$, such that in real terms we have $q_t k_{e,t} = b_{e,t} + n_{e,t}$. In time $t + 1$, entrepreneurs rent out capital services to intermediate firms at a real rental rate z_{t+1} and sell the remaining capital stock after production to a capital producer. The gross real rate of return of capital is thus given by

$$r^k_{t+1} \equiv \frac{z_{t+1} + (1-\delta)q_{t+1}}{q_t},$$

where δ is the rate of capital depreciation. As BGG, we assume that an entrepreneur's returns are affected by an idiosyncratic disturbance, denoted by ω_{t+1}, so the real returns of entrepreneur e in time $t + 1$ are $\omega_{e,t+1} r^k_{t+1} k_{e,t}$. Heterogeneity among entrepreneurs emerges since $\omega_{e,t+1}$ is an i.i.d. random variable across time and types, with a continuous and once-differentiable c.d.f., $F(\omega)$, over a non-negative support, with $\mathrm{E}(\omega) = 1$ and $\mathrm{Var}(\omega) = \sigma_{\omega,t}$. A positive innovation of $\sigma_{\omega,t}$ implies that the distribution of ω widens, so a larger proportion of entrepreneurs may default. Christiano *et al.* (2014) argue that this *risk* shock may explain a large proportion of U.S. business cycle fluctuations. We thus consider this disturbance, which affects directly the credit market, as a shock for concern for both the central bank and the financial authority. Such a shock may indeed trigger interesting interactions between the two policymakers.[4]

Entrepreneurs participate in the labor market by offering one unit of labor at each and every period at the real wage rate w^e_t.[5] Also, entrepreneurs live for finite horizons, as each entrepreneur may exit the economy in each period with probability $1 - \gamma$. This assumption restricts entrepreneurs to accumulate enough wealth to be fully self-financed. Aggregate net worth in period t is thus given

[4] We have actually checked that other shocks, such as a technology shock or a government spending shock, do not imply rich interactions between the central bank and the financial authority. We show in the Appendix that it is optimal for the financial authority to set $a_{rr} = 0$ when facing either of those shocks.

[5] As noticed by BGG, it is necessary to start entrepreneurs off with some net worth in order to allow them to begin operations.

by

$$n_t = \gamma v_t + w_t^e \tag{2.3}$$

where v_t is aggregate equity from capital holdings in period t, which we define in the next subsection.

The first term in the RHS of (2.3) is the equity held by entrepreneurs who survive in t. Those who exit in t transfer their wage to new entrepreneurs entering the economy, consume part of their equity, such that $c_t^e = (1-\gamma)\varrho v_t$ for $\varrho \in [0,1]$, while the rest $\mathcal{A}_t = (1-\gamma)(1-\varrho)v_t$ is transferred to households as a lump sum.

2.3 The lender and the financial contract

In time t, a representative financial intermediary obtains funds from households and faces two options to invest their deposits: lend to entrepreneurs, which is subject to a financial friction, or buy risk-free government bonds. The financial friction emerges since the lender cannot observe the realized returns of an entrepreneur. As BGG, we use the *costly state verification* model of Townsend (1979) to characterize the optimal lending contract between the intermediary and an entrepreneur. However, we deviate from the standard specification as we assume that the lender is subject to a financial tax or subsidy on the return on his portfolio.

Accordingly, in time t, when the financial contract is signed, the idiosyncratic shock $\omega_{e,t+1}$ is unknown to both the entrepreneur and the lender. In period $t+1$, if $\omega_{e,t+1}$ is higher than a threshold value $\bar{\omega}_{e,t+1}$, the entrepreneur repays her debt plus interests, or $r_{e,t+1}^L b_{e,t}$, where r_t^L is the gross real non-default rate. In contrast, if $\omega_{e,t+1}$ is lower than $\bar{\omega}_{e,t+1}$, the entrepreneur declares bankruptcy and gets nothing, while the lender audits the entrepreneur, pays the monitoring cost, and gets to keep any positive income of the entrepreneur. These contract conditions discourage the entrepreneur to fake a bankruptcy. For convenience, BGG assume that the monitoring cost is a proportion $\mu \in [0,1]$ of the entrepreneur's returns, i.e., $\mu\omega_{e,t+1}r_{t+1}^k q_t k_{e,t}$. In turn, the threshold value $\bar{\omega}_{e,t+1}$ is defined as

$$\mathrm{E}_t\left\{\bar{\omega}_{e,t+1}r_{t+1}^k q_t k_{e,t}\right\} = \mathrm{E}_t\left\{r_{e,t+1}^L b_{e,t}\right\}. \tag{2.4}$$

Without loss of generality, we drop the type sub-index to characterize the financial contract. Thus, for a given value of r^k, the expected returns of an entrepreneur are given by

$$\mathrm{E}_t\left\{\left[1-\Gamma(\bar{\omega}_{t+1})\right] r_{t+1}^k q_t k_t\right\}, \tag{2.5}$$

where $\Gamma(\bar{\omega}) = \bar{\omega}\int_{\bar{\omega}}^{\infty} f(\omega)d\omega + \int_0^{\bar{\omega}} \omega f(\omega)d\omega$.[6] As the lender perfectly diversifies the idiosyncratic

[6]For a given r^k, notice that if $\omega \geq \bar{\omega}$ the returns of the entrepreneur are given by $\omega r^k qk - r^L b$. Using equation (2.4), we can rewrite the last expression as $(\omega - \bar{\omega})\, r^k qk$. Taking expectations with respect to ω yields $\int_{\bar{\omega}}^{\infty}(\omega-\bar{\omega})\, r^k qk \mathrm{d}\omega$, which after some algebraic manipulations leads to (2.5).

risk involved in lending, he will lend to entrepreneurs if the expected returns of doing so are greater or equal than buying government bonds. Thus, for a given r^k, the participation constraint of the lender is given by

$$\mathrm{E}_t \left\{ (1+\tau_{f,t}) \left[\Gamma\left(\bar{\omega}_{t+1}\right) - \mu G\left(\bar{\omega}_{t+1}\right) \right] r^k_{t+1} q_t k_t \right\} \geq r_t b_t, \tag{2.6}$$

where $r_t = \frac{R_t}{\mathrm{E}_t\{1+\pi_{t+1}\}}$ is the real interest rate, $\mu G(\bar{\omega}) = \mu \int_0^{\bar{\omega}} \omega f(\omega) d\omega$ represents the expected monitoring costs per unit of aggregate capital returns to be paid by the lender, while $\tau_{f,t}$ is a financial tax/subsidy imposed by the financial authority. The LHS of equation (2.6) are the lender's expected returns from lending to entrepreneurs, while the RHS are the returns he would obtain if he buys government bonds. This participation constraint will hold with equality in equilibrium, because of decreasing returns to scale in capital.

Assume for a moment that the financial instrument τ_f equals 0, which is the original BGG's setup. In such a context, information asymmetries in the financial contract effectively create an efficiency wedge in the allocation of capital. This is the case because the risk of moral hazard induces the lender to offer too little credit in order to avoid large monitoring costs. As a result, credit and capital would be too small in comparison to the efficient allocation (i.e., one with no information asymmetries, or $\mu = 0$). A policy intervention could reduce the financial wedge by eliminating the distortions created by information asymmetries, and it does require that $\tau_f > 0$. Such a policy reduces the lender's opportunity cost of funds and increases the capital stock. In the right amount, it may lead to the steady-state efficient allocation.[7]

The optimal financial contract consists in choosing real capital purchases qk and a financial threshold $\bar{\omega}$ in order to maximize an entrepreneur's expected returns, given by equation (2.5), subject to the participation constraint of the lender, given by equation (2.6). The first order conditions of this problem are shown in the Appendix. Likewise BGG, aggregating across entrepreneurs allows us to express the equilibrium in the credit market as

$$\mathrm{E}_t \left\{ \frac{r^k_{t+1}}{r_t} \right\} = s\left(x_t, \tau_{f,t}\right),$$

where $x_t \equiv q_t k_t / n_t$ is aggregate leverage; k_t and n_t, are aggregate measures of the capital stock and entrepreneurs net worth; and $s(\cdot)$ is a function with $\partial s(\cdot)/\partial x_t > 0$ for $n_t < q_t k_t$, and $\partial s(\cdot)/\partial \tau_{f,t} < 0$. This function represents the key component of the BGG financial accelerator mechanism. If entrepreneurs' net worth is low relative to their assets, they are more likely to

[7] It is worth noticing that models with costly state verification yield too little credit, instead of too much credit in the long run. In this context, financial policymakers could restore efficiency by reducing the financial wedge with appropriate policies.

default on average; consequently, the financial intermediary would be willing to cut private lending, which increases the returns on capital r^k. The ratio $\mathrm{E}_t\left\{r_{t+1}^k/r_t\right\}$ denotes the external finance premium and measures the importance of the financial wedge; the larger the ratio, the bigger the wedge. Without a financial policy, the external finance premium will be greater than one, as in BGG. The financial policy we consider has a dynamic component and a static one. We will set the static component of $\tau_{f,t}$ such that $r^k/r = 1$ at the steady state.

Finally, the optimal financial contract implies that the aggregate capital gains of entrepreneurs are given by:

$$\begin{aligned} v_t &= \left[1-\Gamma(\bar{\omega}_t)\right] r_t^k q_{t-1}k_{t-1}, \qquad \text{or} \\ &= r_t^k q_{t-1}k_{t-1}\left[1-\mu G(\bar{\omega}_t)\right] - \frac{1}{1+\tau_{f,t}} r_{t-1}b_{t-1}. \end{aligned} \tag{2.7}$$

2.4 Capital Producer

Capital producers operate in a perfectly competitive market. At the end of period $t-1$, entrepreneurs buy the capital stock to be used in period t, i.e. k_{t-1}, from the capital producers. Once intermediate goods have been sold and capital services have been paid, entrepreneurs sell back to the capital producer the remaining, un-depreciated stock of capital. The representative capital producer then builds new capital stock, k_t, by combining investment goods, i_t, and un-depreciated capital, $(1-\delta)\,k_{t-1}$. The capital producer problem is thus

$$\max_{i_t} \mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \frac{\lambda_{t+1}}{\lambda_t}\left\{q_t\left[k_t-(1-\delta)k_{t-1}\right]-i_t\right\}, \quad \text{subject to}$$

$$k_t = (1-\delta)\,k_{t-1} + \left[1-\Phi\left(\frac{i_t}{i_{t-1}}\right)\right] i_t,$$

where $\beta^t \frac{\lambda_{t+1}}{\lambda_t}$ defines the appropriate discount factor for this problem and λ_t is the Lagrange multiplier of the budget constraint in the households' problem. The function $\Phi\left(\frac{i_t}{i_{t-1}}\right)$ denotes adjustment costs in capital formation. We consider an *investment* adjustment cost, where the capital producer uses a combination of old investment goods with new investment goods to produce new capital units (see Christiano, Eichenbaum and Evans, 2005), where $\Phi\left(\frac{i_t}{i_{t-1}}\right) = (\eta/2)\left[i_t/i_{t-1}-1\right]^2$. In equilibrium, the relative price of capital q_t is given by

$$q_t = 1+\Phi\left(\frac{i_t}{i_{t-1}}\right)+\frac{i_t}{i_{t-1}}\Phi\prime\left(\frac{i_t}{i_{t-1}}\right)-\beta E_t\left\{\frac{\lambda_{t+1}q_{t+1}}{\lambda_t q_t}\left[\frac{i_{t+1}}{i_t}\right]^2\Phi\prime\left(\frac{i_{t+1}}{i_t}\right)\right\} \tag{2.8}$$

2.5 Final Good

The final good y_t, used for consumption and investment, is produced in a competitive market by combining a continuum of intermediate goods indexed by $j \in [0,1]$, via the CES production function $y_t = \left(\int_0^1 y_{j,t}^{\frac{\theta-1}{\theta}} \mathrm{d}j\right)^{\frac{\theta}{\theta-1}}$, where $y_{j,t}$ denotes the overall demand addressed to the producer of intermediate good j and θ is the elasticity of substitution among intermediate goods. Profits maximization yields typical demand functions $y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\theta} y_t$. The general price index is given by

$$P_t = \left(\int_0^1 P_{j,t}^{1-\theta} \mathrm{d}j\right)^{\frac{1}{1-\theta}}, \tag{2.9}$$

where $P_{j,t}$ denotes the price of intermediate good produced by firm j.

2.6 Intermediate Goods

Intermediate firms produce differentiated goods by assembling labor and capital services, namely $\ell_{j,t}$ and $k_{j,t-1}$, respectively. Type-j firm's total labor input, $\ell_{j,t}$ is composed by household labor, $\ell_{j,t}^h$, and entrepreneurial labor, $\ell_{j,t}^e \equiv 1$, according to $\ell_{j,t} = [\ell_{j,t}^h]^\Omega [\ell_{j,t}^e]^{1-\Omega}$. Type-$j$ intermediate good is produced with the following constant-returns-to-scale technology

$$y_{j,t} = \ell_{j,t}^{1-\alpha} k_{j,t-1}^{\alpha}. \tag{2.10}$$

Let $\mathbb{S}(y_{j,t})$ denote the total real cost of producing $y_{j,t}$, which can be computed as

$$\mathbb{S}(y_{j,t}) = \max_{\ell_{j,t}^h,\ z_t} \left\{ w_t \ell_{j,t}^h + z_t k_{j,t-1} + w_t^e, \text{ subject to } (2.10) \right\}, \tag{2.11}$$

The real marginal cost is simply defined as $s_t \equiv \partial \mathbb{S}(\cdot) / \partial y_{j,t}$.

Price Setting. Intermediate-good firms face a nominal rigidity in his pricing decision, which we model through the Calvo (1983)'s staggering mechanism. Each period, type-j monopolist re-optimizes its price with a constant probability $1-\vartheta$, while with probability ϑ the price of the previous period is updated according to the rule $P_{j,T} = \iota_{t,T} P_{j,t}$, where $t < T$ is the period of last re-optimization and $\iota_{t,T}$ is a price-indexing rule, defined as $\iota_{t,T} = (1+\pi_{t-1})^{\vartheta_p} (1+\pi)^{1-\vartheta_p} \iota_{t,T-1}$ for $T > t$ and $\iota_{t,t} = 1$. The coefficient $\vartheta_p \in [0,1]$ measures the degree of past-inflation indexation of intermediate prices and π is the inflation rate at the steady state. In order to remove the steady-state distortion caused by intermediate-good producers' monopolistic power, we assume the government provides a subsidy τ_p to those firms, so that aggregate output reaches the level of the flexible-price economy at the steady state.

Let $P_{j,t}^{\star}$ denote the nominal price chosen in time t and $y_{j,t,T}$ represent the demand for good j in period $T \geq t$, if the firm last re-optimized its price in period t. Therefore, monopolist j selects $P_{j,t}^{\star}$ to maximize the present discounted sum of expected profits, taking as given the demand curve, i.e.,

$$P_{j,t}^{\star} = \max_{P_{j,t}} \left\{ \begin{array}{c} \mathrm{E}_t \left\{ \sum\limits_{T=t}^{\infty} (\beta\vartheta)^{T-t} \frac{\lambda_T}{\lambda_t} \left[\frac{\iota_{t,T} P_{j,t}}{P_T} y_{j,t,T} - (1+\tau_p)\, s_T y_{j,t,T} \right] \right\} \\ \text{subject to } y_{j,t,T} = \left(\frac{\iota_{t,T} P_{j,t}}{P_T} \right)^{-\theta} y_T \end{array} \right\}.$$

To reach the efficient allocation at the steady state, the production subsidy must equalize the inverse of the price markup, so $1 + \tau_p \equiv (\theta - 1)/\theta$. However, as it is well known, the presence of nominal rigidities creates an additional dynamic distortion in the form of price dispersion. Following Yun (1996), in the appendix we show that aggregate production is given by

$$y_t = \frac{1}{\Delta_t} (k_{t-1})^{\alpha} (\ell_t)^{1-\alpha},$$

2.7 Policymakers

We assume the central bank and the financial authority follow simple rules to set their instruments. For our baseline analysis, we assume that the nominal interest rate is chosen according to

$$R_t = R \times \left(\frac{1+\pi_t}{1+\pi} \right)^{a_\pi}, \tag{2.12}$$

where a_π is the elasticity of R_t with respect to inflation deviations, R is the steady-state gross nominal interest rate, and π is the central bank's inflation target. In Section 3, we explore the possibility that the central bank reacts as well to credit spread deviations in order to analyze the gains, in terms of welfare, of *leaning against the wind* when facing financial imbalances.[8] However, when we analyze the strategic interactions between our policymakers, we restrict attention to rule (2.12). The latter helps us to characterize in a simple way the best responses of each policymaker. The financial authority sets its instrument according to:

$$1 + \tau_{f,t} = (1+\tau_f) \times \left(\frac{\mathrm{E}_t \left\{ r_{t+1}^k / r_t \right\}}{r^k / r} \right)^{a_{rr}}, \tag{2.13}$$

where $r^k/r = 1$ is the value of the external finance premium (credit spread) at the steady state and τ_f is the steady-state value of the macroprudential subsidy that ensures that $r^k = r$.

We assume that each policymaker has an objective function given by L_m for $m \in \{CB, F\}$, i.e., for the central bank and the financial authority. The objective function characterizes the preference

[8] To complete the picture, we also check in Section 3 if our results change if we allow the central to react as well to output deviations.

relationship of each authority. In Section 4 we consider two types of objectives: an *ideal* one and an *implementable* one. Under the ideal case, both policymakers aim at maximizing social welfare. A drawback of this case is that, in practice, households' welfare is hard to quantify. A turnaround to this problem is to consider quantitative targets, such as inflation targeting for the central bank. As such, under our implementable case, we assume that the policymakers aim at minimizing the variance of certain variables of their interest. We provide further details in Section 4.2.

We consider two types of policy games, a non-cooperative and a cooperative. In a non-cooperative game, the policymakers display a strategic behavior characterized by a set of best responses to all the possible strategies by the opponent and the structure of the economy. As we restrict our attention to simple policy rules, we are implicitly assuming commitment to such rules, so we neglect policy-game equilibria under discretion.[9]

Let CB^* and F^* denote the sets of best responses, in terms of coefficients a_π and a_{rr}, of the central bank and the financial authority, respectively. Also, for $n \in \{\pi, rr\}$, A_n denotes the universe of all possible values that coefficient a_n can take. Finally, let vector $\boldsymbol{\varrho}$ describe all the first order conditions of private agents and equilibrium conditions of the economy. Accordingly, the policymakers' best responses can be stated as

$$
\begin{aligned}
CB^* &= \left\{ \left(a_\pi^{s,*}, a_{rr}^{s}\right) : a_\pi^{s,*} \in \underset{a_\pi^s \in A_\pi}{\arg\max} \ \mathrm{E}\left\{L_{CB}\right\}, \text{ s.t. } \boldsymbol{\varrho} \text{ and } a_{rr} = a_{rr}^{s} \right\}_{a_{rr}^s \in A_{rr}}, \\
F^* &= \left\{ \left(a_\pi^{s}, a_{rr}^{s,*}\right) : a_{rr}^{s,*} \in \underset{a_{rr}^s \in A_{rr}}{\arg\max} \ \mathrm{E}\left\{L_{F}\right\}, \text{ s.t. } \boldsymbol{\varrho} \text{ and } a_{\pi} = a_{\pi}^{s} \right\}_{a_{\pi}^s \in A_{\pi}}.
\end{aligned}
$$

Notice that the policymakers maximize the *unconditional* expectation of their objective function, which corresponds to the ergodic mean of this function at the stochastic steady state of the economy. Given CB^* and F^*, the Nash equilibrium of the non-cooperative game is given by the interception between sets CB^* and F^*, i.e. $N = \left\{ \left(a_\pi^N, a_{rr}^N\right) \in CB^* \cap F^* \right\}$.

For the cooperative game, we assume there exists a united policymaker whose objective is a linear combination of L_{CB} and L_F. The cooperative equilibrium is simply defined as

$$
C = \left\{ \left(a_\pi^C, a_{rr}^C\right) \ \in \underset{a_\pi^s, a^{s\prime}rr \ \in A_\pi \times A_{rr}}{\arg\max} \ \mathrm{E}\left\{\varphi L_{CB} + (1-\varphi) L_F\right\}, \text{ s.t. } \boldsymbol{\varrho} \right\}.
$$

[9]See De Paoli and Paustian (2013) and Bodenstein *et al.* (2014).

2.8 Equilibrium

Total production is allocated to consumption, investment, monitoring costs, and government expenditures, denoted by g, which we assume constant. The resource constraint is thus

$$y_t = c_t + i_t + c_t^e + g + \mu G(\bar{\omega}_{e,t}) R_t^k q_{t-1} k_{t-1}. \tag{2.14}$$

The government raises lump-sum taxes to finance its own expenditures and subsidies monopolists and the lender, and we assume it keeps a balanced budget. At equilibrium, all markets clear, and a sequence of prices and allocations satisfies the equilibrium conditions of each sector.

2.9 Welfare and consumption equivalent measures

In order to measure the welfare costs associated with the policy game equilibria analyzed below, we introduce consumption equivalent measures as in Schmitt-Grohé and Uribe (2007). Let $\mathbb{W}(a_\pi, a_{rr}; \boldsymbol{\varrho})$ define the unconditional expected welfare given the policy parameters a_π and a_{rr}, and the structure of the economy, given by vector $\boldsymbol{\varrho}$, i.e.

$$\mathbb{W}(a_\pi, a_{rr}; \boldsymbol{\varrho}) \equiv \mathrm{E}\left\{ \sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(c_t(a_\pi, a_{rr}; \boldsymbol{\varrho}), \ell_t^h(a_\pi, a_{rr}; \boldsymbol{\varrho}) \right) \right\}, \tag{2.15}$$

where $c_t(a_\pi, a_{rr}; \boldsymbol{\varrho})$ and $\ell_t^h(a_\pi, a_{rr}; \boldsymbol{\varrho})$ are the decision rules for consumption and labor for households, which depend as well on the policy parameters (we have taken away the type sub-index i because households are homogeneous). Notice, however, that in the absence of stochastic shocks, welfare does not depend on a_π or a_{rr}. We call $\mathbb{W}_d$, c_d, and ℓ_d^h the levels of welfare, consumption, and labor, respectively, that prevail in a deterministic or non-stochastic economy, such that

$$\mathbb{W}_d = \frac{1}{1-\beta} \mathcal{U}\left(c_d, \ell_d^h \right).$$

We measure the welfare costs associated with a policy regime as a percentage ce of a reference level of consumption, the non-stochastic one. In particular, ce represents a consumption cost that makes the consumer indifferent between the reference level and the one induced by policy, i.e.,

$$\mathbb{W}(a_\pi, a_{rr}; \boldsymbol{\varrho}) = \frac{1}{1-\beta} \mathcal{U}\left((1+ce)\, c_d, \ell_d^h \right).$$

Solving for ce, and imposing our calibrated value for σ, yields

$$ce = 1 - \exp\left\{ (1-\beta) \left[\mathbb{W}(a_\pi, a_{rr}; \boldsymbol{\varrho}) - \mathbb{W}_d \right] \right\}. \tag{2.16}$$

Parameter		Value
Preferences and technology		
β	Subjective discount factor	0.99
σ	Coefficient of relative risk aversion	1.00
υ	Disutility weight on labor	0.06
h	Habit parameter	0.85
α	Capital share in production function	0.40
δ	Depreciation rate of capital	0.02
η	Investment adjustment cost	10.78
$\bar{g}$	Steady state government spending-GDP ratio	0.20
ϑ_p	Price indexing weight	0.10
ϑ	Calvo price stickiness	0.74
θ	Elasticity of demand for intermediate goods	11.00
Financial accelerator		
$1-\varphi$	Transfers from failed entrepreneurs to households	0.99
γ	Survival rate of entrepreneurs	0.98
Ω	Fraction of households' labor on production	0.98
$\bar{\sigma}_\omega$	Standard error of idiosyncratic shock	0.27
Shock		
ρ_{σ_ω}	Persistence of risk shock	0.89

Table 1: Calibration

2.10 Calibration and solution strategy

In Table 1 we present the parameters of the model that are calibrated at a quarterly frequency. We follow closely Christiano *et al.* (2014) for the parameters related to preferences and technology; except for: the subjective discount factor, β, that we calibrate to 0.99, implying an annual real interest rate of 4 percent, the habit parameter, h, that we choose 0.85, and the steady-state inflation, $(1+\pi)$, that equals 1. The coefficient of relative risk aversion, σ, is set to 1, while υ, the disutility of labor, is set such that the household's labor in the steady state, ℓ^h, equals 1/3. The capital share in the intermediate sector, α, is 0.4; the depreciation rate, δ, equals 0.025, and the investment adjustment cost, η, is 10.78.

Regarding the parameters of the financial accelerator mechanism, we take the calibration of BGG. We set the transfer from entrepreneur to households, φ, as 0.01 percent. The entrepreneurial income share is set to 0.01, this implies that the fraction of households' labor on production, Ω, equals 0.9846. We target a 3 percent default rate and a capital-to-net-worth ratio of 2 at the deterministic steady state. Moreover, the idiosyncratic productivity shock obeys a log-normal distribution with an unconditional expectation of 1 and a standard deviation $\bar{\sigma}_\omega$ = 0.2713. We match these moments with a survival rate of entrepreneurs, γ= 0.9792 and the monitoring cost, μ= 0.1175.

	BGG	No Finan Fric	BGG + τ_f
External Finance Premium $\check{r}$, annual rate	2%	0%	0%
Monitoring Cost μ	12%	0%	12%
Financial Policy τ_f	-	-	1%
Consumption over output $\frac{c}{y}$	0.55	0.52	0.50
Investment over output $\frac{i}{y}$	0.25	0.28	0.28
Capital over output $\frac{k}{y}$	9.97	11.40	11.40
Output over efficient output $\frac{y}{y_{nf}}$	0.91	1.00	1.00

Note: The first column corresponds to the BGG model, the second column is the model without financial frictions, where $\check{r} = 0$ and $\mu = 0$, while the third column is the BGG model with financial policy. The efficient output, y_{nf}, is the one without financial frictions.

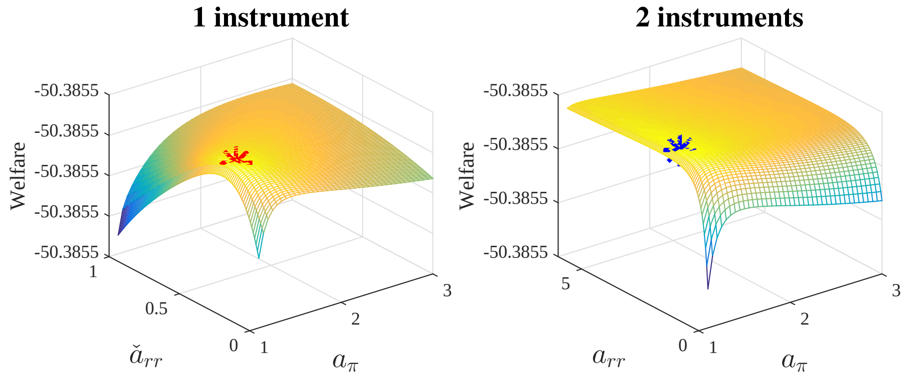
Table 2: Steady State Results

The steady state main ratios that are a result of the benchmark calibration are described in Table 2. The first column corresponds to the standard BGG model. The second column is a model without financial frictions; as we noted above, financial frictions create a lower level of investment with respect to the no financial friction case, the investment-to-output ratio is lower in the BGG case than in the no financial frictions. Also note that there is no external finance premium in this specification. We use the model without financial frictions as the efficient allocation to calibrate the level of the financial tax at the steady state. We show this specification of the model in the third column. With τ_f different from zero at the financial rule, equation (2.13), we manage to decrease the external finance premium to the best-case scenario. In terms of the macro ratios of the model, consumption over output is lower than the efficient allocation because there are monitoring costs. Nevertheless, because of no external finance premium, the investment-to-output ratio and the level of the output are equal to the efficient allocation.

3 Leaning against the wind

Does a monetary-policy rate that leans against the wind a better job, in terms of welfare, than two policy instruments when a financial shock surges? Eichengreen, El-Erian, Fraga, Ito, Pisani-Ferry, Prasad, Rajan, Ramos, Reinhart, Rey *et al.* (2011a); Eichengreen *et al.* (2011b); Smets (2014), and Woodford (2012), among others, claim that monetary policy should respond not only to deviations of inflation from its target but also to financial stability measures. Against this position, Svensson (2012, 2014, 2015) and Yellen (2014) suggest that there should be two different instruments. We contribute to this discussion by analyzing the welfare costs of having one or two instruments in

Figure 1: 1 vs. 2 Instruments, Asymptotic Ergodic Mean



Note: The stars in the figures show the maximum level of welfare for each case.

the context of our model. For the *leaning-against-the-wind* case, we assume that the central bank responds as well to deviations in the credit spread, such that

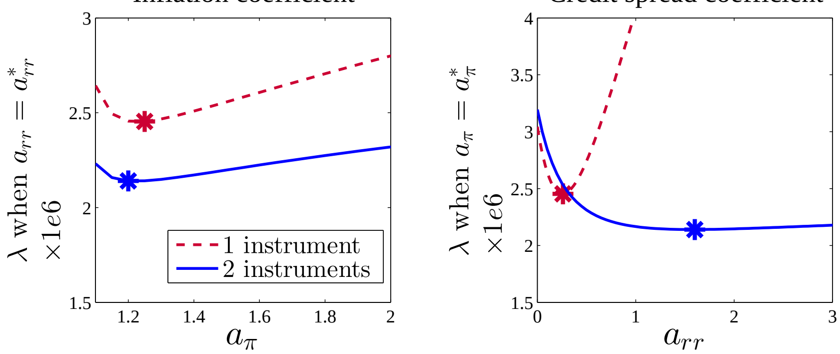
$$R_t = R\left(\frac{1+\pi_t}{1+\pi}\right)^{a_\pi}\left(\frac{\mathrm{E}_t\left\{r^k_{t+1}/r_t\right\}}{r^k/r}\right)^{-\breve{a}_{rr}}, \tag{3.1}$$

for $\breve{a}_{rr} \geq 0$. The minus sign before the credit-spread coefficient indicates that the central bank aims to mitigate the fluctuations created by a counter-cyclical credit spread, e.g., when default and the spread increase, the policy rate falls to counteract a sharp drop in investment. For the *two-instruments* case, we assume the authorities follow the rules given by equations (2.12) and (2.13).

Figure 1 shows the welfare attained by either leaning against the wind (left panel), or two instruments (right panel). For the first case, the ergodic mean of welfare is evaluated for different combinations of a_π and $\breve{a}_{rr}$ while $a_{rr} = 0$; for the second case, the parameters considered are a_π and a_{rr}, while $\breve{a}_{rr} = 0$. The maximum levels of welfare, or bliss points, are given by the asterisks on the surface of each graph. As such, under leaning against the wind, welfare is maximized when $(a_\pi, \breve{a}_{rr}) = (1.25, 0.26)$, while under two instruments, maximum welfare is attained at $(a_\pi, a_{rr}) = (1.20, 1.60)$. These results mean that, under the two scenarios, welfare is improved when the authorities dynamically respond to the financial shock.

In order to measure which regime provides lower welfare losses, we display the consumption equivalent costs in Figure 2. The dashed-red line corresponds to the leaning-against-the-wind case, while the solid-blue line is the two-instruments case. The left panel plots how the consumption equivalent cost varies with the inflation coefficient when the credit-spread parameter is set to its optimal value in each setup. For all the values of a_π, the welfare losses under two instruments are lower than those under one instrument. The right panel shows the consumption equivalent costs

Figure 2: 1 vs. 2 Instruments, Consumption Equivalent Looses for the Optimal Responses



Note: The stars in the figures show the maximum level of welfare for each case.

when the credit-spread coefficient varies while the inflation parameter is set to its optimal level in each setup. For the majority of values of a_{rr}, the two-instruments case has lower losses than the other case. Overall, we find that, at the two welfare bliss points in each regime, the consumption equivalent of leaning against the wind is almost 15 percent higher than that of the two-instruments case.[10] These results suggest that there exist clear benefits for using two instruments rather then one when facing a financial shock.[11]

Finally, we present in Figure 3 the impulse responses to a risk shock, for three different policy settings. The solid-blue line corresponds to an scenario in which the central bank responds only to inflation deviations with a standard coefficient value of $(a_\pi = 1.5)$, and the financial authority remains passive, i.e. $(a_{rr} = 0)$. The two-instruments case is the dashed-red line with the welfare-maximizing parameters, and the leaning-against-the-wind case is the dashed-dotted-black line, which is drawn too for its welfare-maximizing parameters.

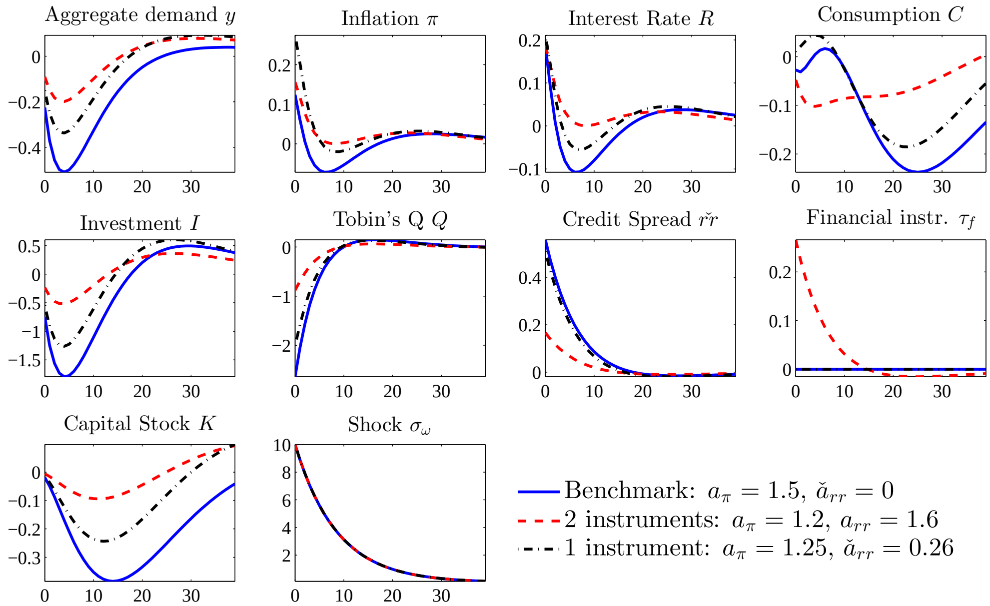
A higher risk shock prompts default to increase, which moves the credit spread up. As borrowing is more expensive for entrepreneurs, they decrease investment, which brings output and inflation down. When the interest rate policy reacts only to inflation, there is a large fall of the policy rate, which slightly moves consumption on impact, but generates a large drop after few periods.

When there is a leaning-against-the-wind policy, the interest rate reacts less to inflation, in comparison to the solid-blue line, but it also moves with the credit spread. This prompts a less volatile

[10] The ratio between $ce_{leaning}/ce_{two-instr.}$ is 1.1466

[11] For robustness, we have consider an alternative monetary-policy rule in the two-instruments case, such that the central bank responds to deviations in inflation, the credit spread, and the output gap, i.e. $R_t/R = (\pi_t - \pi)^{a_\pi} \left(\mathrm{E}_t \left\{r_{t+1}^k / r_t\right\}\right)^{-\breve{a}_{rr}} (y_t/y)^{a_y}$. In this case, we find a quadruplet of optimal values given by $(a_\pi, \breve{a}_{rr}, a_y, a_{rr}) = (1.2, 0.1, 0, 1.3)$. The latter means that, even in the two-instruments case, there is room for a small leaning-against-the-wind role by the central bank. However, the welfare gains associated with this extended monetary rule are quite modest, as the ratio between the consumption equivalent costs is very close to 1, i.e. $ce_{two-instr.}/ce_{extend.} = 1.007$.

Figure 3: 1 vs. 2 Instruments, Impulse Response Functions



Note: The y axis represents deviation from the deterministic steady state, the x axis are quarters.

policy rate: a lower decrease of the rate makes consumption even to increase after the shock. Moreover, the credit spread is slightly smoother than with the standard Taylor rule, causing capital, investment, and output to fall less.

Lastly, when there are two different instruments, the financial tax smooths the credit spread on impact. Capital, investment, and output drop by less. Inflation moves less and so does to policy rate. Consumption is smoother after the shock. We can see that the 2 instruments setup prompts the lower volatility in the variables, suggesting the result obtained above: consumers are better-off with two rather than with one instrument.

4 Strategic Interactions

In this section, we analyse the strategic behavior of the two policymakers when facing a financial shock, such as $\sigma_{\omega,t}$. The fully optimal response involves a Ramsey rules for the policy instruments and implemented by a benevolent social planner, who maximizes social welfare. However, there are two drawbacks with this solution. First, the Ramsey rules are not likely to be implemented given their complexity, so we prefer to have as benchmark a maximum welfare level that may be achieved with implementable simple rules, even if this solution is suboptimal (see Taylor and Williams, 2010, for further details). Second, since we are solving a second-order approximation of the model, we ignore how the stochastic terms associated with this solution may affect the Ramsey policies.

Our approach based on simple rules allow us to characterize how a policymaker may want to change his reaction function in response to that of this counterpart. In an ideal setting, we assume that both policymakers aim to maximize welfare, and study the strategic interactions therein. Because welfare is not an implementable objective for policymakers in practice, we then introduce loss functions for the two authorities and study their strategic behavior when their objectives differ. As an alternative, we also consider a case in which the implementable objectives are the same. We analyze the *ideal* case in Section 4.1 and the *implementable* case in Section 4.2.

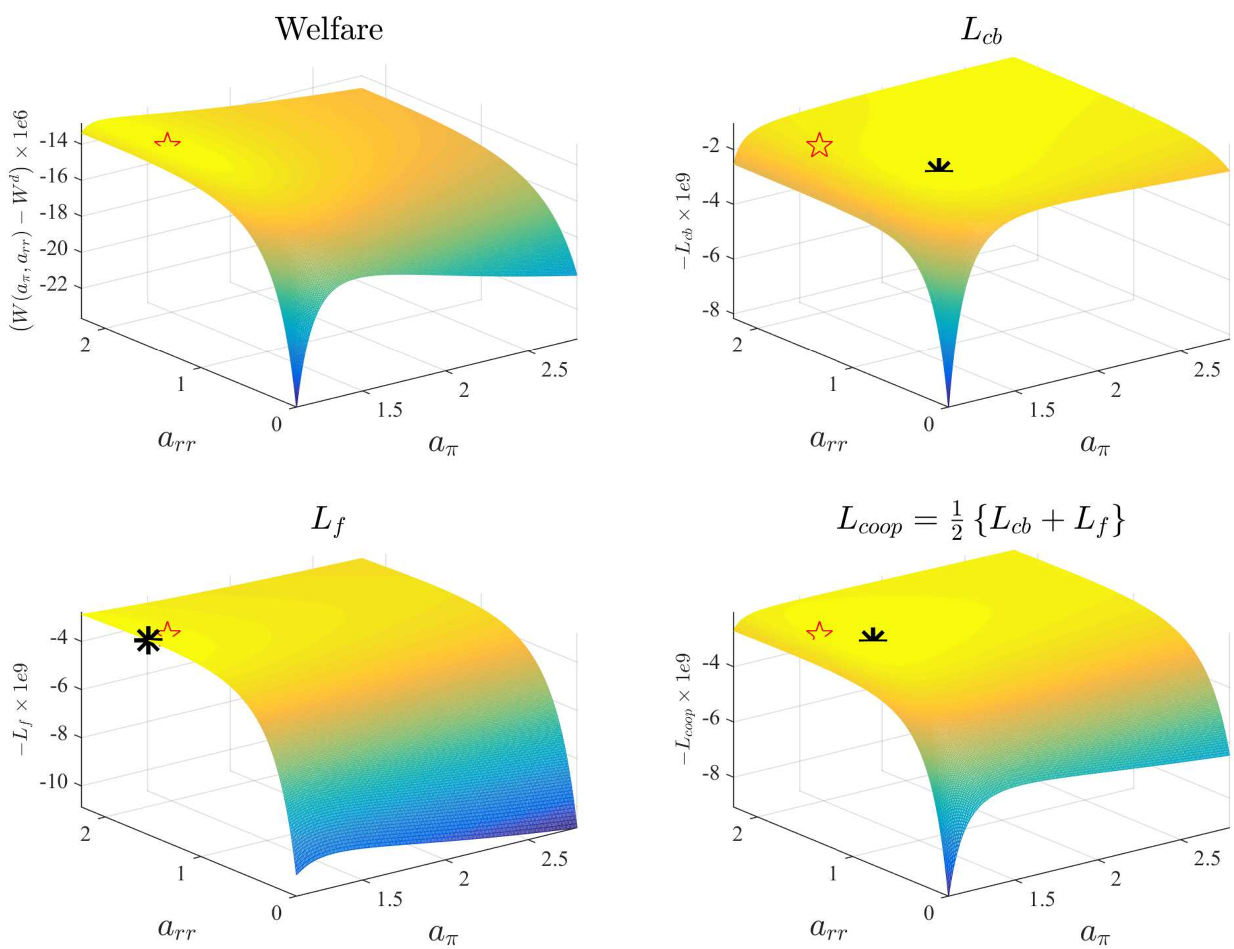
4.1 Welfare as objective

Assume that both the monetary and the financial authority search to maximize social welfare, given by equation (2.15), when deciding on the coefficients of their rules, so $L_m = \mathbb{W}\left(a_\pi, a_{rr}; \boldsymbol{\varrho}\right)$ for $m \in \{CB, F\}$. The upper-left panel of Figure 4 shows the social welfare function with a finer grid, and marks with a star the maximum or bliss point of that function. Accordingly, when using simple rules, the social welfare function is at its highest when $\left(a_\pi^\star, a_{rr}^\star\right) = (1.22, 1.56)$. Given the structure of the model economy, the welfare function is single peaked, so any combination of coefficients different than $\left(a_\pi^\star, a_{rr}^\star\right)$ within our simple-rules approach implies welfare losses.

The strategic interactions of the policymakers in the ideal case, where the both authorities have the same objective and the latter is welfare, is depicted in the upper-right panel of Figure 5. The solid-blue line describes the set of best responses of the financial authority, given by set F^* whereas the best responses of the central bank are given by the dashed-red line, which portrays set CB^*. The strong non-linearity of the best responses highlights the importance of strategic interactions between agents. For instance, notice that the financial authority wants a more aggressive rule either when a_π is too low or when it is higher than a certain threshold. In turn, the central bank wants a more aggressive rule when the financial authority is relatively passive; conforming the latter becomes more active, the central bank moderates its reaction function. The Nash equilibrium occurs at the intersection of sets F^* and CB^*.

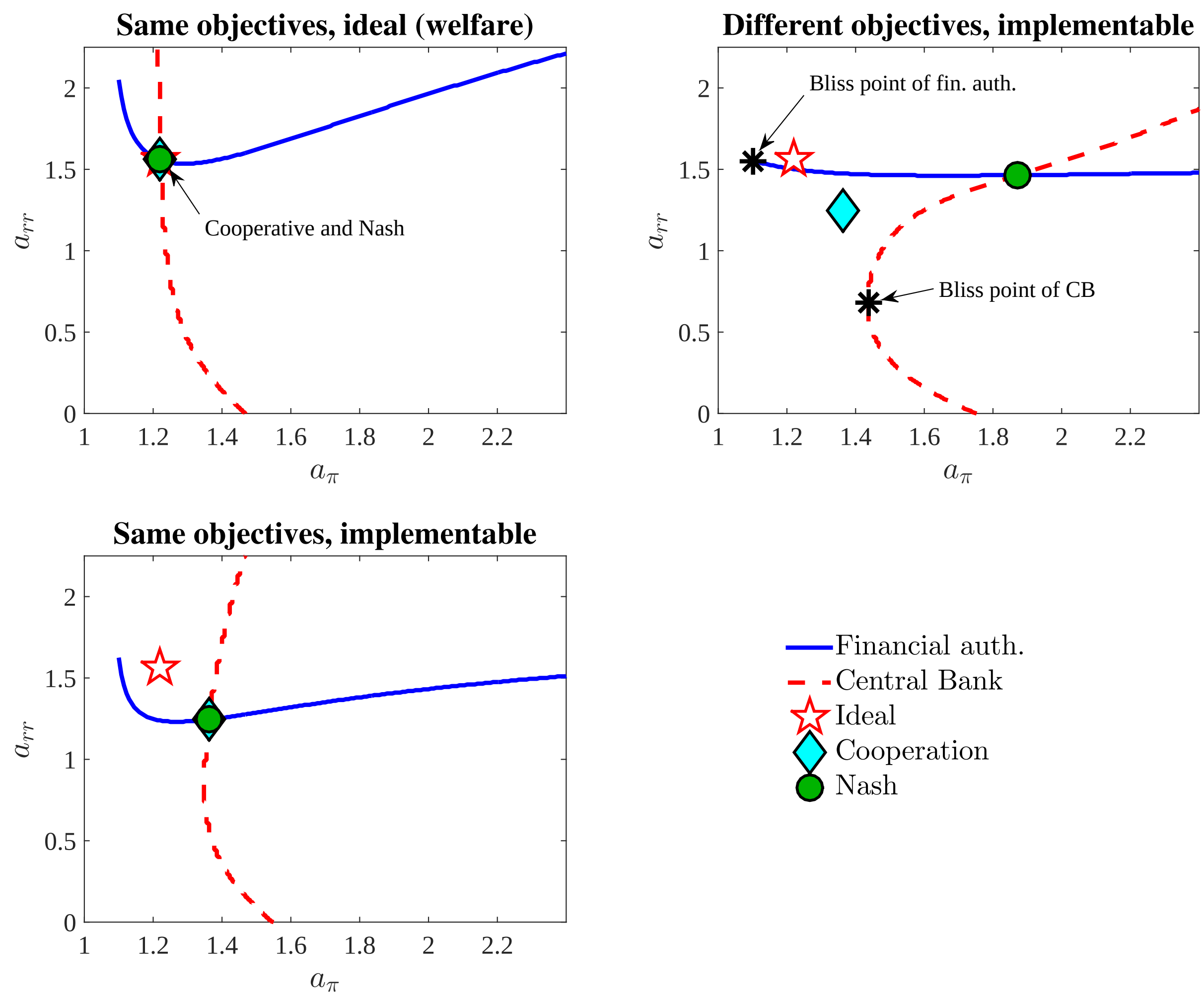
In the ideal case, since both authorities have the same objectives, the cooperative game yields exactly the same outcome than the non-cooperative game. To see why, notice that the policymakers' objectives under the two games have exactly the same bliss point, which implies that the most-preferred point for one policymaker is also the most-preferred point for the other. This result is not new in the literature. For example, Dixit and Lambertini (2001) show in a monetary-union model that, when all countries and the central bank have the same objective, the ideal outcomes can be achieved in cooperative and non-cooperative games; Blake and Kirsanova (2011) show in a model with a monetary-fiscal interaction that strategic behavior can only be of importance if the policymakers have distinct objectives; and Bodenstein *et al.* (2014) show a similar result in a model with monetary-macroprudential interactions with open-loop Nash strategies. Technically speaking, Blake and Kirsanova argue that a Nash equilibrium with identical objectives coincide with a cooperative equilibrium because the first-order conditions of either problem are identical. Intuitively speaking, we could argue that when the objectives are the same, the policymakers use their instruments to stir the economy towards the same direction. This setting implies that under the non-cooperative game, there will be a tacit cooperation if both policymakers pursue the same goals. In the Appendix, we show a simple example that illustrates this point.

Figure 4: Different objectives for policymakers



Note: The stars in the figures show the maximum level of welfare for each case.

Figure 5: Strategic Interaction between the Monetary and the Financial Authorities



Note: The stars in the figures show the maximum level of welfare for each case.

4.2 Implementable objectives

Assume the policymakers cannot observe welfare and adopt objectives with measurable variables. To simplify terms, let the central bank minimize the volatility of inflation and the nominal interest rate, so $L_{CB} = -\text{Var}(\pi_t) - \text{Var}(R_t)$, and the financial authority minimize the volatility of the credit spread and the financial instrument, so $L_F = -\text{Var}\left(r_t^k/r_t\right) - \text{Var}(\tau_{f,t})$, where $\text{Var}(x)$ denotes the unconditional variance of variable x_t. As such, the objective of the united policymaker, that we use in the cooperative game, is simply defined as $\frac{1}{2}\{L_{CB} + L_F\}$, where we have set $\varphi = 1/2$.[12]

For the central bank, the motivation for adopting inflation as objective comes from modern monetary policymaking, in which inflation targeting has become the standard. Also, given the structure of the model, focusing in inflation is justified because of the welfare losses that price dispersion bring about (see Woodford, 2003). For the financial authority, institutions such as the BIS and the IMF have emphasized that a desirable macroprudential or financial policy should be one that counters financial instability (see IMF, 2013; Galati and Moessner, 2013). In such a respect, authors such as Angelini *et al.* (2014), Bodenstein *et al.* (2014), De Paoli and Paustian (2013), among others, have put forward financial objectives in DSGE models that include a targeted credit-to-output ratio, a targeted level for credit growth, or the volatility of the credit spread. We adopt a similar approach here. Similarly, given the model's structure, excessive fluctuations in the credit spread caused by agency costs create inefficient fluctuations in investment and output. Therefore, minimizing the variance of the credit spread seems as a natural target for the financial authority.[13]

Finally, a rationale for adopting gradual changes in the policy instruments can be found in the seminal contribution of Brainard (1967), who shows that such strategy is optimal when policymakers face uncertainty.[14] The upper-right and bottom-left panel of Figure 4 show the shape of the policymakers' objective functions, while the bottom-right panel depicts the united objective function. All of these functions are single peaked,but more importantly, the bliss points of these functions are different.[15] Such a conflict in objectives will bring about non-trivial strategic behaviors, in which the Nash equilibrium will not typically coincide with the cooperative equilibrium, as we show next.

[12] We recognize that the best approach to motivate loss functions would be through a linear-quadratic approximation of the utility function à la Woodford (2003). However, we are constraint by the size and complexity of the model.

[13] Also, De Paoli and Paustian (2013) show, in a model with credit constraints, that the credit spread appears in their linear-quadratic approximation of the utility function, and it is thus a source of welfare costs.

[14] In terms of welfare, it can also be argued that large changes in asset prices cause welfare costs. See Taylor and Williams (2010).

[15] Actually, we can show that the $\text{Var}(\pi)$ and $\text{Var}\left(r^k/r\right)$ decreases monotonically with a_π and a_{rr}, respectively. In contrast, $\text{Var}(R)$ and $\text{Var}(\tau_f)$ increase monotonically with large values of a_π and a_{rr}, respectively. The combination between the efficient objective and gradualism leads to the single-peaked objective functions.

The upper-right panel of Figure 5 displays the best responses of the central bank and the financial authority when their objectives are given by L_{CB} and L_F. In the graph, the star shows the equilibrium corresponding to the ideal case, when welfare was the objective. The asterisks on the best-responses curves mark the most-preferred points for each policymaker. As these points are different, the cooperative game yields an equilibrium in between these points (which is not exactly a linear combination of the two bliss points because of the curvature of the objective function under cooperation). In turn, the non-cooperative equilibrium lies far away from the bliss point of any authority and the ideal equilibrium. Although this result is particular to the objective functions we have assumed, it is generally the case that the cooperative and non-cooperative cases do not coincide when the policymakers' objectives are different. In terms of welfare losses associated with these policy games, the Nash equilibrium is a third-best solution, while the cooperative equilibrium is a second-best solution.[16] In such a setting, one would like the two authorities to cooperate. Furthermore, if one would like to choose an optimal weight φ^* in the cooperative objective function such that the solution under cooperation resembles as much as possible the ideal equilibrium, we find that such value is $\varphi^* = 0.13$, i.e., most of the weight would go to the financial authority.

An alternative scenario is to give both policymakers the same implementable objectives, such as $\tilde{L}_{CB} = \tilde{L}_F = -\text{Var}(\pi_t) - \text{Var}(R_t) - \text{Var}\left(r_t^k/r_t\right) - \text{Var}(\tau_{f,t})$, i.e. both authorities worry about the volatility of inflation, the credit spread, and their policy instruments. In such a case, the objective under cooperation is trivially determined, and equals the one prevailing when the objectives are different. The bottom-left panel of Figure 5 displays this alternative scenario. Since the objectives are the same, we find again that the cooperative and non-cooperative equilibrium coincide. Further, this solution is second best. The advantage to give both authorities the same objectives is that it eliminates the tough fight that happens when there is a conflict in objectives and the policymakers act non-cooperatively.

5 Conclusion

This paper studies the strategic interaction between the monetary and the financial authority in a BGG setup under financial shocks. The interaction between the two authorities is of particular interest because there is no consensus across policymakers or academicians on how to design the financial authority and its interaction with the central bank.

[16]To verify the ordering of the solutions, we have computed their consumption-equivalent welfare costs. The consumption equivalent of the Nash equilibrium is 7 percent higher than the ideal point, whereas that of the cooperative equilibrium is just 1 percent higher.

Our analysis provides useful insights. One conclusion that emerges from our work is that two different instruments, one that targets the nominal wedge and another one that targets the financial wedge, are welfare enhancing in comparison with a *leaning against the wind* monetary policy that responds to financial imbalances by itself. This result leads us to investigate the strategic interaction between the two authorities.

Then, when both policymakers have welfare as their objective, the cooperative equilibrium coincides with Nash and corresponds to the first best. We show that the reaction functions of the authorities affect each other, and thus cause a strategic change in behavior until an equilibrium is reached. Because welfare is not observable by the policymakers, we analyze implementable objectives. The objective of the monetary policy is to minimize the variance of inflation and the interest rate, while the objective of the financial authority is to minimize the variance of the credit-spread and the financial instrument. When each authority has a different mandate, the cooperative equilibrium results in a second-best solution and the Nash equilibrium in a third-best solution. However, if we give the same implementable objectives to both authorities (i.e., the sum of the variances of inflation, the credit spread, and the instruments), the cooperative and the Nash equilibrium coincide and the welfare losses are small with respect to the first best. Then, when both authorities have the same objective, the conflict between authorities vanishes.

One of the limitations of our analysis is that we are only investigating the results for risk shocks; this corresponds to the case in which the financial accelerator mechanism generates more amplification and then the financial authority has room for improvement. Moreover, we are not looking at the systemic risks of the economy, and therefore we cannot talk about macro prudential policy as it is broadly defined.

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