Tight Money-Tight Credit: Tinbergen's Rule and Strategic Interaction in the Conduct of Monetary and Financial Policies*

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Abstract

We study the quantitative implications of strategic interaction and Tinbergen's Rule for the analysis of monetary and financial policies in a New Keynesian model with financial frictions and "risk shocks." Tinbergen's Rule is relevant: Separate monetary and financial policies, with the latter taxing the opportunity cost of lenders more to encourage lending when credit markets tighten, produce higher social welfare than a one-policy setup adding spreads to the monetary policy rule. In fact, the latter yields a regime in which policy rule elasticities imply tighter policies (i.e. a tight money-tight credit regime). In the strategy space, reaction curves are nonlinear, reflecting shifts from strategic substitutes to complements in the best responses of policy-rule elasticities. Coordination is unnecessary when the two policies are set separately but each aiming to maximize welfare: The Nash equilibrium matches the first-best outcome of setting policies jointly with the same goal. If the goals differ, with each policy minimizing the variance of its targets and instruments, Cooperation dominates Nash. Both are inferior to the first best and again produce tight money-tight credit regimes. These findings favor separate but well-coordinated monetary and financial policies.

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1 Introduction

A broad consensus formed after the 2008 Global Financial Crisis around the ideas of implementing macroprudential financial regulation and incorporating financial stability considerations into monetary policy analysis. Despite this consensus, however, putting these two ideas into practice has proven difficult largely because of heated debates surrounding two key questions: First, should monetary policy rules be expanded to introduce financial stability considerations? Second, is there a need to coordinate the actions of financial and monetary authorities? 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 conditions, even if there is a separate financial authority. For example, countercyclical monetary policy could *lean against the wind* in the case of financial headwinds. Opposing this view, Svensson (2014, 2015) and Yellen (2014) argue in favor of having a different authority addressing financial imbalances, while keeping the central bank focused on price stability. Other authors, such as De Paoli and Paustian (2013) or Angelini, Neri and Panetta (2014), are concerned with whether monetary and financial authorities should cooperate or not, what goals financial policy should pursue, and what settings are better for an optimal-policy arrangement.

This paper provides quantitative answers for the above two questions using a New Keynesian model with financial frictions and "risk shocks." The model features inefficiencies that justify the use of monetary and financial policies along the lines of the model proposed by Bernanke, Gertler and Gilchrist (1999). Monetary policy addresses the inefficiencies due to Calvo-style staggered pricing by monopolistic producers of differentiated intermediate goods. Financial policy addresses the inefficiencies that result from the well-known Bernanke-Gertler costly state verification friction affecting financial intermediaries. Monetary policy is modeled in terms of an interest rule, while financial policy is formulated as a rule setting a tax on the expected returns of lenders. The effectiveness of alternative policy regimes can then be assessed in terms of what they imply for social welfare, macroeconomic dynamics, policy targets, and the elasticities of policy instruments to their determinants. Because of the convexity of the Bernanke-Gertler external financing premium, we use a second-order approximation solution method to improve the accuracy of the model's dynamics, welfare assessments, and strategic interaction outcomes.

We emphasize the role of "risk shocks" because of their implications for the financial system in our setup. Christiano, Motto and Rostagno (2014) defined risk shocks as shocks to the variance of the returns to entrepreneurs' investment projects, which increase the riskiness of the economy.[1] Because of the agency costs in the credit market, which result from a real rigidity (i.e. costly state verification), these risk shocks are akin to financial shocks that create inefficient fluctuations in output. These fluctuations are caused by the effect of risk shocks on the interest rate charged by lenders to entrepreneurs which in turn affects macroeconomic aggregates.

The question of whether the monetary policy rule should be expanded to introduce financial stability considerations, or there should be instead a separate financial policy rule, is equivalent to asking whether Tinbergen's Rule applies in this context. That is, do we need two policy instruments for two policy targets (price and financial stability)? Hence, to answer this question, we compare quantitatively a two-rules regime in which a monetary policy rule sets the interest rate as a function of the deviation of inflation from its long-run value and a financial policy rule sets the lender's tax as a function of the expected credit spreads (i.e. a financial rule), with a one-rule regime with a monetary policy rule that depends on both inflation and expected spreads. Tinbergen's Rule predicts that the two-rule regime has to be at least as good as the one-rule regime. Hence, our contribution is in determining whether this is a quantitatively significant issue, and if so in deriving its policy implications.

The question of whether coordination of financial and monetary authorities is needed is relevant in general for the various institutional arrangements that are in place today. In some countries, like the United Kingdom, the two are within the domain of the central bank, but their policies are designed by separate committees or departments, while in other countries the two policies are set by separate government agencies altogether. To answer this question, we examine whether there is scope for strategic interaction between the two authorities in the absence of coordination and quantify its implications. We start with a "first-best" scenario in which one planner sets the elasticities of monetary and financial policy rules to maximize social welfare. Then we consider two separate policy authorities but each setting the elasticity of its individual rule still to maximize social welfare, and find that the resulting Nash equilibrium produces the same first-best outcome, so coordination is irrelevant. On the contrary, if the payoffs of the two authorities differ, so do the Nash equilibrium and the first-best outcome, and since their instruments affect the targets and payoffs of both, the potential for strategic interaction emerges. Analytically, the argument is similar to those

[1] Christiano *et al.* (2014) argue that these shocks explain a large fraction of U.S. business cycles. In the Appendix, we examine the effects of introducing other shocks into the model, such as those hitting technology or government spending. Financial policy tends to be less relevant because of the standard result that in New Keynesian models the inefficiencies created by the Bernanke-Gertler accelerator in response to typical shocks are small.

exposed in other contexts, such as in the large literature dealing with international coordination of tax, monetary or exchange-rate policies, so again our contribution is in determining whether strategic interaction is quantitatively relevant and in fleshing out its policy implications.

We focus on monetary and financial policy rules defined as linear functions with parametric elasticities linking policy instruments to their determinants. For monetary policy, it is well-known that rules of this type (such as the Taylor rule) can be derived as optimal policies from linear-quadratic problems in which policmaker's payoffs are quadratic in target variables (or linear in their variances), but it has also been established that these rules do not always match the solution of Ramsey (i.e. utility maximizing) optimal policy problems under commitment.[2] We follow this "rules approach" because it is the dominant approach to evaluate monetary policy scenarios in policy institutions, and because Ramsey optimal financial policies require global, non-linear solution methods and have been solved for only in stylized models (see **?**). Still, monetary and financial authorities act optimally, in that they set the elasticities of their rules so as to maximize their particular payoff functions, considering payoffs that minimize the sum of the variances of their instruments and targets (as in Taylor and Williams, 2010; Williams, 2010) and scenarios in which the payoff is social welfare for both authorities. We also compute reaction functions that show the best response of each authority's elasticity to a given choice of the other authority's elasticity, and use them to solve for Nash and Cooperative equilibria of one-shot games between the two authorities. This methodology is analogous to that used by Mendoza and Tesar (2005) to study international tax competition, and is also closely related to Dixit and Lambertini (2003)'s analysis of monetary-fiscal interactions.

The quantitative analysis yields three key results. First, the Tinbergen Rule is relevant. Welfare is higher with separate monetary and financial policy rules than with a monetary policy rule expanded to include the credit spreads. The latter is welfare-improving relative to not responding to financial conditions, since welfare increases if the central bank responds to credit-spread deviations with the financial authority assumed to keep its instrument constant (in line with previous findings, see Cúrdia and Woodford, 2010). But the regime with separate financial and monetary rules yields welfare gains that are 15 percent higher than the one-rule case. In addition, the regime with one rule yields an elasticity in the response to inflation (credit spreads) that is higher (smaller) than the regime with two rules. We refer to this situation as a "tight money-tight credit" regime. The

[2]**?** review of optimal monetary policy in New Keyenesian models provides a detailed analysis of the conditions under which the two match. Bodenstein, Guerrieri and LaBriola (2014) analyze strategic interaction in monetary policy between countries and in monetary v. financial policy in a Ramsey setup.

rationale behind these results reflects the general principle of the Tinbergen Rule, requiring two instruments for two targets. There are two inefficiencies in the model, price stickiness in input markets and costly state verification in the credit markets, and the single monetary policy instrument (i.e. the short-run nominal interest rate) with a rule augmented to respond to credit spreads cannot do as well at tackling both inefficiencies using separate monetary and financial policy rules with separate instruments (the interest rate and the credit tax).[3] The stronger response to inflation than to credit spreads with one rule is natural, because monetary policy is more effective than financial policy at addressing nominal rigidities, and since we compute rule elasticities that maximize welfare, the elasticities under the one-rule regime reflect this relative advantage.

Second, the reaction curves of monetary and financial authorities are non-linear, and optimal elasticity responses can change from strategic substitutes to complements depending on payoff functions and parameters. Under our baseline calibration to U.S. data and using welfare as the payoff of both authorities, the reaction function of the financial authority shows that the best elasticity response of the financial rule is a strategic substitute if the elasticity of the monetary rule is sufficiently low, and otherwise is a strategic complement (i.e. the financial authority's reaction function shifts from downward to upward sloping as the monetary rule elasticity rises). The reaction function of the monetary authority is convex but always consistent with strategic substitutes. When the payoffs are loss functions of the volatility of targets and instruments, similar results are obtained, except that now, the reaction function of the monetary rule is the one that changes from strategic substitutes to strategic complements as the elasticity of the financial rule raises, and the reaction function of the financial authority is convex but always consistent with strategic substitutes.

Third, whether strategic interaction is important (and hence whether policy coordination is desirable) also depends on the payoff structure. When both authorities have a common payoff and the payoff is social welfare, the "first best" combination of policy rule elasticities chosen by a single planner to maximize welfare is the same as the one obtained in the Nash equilibrium. Hence, in this case strategic interaction is irrelevant and coordination unnecessary. In contrast, when the two authorities have different payoff functions given by the sum of the variances of their individual instrument and target, strategic interaction is quantitatively significant. The Nash equilibrium results in a welfare loss of 6 percent relative to the Cooperative equilibrium, with both inferior to the first-best outcome. The Nash and Cooperative outcomes are again tight money-tight credit regimes

[3]For example, with the one-rule regime, a countercyclical reaction of the monetary policy rate could reduce the undesired impact on credit and investment caused by a sudden change in the credit spread. However, the same change also affects savings and consumption decisions, and can add volatility to aggregate demand and inflation.

relative to the first-best regime, with a much larger inflation bias in the Nash equilibrium than in both the Cooperative and first-best outcomes.

The inferior Nash equilibrium when the payoff functions differ arises because of strategic incentives when each authority is free to act unilaterally, taking the other authority's choice as given. These incentives are neutralized when the payoff is social welfare for both, but not when the central bank minimizes the volatility of inflation and the interest rate, and the financial authority minimizes the volatility of the credit spread and the credit tax. In such a case, each authority implicitly focus on only one of the two sources of inefficiency in the model (inflation proxies for the inefficiencies due to the nominal rigidities and credit spreads for those due to the financial friction). In the neighborhood of the Nash equilibrium, the financial authority's best response is nearly independent of the elasticity choice of the monetary authority (albeit at a higher level than in the Cooperative outcome), but the best response of the monetary authority is a strong strategic complement of the financial authority's elasticity. This indicates that there are quantitatively significant: adverse spillover effects of credit tax hikes on the volatility of inflation and/or interest rates through the model's general equilibrium dynamics. A small increase in the financial rule elasticity increases volatility of inflation and the nominal interest rate sufficiently to justify sizable increases in the elasticity of the monetary rule as the best response.

Cooperation tackles the adverse spillovers by lowering both the inflation and spreads elasticities relative to the Nash equilibrium. Without coordination, this is not sustainable because both authorities have incentives to deviate (i.e. the cooperative equilibrium is not a point in either authority's reaction function). The financial authority would increase the elasticity of its rule slightly and keep it nearly constant regardless of what the monetary authority does, while the monetary authority increases significantly its elasticity until it attains the best response for that elasticity of the financial rule.

This paper is related to the growing literature on monetary and financial policy interactions. Some of our results complement existing findings. For instance, similar to De Paoli and Paustian (2013), we identify the sources of inefficient allocations in the model, and argue that the monetary and financial policy instruments can be designed to reduce the welfare costs of inefficiencies. Also, as De Paoli and Paustian (2013) and Bodenstein *et al.* (2014), we study the strategic interaction between a central bank and a financial authority in cooperative and non-cooperative games.[4] However, while

[4]Nevertheless, we focus on solutions under commitment (to a policy rule) and neglect solutions under discretion.

these authors focus on the aggregate dynamics resulting from the equilibrium outcomes of their policy games, we emphasize the trade-offs faced by each authority in and outside the policy-game equilibria. As such, we can characterize regions of the policy-reaction space in which the policy instruments are substitutes or complements, so the strategic interaction between the two authorities can lead to regimes with tighter-money and tighter-credit than the first-best 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 Aoki, Benigno and Kiyotaki (2015), who analyze the interaction between monetary and macroprudential policy, such as bank capital requirements and a tax on currency borrowing; however, they develop a small open economy framework and study external shocks, while we focus on a closed economy.

The rest of the paper is organized as follows: Section 2 introduces the model economy and the baseline calibration. Section 3 examines the quantitative relevance of Tinbergen's rule in the assessment of monetary and financial policies. Section 4 analyzes the quantitative implications of strategic behavior in the interaction of the central bank and the financial authority. The final section presents conclusions.

2 New Keynesian Model with Financial Accelerator

The model is an extension of Bernanke *et al.* (1999), BGG hereafter, enriched to introduce risk shocks and financial policy. It consists of six types of agents: a final-goods producer, a set of intermediate-goods producer, a physical capital producer, a financial intermediary, entrepreneurs, and households. As mentioned earlier, there are two sources of inefficiency in the model: Calvo staggered price-setting by producers of intermediate goods, and costly state verification in financial intermediation. In general, these two frictions affect both the steady state and cyclical dynamics. In our analysis, however, the emphasis is in the use of monetary and financial policies to tackle the latter, while the distortions vanish from the stationary equilibrium. In order to ensure that this is the case, we construct policy rules with long-run properties such that the steady-state inefficiencies due to sticky prices and costly monitoring are fully neutralized. We focus on log-linear policy rules (i.e. rules with paramteric elasticities linking policy instruments to policy targets or determinants). Several of the model elements are fairly standard and similar to elements in BGG, so the presentation is kept short except for the elements that are either non-standard or key for the questions this paper addresses. Full details are provided in the Appendix.

2.1 Households

The economy is inhabited by a representative agent. The agent chooses sequences of consumption, $c_{i,t}$, labor supply, $\ell_{i,t}$, and real deposit holdings, $d_{i,t}$, to maximize her discounted lifetime utility. The optimiazation problem of this agent is:

$$\max_{c_t,\ell_t,d_t} \mathrm{E}_t \left\{ \sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(c_t, \ell_t^h\right) \right\}, \text{ with } \mathcal{U}\left(c_t, \ell_t^h\right) = \frac{\left[(c_t - hC_{t-1})^{\upsilon} \left(1 - \ell_t^h\right)^{1-\upsilon} \right]^{1-\sigma} - 1}{1-\sigma} \tag{2.1}$$

subject to the budget constraint

$$c_t + d_t \leq w_t \ell_t^h + \frac{R_{t-1}}{1+\pi_t} d_{t-1} - \Upsilon_t + \mathcal{A}_t + \mathrm{div}_t \text{ for all } t, \tag{2.2}$$

where $\beta \in (0,1)$ is the subjective discount factor, $h \in [0,1]$ denotes the degree of external habits driven by 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 the labor share parameter 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 nominal deposits, which is also the central bank's policy instrument, and finally, div_t, Υ_t, $\mathcal{A}_t$ denote real profits from monopolistic firms, lump-sum taxes, and transfers from entrepreneurs, respectively. The first-order conditions of this problem 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. As BGG, we assume that an entrepreneur's returns are affected by an idiosyncratic disturbance, denoted by ω_{t+1} with $\mathrm{E}(\omega_{t+1}) = 1$ and $\mathrm{Var}(\omega_{t+1}) = \sigma_{\omega,t+1}$, so the real returns of entrepreneur e in time $t+1$ are $\omega_{e,t+1} r_{t+1}^k k_{e,t}$. The term r_{t+1}^k represents the aggregate gross real rate of returns per unit of capital, and is given by

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

where δ is the rate of capital depreciation. 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., $F(\omega_{t+1})$, over a non-negative support. Notice that the variance of this distribution varies with time. A positive innovation of $\sigma_{\omega,t}$ implies that $F(\omega_{t+1})$ widens, so a larger proportion of entrepreneurs may default. As a consequence, a rise of $\sigma_{\omega,t+1}$ yield a deterioration in financial conditions that affect negatively economic activity through a drop in investment demand. Interestingly, Christiano *et al.* (2014) argue that this *risk* shock may explain more than 60% of fluctuations in the U.S. output growth rate since 1985. In this paper we assume that such a shock concerns both the central bank and the financial authority, and that it can indeed trigger strategic interactions between the two policymakers.[5]

Entrepreneurs participate in the labor market by offering one unit of labor at each and every period at the real wage rate w_t^e.[6] Also, entrepreneurs live for finite horizons, as each entrepreneur may exit the economy in each period with probability $1-\gamma$. This assumption prevents entrepreneurs to accumulate enough wealth to be fully self-financed. Aggregate net worth in period t is thus given 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 on 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

[5] 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 do not react dynamically when facing either of those shocks.

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

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 of 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 $r^L_{e,t+1}b_{e,t}$, where r^L_t 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., $\mu\omega_{e,t+1}r^k_{t+1}q_tk_{e,t}$. In turn, the threshold value $\bar{\omega}_{e,t+1}$ is defined as

$$\mathrm{E}_t\left\{\bar{\omega}_{e,t+1}r^k_{t+1}q_tk_{e,t}\right\} = \mathrm{E}_t\left\{r^L_{e,t+1}b_{e,t}\right\}. \tag{2.4}$$

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

$$\mathrm{E}_t\left\{\left[1-\Gamma(\bar{\omega}_{t+1})\right]r^k_{t+1}q_tk_t\right\}, \tag{2.5}$$

where $\Gamma(\bar{\omega}) = \bar{\omega}\int_{\bar{\omega}}^{\infty} f(\omega)d\omega + \int_0^{\bar{\omega}} \omega f(\omega)d\omega$.[7] As the lender perfectly diversifies the idiosyncratic 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

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

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 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. 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

[7] 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 $(\omega-\bar{\omega})\,r^kqk$. Taking expectations with respect to ω yields $\int_{\bar{\omega}}^{\infty}(\omega-\bar{\omega})\,r^kqk\mathrm{d}\omega$, which after some algebraic manipulations leads to (2.5).

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 $\partial s(\cdot)/\partial \tau_{f,t} < 0$.[8] The ratio $\mathrm{E}_t \left\{ r^k_{t+1}/r_t \right\}$ denotes the external finance premium and measures the importance of the financial wedge; the larger the ratio, the bigger the wedge.

Assume for a moment that the financial policy instrument $\tau_{f,t} = 0$, 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. To see why, focus on the lender's participation constraint as given by equation (2.6). 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.[9] In principle, the lender's opportunity cost of funds can be modified through two channels: the interest-rate channel, and a financial tax/subsidy channel. With respect to the first one, the central bank could reduce the risk-free interest rate R_t in order to make government-bond holdings less attractive, and thus increase private credit and investment. On the other hand, the financial authority could also set $\tau_{f,t} > 0$ to increase the expected returns of private lending, which also would increase credit and investment. In this sense, monetary policy and the financial policy have similar direct effects on the financial contract, and share a certain degree of isomorfism.

However, the general-equilibrium effects of the two instruments are very different. While the first-order effects of $\tau_{f,t}$ are restricted to the financial market, R_t affects as well the saving-spending decisions of consumers. Monetary policy has thus a broader transmission channel that a central bank must take into consideration when deciding the optimal path for the nominal interest rate. For instance, it is likely that the interest-rate path needed to reduce the costs caused by nominal price rigidities could be very different that the path needed to stabilise the financial market. In such a case, the financial authority could intervene by setting an optimal path for $\tau_{f,t}$, conditional on the

[8]This function represents the key component of the BGG financial accelerator mechanism. If entrepreneurs' net worth is low relative to their assets, on average, they are more likely to default; consequently, the financial intermediary would be willing to cut private lending, increasing the returns on capital r^k.

[9]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, policymakers could restore efficiency by reducing the financial wedge with appropriate policies.

path for R_t, such that the costs caused by financial imperfections are minimized. In fact, in the case of perfect foresight, $\tau_{f,t}$ could be set to achieve the steady-state efficient allocation. In the case of the stochastic equilibrium, we will consider a financial policy with two components: a dynamic one and a static one. We will set the static component of $\tau_{f,t}$ such that $r^k/r = 1$ at the steady state, while the dynamic part will answers to deviations of the external finance premium from its desired long-term level.

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

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

As we explained above, we assume that the variance of the distribution of ω, σ_ω fluctuates exogenously. This is the *risk* shock of Christiano *et al.* (2014); an increase in σ_ω implies more risk that is associated with a higher probability of a low ω for entrepreneurs, and higher probability of default. Then, the interest rate that financial intermediaries charge on loans to entrepreneurs increases; so entrepreneurs borrow less, credit falls and so does capital, investment, output and consumption. Because of the decrease in investment, the price of capital falls, prompting a reduction in the net worth of entrepreneurs accelerating the consequences of the bad shock.
An increase in the cost of lending to entrepreneurs prompts the financial tax to increase to compensate for this movement. From the last equation we learn that the capital gains increase, then the net worth goes up too. Moreover, the monetary policy will try to reduce the nominal interest rate, R and r fall, the capital gains also increase and the effects are similar to an increase in the macroprundential policy instrument. However, the effects of the monetary policy are stronger because it also affects directly inflation and consumption. The financial policy has a direct impact on the net worth, the spread and investment, but not on inflation or consumption. Then, the two policy instruments are complements but they can disturb each other.

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 producers 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

$$\max_{i_t}\ \mathrm{E}_t\sum_{t=0}^{\infty}\beta^t\frac{\lambda_{t+1}}{\lambda_0}\left\{q_t\left[k_t-(1-\delta)k_{t-1}\right]-i_t\right\},\ \ \text{subject to}$$

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

where $\beta^t\frac{\lambda_{t+1}}{\lambda_0}$ for $t\geq 0$ 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 the 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, $\ell^h_{j,t}$, and entrepreneurial labor, $\ell^e_{j,t}\equiv 1$, according to $\ell_{j,t}=[\ell^h_{j,t}]^{\Omega}[\ell^e_{j,t}]^{1-\Omega}$. 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

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

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 their 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 $P^\star_{j,t}$ denote the nominal price chosen in time t and $y_{j,t,T}$ represents 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 $P^\star_{j,t}$ to maximize the present discounted sum of expected profits, taking as given the demand curve, i.e.,

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

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.[10] 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 financial wind* when facing financial imbalances.[11] 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:

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

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 financial tax that ensures that $r^k = r$.

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

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

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.

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

[10] We abstract for a term related to the output gap because, as we explain later on, there are no gains of having an interest rate depending on output when the economy is hit by risk shocks.

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

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

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

2.10 Payoffs and reaction functions

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 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 of 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.[12]

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

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

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 exist a united policymaker whose objective is a linear combination of L_{CB} and L_F. The cooperative equilibrium is simply defined as

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

2.11 Calibration and solution strategy

In Table 1 we present the parameters of the model that are calibrated at a quarterly frequency. We calibrate the subjective discount factor, β, to 0.99, implying an annual real interest rate of 4 percent, and we choose 0.85 for the habit parameter, h; these two values are standard in the literature. For simplicity, we assume that the steady-state inflation, $(1+\pi)$, equals 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 following parameters follow closely Christiano *et al.* (2014), an estimated model for the U.S. economy. The coefficient of relative risk aversion, σ, is set to 1. 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 entrepreneurs 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.

The steady state main ratios that are a result of the benchmark calibration are described in Table

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. 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 financial headwinds

Does a monetary-policy rate that *leans against the financial wind* do 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

	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

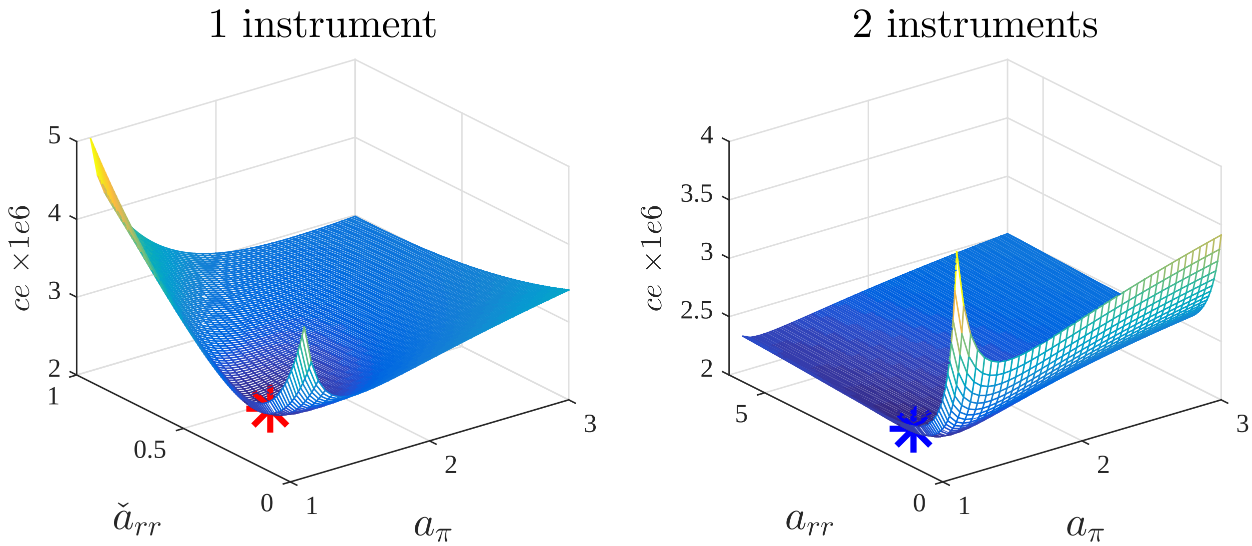
not only to deviations of inflation from its target but also to financial stability measures. Against this position, Svensson (2012, 2014, 2015) and Yellen (2014) suggest that there should be two different instruments. We contribute to this discussion by analyzing the welfare costs of having one or two instruments in the context of our model. For the *leaning-against-the-financial-wind* case, we assume that the central bank responds additionally to deviations in the credit spread, such that

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

for $\check{a}_{rr} \geq 0$. 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 consumption equivalent levels attained by either *leaning- against-the-financial-wind* case (left panel), or two-instruments case (right panel). The x and y axes correspond to the space of a_π and a_{rr}, while the z axis is the consumption equivalent. Then, the surface plot corresponds to the level of consumption equivalent for every possible combination of intervention level of the state space. For the *leaning-against-the-financial-wind* policy, the consumption equivalent is evaluated for different combinations of a_π and $\check{a}_{rr}$, while $a_{rr} = 0$; for the two-instruments case, the parameters considered are a_π and a_{rr}, while $\check{a}_{rr} = 0$.

In the *leaning-against-the-financial-wind* case, on the one hand, when the authority does not react to the credit spread ($\check{a}_{rr} = 0$), it is optimal to react to inflation but not too aggressively because it would imply too much volatility for the consumers. On the other hand, when the authority is

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



Note: ce corresponds to the consumption equivalent measure that we defined in equation (2.16). The asterisks in the figures show the minimum level of consumption equivalent losses (or the maximum level of welfare) for each case.

very passive with respect to inflation ($a_\pi = 1.1$), it is optimal for the authority to react moderately to the credit spread. These interactions are consequence of having only one instrument to offset the effects of the initial shock, if the interest rate reacts much, consumption would be hurt. Then, when the authority reacts somewhat to the credit spread, the aggressiveness regarding inflation goes down, similarly when there is a higher reaction to inflation.

In the two-instruments case, when there is no financial authority ($a_{rr} = 0$), the monetary authority reacts as in the one-instrument case when $\breve{a}_{rr} = 0$. What is clearly different from the previous case is the financial authority's reaction, because now there is an independent instrument. When the interest rate reacts slightly to inflation, there are severe losses of doing nothing for the financial authority. Moreover, with scant intervention from the financial side, the losses are reduced abruptly; there is a point in which the gains of intervening more aggressively for the financial authority are negligible. Once we allow both instruments to be active, the losses of an aggressive reaction to inflation for the monetary policy are reduced and smoothed when the financial authority starts acting.

The maximum levels of welfare, or the minimum consumption equivalent losses, are given by the asterisks on the surface of each graph. As such, under *leaning against the financial 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 imply that, under the two scenarios, welfare is improved when the authorities respond dynamically to the financial shock; in particular, the consumption equivalent is 17% higher when there is a *leaning-against-the-wind* policy with respect to

a non-dynamic financial policy, and 34% higher when there are two instruments.
CHECK Moreover, from the figures we see that the one-instrument case brings about more curvature to the consumption equivalent losses than the two-instruments case. This implies that missing the optimal parameter combination can be very costly for the consumers.
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-financial-wind* case, while the solid-blue line is the two-instruments case. The left panel shows 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 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 maximum welfare points in each regime, the consumption equivalent of *leaning against the financial wind* is almost 15% higher than that of the two-instruments case.[13] These results suggest that there exist clear benefits for using two instruments rather than one when facing a financial shock.[14]

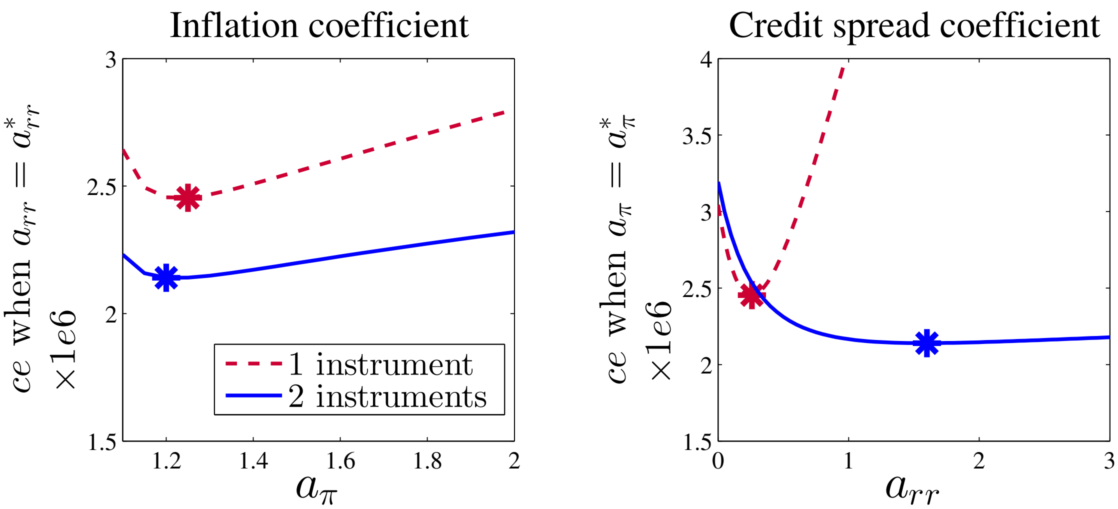
Finally, in Figure 3 we present the impulse responses to a risk shock for three different policy settings.[15] The solid-blue line corresponds to a scenario in which the central bank responds only to inflation deviations with a standard coefficient value of $a_\pi = 1.5$, and the financial authority 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 also drawn for its welfare-maximizing parameters.
A positive 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 com-

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

[14]For robustness, we have considered 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. $R_t/R = (\pi_t - \pi)^{a_\pi} \left(\mathrm{E}_t \left\{r^k_{t+1}/r_t\right\}\right)^{-\check{a}_{rr}} (y_t/y)^{a_y}$. In this case, we find a quadruplet of optimal values given by $(a_\pi, \check{a}_{rr}, a_y, a_{rr}) = (1.2, 0.1, 0, 1.3)$. The latter means that, even in the two-instruments case, there is room for a small *leaning against the financial 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. $ce_{two-instr.}/ce_{extend.} = 1.007$.

[15]The impulse responses are done with a first order approximation of the model around the deterministic steady state. The shock is a 10% increase in the variance of the distribution of $\sigma_{\bar{\omega}}$.

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



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

parison to the solid-blue line, but it also moves with the credit spread. This prompts a less volatile 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.

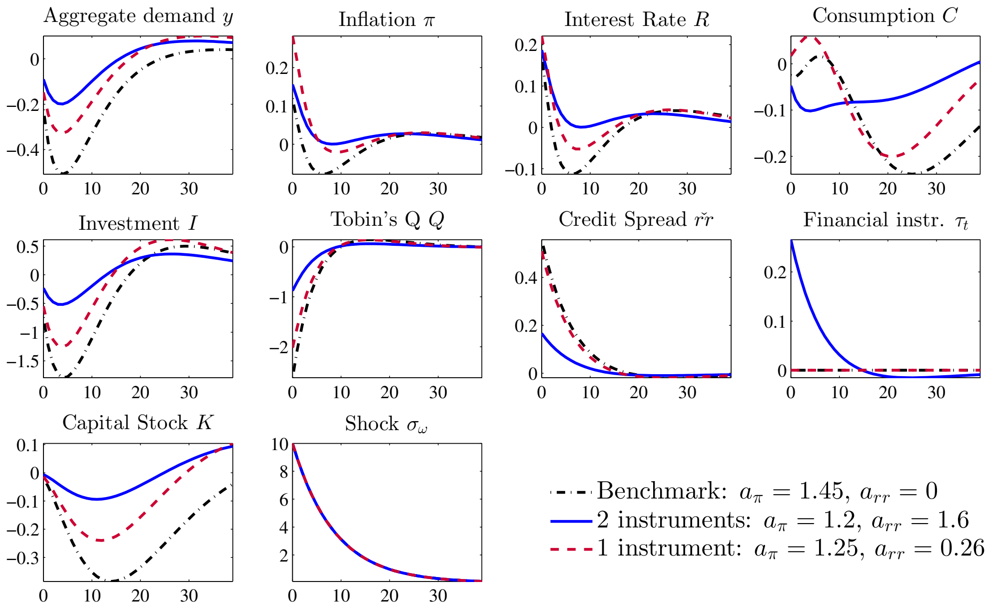
Lastly, when there are two different instruments, the financial tax smooths the credit spread on impact. Capital, investment, and output drop by less than with one instrument. Inflation moves less and so does the policy rate. Consumption is smoother after the shock. We can see that the two-instruments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

Summing up, we have found that two instruments, the interest rate that moves with inflation and the financial tax that moves with the credit spread, prompt welfare gains for the consumers in comparison to an interest rate rule that reacts not only to inflation but also to the credit spread, when the economy is hit by risk shocks. Then, there is a role to play for the financial authority. In the next section, we analyze the strategic interactions between the monetary and the financial authority and we study different policy objectives.

4 Strategic Interactions

In this section, we analyze the strategic behavior of the two policymakers. Our approach based on simple rules allows us to characterize how a policymaker may want to change his reaction function in response to that of his counterpart. In an ideal setting, we assume that both policymakers

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.

aim to maximize welfare, and study the strategic interactions therein. Because welfare is not an implementable objective for policymakers in practice or because we might not believe in the welfare measure, 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, the policy rules, are the same. We analyze the *first best - ideal* case in Section 4.1 and the *policy rules - implementable* case in Section 4.2.

4.1 Welfare as policy objective

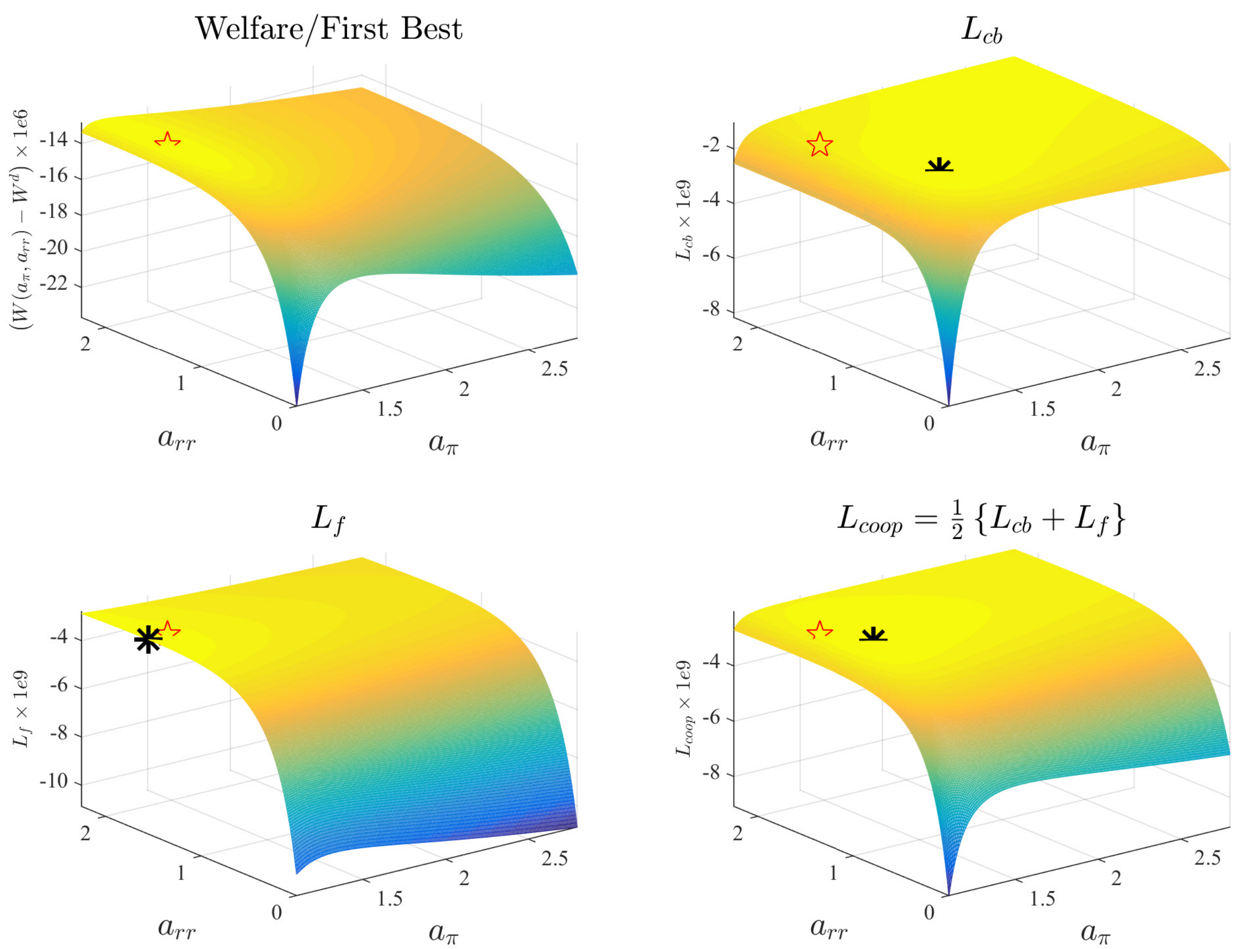
Assume that both the monetary and the financial authority search to maximize social welfare, given by equation (2.15), when deciding on the coefficients of their rules, so $L_m = \mathbb{W}(a_\pi, a_{rr}; \boldsymbol{\varrho})$ for $m \in \{CB, F\}$. The upper-left panel of Figure 4 shows the social welfare function with a finer grid, and marks with a star the maximum of that function. This plot is similar to the right hand panel on Figure 1, the y and x axises correspond to the different aggressiveness of intervention for the monetary and the financial authority, different levels of a_π and a_{rr}, however the surface plot here is welfare, while before was the consumption equivalent losses. Accordingly, when using simple rules, the social welfare function is at its highest when $(a^\star_\pi, a^\star_{rr}) = (1.22, 1.56)$. Given the structure of the model economy, the welfare function is single peaked, so any combination of coefficients different than $(a^\star_\pi, a^\star_{rr})$ within our simple-rules approach implies welfare losses.
The strategic interactions of the policymakers in the first-best case, where both authorities have

the same objective and the latter is welfare, are 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 first-best scenario, 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 maximum 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-financial 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.

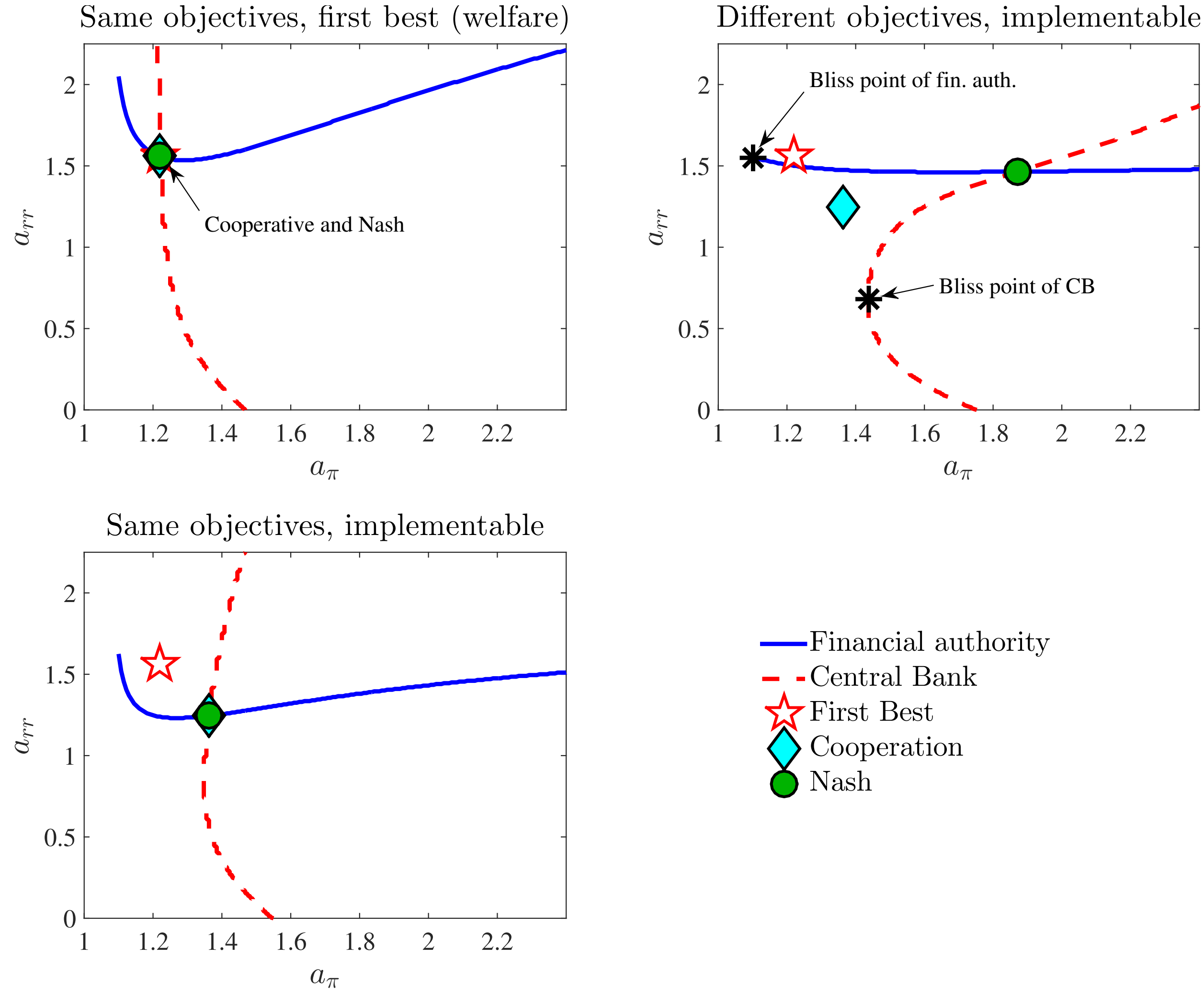
For robustness, we have also tried with different intensity of nominal rigidity ($\vartheta = 0.88$) and financial frictions ($\mu = 0.25$). The results are in the Appendix. When the nominal rigidities are stronger, the central bank has incentives to react more to inflation, and for a given level of a_{rr}, the central bank chooses a higher a_π. Once the monetary authority has a more aggressive reaction, the financial authority is less aggressive than the baseline model. When the financial frictions are stronger, the monetary authority is marginally more aggressive than in the baseline, this is a consequence of the feedback loop that the risk shock has on the aggregate demand. Because there is a stronger reaction of the central bank, the financial authority has to do less.

Figure 4: Different objectives for policymakers



Note: The stars in the figures show the first best (the maximum welfare), while the asterisks are the maximum for each case.

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



4.2 Target-oriented policies

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 policy 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. This approach has been used by Williams (2010). 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 $\varphi = 1/2$.[16]

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 brings about (see Woodford, 2003). For the financial authority, institutions such as the BIS and the IMF have emphasized that a desirable 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.[17] 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.[18]

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.[19] 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.

The upper-right panel of Figure 5 displays the best responses of the central bank and the finan-

[16] 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.

[17] 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.

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

[19] 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.

cial 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.[20] 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 $\tilde{L}_{CB} = \tilde{L}_F = -\mathrm{Var}\left(\pi_t\right) - \mathrm{Var}\left(R_t\right) - \mathrm{Var}\left(r_t^k / r_t\right) - \mathrm{Var}\left(\tau_{f,t}\right)$, 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.

Our analysis provides useful insights. One conclusion that emerges from our work is that two

[20] 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.

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-financial-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 authority 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 policy 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 financial policy as it is broadly defined.

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