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TIGHT MONEY-TIGHT CREDIT: COORDINATION FAILURE IN THE CONDUCT OF MONETARY AND FINANCIAL POLICIES

Julio A. Carrillo
Enrique G. Mendoza
Victoria Nuguer
Jessica Roldán-Peña

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Tight Money-Tight Credit: Coordination Failure in the Conduct of Monetary and Financial Policies
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ABSTRACT

Violations of Tinbergen rule and strategic interaction undermine monetary and financial policies in a New Keynesian model with the Bernanke-Gertler accelerator. Welfare costs of risk shocks are large because of efficiency losses and income effects of costly monitoring, but they are larger under a simple Taylor rule (STR) and a Taylor rule augmented with credit spreads (ATR) than under a dual rules regime (DRR) with a Taylor rule and a financial rule targeting spreads, by 264 and 138 basis points respectively. ATR and STR are tight money-tight credit regimes that respond too much to inflation and too little to spreads, and yield larger fluctuations in response to risk shocks. Reaction curves display shifts from strategic substitutes to complements in the choice of policy-rule elasticities. The Nash equilibrium is also a tight money-tight credit regime, with lower welfare than Cooperative equilibria and the DRR, but still higher than in the ATR and STR regimes.

Julio A. Carrillo
Dirección General de Investigación Económica
Banco de México
Av. 5 de Mayo,18
Mexico
jcarrillo@banxico.org.mx

Enrique G. Mendoza
Department of Economics
University of Pennsylvania
3718 Locust Walk
Philadelphia, PA 19104
and NBER
egme@sas.upenn.edu

Victoria Nuguer
Inter-American Development Bank
1300 New York Ave. NW
Washington, DC 20577
victorian@iadb.org

Jessica Roldán-Peña
Dirección General de Investigación Económica
Banco de México
Av. 5 de Mayo, 18
Mexico
jroldan@banxico.org.mx

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. Putting these ideas into practice has proven difficult, however, partly because of heated debates surrounding two key questions: First, should financial stability considerations be added into monetary policy rules or be dealt with using separate financial policy rules? Second, if separate rules are used, should financial and monetary authorities coordinate their actions? For instance, Cúrdia and Woodford (2010), Eichengreen, Prasad and Rajan (2011), and Smets (2014), among others, have argued that central banks should react to financial stability conditions (i.e. *lean against the wind*), even if there is a separate financial authority. In contrast, Svensson (2014, 2015) and Yellen (2014) favor having a different authority addressing financial imbalances, while keeping the central bank focused on price stability.[1]

This paper provides quantitative answers to the above questions using a New Keynesian model with the Bernanke-Gertler financial accelerator. The model features two inefficiencies that justify the use of monetary and financial policies. Monetary policy addresses the inefficiencies due to staggered pricing by monopolistic input producers. Financial policy addresses the inefficiencies due to costly state verification of entrepreneurs' returns by financial intermediaries.

The effectiveness of alternative policy regimes is assessed in terms of their implications for social welfare, macroeconomic fluctuations, policy targets, and the elasticities of policy rules. Monetary policy is modeled as either a simple Taylor rule (STR) governing the nominal interest rate, or an augmented Taylor rule (ATR) targeting both inflation and credit spreads. To study the relevance of Tinbergen rule, we compare the effectiveness of the STR and ATR v. a dual rules regime (DRR) with a Taylor rule and a separate financial policy rule. The latter targets the external finance premium using as policy instrument a subsidy on lenders that incentivizes lending when credit spreads rise. To make these regimes comparable, we implement each with welfare-maximizing values of the corresponding policy rule elasticities, defined as those that minimize welfare costs of risk shocks. Welfare costs are measured as compensating lifetime-utility-equivalent consumption variations relative to a deterministic steady state with zero inflation, zero external financial premium, and a subsidy neutralizing the distortion of monopolistic competition.

To examine the importance of strategic interaction, we construct reaction curves in a strategy space defined over the elasticities of the Taylor and financial policy rules. We construct grids of these elasticities and compute the value of the elasticity that maximizes the payoff of the monetary (financial) authority for each value of the financial (monetary) rule elasticity. The payoff functions are in the class of quadratic loss functions widely used in monetary policy studies, defined in terms of the sum of variances of the instrument and target of each authority (as in Taylor and Williams, 2010; Williams, 2010). We then compute Nash and Cooperative equilibria for one-shot games between the two policy authorities, and contrast their implications for welfare and for policy rule

[1] Other authors, such as De Paoli and Paustian (2017) or Angelini, Neri and Panetta (2014), study cooperation between monetary and financial authorities, financial policy goals, and optimal policy arrangements.

elasticities.[2] Since the case in which a planner sets the elasticities of both rules to maximize welfare (i.e. the DRR with welfare-maximizing elasticities) is equivalent to the outcome of a game in which both authorities share welfare as a common payoff, we label this the "Best Policy" scenario.

The analysis is conducted using the risk-shocks framework proposed by Christiano, Motto and Rostagno (2014), because risk shocks make financial policy more relevant by strengthening the Bernanke-Gertler accelerator.[3] Risk shocks affect the standard deviation of the entrepreneurs' returns on investment projects, which in turn affects the entrepreneurs' probability of default altering the supply of credit and investment. As banks cut lending, capital expenditures fall causing a decline in the price of capital and in net worth, which triggers the financial accelerator. Since the agency costs in the credit market result from a real rigidity, namely costly state verification, risk shocks are akin to financial shocks that create inefficient fluctuations in credit spreads. Christiano *et al.* argue that these shocks can explain about 60% of U.S. GDP fluctuations.

We study monetary and financial policies in terms of rules, rather than optimal Ramsey policies, because of the widespread use of the Taylor rule for evaluating monetary policy in DSGE models, and because Ramsey optimal financial policies often require global, non-linear solution methods and have been solved mainly in parsimonius models (see Bianchi and Mendoza, 2018). For monetary policy, it is well-known that the Taylor rule can be the Ramsey optimal policy when the policymakers' payoffs are quadratic functions of target variables (or linear in their variances), but it has also been established that in most widely-used DSGE models the Taylor rule is not the Ramsey optimal policy under commitment.[4] Still, policymakers act optimally in our setup, in the sense that they set the elasticities of their rules so as to maximize explicit payoff functions.

In the model we propose, Tinbergen rule applies because two instruments are needed to tackle two inefficiencies (sticky prices and costly state verification). Hence, the question is not whether Tinbergen rule is valid in the model, but whether it is quantitatively relevant. In particular, whether there are important differences in policy rule elasticities, welfare, and the macro effects of risk shocks across the STR, ATR, and DRR regimes. Similarly, the result that incentives for strategic interaction are present in the model is straightforward, so the contribution of the paper focuses on whether strategic interaction is quantitatively significant for the effectiveness of financial and monetary policies. Incentives for strategic interaction exist because the target variable of each au-

[2] This methodology is analogous to the one used by Mendoza and Tesar (2005) to study international tax competition, and is also related to Dixit and Lambertini (2003)'s analysis of monetary-fiscal interactions.

[3] We show in Section 4 that our results still hold if we add TFP, government expenditure, and input-price markup shocks. With only TFP or government expenditure shocks, financial policy is less relevant because of the standard result that in New Keynesian models solved with local methods the amplification produced by the Bernanke-Gertler accelerator is small (see Appendix B.6). Financial policy is relevant with markup shocks only because they move inflation and output in opposite directions, and hence financial policy complements monetary policy by reducing the output loss of lowering inflation.

[4] Woodford (2010) reviews optimal monetary policy in New Keynesian models, including the conditions under which monetary policy rules match Ramsey optimal policies. Bodenstein, Guerrieri and LaBriola (2014) analyze strategic interaction in monetary policy between countries and in monetary v. financial policy in a Ramsey setup.

thority is influenced by the instruments of both authorities. Inflation is partly determined by the effect of financial policy on investment and hence aggregate demand, and the credit spread is partly determined by the effect of the nominal interest rate on the lenders' participation constraint.

The risk of costly strategic interaction between financial and monetary authorities is relevant under various institutional arrangements that exist today. This is clearly the case in countries where the two policies are set by separate authorities, or where financial policy is only partially the purview of the central bank. But strategic interaction can still be an issue even in countries like the United Kingdom, where the two policies are within the domain of the central bank but designed by separate committees.

The quantitative analysis yields four key results:

(1) Welfare costs of risk shocks are large. Welfare in the three policy regimes is 3.9 to 6.5% lower than in the *deterministic* stationary state, compared with typical measures of the cost of U.S. business cycles of around $1/10$ of a percent or of the cost of U.S. tax distortions of around 2%. This is the result of income effects and efficiency losses due to changes in the long-run averages of the external finance premium and the resources allocated to monitoring costs, which in turn result from the effects of risk shocks and costly monitoring on the *stochastic* stationary state.

(2) Violating Tinbergen rule is very costly. Welfare is 264 and 138 basis points lower under STR and ATR, respectively, than under DRR, and macro fluctuations in response to risk shocks are markedly smoother with DRR. Hence, while "leaning against the wind" of financial conditions is welfare-improving relative to not responding to financial conditions at all, the DRR regime is significantly better. Moreover, the STR regime yields a higher inflation elasticity than the ATR and DRR regimes, and by construction it does not respond to spreads. The ATR has a marginally higher inflation response but again a much weaker response to spreads than the DRR. Hence, ATR and STR are "tight money-tight credit" regimes: the interest rate responds too much to inflation and not enough to adverse credit conditions. The STR and ATR violate Tinbergen rule, requiring two instruments for two targets. One instrument cannot do as well at tackling the two sources of inefficient fluctuations as the DRR does using two separate instruments. The DRR regime weakens significantly the adverse long-run effects of risk shocks on the external finance premium and monitoring costs, and provides an insurance-like mechanism against risk shocks for consumption.

(3) Reaction curves of monetary and financial authorities shift from strategic substitutes to complements in the choice of policy rule elasticities. For the monetary authority, the best elasticity response for the Taylor rule is a strategic substitute of the elasticity of the financial rule if the latter is sufficiently high but a strategic complement otherwise (i.e. the monetary authority's reaction

function shifts from downward to upward sloping if the financial rule elasticity is high enough).[5] The reaction function of the financial authority is convex, with the elasticity of the financial rule changing from strategic complement to substitute as the elasticity of the monetary rule increases.

(4) Strategic interaction is quantitatively significant. The Nash equilibrium yields a welfare loss of about 30 basis points relative to the Best Policy scenario or cooperative equilibria with either equal welfare weights or weights "optimized" to yield the smallest welfare cost. These cooperative equilibria yield welfare outcomes that are very similar to the Best Policy. The Nash outcome yields again a tight money-tight credit regime relative to the Best Policy case. A Stackelberg game with the financial authority as leader yields a similar outcome as the Nash equilibrium, but if the monetary authority leads the Stackelberg game yields an even tighter money regime with a larger welfare cost. In addition, the Nash equilibrium dominates the STR and ATR regimes by large margins, with welfare outcomes that are 234 and 108 basis points higher than each of these regimes, respectively. Hence, even a regime in which separate authorities engage in non-cooperative Nash competition is better than regimes with just a monetary rule (either STR or ATR).

The gains from coordination arise because, around the Nash equilibrium, the reaction function of the monetary authority is almost at the point where the Taylor rule elasticity switches from strategic substitute to complement of the financial rule elasticity, while the financial authority's best response is nearly independent of the elasticity choice of the monetary authority (albeit at a higher level than under cooperation). This indicates that there are large adverse spillovers of financial subsidy changes on the volatility of inflation and/or interest rates through the model's general equilibrium dynamics. A small change in the financial rule elasticity around the Nash equilibrium increases the volatility of inflation and the nominal interest rate sufficiently to justify an increase in the elasticity of the monetary rule as the best response. Cooperation tackles these adverse spillovers by correcting the tight money-tight credit nature of the Nash policy rules, which implies lowering (increasing) the inflation (spread) elasticity relative to the Nash equilibrium. Without coordination, this is not sustainable because both authorities have incentives to deviate, since the cooperative equilibrium is not a point in either authority's reaction function. At the symmetric cooperative equilibrium, the financial authority acting unilaterally would aim to reduce its elasticity sharply, and the monetary authority would increase its Taylor rule elasticity sharply.

Our findings on Tinbergen rule are consistent with results from studies comparing standard with augmented monetary policy rules by Angeloni and Faia (2013), Angelini *et al.* (2014), Kannan, Rabanal and Alasdair (2012) and Quint and Rabanal (2014). Angeloni and Faia study a model with bank runs and nominal rigidities driven by TFP shocks, quantifying the implications of monetary and bank capital rules with given coefficients. They find that responding to financial conditions always dominates in terms of welfare and output variability. Moreover, monetary rules with more aggressive inflation responses are better, in line with our tight money result. Angelini *et al.* also find that a monetary rule that responds to the loan-output ratio yields lower output variability than a standard monetary policy rule, but did not examine welfare implications. Kannan *et al.* examine a

[5] In our setup, lowering the elasticity of the financial rule when the elasticity of the Taylor rule rises means tightening financial policy when monetary policy tightens. Thus, the policy rule elasticities are strategic complements (substitutes) when reaction functions are downward (upward) sloping.

model with housing assuming that the credit spread is given by an exogenous function, increasing in the borrowers' leverage and in a financial policy instrument. In line with our findings, they find that (using a variance loss function) ATR dominates STR, and a regime with separate monetary and financial rules is best. Our work differs in that we examine risk shocks, derive the credit spread for an optimal contract with financial policy, and study strategic interaction. Quint and Rabanal study a two-country (core v. periphery) model with risk shocks in housing, and find that an ATR yields higher welfare if it responds to nominal credit growth but not if it responds to the credit-GDP ratio. Welfare assessments are complex, however, because the model separates savers and borrowers, and financial policy can be costly for the latter. The augmented monetary rule can improve welfare in the periphery because it can reduce macro volatility in that region.

Our work is also related to Aoki, Benigno and Kiyotaki (2015), who analyze the quantitative interaction between monetary and financial policy in a small open economy subject to world interest rate shocks with financial frictions à la Gertler-Karadi-Kiyotaki. They compare welfare effects for a small set of elasticity pairs of the Taylor rule and a tax on bank external debt for different variances of interest-rate shocks and with fixed v. flexible prices. They do not study strategic interaction or Tinbergen rule, but their findings are in line with ours in that they find that welfare displays significant interaction effects as the two elasticities change, which are consistent with our finding of shifts between strategic complements and substitutes in reaction functions: For sufficiently high variance of interest-rate shocks, welfare is monotonically decreasing (increasing) as the Taylor-rule elasticity rises for a lower (higher) elasticity of the financial rule.

Finally, this paper is also related to the quantitative literature using DSGE models with financial frictions to compare cooperative and noncooperative outcomes by Angelini *et al.* (2014), Bodenstein *et al.* (2014), De Paoli and Paustian (2017) and Van der Ghote (2016). Our work differs in that we consider the role of risk shocks, construct reaction curves to analyze strategic behavior finding the changing incentives to adjust policy rule elasticities as strategic substitutes v. strategic complements, and find nontrivial gains from policy coordination. De Paoli and Paustian find that the gains from policy coordination are non-negligible in games without commitment and for mark-up shocks, while for shocks to net worth or productivity the gains are negligible. Bodenstein *et al.* solve for Nash equilibria with commitment using only TFP shocks and payoff functions with a varying degree of bias in favor of inflation (for the central bank) and the credit spread (for the financial authority), and find that gains from cooperation can be significant. Angelini *et al.* find that the benefits of introducing financial policy, in the form of a time-varying capital requirement, are substantial when financial shocks are the driver of business cycle, but policy coordination results in small differences in output, inflation, and credit. Van der Ghote proposes a continuous time-model with TFP shocks and an occasionally-binding leverage constraint but without capital accumulation. He studies welfare-based payoff functions allowing financial policy to produce long-run efficiency gains but using a tax to neutralize those resulting from price stability, and finds a modest gain from coordinating policies of 0.21%.

The rest of the paper is organized as follows: Section 2 describes the model. Section 3 provides a diagrammatic analysis of the effects of risk shocks and the interaction of financial and monetary policies. Section 4 describes the calibration of the model and discusses the quantitative findings. Section 5 presents conclusions.

2 Model Structure

The model is based on the one proposed by Christiano *et al.* (2014) to introduce risk shocks into the New Keynesian model with the Bernanke-Gertler financial accelerator developed by Bernanke, Gertler and Gilchrist (1999), CMR and BGG, respectively hereafter. The model includes six types of agents: a final-goods producer, a set of producers of inputs, a physical capital producer, a financial intermediary, entrepreneurs, and households. The model features Calvo staggered price-setting by non-competitive input producers and costly state verification in financial intermediation. Since our analysis focuses on stabilization policies, we introduce adjustments that neutralize the effects of these frictions on the *deterministic* steady state. In particular, we postulate Taylor and financial rules that yield zero inflation and zero external finance premium at steady state, respectively, and introduce a time-invariant subsidy on input producers that removes the steady-state effect of monopolistic competition.[6] Because asset markets are incomplete, however, alternative policy regimes yield *stochastic* steady states that differ from the deterministic steady state due to differences in long-run averages of monitoring costs and the external finance premium (as shown in Section 3). Since several features of the model are similar to those in BGG and CMR, the presentation is kept short. Full details are provided in Sections A.1-A.9 of the Appendix.

2.1 Households

A representative agent chooses sequences of consumption, c_t, labor supply, ℓ_t^h, and real deposits, d_t, to maximize expected lifetime utility. The agent's optimization problem is:

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

subject to the budget constraint

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

In the utility function (2.1), $\beta \in (0,1)$ is the subjective discount factor, $h \in [0,1]$ determines the degree of dependence on external habits, which is driven by aggregate consumption from the previous period (C_{t-1}), $\sigma > 0$ is the coefficient of relative risk aversion, $\upsilon \in (0,1)$ is the labor share parameter, and E_t is the expectations operator conditional on the information available at date t. In the budget constraint (2.2), the uses of income in the left-hand-side are assigned to purchases of consumption goods and bank deposits. The sources of income in the right-hand-side derive from wages, where w_t is the real wage rate, the real return on deposits carried over from the previous period, where $1+\pi_t = P_t/P_{t-1}$ is the gross inflation rate from period $t-1$ to t (P_t is the price of final goods at date t) and R_{t-1} is the gross nominal interest rate paid on one-period nominal deposits (which is also the central bank's policy instrument), from real profits paid by monopolistic firms (div_t) and from transfers from entrepreneurs ($\mathcal{A}_t$) net of lump-sum taxes levied by government (Υ_t). The first-order conditions of this problem are included in Appendix A.1.

[6]Subsidies to producers and financial intermediaries are financed with lump-sum taxes on households, set at rates such that output in the deterministic steady state is the same as under flexible prices and costless monitoring.

2.2 Entrepreneurs

There is a continuum of risk-neutral entrepreneurs, indexed by $e \in [0,1]$. At time t, a type-e entrepreneur purchases physical capital, $k_{e,t}$, at a relative price, q_t, using her own net worth, $n_{e,t}$, and one-period debt, $b_{e,t}$. The entrepreneur's budget constraint is: $q_t k_{e,t} = b_{e,t} + n_{e,t}$. At date $t+1$, entrepreneurs rent out capital to input producers at a real rental rate z_{t+1} and sell the capital stock that remains after production to a capital producer. The return gained by an individual entrepreneur is affected by an idiosyncratic shock $\omega_{e,t+1}$. Hence, an entrepreneur's real return at time $t+1$ is $\omega_{e,t+1} r^k_{t+1} k_{e,t}$, where r^k_{t+1} is the aggregate real rate of return per unit of capital, given by

$$r^k_{t+1} \equiv \frac{z_{t+1} + (1-\delta) q_{t+1}}{q_t}, \tag{2.3}$$

where δ is the rate of capital depreciation.

The random variable $\omega_{e,t+1}$ is i.i.d. across time and entrepreneurs, with $\mathrm{E}(\omega_{e,t+1}) = 1$, $\mathrm{SD}(\omega_{e,t+1})$ $= \sigma_{\omega,t+1}$, and a continuous and once-differentiable c.d.f., $F(\omega_{e,t+1})$, over a non-negative support. Following CMR, the stochastic process of $\omega_{e,t+1}$ features risk shocks, which are represented by the time-varying standard deviation $\sigma_{\omega,t+1}$, with a long-run average $\bar{\sigma}_\omega$. An increase in $\sigma_{\omega,t+1}$ implies that $F(\omega_{e,t+1})$ widens.

Entrepreneurs participate in the labor market by offering one unit of labor each period at the real wage rate w^e_t.[7] Also, entrepreneurs have finite life horizons, with each entrepreneur facing a probability of exit given by $1-\gamma$. This assumption prevents entrepreneurs from accumulating enough wealth to be fully self-financed. Aggregate net worth in period t is thus given by

$$n_t = \gamma v_t + w^e_t. \tag{2.4}$$

where v_t is the aggregate equity from capital holdings of entrepreneurs who survive at date t, which is defined in the next subsection. Entrepreneurs who exit at t transfer their wages to new entrepreneurs entering the economy and consume part of their equity, such that $c^e_t = (1-\gamma)\varrho v_t$ for $\varrho \in [0,1]$, and the remainder of their equity, $\mathcal{A}_t = (1-\gamma)(1-\varrho) v_t$, is transferred to households.

2.3 The lender and the financial contract

The financial intermediary takes deposits from households at the riskless rate R_t. Deposits are used to fund risky loans to entrepreneurs. These loans are made before the entrepreneurs' returns are realized and these returns can only be verified at a cost.[8] The optimal loan contract is modeled following Bernanke and Gertler (1989), adding a financial subsidy on the lender's participation constraint as the instrument of financial policy.

At time t, when the financial contract is signed, the idiosyncratic shock $\omega_{e,t+1}$ is unknown to both the entrepreneur and the lender. At $t+1$, if $\omega_{e,t+1}$ is higher than a threshold value $\bar{\omega}_{e,t+1}$, the entrepreneur repays her debt plus interest, $r^L_{e,t+1} b_{e,t}$, where r^L_t is the gross real interest rate on loans. If $\omega_{e,t+1}$ is lower than $\bar{\omega}_{e,t+1}$, the entrepreneur declares bankruptcy and gets nothing, while

[7] As noted by BGG, this is necessary so that entrepreneurs have some net worth to begin operations.

[8] For convenience, we express the returns of entrepreneurs and the lender in real terms, but we emphasize in the lender's participation constraint that the relevant opportunity cost of funds is the nominal interest rate R_t.

the lender audits the entrepreneur, pays the monitoring cost, and keeps any income generated by the entrepreneur's investment. The monitoring cost is a proportion $\mu \in [0, 1]$ of the entrepreneur's returns, i.e. $\mu\omega_{e,t+1}r_{t+1}^k q_t k_{e,t}$. The threshold value $\bar{\omega}_{e,t+1}$ satisfies:

$$\bar{\omega}_{e,t+1}r_{t+1}^k q_t k_{e,t} = r_{e,t+1}^L b_{e,t}. \tag{2.5}$$

The optimal contract sets an amount of capital expenditures and a threshold $\bar{\omega}_{e,t+1}$ such that the expected return of entrepreneurs is maximized subject to the lender's participation constraint holding for each value that r_{t+1}^k can take.[9] The type sub-index can be dropped without loss of generality to characterize the optimal contract. The expected return of entrepreneurs is:

$$\mathrm{E}_t \left\{ [1 - \Gamma(\bar{\omega}_{t+1})] \, r_{t+1}^k q_t k_t \right\}, \tag{2.6}$$

where $\Gamma(\bar{\omega}) = \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega + \int_0^{\bar{\omega}} \omega f(\omega) d\omega$.[10] The participation constraints of the lender satisfy this condition for each value of r_{t+1}^k:

$$(1 + \tau_{f,t}) \left[\Gamma\left(\bar{\omega}_{t+1}\right) - \mu G\left(\bar{\omega}_{t+1}\right) \right] r_{t+1}^k q_t k_t \geq r_t b_t, \tag{2.7}$$

where $r_t = \frac{R_t}{1+\pi_{t+1}}$ is the ex-post real interest rate, which reflects the fact that the debt contracts are denominated in nominal terms, $\mu G(\bar{\omega}) = \mu \int_0^{\bar{\omega}} \omega f(\omega) d\omega$ represents the expected monitoring costs per unit of aggregate capital returns, and $\tau_{f,t}$ is a subsidy (a tax if negative) that the financial authority provides to the financial intermediary on its net loan revenues, with the associated cost financed with a lump-sum tax on households. The left-hand-side of equation (2.7) is the after-subsidy lender's income from lending to entrepreneurs, both those who default and those who repay, net of monitoring costs, and the right-hand-side is the cost of funding all the loans.

The optimal financial contract consists of the pair $(qk, \bar{\omega})$ that maximizes (2.6) subject to the set of constraints (2.7). The first-order conditions of this problem are provided in Appendix A.3. Since the subsidy is non-state-contingent, the results in BGG apply directly by simply considering the after-subsidy interest rate determining funding costs $R_t/(1+\tau_{f,t})$. Thus, the equilibrium in the credit market can be summarized by the following external finance premium (efp) condition:

$$\mathrm{E}_t \left\{ \frac{r_{t+1}^k}{r_t} \right\} = \frac{s\left(x_t\right)}{1 + \tau_{f,t}}. \tag{2.8}$$

The ratio $\mathrm{E}_t \left\{ r_{t+1}^k / r_t \right\}$ is the efp or credit spread, $x_t \equiv q_t k_t / n_t$ is aggregate leverage, and $s(\cdot)$ is a function such that $s(\cdot) \geq 1$ and $\partial s(\cdot)/\partial x_t > 0$ for $n_t < q_t k_t$.

The above expression reflects the equilibrium requirement that, for entrepreneurs that need external financing, the return to capital must equal the marginal external financing cost. efp depends positively on the leverage ratio, because higher leverage reflects higher reliance on debt to finance capital expenditures. The financial subsidy is akin to a subsidy on monitoring costs that lowers efp

[9] The contract has an equivalent representation in terms of a loan amount and an interest rate. The loan size follows from the fact that net worth is pre-determined when the contract is entered and $q_t k_{e,t} = b_{e,t} + n_{e,t}$, and the interest rate is given by condition (2.5).

[10] 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 (2.5), 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 (2.6).

for a given value of $s(\cdot)$. Risk shocks increase efp, because an increase in σ_ω implies more risk, in the sense of a higher probability of a low ω for entrepreneurs. This increases the interest rate that financial intermediaries charge for loans, and thus $s(\cdot)$ rises.

The credit spread is both the engine of the Bernanke-Gertler financial accelerator and an efficiency wedge in the allocation of capital. If entrepreneurs' average net worth falls and is sufficiently low relative to their assets to generate a positive credit spread, they are more likely to default, which leads the financial intermediary to cut lending, which in turn reduces capital expenditures and increases r^k. This causes a decline in the price of capital, which reduces net worth further and triggers the accelerator mechanism. Risk shocks operate through the same mechanism, because an increase in $\sigma_{\omega,t}$ also makes it more likely that entrepreneurs default, everything else the same. Conversely, the financial subsidy aims to offset the higher spreads and adverse amplification effects that would otherwise result from shocks that increase $s(\cdot)$. The inefficiency follows from the lender's participation constraint (2.7), because moral hazard induces lenders to offer too little credit in order to avoid large monitoring costs. Hence, credit and capital are smaller than in the efficient allocation (i.e. one with no information asymmetries, or $\mu = 0$, and no credit spread).

The inefficiently low credit and capital allocation justifies the policy intervention with the financial subsidy. In principle, if the financial regulator had complete information and could impose state-contingent subsidies, the subsidy could be managed optimally to fluctuate over time and across states of nature to remove the credit spread and the inefficiency completely. This is not possible, however, because credit contracts are signed at date t with the value of the subsidy known, but before the realizations of aggregate and idiosyncratic shocks for $t+1$ are known.

The optimal credit contract implies that the aggregate capital gains of entrepreneurs (i.e. the entrepreneurs' equity for the beginning of the next period) can be written as:

$$v_t = r_t^k q_{t-1} k_{t-1} \left[1 - \mu G(\bar{\omega}_t)\right] - \frac{r_{t-1} b_{t-1}}{1 + \tau_{f,t}}. \tag{2.9}$$

2.4 Capital Producer

The capital producer operates in a perfectly competitive market. At the end of $t-1$, entrepreneurs buy from it the capital to be used in period t, i.e. k_{t-1}. Once intermediate goods are sold and capital services paid, entrepreneurs sell back to the capital producer the remaining capital, net of depreciation. The capital producer then builds new capital, k_t, by adding investment, i_t, net of adjustment costs, $\Phi\left(\frac{i_t}{i_{t-1}}\right)$, to the existing capital, $(1-\delta)\,k_{t-1}$. The capital producer's problem is:

$$\max_{i_t} \mathrm{E}_T \sum_{t=T}^{\infty} \beta^{t-T} \frac{\lambda_t}{\lambda_T} \left\{ q_t \left[k_t - (1-\delta) k_{t-1}\right] - i_t \right\}, \text{ subject to} \tag{2.10}$$

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

Since households own the firm that produces capital, its profits are discounted at the rate $\beta^{t-T}\frac{\lambda_t}{\lambda_T}$ for $t \geq T$, where λ_t is the Lagrange multiplier of the household's budget constraint. We use the formulation of *investment* adjustment costs from Christiano, Eichenbaum and Evans (2005), according to which old and new investment goods are combined to produce new capital units, with a quadratic form $\Phi\left(\frac{i_t}{i_{t-1}}\right) = (\eta/2)\left[i_t/i_{t-1} - 1\right]^2$.

2.5 Final Goods Producer

Final goods, y_t, are used for consumption and investment, and produced in a competitive market by a representative producer who combines a continuum of inputs 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 demand for intermediate good j at date t, and θ is the elasticity of substitution among intermediate goods. Profit maximization yields standard demand functions $y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\theta} y_t$. The general price index is given by $P_t = \left(\int_0^1 P_{j,t}^{1-\theta} \mathrm{d}j\right)^{\frac{1}{1-\theta}}$, where $P_{j,t}$ denotes the price of the intermediate good produced by firm j.

2.6 Intermediate Goods Producers

Input producers engage in monopolistic competition and produce differentiated goods using labor $\ell_{j,t}$ and capital $k_{j,t-1}$ to produce good j at date t. Total labor input in each firm combines household labor, $\ell_{j,t}^h$, and entrepreneurial labor, $\ell_{j,t}^e \equiv 1$, with a Cobb-Douglas function $\ell_{j,t} = \left(\ell_{j,t}^h\right)^{\Omega}\left(\ell_{j,t}^e\right)^{1-\Omega}$. Each input is also produced with a Cobb-Douglas technology $y_{j,t} = \ell_{j,t}^{1-\alpha} k_{j,t-1}^{\alpha}$.

Input producers set prices according to Calvo (1983)'s staggered pricing mechanism. At every date t, each producer gets to adjust its price optimally with a constant probability $1-\vartheta$, and with probability ϑ it can only adjust its price following a passive indexation 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 goods prices and π is the inflation rate at the deterministic steady state. In order to remove the distortion of monopolistic competition on this steady state, we assume that the government provides a time-invariant subsidy τ_p so that aggregate output in the deterministic steady state reaches the same level as in the flexible-price economy.

Let $P_{j,t}^{\star}$ denote the nominal price optimally chosen ar time t and $y_{j,t,T}$ denote the demand for good j in period $T \geq t$ for a firm that last re-optimized its price in period t. Producer j selects $P_{j,t}^{\star}$ to maximize the expected present discounted value of profits (again discounting using the household's stochastic discount factors), taking as given the demand curve for its product:

$$P_{j,t}^{\star} = \max_{P_{j,t}} \left\{ \begin{array}{c} \mathrm{E}_t \left\{ \sum\limits_{T=t}^{\infty} (\beta\vartheta)^{T-t} \frac{\lambda_T}{\lambda_t} \left[\frac{\iota_{t,T} P_{j,t}}{P_T} y_{j,t,T} - (1-\tau_p)\, mc_T y_{j,t,T} \right] \right\} \\ \text{subject to } y_{j,t,T} = \left(\frac{\iota_{t,T} P_{j,t}}{P_T}\right)^{-\theta} y_T \end{array} \right\}, \tag{2.11}$$

where mc_t is the marginal cost of production corresponding to the derivative of the cost function with respect to $y_{j,t}$ (see Appendix A.6 for details). To support the flexible price production levels at the deterministic steady state, the subsidy must be equal to the inverse of the price markup, so $1 - \tau_p = (\theta - 1)/\theta < 1$. Sticky prices still create a distortion that affects macroeconomic fluctuations in the form of price dispersion. Following Yun (1996), we show in Appendix A.6, that aggregate production can be expressed as:

$$y_t = \frac{1}{\Delta_t} (k_{t-1})^{\alpha} (\ell_t)^{1-\alpha}, \tag{2.12}$$

where $\Delta_t = \int_0^1 (P_{j,t}/P_t)^{-\theta} \mathrm{d}j \geq 1$ represents the efficiency cost of price dispersion.

2.7 Policy rules

In the STR regime, there is no financial policy rule and the monetary policy rule sets the nominal interest rate following this simple Taylor rule:

$$R_t = R \times \left(\frac{1 + \pi_t}{1 + \pi} \right)^{a_\pi}, \quad a_\pi > 0, \tag{2.13}$$

where a_π is the elasticity of R_t with respect to inflation deviations from target, R is the steady-state gross nominal interest rate, and π is the central bank's inflation target.[11] In the ATR regime, the Taylor rule is augmented with the deviation of efp from its target:

$$R_t = R \times \left(\frac{1 + \pi_t}{1 + \pi} \right)^{a_\pi} \left(\frac{\mathrm{E}_t \left\{ r_{t+1}^k / r_t \right\}}{r^k / r} \right)^{-\check{a}_{rr}}, \quad \check{a}_{rr} > 0, a_\pi \geq 0, \tag{2.14}$$

where r^k/r is the target value of the credit spread at steady state, which is set to $r^k/r = 1$ so as to remove the steady-state effect of efp. The elasticity with respect to the credit spread enters with a negative sign because increases in the credit spread cause a decline in investment and hence aggregate demand, to which the monetary authority responds by lowering R_t.

In the DRR regime, monetary policy follows the same Taylor rule as in the STR regime, but in addition the financial authority follows this rule to set the financial subsidy:

$$1 + \tau_{f,t} = (1 + \tau_f) \times \left(\frac{\mathrm{E}_t \left\{ r_{t+1}^k / r_t \right\}}{r^k / r} \right)^{a_{rr}}, \tag{2.15}$$

τ_f is the value of the financial subsidy that ensures that $r^k = r$ in the deterministic steady-state. Notice that τ_f is present even in the STR and ATR regimes that do not have a financial policy rule for targeting efp, so that all policy regimes yield the same steady-state capital-output ratio.

[11] We do not include the output gap for simplicity and because quantitatively this model yields higher welfare if the Taylor rule does not respond to the output gap than if it does (see Subsection 4.4.2 for details).

2.8 Resource and government budget constraints

The government's budget constraint is:

$$\Upsilon_t = g + \tau_p s_t \int_0^1 y_{j,t}\mathrm{d}j + \tau_{f,t}\left[\Gamma(\bar{\omega}_t) - \mu G(\bar{\omega}_t)\right] r_t^k q_{t-1} k_{t-1}. \tag{2.16}$$

Government expenditures, g, are kept constant. The government runs a balanced budget, so that the sum of government expenditures, plus subsidies to monopolist producers, plus financial subsidies is paid for by levying lump-sum taxes in the amount Υ_t on households.

Combining the resource flow conditions of the various agents in the model (budget constraints, net worth, equity of entrepreneurs, firm dividends, etc.) together with the above government budget constraint yields the following aggregate resource constraint:

$$y_t = c_t + i_t + c_t^e + g + \mu G(\bar{\omega}_{e,t}) r_t^k q_{t-1} k_{t-1}. \tag{2.17}$$

Total production is allocated to consumption, investment, government expenditures, and monitoring costs. At equilibrium, all markets must clear, and the intertemporal sequences of prices and allocations must satisfy the optimality conditions of each set of agents.

2.9 Social welfare

In order to compare welfare across equilibria with different policy rules, we use standard compensating lifetime consumption variations that make agents indifferent between the levels of expected lifetime utility attainable under a given policy regime and a reference level, as proposed by Lucas (1987). We use the deterministic stationary equilibrium as the reference level, because it is constructed with the adjustments mentioned earlier that neutralize long-run effects of price stickiness, the external finance premium, and monopolistic competition. If welfare is lower under the stochastic version of the model with any of the three policy regimes, our welfare measures show the welfare *cost* of that particular regime with its particular policy rule elasticities.

The welfare measures are constructed as follows: Define $\mathbb{W}\left(a_\pi, a_{rr}; \varrho\right)$ as the unconditional expected lifetime utility attained for a given parameterization defined in the vector ϱ and a pair of policy rule elasticities a_π and a_{rr}, (or $\breve{a}_{rr}$ for the ATR):

$$\mathbb{W}\left(a_\pi, a_{rr}; \varrho\right) \equiv \mathrm{E}\left\{\sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(c_t\left(a_\pi, a_{rr}; \varrho\right), \ell_t^h\left(a_\pi, a_{rr}; \varrho\right), C_{t-1}\left(a_\pi, a_{rr}; \varrho\right)\right)\right\}, \tag{2.18}$$

where $c_t\left(a_\pi, a_{rr}; \varrho\right)$, $\ell_t^h\left(a_\pi, a_{rr}; \varrho\right)$, and $C_{t-1}\left(a_\pi, a_{rr}; \varrho\right)$ are equilibrium allocations of individual consumption, labor supply, and aggregate consumption for specific parameter values and policy rule elasticities, and $\mathcal{U}\left(c_t, \ell_t^h, C_{t-1}\right)$ is the period utility function used in equation (2.1). Since we are assuming a representative agent, $C_{t-1}(.) = c_{t-1}(.)$.

Define next $\mathbb{W}_d$, $c_d = C_d$, and ℓ_d^h as the welfare and allocations at the deterministic steady state, so that:

$$\mathbb{W}_d \equiv \frac{\mathcal{U}\left(c_d, \ell_d^h, C_d\right)}{1-\beta} = \frac{\left\{\left[c_d(1-h)\right]^{\upsilon}\left(1-\ell_d^h\right)^{1-\upsilon}\right\}^{1-\sigma} - 1}{(1-\beta)(1-\sigma)},$$

The welfare effect of a particular pair of policy elasticities is then defined as the percent change in consumption, ce, relative to the reference consumption levels (i.e. those in the deterministic steady state), such that the following condition holds:

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

With CRRA utility, we can solve for ce as:

$$ce\left(a_{\pi}, a_{rr}; \varrho\right) = 1 - \exp\left\{(1-\beta)\frac{\left[\mathbb{W}\left(a_{\pi}, a_{rr}; \varrho\right) - \mathbb{W}_d\right]}{\upsilon(1-\sigma)}\right\}. \tag{2.19}$$

Thus, $ce > 0$ ($ce < 0$) is a welfare cost (gain) relative to the deterministic steady state. Since $ce\left(a_{\pi}, a_{rr}; \varrho\right)$ is always measured relative to the same deterministic steady state, the welfare cost or gain of changing from a policy regime with elasticities (a_{π}^x, a_{rr}^x) to one with elasticities (a_{π}^y, a_{rr}^y) is given by the difference between $ce\left(a_{\pi}^x, a_{rr}^x; \varrho\right)$ and $ce\left(a_{\pi}^y, a_{rr}^y; \varrho\right)$.

3 Risk Shocks & Policy Responses: Diagrammatic Analysis

This Section provides a diagrammatic analysis of the effects of risk shocks and of how financial and monetary policy responses alter those effects. The aim is to show how each policy instrument affects its goal, which is behind the validity of Tinbergen rule, and to illustrate the spillovers from monetary (financial) policy into the credit spread (inflation), which drive the incentives for strategic interaction.

The three panels of Figure 1 show plots with the equilibrium of the markets for credit (external financing), capital goods and final goods. These charts are only a one-period snapshot of the full model's equilibrium.[12] The equilibrium of the market for external financing is determined where the demand for capital by entrepreneurs (which is also the demand for credit) intersects the supply of funds. The demand for capital follows from condition (2.3), taking into account that the rental rate of capital at equilibrium matches the decreasing marginal product of capital. The supply of credit, labeled $\frac{s(x)}{1+\tau_f}$, follows from the equilibrium condition (2.8) which determines the efp. Equilibrium in this market determines k and r^k. Notice that $r^k \geq r$, otherwise the financial intermediary would not participate in the contract.

In the capital goods market, the supply schedule, labeled k^s, is given by the standard Tobin's Q investment optimality condition. This schedule is upward sloping because of the investment adjustment costs. The demand is given again by the marginal product of capital that pins down the gross real returns of capital goods. Equilibrium in this market determines the relative price of capital goods, q, and the optimal investment amount k.

[12] Note that the model does not yield closed-form solutions for the functions plotted and includes dynamic, stochastic general equilibrium effects absent from these plots.

In the final goods market, aggregate supply is given by the standard Phillips curve, labeled PC, which is upward sloping due to nominal rigidities. Aggregate demand, labeled y^d, is given by the resource constraint, and it is downward sloping because of standard assumptions regarding income and substitution effects so that consumption declines with the interest rate, and because investment also falls as the interest rate rises. For ease of exposition, we abstract from monitoring costs in this graphic analysis, which reduces the resource constraint to $y_t = c_t + c_t^e + i_t + g_t$. We briefly explain later in this Section how monitoring costs affect the trade-off between financial and price stability.

Panel (a) of Figure 1 shows the effects of an increase in σ_ω. For simplicity, we assume that the economy starts at its steady state equilibrium (denoted by asterisks). The risk shock increases the entrepreneurs' probability of default, which shifts the supply of external financing to the left. The vertical intercept is unchanged, because the nominal interest rate is set by the central bank and we are abstracting in these plots from changes in expected inflation for $t+1$, and the horizontal segment shrinks, because the risk shock reduces the maximum level of capital covered by internal financing. The shift in the supply of loans reduces capital purchases and increases efp to $k_1 < k^*$ and $r_1^k > r^*$ respectively. Investment falls along with the demand for capital goods, which reduces the relative price of capital ($q_1 < 1$) as well as the net worth of entrepreneurs (not shown in the plots). The latter feeds into the Bernanke-Gertler accelerator and creates a wedge between the returns of capital and deposits, so after the shock efp is positive (i.e. $r^k > r$), which lowers output and inflation to $\pi_1 < \pi^*$ and $y_1 < y^*$, respectively.

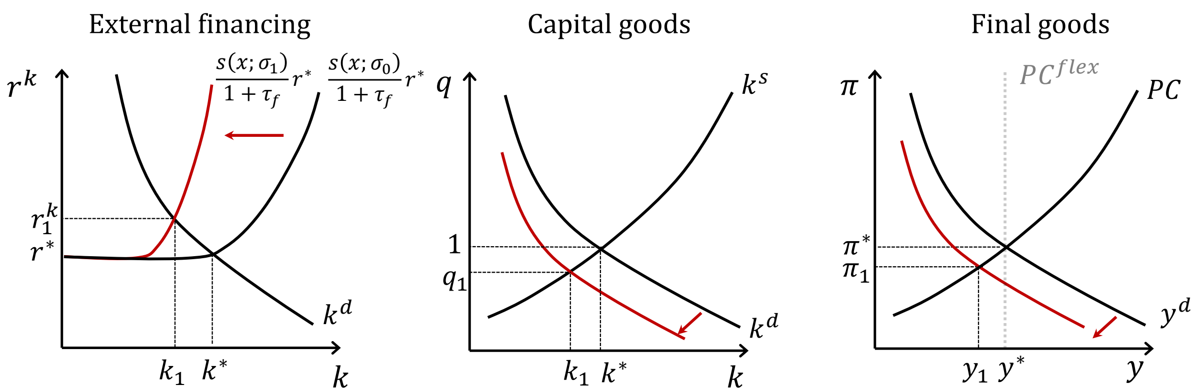
Panel (b) shows the effects of a financial policy response to the risk shock, by increasing τ_f. This increases the expected return on loans, which helps counter the drop in the supply of external financing. Notice that again the vertical intercept of the supply of loans does not change, and now the horizontal segment extends. The extent to which the supply of loans recovers depends on the parameters of the financial policy rule, and on general equilibrium feedback effects not captured in the plots, including those that depend on the parameters of the monetary policy rule. In the scenario as plotted, the financial policy is effective but falls short of returning the economy to the initial equilibrium. Hence, financial policy yields the equilibrium identified with "f" subscripts.

Panel (c) shows the effects of a monetary policy response to the risk shock, by cutting R. Since we are abstracting from changes in expected inflation, this lowers the real interest rate r, which shifts the entire supply of funds curve down and to the right, because it lowers the intermediaries' cost of raising deposits. The price and quantity effects on the three markets are qualitatively similar to those obtained with the financial policy, but monetary policy exerts a stronger effect on aggregate demand, because in addition to the effect on credit markets, it also affects saving-spending decisions of households via the standard effects present in New Keynesian DSGE models. Hence, the transmission channel of monetary policy is likely to be stronger.

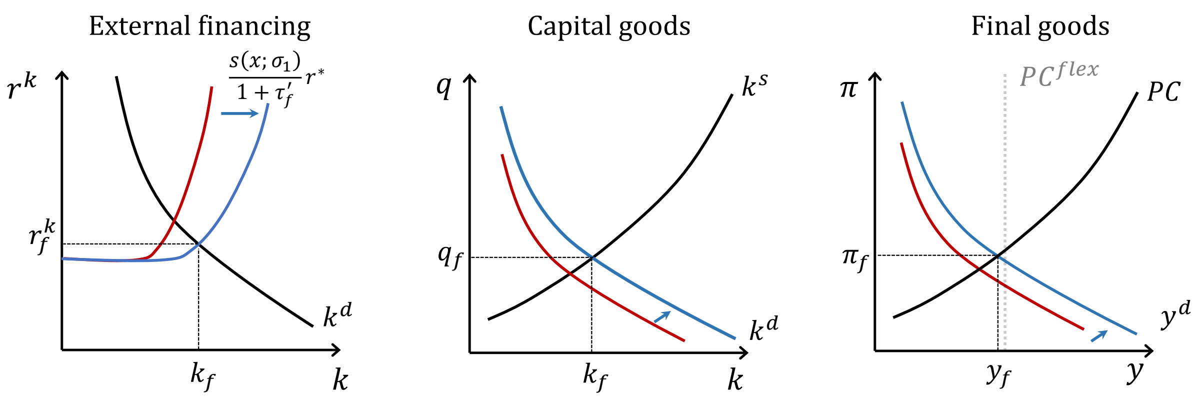
As drawn in Panel (c), the cut in R helps increase capital purchases and reduce efp towards their initial values, but at the cost of pushing inflation above its initial level ($\pi_R > \pi^*$). Moreover, if we add monitoring costs to aggregate demand, the trade-off between lower efp and higher π worsens, because aggregate demand rises more as monitoring costs increase with the risk shock (as more entrepreneurs default and the intermediary spends resources to audit them). Hence, this example suggests that the interest-rate path needed to achieve financial stability may be very different than

Figure 1: Risk Shocks and Policy Responses

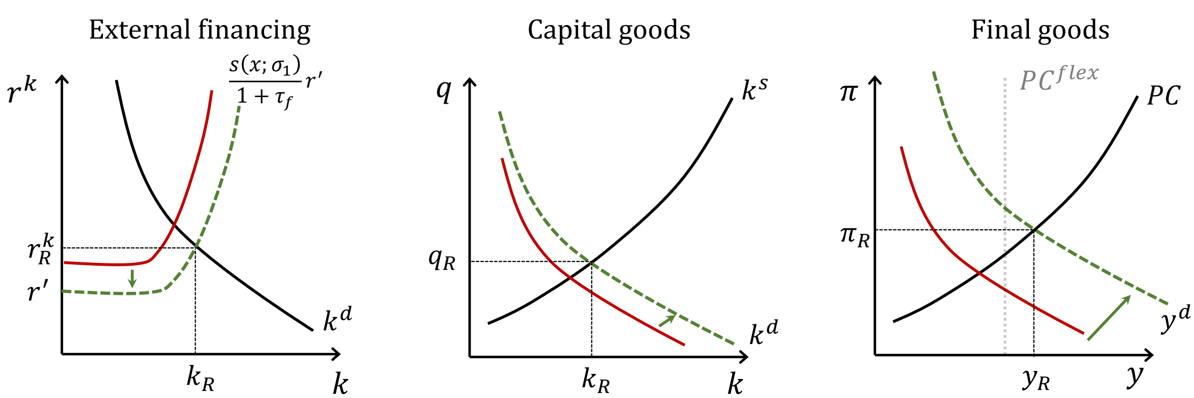
Panel (a): Effects of a positive risk shock



Panel (b): Countercyclical financial policy



Panel (c): Countercyclical monetary policy



the path needed to achieve price stability. In turn, this argument is indicative of the relevance of Tinbergen rule: Dual policy rules, one aimed at the financing premium and one aimed at inflation, are more likely to succeed because they adjust two instruments to target two variables.

The need for two instruments to target π and efp can be illustrated as a feature of the full DSGE model by noting that condition (2.8) implies that, if the central bank is expected to target inflation successfully using rule (2.13), then in the neighborhood of the stochastic steady state $r_t = R/(1+\pi)$. Hence, monetary policy cannot be used to target the credit spread, because once it is targeting inflation, the spread still fluctuates as implied by condition (2.8), with r_t approximately constant at the value implied by inflation targeting. Then, the financial subsidy is needed in order to target the spread with an instrument independent of the monetary policy instrument. Notice that under flexible prices (the scenario represented by the PC^{flex} curve in Figure 1), the monetary and financial instruments could be used indistinctly, because the inefficiencies due to nominal rigidities vanish. Tinbergen rule is irrelevant because inflation becomes an irrelevant target. In this case, there are two possible instruments to target one variable, the credit spread.

Using separate policy rules raises the potential for strategic interaction. As Panels (b) and (c) show, inflation and output are affected by $\tau_{f,t}$, while efp, credit and leverage are affected by R_t. Hence, if the payoff functions of the two authorities differ, strategic interaction would yield inferior outcomes when they act unilaterally than when they coordinate their actions. Moreover, Panels (b) and (c) suggest that the relative size of the policy rule elasticities matters for whether each authority sees the elasticity of its own rule as an strategic substitute or complement of the other authority's elasticity. For example, if a_{rr} is high enough, the monetary authority may find optimal to increase a_π when the financial authority increases a_{rr}, so as to tighten monetary policy more to keep π from rising when the financial authority is increasing τ_f by more. In this case, the curves in Panel (b) would shift out significantly more, and hence the central bank may find optimal to adjust its elasticity so that the curves in Panel (c) shift out less. Conversely, if a_{rr} is low enough, the central bank may prefer to lower the elasticity of the monetary rule. The quantitative analysis of the next Section yields results in line with these arguments.

4 Quantitative Analysis

4.1 Calibration & Deterministic Steady State

In the remainder of the paper we conduct a quantitative analysis to study the model's implications for the relevance of Tinbergen rule and strategic interaction in the management of monetary and financial policies. The model is calibrated to a quarterly frequency, with most parameters taken from CMR and BGG. Table 1 lists the values of the model's parameters in the Baseline calibration. As explained earlier, we set inflation in the deterministic steady state to zero ($\pi = 0$) in order to remove the steady-state effects of price stickiness. We also set υ, the parameter governing the disutility of labor, such that the household's steady-state labor allocation is 1/3rd (i.e. $\ell^h = 1/3$), and set the habit persistence parameter to $h = 0.85$ as in Schmitt-Grohé and Uribe (2008).

The values of the discount factor, the coefficient of relative risk aversion, the capital share in the intermediate sector, the elasticity of demand for intermediate goods, the depreciation rate, the investment adjustment costs, the government expenditures-GDP ratio, the price indexing weight, and the degree of price stickiness are taken from CMR. They set some of these parameters by calibrating to data targets or estimates from the literature, and obtain others as estimation results using U.S. quarterly data for the period 1985:I-2010:II. The calibrated parameter values are: $\beta = 0.99$, $\sigma = 1$, $\alpha = 0.4$, $\theta = 11$, $\delta = 0.025$, and $g = 0.2$. The estimated parameters, which correspond to modes of the posterior distribution of the estimation, are: $\eta = 10.78$, $\vartheta_p = 0.1$ and $\vartheta = 0.74$. Given these parameter values, the value of the subsidy to intermediate goods producers that neutralizes the steady-state effects of monopolistic competition is $\tau_p = 9.1\%$.

Table 1: Baseline Calibration

Parameter		Value	Source or Target
Preferences, technology & policy parameters			
β	Subjective discount factor	0.99	CMR
σ	Coefficient of relative risk aversion	1.00	CMR
υ	Disutility weight on labor	0.06	$\ell^h = 1/3$
h	Habit parameter	0.85	Schmitt-Grohé and Uribe (2008)
α	Capital share in production function	0.40	CMR
δ	Depreciation rate of capital	0.02	CMR
η	Investment adjustment cost	10.78	CMR
$\bar{g}$	Steady state government spending-GDP ratio	0.20	CMR
ϑ_p	Price indexing weight	0.10	CMR
ϑ	Calvo price stickiness	0.74	CMR
θ	Elasticity of demand for intermediate goods	11.00	CMR
π	Inflation in the deterministic steady state	0	target value[1]
τ_p	Subsidy to intermediate goods producers	9.1%	target value[2]
Financial sector			
$1-\varrho$	Transfers from failed entrepreneurs to households	0.01%	BGG
γ	Survival rate of entrepreneurs	0.98	BGG
μ	Monitoring cost	0.118	BGG
Ω	Share of households' labor on total labor	0.98	BGG
$\bar{\sigma}_\omega$	Mean of stnd. dev. of entrepreneurs shocks	0.27	BGG
ρ_{σ_ω}	Persistence of risk-shock process	0.97	CMR
σ_ϵ	Standard deviation of risk-shock innovations	0.1	CMR
τ_f	Financial subsidy in the deterministic steady state	0.96%	target value[3]

[1]Targeted to remove steady-state effects of nominal rigidities.

[2]Targeted to remove steady-state effects of monopolistic competition.

[3]Targeted to obtain $\mathrm{efp} = 0$ in the steady state.

The financial sector parameters are taken mostly from BGG. Accordingly, the transfers from failed entrepreneurs to households are set to a very small value ($1 - \varrho = 0.01\%$), so that the entrepreneurs' consumption process, which is quite volatile, does not affect aggregate consumption significantly. We take from BGG their calibrated values for the survival rate of entrepreneurs ($\gamma = 0.98$), the monitoring cost coefficient ($\mu = 0.118$), the unconditional standard deviation of the entrepreneurs idiosyncratic shocks ($\bar{\sigma}_\omega = 0.27$), and the fraction of households' labor on production ($\Omega = 0.98$).[13] BGG obtained these calibrated parameters so that the deterministic steady state of their model matches an entrepreneurial labor income share of 0.01, a default rate of entrepreneurs of 3% per year, a capital-net worth ratio of 2, and a 2% long-run external finance premium, which are figures based on historical U.S. averages. Here, we take the financial sector parameters they obtained as given, and solve for the value of the steady-state financial subsidy τ_f that reduces the steady state efp to zero. This yields $\tau_f = 0.96\%$.[14]

The entrepreneurs' idiosyncratic productivity shocks, ω_t, follow an i.i.d. log-normal process with an unconditional expectation of 1 and a time-varying standard deviation characterized by the following AR(1) process:

$$\log(\sigma_{\omega,t}) = (1 - \rho_{\sigma_\omega})\log(\bar{\sigma}_\omega) + \rho_{\sigma_\omega}\log(\sigma_{\omega,t-1}) + \sigma_\epsilon \epsilon_t \tag{4.1}$$

where $\sigma_{\omega,t}$ is the standard deviation of ω_t, and σ_ϵ is the standard deviation of the innovations to the risk shock process. We set $\rho_{\sigma_\omega} = 0.97$ and $\sigma_\epsilon = 0.1$ using the estimates from CMR, including in σ_ϵ both surprise and anticipated components.

The key ratios of the model's deterministic steady state under the Baseline calibration are listed in Table 2, together with the ratios for two alternative cases: the BGG model and a variant of the model without financial frictions. The Baseline case differs from BGG in that it includes the financial subsidy that removes the external finance premium at steady state, and it differs from the case without financial frictions in that it still uses up resources in monitoring costs. In the Baseline case, monitoring costs amount to $\mu G(\bar{\omega})rk$, where $\bar{\omega}$ is the threshold value of ω below which an entrepreneur defaults with zero efp (i.e. $r^k = r$) and k is the associated steady-state capital stock. All three scenarios include the subsidy to intermediate producers and assume zero inflation to neutralize the steady-state effects of monopolistic competition and nominal rigidities, respectively.

In the BGG case, the steady state is affected by both the distortionary effects of the external finance premium and by the resources spent in monitoring costs. Because $\mathrm{efp} > 0$, the investment rate and the capital-output ratio are lower than in the other two scenarios which have zero efp. For the same reason, the steady-state investment rates and capital-output ratios are the same without

[13] $\bar{\sigma}_\omega = 0.27$ is close to the value of 0.2713 estimated by Lambertini, Nuguer and Uysal (2017) and the 0.26 estimate used by CMR. Lambertini *et al.* (2017) estimated a model with nominal and real rigidities, a housing sector with risk shocks, mortgages, and endogenous default using quarterly U.S. data.

[14] This approach implies that with $\mathrm{efp} = 0$ our model yields higher steady-state values for the default rate of entrepreneurs and the capital-net worth ratio than in BGG. As shown in Appendix B.3 however, our results on Tinbergen rule and strategic interaction for the three policy rules we examined do not vary much if we set $\tau_f = 0$, so that the steady state of the model matches the same data targets as the BGG calibration.

Table 2: Comparison of Steady State Equilibria

	BGG	No Finan Fric	Baseline
External Finance Premium efp, annual rate	2%	0%	0%
Monitoring Cost μ	12%	0%	12%
Financial Policy τ_f	-	-	1%
c/y	0.55	0.52	0.50
i/y	0.25	0.28	0.28
k/y	9.97	11.40	11.40
y/y_{nf}	0.91	1.00	1.00

Note: The model without financial frictions corresponds to the case in which $\mu = 0$. The efficient output, y_{nf}, is the one attained without financial frictions, which is also the one attainable in a standard Neoclassical model (since it is a steady state with zero inflation and with a subsidy removing the distortion of monopolistic competition on production).

financial frictions and in the Baseline case, and in both scenarios steady-state output equals its efficient level. In contrast, in the BGG setup the capital-output ratio is about 150 percentage points lower and output is nearly 10% lower.

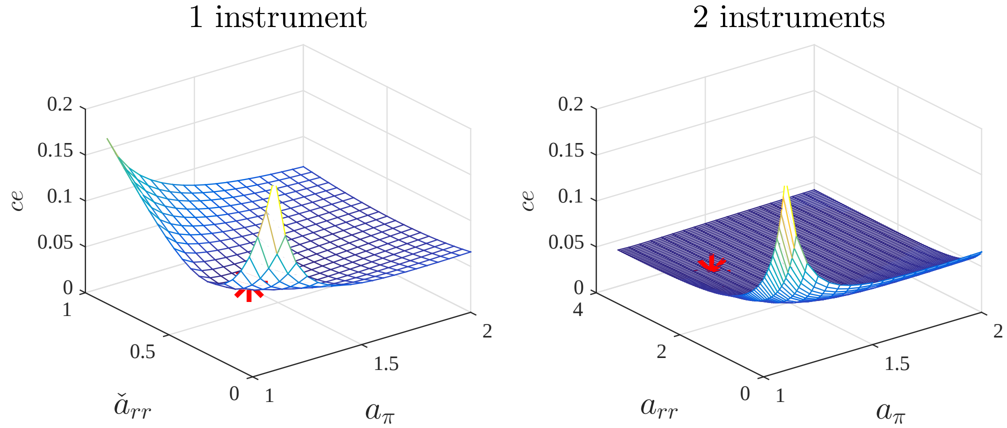
Removing the external finance premium using τ_f removes the investment inefficiency in the Baseline case, but c/y is lower than in either BGG or without financial frictions. BGG has a higher c/y because, although resources are going into paying monitoring costs, the positive efp reduces the investment rate below that in the Baseline case. Without financial frictions, c/y is higher than in the Baseline because now the investment rate and the output level are the same but in the Baseline some resources are used up to pay monitoring costs. These differences are worth noting because, as we show later, in the stochastic stationary state, alternative policy regimes yield different long-run averages for efp and monitoring costs which have important welfare implications. Qualitatively, these stochastic steady states are more similar to the deterministic BGG case than to the Baseline case, because they feature both monitoring costs and efficiency losses due to positive efp.

We solved the model using a second-order perturbation method, as proposed by Schmitt-Grohé and Uribe (2004). This improves the accuracy of the welfare calculations critical for our anaylsis. To avoid explosive sample paths when computing expected lifetime utility, we simulated the second-order solutions using the pruning method developed by Andreasen, Fernández-Villaverde and Rubio-Ramírez (2017). The model is solved using Dynare, version 4.

4.2 Tinbergen rule

To evaluate the relevance of Tinbergen rule, we compare the DRR, STR and ATR regimes in terms of social welfare for a set of policy rule elasticities, the elasticities that yield the lowest welfare cost (denoted “optimized elasticities”), and the macroeconomic dynamics in response to risk shocks.

Figure 2: Welfare Costs under Alternative Policy Regimes



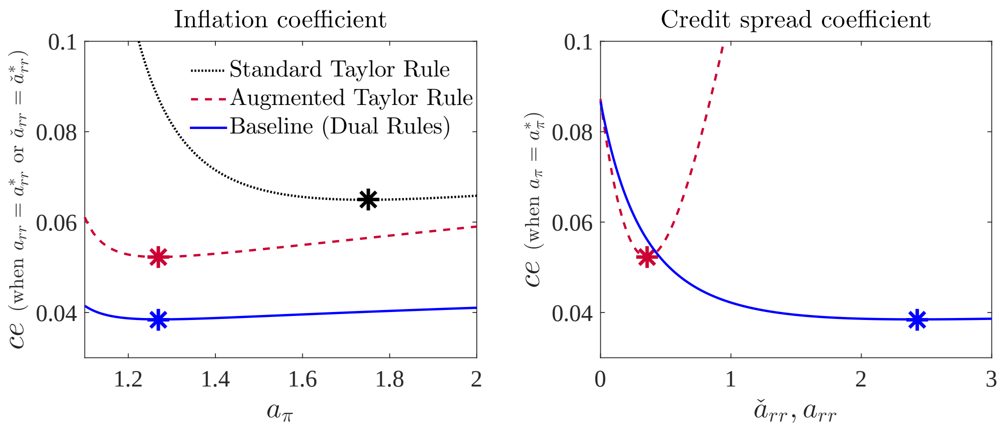
Note: ce is the welfare cost for each elasticity pair, computed as averages over the ergodic distribution of the welfare measure defined in eq. (2.19). The optimized elasticities that minimize ce are marked with asterisks.

Figure 2 shows surface plots of welfare costs for a set of elasticity pairs under the ATR (labeled "1 instrument" in the left plot) and the DRR (labeled "2 instruments" in the right plot). The results for the STR regime are also included. They correspond to the cases with $\check{a}_{rr} = 0$ in the ATR case or $a_{rr} = 0$ in the DRR case. These are identical because in these cases ATR and DRR are equivalent STR regimes at the given a_π (recall that ATR and DRR have the same constant τ_f).

These surface plots show two key results. First, welfare costs are large in all regimes and elasticity pairs considered, with ce ranging from about 6 to 17%. This is due to long-run effects of changes in efp and monitoring costs, as we explain in more detail below. Second, the curvature of the surface plots is indicative of the relevance of Tinbergen rule and strategic interaction. In particular, for low a_π, welfare costs in the ATR show a marked U shape as $\check{a}_{rr}$ varies, whereas in the DRR regime they first fall sharply as a_{rr} rises from 0 but then change only slightly. Welfare costs are slightly higher with the DRR than with the ATR for a_{rr} and $\check{a}_{rr}$ near 0 for all values of a_π, but lower if those efp elasticities are sufficiently high. Moreover, for $a_{rr} \geq 1.2$, welfare costs for $a_\pi = 1$ are nearly unchanged as a_{rr} rises in the DRR, whereas under the ATR they are sharply increasing in $\check{a}_{rr}$ when a_π is low but moderately decreasing in $\check{a}_{rr}$ when a_π is high. These differences in the curvature of the two surface plots indicate that Tinbergen rule is relevant because they show that the DRR can avoid sharply increasing welfare costs as a_{rr} rises for a given a_π, which is possible because it has separate instruments to tackle price and financial stability. The curvature is also indicative of large policy spillovers, providing incentives for strategic interaction.

Figure 3 illustrates further the differences in welfare costs across policy regimes by showing how ce varies as each elasticity changes, keeping the other fixed at its optimized value. The plot on the left is for a_π and the one on the right is for $\check{a}_{rr}$ and a_{rr}. The dashed-red curves are for the ATR and the solid-blue curves are for the DRR, and in the left plot the dotted-black line is for the STR. In each curve, asterisks identify the optimized elasticities. The left plot shows that, for all values of a_π, ce is uniformly lower under the DRR than under the ATR, and much lower than under the STR. The right plot shows that for spread elasticities below 0.5 ce does not differ much between

Figure 3: Welfare Costs as Policy Elasticities Vary



Note: Asterisks show the lowest welfare cost on each curve.

the DRR and ATR, but for higher spread elasticities ce is much lower under the DRR. Welfare costs under the ATR rise much faster with the spread elasticity, producing a markedly U-shaped curve, while under the DRR welfare costs are nearly unchanged as the spread elasticity rises. This is again evidence of Tinbergen rule relevance: a_{rr} in the DRR can rise with much less adverse welfare consequences than $\check{a}_{rr}$ in the ATR because DRR targets efp with its own instrument without affecting the instrument of monetary policy. Notice also that in all curves there is an internal solution for the optimized elasticities and those solutions differ markedly. These findings show that the different policy regimes have sharply different implications for the inefficiencies due to the financial accelerator and the nominal rigidities, and hence yield sharply different equilibrium allocations and welfare, and cause non-trivial interaction between monetary and financial policies.

Table 3: Comparison of Policy Regimes

Regime	Optimized Elasticities			ce v. DRR	Decomposition of ce			
					Full ce	Mean eff.		SD eff.
	a_π	a_{rr}	$\check{a}_{rr}$			Total	Net	
Dual rules (Best Policy)	1.27	2.43	0	-	3.85%	3.75%	2.51%	0.10%
Augmented Taylor rule	1.27	0	0.36	138bp	5.23%	4.97%	4.07%	0.26%
Simple Taylor rule	1.75	0	0	264bp	6.49%	6.08%	5.41%	0.41%

Note: "Optimized Elasticities" are the elasticities from the sets used in constructing Figure 2 that produce the lowest welfare cost under each policy regime. ce v. DRR is the difference in ce under the ATR or STR relative to the DRR in basis points. "Full ce" is the welfare measure defined in equation (2.19) which is decomposed into an effect due to changes in long-run averages ("Mean eff. Total") and an effect due to fluctuations ("SD eff."). Mean eff. Total is computed as in equation (2.19) but replacing $\mathbb{W}\left(a_\pi, a_{rr}; \varrho\right)$ with $\mathcal{U}\left(E[c], E[\ell^h], E[C]\right)/(1-\beta)$, where $E[c], E[\ell^h], E[C]$ are long-run averages of the model solved under each policy regime. "Mean eff. Net" removes the long-run average of monitoring costs from the Mean eff. calculation, by treating monitoring costs as private consumption in the resource constraint.

Table 3 shows the quantitative relevance of Tinbergen rule by comparing the DRR, ATR, and STR, each operating with its optimized elasticities. The Table lists the optimized elasticities, the difference in ce in the ATR and STR relative to the DRR, and a decomposition of ce in terms of Mean and Standard Deviation (SD) components. We denote the DRR as the "Best Policy" scenario because it yields the best welfare outcome of the three regimes, and also because it matches the outcome of a cooperative game in which social welfare is the common payoff of the two policy authorities. In the welfare effect decompositions, the Total Mean Effect is computed using equation (2.19) but replacing the value of welfare under a given regime with the welfare value of a hypothetical stationary state in which equilibrium allocations are constant at the average values of the same regime's stochastic stationary state. The SD effect is just ce minus the Mean effect. We also show the Mean effect net of monitoring costs, which is calculated by treating the long-run mean of monitoring costs as private consumption in the resource constraint. The aim is to illustrate the relevance of long-run changes in resources used up in costly monitoring for the welfare costs.

The optimized elasticities in the DRR are $a_{\pi} = 1.27$ and $a_{rr} = 2.43$ v. $a_{\pi} = 1.27$ and $\breve{a}_{rr} = 0.36$ in the ATR. The inflation elasticities are similar (with the one in the ATR marginally higher), and both are about 50 basis points smaller than the inflation elasticity of the STR regime. The efp elasticities, however, differ markedly. The one under DRR is much higher than in the other regimes, 2.43 in the DRR v. 0.36 in the ATR and 0 in the STR. The STR and ATR regimes are tight money-tight credit regimes because financial policy does not respond enough to worsening spreads and monetary policy responds too much to higher inflation, albeit by a negligible amount in the ATR case. In line with Tinbergen rule, policy responds less to worsening financial conditions under the ATR because it cannot respond with an instrument independent from the monetary policy instrument. Moreover, the only instrument it can respond with, the interest rate, is the one with the stronger transmission mechanism, because as we explained earlier, it has first-order effects on the inefficiencies caused by both Calvo pricing and the financial accelerator.

The violations of Tinbergen rule entail large welfare costs: ce in the ATR and STR is 138 and 264 basis points larger than in the DRR, respectively, and 126 basis points lower in the ATR than in the STR. Hence, allowing the Taylor rule to respond to the credit spread is better than not but using separate financial and monetary rules is significantly better.

The welfare costs of the three regimes with optimized elasticities are large relative to other standard measures. The STR regime yields a cost of 6.5% v. 5.2 and 3.9% under the ATR and DRR, respectively. These are all much larger than typical estimates of the welfare cost of business cycles of about 0.1% (see Lucas, 1987), and larger even than estimates of the welfare costs of distortionary taxation in the $1 - 3\%$ range. In order to understand the factors behind this result, we conducted a series of counterfactual experiments isolating the welfare implications of key model parameters (monitoring costs coefficient, habit persistence, price stickiness, properties of risk shocks, labor elasticity, etc.) and we found that by far changing the coefficient of monitoring costs contributes the most to the large welfare costs, followed by habit persistence.[15]

[15]Schmitt-Grohé and Uribe (2005) also found that increasing habit persistence increases welfare costs. Appendix B.5 provides a detailed analysis of the role of the model's key parameters in determining welfare costs.

Table 3 provides two sets of results to illustrate this point. First, the decomposition of ce into Mean and SD effects shows that the Mean effects are the main source of the large welfare costs. These in turn are due to differences in the long-run averages of consumption and leisure across policy regimes, of which further analysis showed consumption differences are more important. The SD effects isolate the contribution of business cycle variability per-se, and the results are in line with typical measures of the welfare cost of business cycles. Second, the Table shows that net mean effects are markedly smaller than total mean effects (by 124, 90, and 67 basis points in the DRR, ATR, and STR respectively). This is because although the *deterministic* steady-state effects of nominal rigidities, monopolistic competition, and efp have been neutralized, each regime yields different results for the long-run averages of efp and resources assigned to monitoring costs in the corresponding *stochastic* steady state, and also because in the DRR the average financial subsidy changes as the average efp changes. It is important to note, however, that these changes are long-run implications of the business cycle volatility induced by risk shocks: The means of monitoring costs and efp are higher in the stochastic than in the deterministic steady states because of the dynamic equilibrium effects of risk shocks under incomplete markets, which differ markedly across regimes.[16] We document these differences and their effects on the welfare calculations by studying differences in long-run moments and impulse response functions for risk shocks under each regime.

Table 4 shows the moments of the model's key variables in the stochastic steady state of each regime with optimized elasticities, and their corresponding deterministic steady state values. The Table shows means, standard deviations relative to the standard deviation of output, and correlations with output. A comparison of model averages v. the deterministic steady state provides further evidence of the role that changes in efp and monitoring costs play in explaining the large welfare costs of risk shocks. In the deterministic steady state, $\mathrm{efp} = 0$ and monitoring costs are about 1.1% of output. In contrast, the long-run averages of monitoring costs rise to 1.6, 1.7, and 2% of output in the DRR, ATR, and STR, respectively, and the long-run averages of efp rise to 0.18, 0.65, and 0.99% in each regime, respectively. The resulting effects on average household leisure are small, but the changes in average consumption, investment, and capital are large. Relative to their deterministic steady-state values, mean consumption falls -1, -2.6 and -3.2% in the DRR, ATR, and STR, respectively. The changes in average consumption are the main determinant of the large welfare costs, and they are due to both the increases in monitoring costs and the efficiency losses caused by the increases in efp. Investment in the DRR (ATR and STR) falls by -1.7 (-5.6 and -7.5)% relative to the deterministic steady state, while capital falls by -1.6 (-5.1 and -6.7)%.

The DRR is significantly inferior to the deterministic steady state in terms of welfare, but also much better than the ATR and STR regimes, and this is the case because the increases in monitoring costs and efp, and their associated declines in consumption, investment and capital are smaller. In turn, these differences are due to the ability of the DRR to respond to the movements in efp by adjusting the financial subsidy. The subsidy rises from 0.96% in the deterministic steady state to 1.07% in the average of the stochastic steady state of the DRR.This higher subsidy results in higher lump-sum taxes in the DRR, but welfare is higher because the higher lump-sum taxes are not dis-

[16]The welfare calculations based on pruned (stable) time-series simulations of the model's second-order dynamics are critical for these results.

Table 4: Aggregate Statistics of the Deterministic and Stochastic Steady States under Each Policy Regime

Variable	DSS		DRR					ATR					STR				
	Mean	Share of y	Mean	Share of y	Change rel. to DSS	Std.dev. rel. to y	Corr. with y	Mean	Share of y	Change rel. to DSS	Std.dev. rel. to y	Corr. with y	Mean	Share of y	Change rel. to DSS	Std.dev. rel. to y	Corr. with y
y	1.717	1.000	1.709	1.000	-0.47%	1.000	1.000	1.680	1.000	-2.12%	1.000	1.000	1.672	1.000	-2.61%	1.000	1.000
c	0.865	0.504	0.856	0.501	-1.02%	0.881	0.296	0.843	0.502	-2.55%	1.103	0.202	0.837	0.501	-3.18%	1.055	0.290
i	0.489	0.285	0.481	0.281	-1.70%	3.669	0.103	0.462	0.275	-5.58%	4.877	0.516	0.453	0.271	-7.45%	4.872	0.567
g	0.343	0.200	0.343	0.201	-	-	-	0.343	0.204	-	-	-	0.343	0.205	-	-	-
mont. costs	0.020	0.011	0.028	0.016	43.47%	2.412	0.473	0.029	0.017	47.73%	1.557	0.129	0.033	0.020	70.55%	1.582	0.054
$c+i+g$	1.697	0.989	1.681	0.984	-0.98%	1.230	0.202	1.651	0.983	-2.71%	1.258	0.686	1.638	0.980	-3.48%	1.341	0.709
k	19.564	2.849*	19.248	2.816*	-1.62%	1.604	0.544	18.574	2.763*	-5.06%	2.050	0.777	18.259	2.730*	-6.67%	2.076	0.815
b	10.677	1.555*	10.087	1.476*	-5.53%	12.179	0.444	9.537	1.419*	-10.7%	7.321	0.708	9.274	1.387*	-13.1%	5.556	0.753
ℓ^h	0.333	-	0.335	-	0.36%	1.417	0.553	0.334	-	0.32%	1.121	0.416	0.335	-	0.39%	1.001	0.387
$U(c,\ell^h,C)$	-0.504	-	-0.506	-	0.47%	1.366	0.509	-0.507	-	0.64%	1.076	0.326	-0.508	-	0.80%	0.997	0.295
R, annual%	4.102	-	4.100	-	0.00%	0.338	0.762	4.901	-	0.80%	0.322	0.607	4.096	-	-0.01%	0.291	0.744
τ_f	0.960	-	1.073	-	0.11%	0.577	0.409	0.960	-	0.00%	0.000	-	0.960	-	0.00%	0.000	-
efp, annual%	0.000	-	0.184	-	0.18%	0.238	0.364	0.654	-	0.65%	0.510	-0.004	0.992	-	0.99%	0.496	-0.064
π, annual%	0.000	-	-0.001	-	0.00%	0.266	0.762	0.790	-	0.79%	0.328	0.471	-0.003	-	0.00%	0.166	0.744
q	1.000	-	1.000	-	-0.03%	1.350	-0.706	0.996	-	-0.38%	1.980	-0.261	0.994	-	-0.58%	2.240	-0.236

Note: DSS is the deterministic steady state. "mon. costs" is the total amount of resources allocated to monitoring costs. Output is $y = c + i + g$+mon. costs. $U(c, \ell^h, C)$ is period utility.
"Std.dev. rel. to y" is the ratio of the standard deviation of the corresponding variable divided by the standard deviation of output. The standard deviation of output equals 0.014, 0.028, and 0.037 in the DRR, ATR, and STR, respectively.
* Annualized ratio.

tortionary and help offset the higher efficiency losses under the ATR and SDR. These movements also allow the DRR to sustain more credit than in the ATR and STR regimes. Credit in the DRR is 5.5% lower than in the deterministic steady state, but this is a smaller decline than 10.7 and 13.1% in the ATR and STR, respectively.

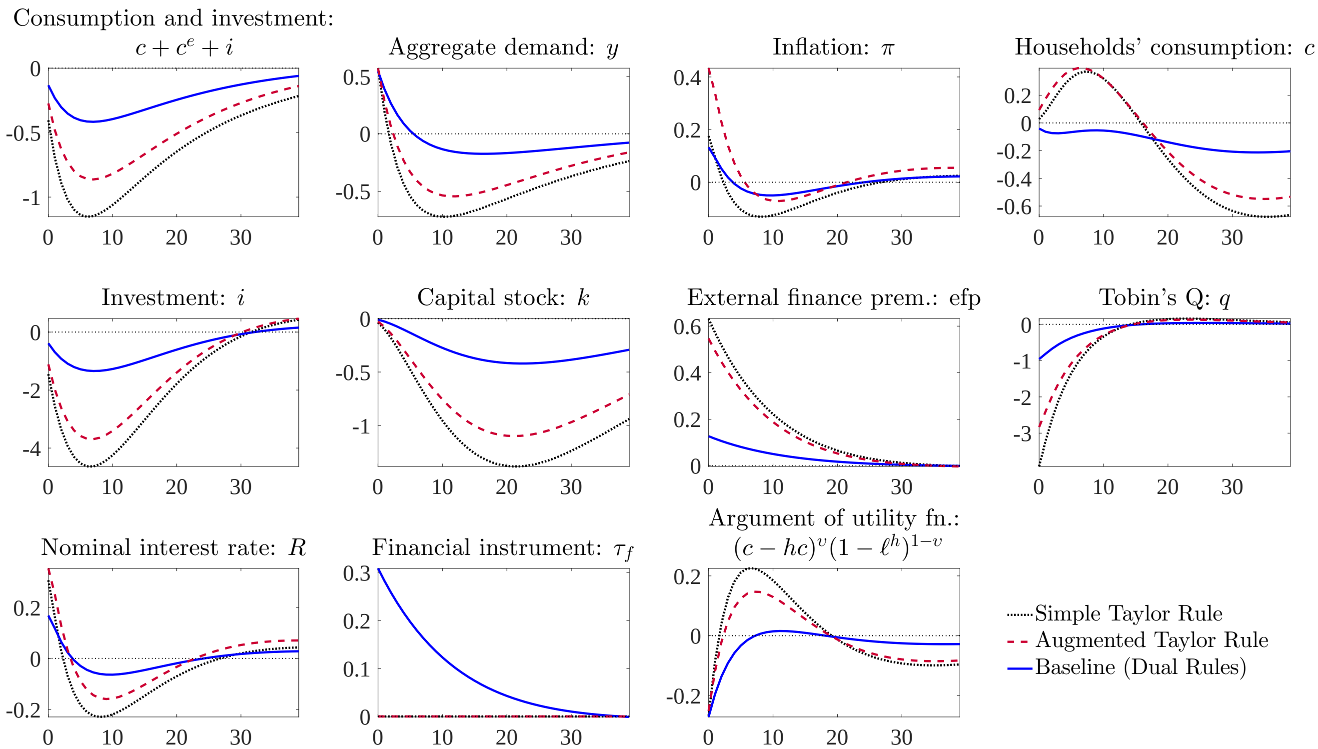
The DRR's ability to respond to financial headwinds with $\tau_{f,t}$ also reduces business cycle variability. The relative standard deviations of consumption, investment, and the capital stock are 0.9, 3.8, and 1.7 in the DRR, while in both the ATR and STR these are about 1.1, 4.9, and 2.1. The correlations of investment and the capital stock with output are also significantly smaller, at 0.1 and 0.55 in the DRR v. 0.52 (0.57) and 0.78 (0.82) in the ATR (STR).

Next we compare the responses of macro variables to risk shocks in the three optimized policy regimes. Figure 4 shows impulse response functions for a one-standard-deviation shock to σ_ϵ at $t = 0$ (equivalent to a 10-percent increase in $\sigma_{\omega,t}$), plotted as percent deviations from long-run averages under each regime. The continuous-blue curves are for the DRR, the dashed-red curves are for the ATR, and the dotted-black curves are for the STR. The responses of all variables are qualitatively similar across the three regimes but significantly smoother under the DRR, with the exception of the consumption response, which differs both quantitatively and qualitatively in the DRR. In all three regimes, the risk shock increases the probability of default on impact, and thus increases efp, and as the risk shock fades monotonically the rise in efp also reverses monotonically. The efp rises to about 0.6% on impact under the STR and the ATR, while in the DRR it only rises to 0.13%, illustrating again the ability of the DRR to respond to risk shocks with the financial subsidy, and the relevance of Tinbergen rule: Separate financial and monetary rules are much more effective at stabilizing prices and the spreads than the ATR and STR regimes. Inflation rises on impact in all three regimes, because although aggregate demand excluding monitoring costs falls, total demand inclusive of monitoring costs rises and exerts upward pressure on prices.

The higher π and efp trigger different policy responses determined by the rules of each regime. Inflation rises significantly more in the ATR regime than in the other two, yet the impact increases in R are similar. The STR and the ATR yield nearly the same initial interest rate, because the former has a higher a_π but experiences a smaller rise in π. The interest rate rises more in these regimes than in the DRR, reflecting their tight money-tight credit nature. Under the STR, the inflation elasticity is higher than in the DRR, and hence with a similar impact increase in π it yields a higher R. Under the ATR, the inflation elasticity is similar than in the DRR but the impact increase in π is larger, and even tough the increase in the efp contributes to lower R, the spread elasticity is not big enough to prevent the interest rate from rising more than with the DRR.

In the DRR, the financial subsidy displays the same monotonic mean reversion as efp in about 30 quarters. Interestingly, the nearly identical efp responses under the STR and the ATR indicates that, although the interest rate responds to the credit spread in the latter but not in the former, the resulting equilibrium credit spreads do not differ much. This is again showing the relevance of Tinbergen rule: the ATR does a poor job at altering efp because it does not use a separate instrument. In contrast, the financial subsidy results in significantly lower spreads with the DRR.

Figure 4: Impulse Response Functions to Risk Shocks

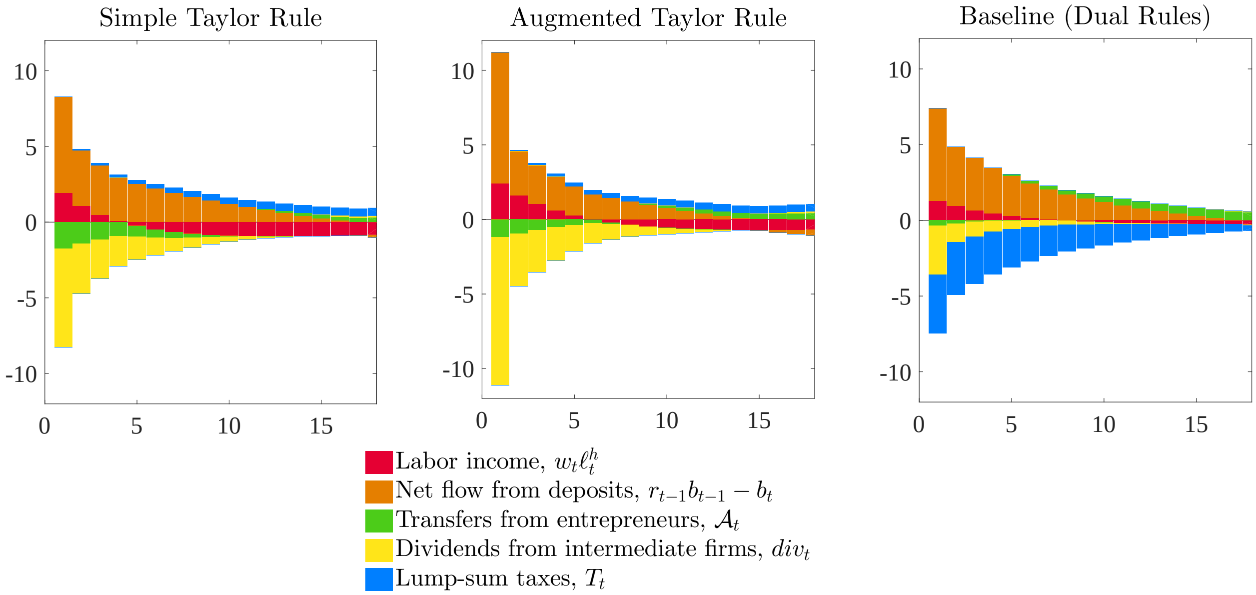


Note: Responses to a one-standard deviation shock to $\sigma_{\omega,t}$. The y axis is measured as percent deviations from the long-run averages of each policy regime, the x axis are quarters.

In all three regimes, higher spreads, combined with the investment adjustment costs, produce a gradual but large decline in investment. This in turn produces gradual declines in the capital stock, aggregate demand, and inflation. The fluctuations of these variables, along with those of the efp and the short-term interest rate, are significantly smoother under the DRR than under the other two regimes, and those under the ATR are in turn smaller than with the STR. This is due to the higher spreads under the ATR and STR, both of which lack a separate instrument to respond to the effect of risk shocks on credit spreads. Note that interest rates between the 4th and 20th quarter are in fact higher under the DRR, but since this regime has the financial subsidy as a separate instrument, it yields lower spreads and can thus smooth investment and aggregate demand more effectively, again indicating the relevance of Tinbergen rule.

Consumption is smoother and displays very different dynamics under the DRR than in the other regimes. It falls slightly on impact and then continues to decline slowly down to a through of about -0.2% below its long-run average by the 40th quarter. In contrast, in the other regimes consumption rises to a peak about 0.4% above their long-run averages by the 8th quarter, and then falls sharply and steadily for 26 quarters down to a through about 0.65 below their long run averages. These different consumption dynamics are due to the increase in lump-sum taxes needed to pay for the financial subsidy that smooths the effects of the risk shock on spreads and investment. As we show below, this subsidy reduces the size of the declines in the income households obtain via dividends and transfers from entrepreneurs, partially offsetting the higher lump-sum taxes. After

Figure 5: Decomposition of Income Disposable for Consumption



Note: The graphs display the different components of income disposable for consumption in the households' budget constraint, equation (2.2). The y axis shows weighted deviations from the long-run averages under each regime, such that the bars add up to the values shown in the consumption impulse response functions. The x axis are quarters.

the 20th quarter, consumption becomes higher in the DRR than in the other regimes, as the financial subsidy and lump-sum taxes fall. In the long-run, consumption reaches a level slightly higher in the DRR than in the two regimes, as shown in Table 4.

The different consumption dynamics of the DRR reflect differences in the evolution of disposable income and its components. Figure 5 shows the contributions of these components to the consumption impulse response functions. The plots show the contributions of labor income, $w_t\ell_t$, net resources from deposits, $r_{t-1}b_{t-1} - b_t$, transfers from entrepreneurs, $\mathcal{A}_t$, dividends, div_t, and lump-sum taxes, Υ_t. On impact, div_t falls more under the ATR than in the other regimes but yet consumption is actually higher in this regime. This happens largely because faced with reduced dividend income, households reduce deposits sharply (i.e. $r_{t-1}b_{t-1} - b_t$ rises). After the impact effect, the components of income display a similar evolution under the ATR and STR regime.

The key finding from Figure 5 is that it shows how the DRR smooths disposable income, and hence yields a consumption path with higher welfare than the other regimes. By producing smaller hikes in efp that yield smaller efficiency losses and smaller increases in monitoring costs, the DRR provides implicit insurance for disposable income against risk shocks that is more effective than under the other regimes. The components of income fluctuate less on impact, and their changes are spread more evenly over the first 10 quarters. Moreover, while lump-sum taxes reduce disposable income much more than under the ATR and STR, since they are needed to pay the high financial subsidy of the early periods, the smaller associated efficiency losses and monitoring costs produce a much smaller fall in dividends under the DRR than in the other two regimes. In fact, on impact the combined loss of disposable income due to dividends and taxes is much smaller than under the ATR and STR. This implies also that resources drawn from deposits need to increase less on impact and are more evenly allocated intertemporally. This is also possible because of the temporarily higher interest rates from the 4th to the 20th quarter under the DRR. Since inflation rates are not that different from those under the ATR, real interest rates are higher in the DRR, generating higher returns on deposits and incentives to reallocate them intertemporally.

These results show that, even though the direct effect of the financial policy instrument is on the lender's participation constraint, it has nontrivial effects on the demand and supply sides of the economy and on the dynamics of disposable income. In computing the optimized elasticities of the DRR, the financial authority trades off the effects of $\tau_{f,t}$ as it tilts the consumption profile over time, reducing consumption initially but increasing it steadily in future periods. The last plot of Figure 4 shows that period utility has a similar response on impact in all three regimes, then from the 2nd to the 20th period it is lower with the DRR, but after that it is higher under the DRR and converges to a higher long-run average (see Table 4).

In summary, the results reported in this Section show that the implications of violating Tinbergen rule in the design of monetary and financial policies are quantitatively large. A regime with dual rules for monetary and financial policies yields higher welfare, smaller efficiency losses, and smoother fluctuations in response to risk shocks than regimes in which the monetary policy rule is augmented with the credit spread or follows an STR. The results also show, however, that spillovers from changes in the policy instrument of one authority to the target variable of the other are large, raising the potential for strategic interaction. The DRR sidesteps this issue, because it is equivalent to a regime in which the two authorities choose policy rule elasticities so as to maximize welfare as a common payoff. In the next Section we relax this assumption and quantify the effects of strategic interaction.

4.3 Strategic Interaction

This Section analyzes the effects of strategic interaction. The payoff functions of are denoted by L_m for $m \in \{CB, F\}$, where CB is the central bank and F is the financial authority. The payoff functions are in the class of quadratic loss functions, and in particular they are defined by the sum of the variances of each authority's instrument and target: $L_{CB} = -\left[\mathrm{Var}\left(\pi_t\right) + \mathrm{Var}\left(R_t\right)\right]$ and $L_F = -\left[\mathrm{Var}\left(r_t^k/r_t\right) + \mathrm{Var}\left(\tau_{f,t}\right)\right]$, where $\mathrm{Var}\left(x_t\right)$ is the unconditional variance of x_t in the stochastic steady state. We also compare results vis-à-vis a case in which both authorities share a common payoff function given by the household's expected lifetime utility function (i.e. social welfare): $L_m = \mathbb{W}\left(a_\pi, a_{rr}; \varrho\right)$ for $m \in \{CB, F\}$. Sharing a common payoff precludes strategic interaction, but we use this scenario to provide intuition about some of the results.

The above payoff functions are in line with those used by Williams (2010) and Angelini *et al.* (2014), which include the variability of instruments and targets. This class of payoff functions are viewed as capturing different sources of economic distortions. Using a second-order approximation to the utility function in a New Keynesian model, Woodford (2003) shows that the inflation term accounts for the inefficient fluctuations caused by price dispersion under sticky prices. Woodford also shows that an output-gap term appears in the loss function, but quantitatively its weight is fairly small. Cúrdia and Woodford (2010) and De Paoli and Paustian (2017) show that financial frictions generate extra terms that reflect resource misallocation caused by suboptimal credit supply.[17] In addition, large changes in asset prices can induce financial instability, which in turn has welfare costs and favors reducing the volatility of policy instruments (see Rudebusch, 2006).[18]

Following the above arguments, we included $\text{Var}(\pi_t)$ in L_{CB} to be consistent with the view that the monetary authority sees higher inflation variability as painful, as part of an inflation targeting strategy. For the financial authority, including $\text{Var}\left(r_t^k/r_t\right)$ in L_F is consistent with the aim to use financial policy to counter financial instability (e.g. IMF, 2013; Galati and Moessner, 2013) and with the literature on quantitative financial policy analysis using DSGE models. In this literature, financial policy generally targets the credit-output ratio, credit growth, or the volatility of credit spreads (see Angelini *et al.*, 2014; Bodenstein *et al.*, 2014; De Paoli and Paustian, 2017). As we showed earlier, in our model targeting efp is desirable because of its effects on monitoring costs and efficiency losses. Moreover, as noted later in this Section, targeting credit is equivalent to targeting efp up to a first-order approximation.

To conduct the quantitative analysis of strategic interaction, we construct reaction functions that return the payoff-maximizing choice of one authority's rule elasticity for a given value of the other authority' elasticity.[19] Denote the reaction function of the monetary authority $a_\pi^*(a_{rr})$ and that of the financial authority $a_{rr}^*(a_\pi)$, both defined over discrete grids of values of elasticities $A_\pi = \left\{a_\pi^1, a_\pi^2, ..., a_\pi^M\right\}$ and $A_{rr} = \left\{a_{rr}^1, a_{rr}^2, ..., a_{rr}^N\right\}$ with M and N elements, respectively. Hence, the strategy space is defined by the $M \times N$ pairs of rule elasticities. Also, denote as $\varrho(a_{rr}, a_\pi)$ the equilibrium allocations and prices for a given set of parameter values (e.g. the baseline calibration) and a particular pair of elasticities (a_{rr}, a_π). The reaction functions are defined as follows:

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

In these definitions, the authorities maximize the *unconditional* expectation of their payoff, which corresponds to its mean in the stochastic steady state.

A Nash equilibrium of a non-cooperative game between the two authorities is defined by the intersection of the reaction curves: $N = \left\{\left(a_\pi^N, a_{rr}^N\right) : a_\pi^N = a_\pi^*(a_{rr}^N), a_{rr}^N = a_{rr}^*(a_\pi^N)\right\}$. A cooperative equilibrium is defined by a pair of policy elasticities that maximizes a linear combination of L_{CB} and L_F, with a weight of φ on the former, subject to the constraints that the equilibrium must

[17] De Paoli and Paustian (2017) show that the credit spread appears in a linear-quadratic approximation of the utility function in a model with credit constraints, and hence represents a source of welfare costs. Cúrdia and Woodford (2010) show that allocation inefficiencies coming from financial frictions can be represented by either changes in credit spreads or in aggregate credit.

[18] Rudebusch (2006) argues that policymakers are keen to reduce the volatility of their instruments for two reasons. First, uncertainty, which leads authorities to act with caution acknowledging their partial understanding of the sources of shocks and/or the structure of the economy. Second, small changes in instruments are useful as a lever to manage agents' expectations, so that forward-looking agents can read those small changes as news about future policy.

[19] We assume commitment to the log-linear policy rules and abstract from studying strategic interaction under discretion (see also De Paoli and Paustian, 2017; Bodenstein *et al.*, 2014).

be a Pareto improvement over the Nash equilibrium and the arguments of the loss functions must correspond to equilibrium allocations and prices for the corresponding elasticity pair:

$$C(\varphi) = \left\{ \begin{array}{c} \left(a_{\pi}^{C}, a_{rr}^{C}\right) \;\in \arg\max_{a_{\pi}^{s}, a_{rr}^{s'} \in A_{\pi} \times A_{rr}} \; L_{coop} = \mathrm{E}\left\{\varphi L_{CB} + (1-\varphi) L_F\right\} \\ \\ \text{s.t.} \quad \varrho(a_{\pi}^{s}, a_{rr}^{s'}), \quad \mathrm{E}[L_{CB}] \geq \mathrm{E}^N[L_{CB}], \quad \& \quad \mathrm{E}[L_F] \geq \mathrm{E}^N[L_F] \end{array} \right\},$$

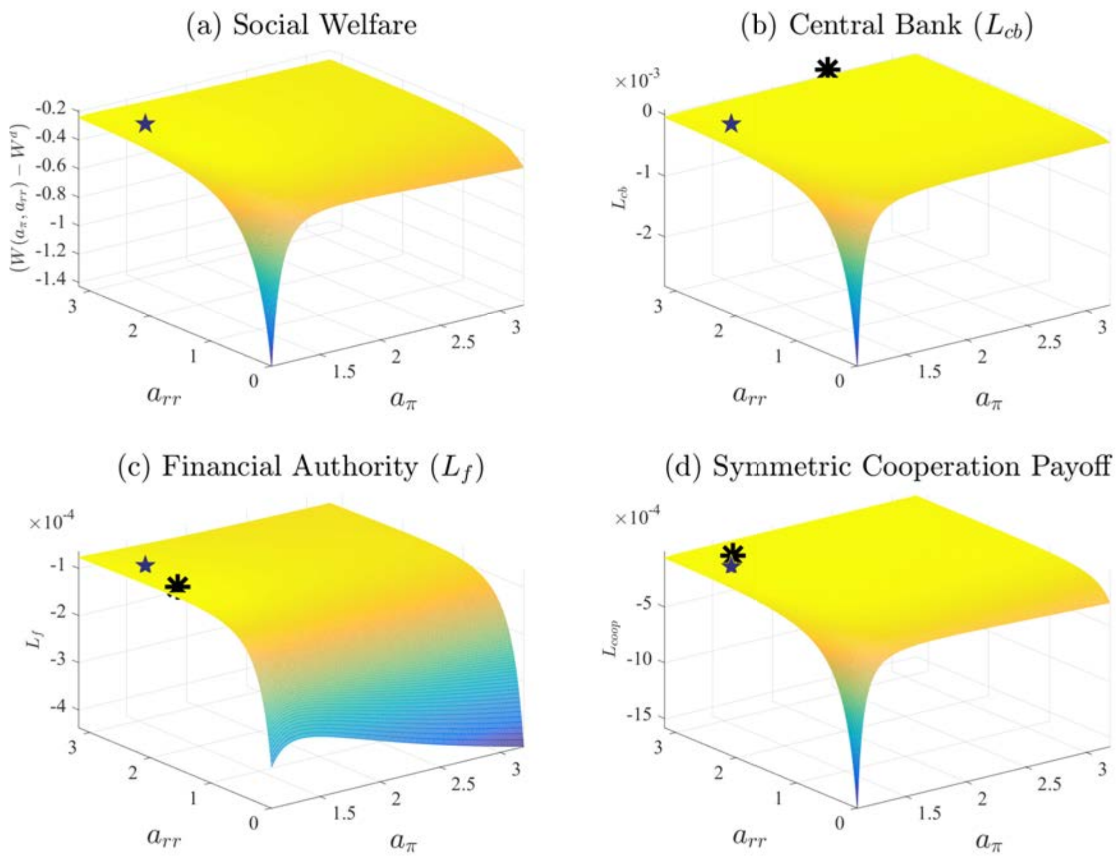
where $\mathrm{E}^N[L_{CB}]$ and $\mathrm{E}^N[L_F]$ are the payoffs of the central bank and the financial authority in the Nash equilibrium. There can be more than one cooperative equilibrium depending on the value of φ (i.e. the set of cooperative equilibria corresponds to the core of the contract curve of the two authorities). For simplicity, we study the symmetric cooperative equilibrium ($\varphi = 1/2$) and one with the value of φ such that the cooperative equilibrium yields the highest social welfare, denoted φ^*. We also compute Stackelberg equilibrium solutions with either the monetary or the financial authority as leaders. When the monetary (financial) authority is the leader, we compute the value of a_π (a_{rr}) that maximizes L_{CB} (L_F) along the financial (monetary) authority's reaction function.

Figure 6 shows four surface plots of different payoff functions for the elasticities in the strategy space. Plot (a) shows social welfare in terms of welfare costs relative to the deterministic steady state, (b) shows L_{CB}, (c) shows L_F, and (d) shows the symmetric cooperative payoff. The blue star in plot (a) identifies the elasticity pair that maximizes welfare, and the blue stars in plots (b)-(d) identify the location of that same elasticity pair in L_{CB}, L_F, and the symmetric cooperative payoff. The black asterisks identify the elasticity pairs that maximize each payoff function (for (b) and (c) these are the bliss points that maximize each authority's payoff unconditionally). All of these payoffs are single peaked, and more importantly, the bliss points of the monetary and financial authorities differ from each other and also differ from the welfare-maximizing and cooperative outcomes. These differences reflect the conflict of objectives of the two authorities and their incentives for acting strategically.

By construction, the pair of elasticities that maximizes welfare in plot (a) matches the "Best Policy" scenario under the DRR (i.e. the optimized elasticity pair). As noted earlier, the elasticities in the Best Policy case are $(a_{\pi}^{\star}, a_{rr}^{\star}) = (1.27, 2.43)$. It is straightforward to see that this Best Policy outcome is also the cooperative equilibrium of a game in which both authorities share welfare as a common payoff, for any value of φ.

Figure 7 displays the reaction functions of the central bank (red-dashed curve) and the financial authority (blue-solid curve) and the equilibria of the various games: Cooperative with $\varphi = 0.5$ (blue rhombus), Nash (pink dot), and Stackelberg with CB (F) as leader (green and transparent squares, respectively). The plots also identify the locations of each authority's bliss point (black asterisks) and of the Best Policy elasticity pair (blue star).

Figure 6: Payoffs and Policy Rule Elasticities



Note: The blue stars in each figure show the point that maximizes welfare in Plot (a). The black asterisks show the maximum point for each of the corresponding plots.

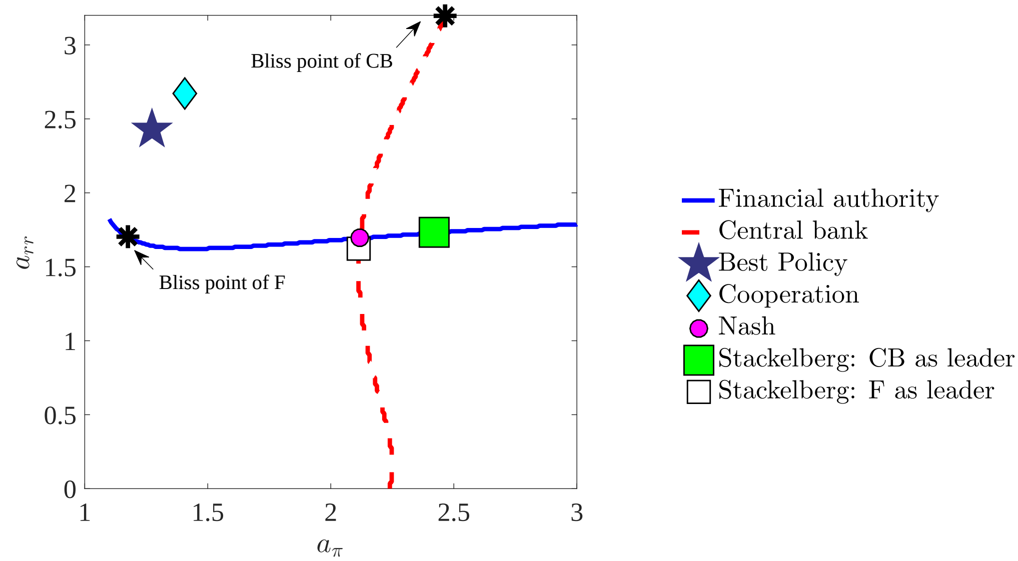
The two reaction curves are convex and change slope, reflecting the incentives for strategic interaction. In the financial authority's reaction curve, for $a_\pi < 1.5$, $a^*_{rr}(a_\pi)$ falls slightly as a_π rises, while the opposite happens for $a_\pi \geq 1.5$. Hence, the financial authority shifts from treating the elasticities as strategic complements to treating them as strategic substitutes.[20] The monetary authority's reaction curve has analogous features but with stronger curvature. For $a_{rr} \geq 1.7$, $a^*_\pi(a_{rr})$ rises as a_{rr} rises, so the elasticities are seen as strategic substitutes, but for most values in the interval $a_{rr} < 1.77$, $a^*_\pi(a_{rr})$ falls as a_{rr} rises, so the elasticities are treated as strategic complements.[21]

The above features of the reaction curves can be rationalized with the diagrammatic analysis of Section 3. The relative magnitude of the shifts in credit, investment, and aggregate demand induced by one policy v. another depend on the relative values of the elasticities. For instance, the shift from strategic complements to strategic substitutes in the monetary authority's reaction curve

[20]The change would be from substitutes to complements considering only the slope of the reaction curve, but recall that lower a_{rr} means that the financial subsidy increases by less as efp rises, and thus lowering a_{rr} when a_π rises means tightening financial policy when monetary policy tightens. Hence, in terms of strategic interaction, the two policies are strategic complements (substitutes) if a_{rr} falls (rises) when a_π rises, or if a_π falls (rises) when a_{rr} rises.

[21]For a_{rr} very close to 0, $a^*_\pi(a_{rr})$ is negligibly upward slopping but this can be due to numerical approximation.

Figure 7: Reaction Curves and Equilibrium Outcomes



occurs because, at low a_{rr}, τ_f does not rise as needed to prop up aggregate demand in response to a risk shock, thus making it optimal for the central bank to lower a_π as a_{rr} rises. For $a_{rr} \geq 1.7$, the situation reverses. Now the monetary authority finds that the financial subsidy props up demand too much and thus aims to increase a_π as a_{rr} rises. A similar argument explains the shift from strategic complements to substitutes in the financial authority's reaction curve.

Qualitatively, the relative location of the equilibria in Figure 7 is consistent with standard results when coordination failure is present: The cooperative outcome is in between the two bliss points (connected by a contract curve not shown in the Figure), and the Nash equilibrium differs sharply from the cooperative equilibrium. Interestingly, the Stackelberg equilibrium when the financial authority leads is very close to the Nash outcome, and not too different from the Stackelberg equilibrium with the monetary authority as leader.

Table 5 compares the Nash and cooperative equilibria against the Best Policy DRR. Nash has a higher a_π than the two cooperative equilibria and the DRR outcome (2.12 v. 1.41, 1.33 and 1.27, respectively). Nash also has a lower a_{rr} than in the cooperative and DRR equilibria (1.69 v. 2.67, 2.1 and 2.43, respectively). Hence, relative to the those equilibria, the Nash equilibrium is a tight money-tight credit regime. Comparing cooperative equilibria v. the DRR, the former are still tight-money regimes, but the symmetric cooperative equilibrium is a loose-credit regime (the financial subsidy rises too much when the spread is above target). The welfare-maximizing cooperative equilibrium, however, is a tight money-tight credit regime compared with the DRR.

In terms of welfare, Nash is a "third-best" outcome, in the sense that it is inferior to both the Best Policy regime and the cooperative outcomes. The gains from policy coordination are sizable: Relative to the DRR, the Nash equilibrium implies a welfare loss of 30 basis points in the ce welfare measure. In contrast, the cooperative equilibrium with $\varphi^* = 0.23$ implies a loss of only 1 basis point. Hence, the cost of coordination failure is roughly 29 basis points (or 26 if we compare v. the symmetric cooperative equilibrium). It is worth noting that the welfare-maximizing cooperative outcome weighs the financial authority more (77 instead of 50%) as the planner compensates for the large cost of risk shocks due to efficiency losses and monitoring costs as efp rises.

A comparison of Tables 3 and 5 adds to the previous result noting that ATR dominates STR but both are inferior to DRR by showing that the Nash and Cooperative equilibria also dominate the ATR and STR regimes. Hence, strategic interaction of the monetary and financial authorities is preferable to a STR regime and to a regime in which the Taylor rule is augmented with a response to financial conditions. In other words, designing a regime of monetary and financial policies that complies with Tinbergen rule is relatively more important than dealing with strategic interaction.

Table 5: Strategic Interaction Results

Regime x v. regime y	Param. values of x		ce v.	Decomp. of ce into mean and SD eff.		
	a_π	a_{rr}	DRR	Full ce	Mean eff.	SD eff.
Nash	2.12	1.69	30bp.	4.15%	4.06%	0.09%
Cooperative ($\varphi = 0.5$)	1.41	2.67	4bp.	3.89%	3.80%	0.09%
Cooperative ($\varphi^* = 0.23$)	1.33	2.10	1bp.	3.85%	3.76%	0.09%
DRR (Best Policy)	1.27	2.43		3.85%	3.75%	0.10%

Note: ce corresponds to the consumption equivalent welfare measure defined in equation (2.19).

In Appendix B.1, we study reaction curves for cases in which either welfare or the sum of L_{CB} and L_F are used as a common payoff. In both cases, the financial authority displays the same shift from strategic complements to substitutes in policy elasticities, albeit with more curvature than in Figure 7. The monetary authority's reaction curve is always downward sloping when welfare is the common payoff, so it always treats the elasticities as strategic complements. Interestingly, when the sum of L_{CB} and L_F is the common payoff, the monetary authority's reaction curve shifts from strategic substitutes to complements as a_{rr} increases, with an inflection point near $a_{rr} = 0.25$. Regardless of the shape of the common payoff, the Cooperative, Nash, and Stackelberg equilibria coincide, because there is no coordination failure. What changes, however, is that when social welfare is the payoff, the cooperative and noncooperative equilibria also match the DRR Best Policy outcome, which is not the case in general for other common payoff functions.

4.4 Extensions & robustness

We examine below the robustness of our findings to changes in key features of the model, and the implications of important extensions, such as adding the output gap to monetary rules, introducing shocks to government expenditures, TFP and price markups, and modifying the targets of the financial policy rule. Overall, the qualitative features of our main findings continue to hold, with the exception that with only TFP or government expenditure shocks financial policy has negligible effects. Full details are provided in Sections B.1-B.8 of the Appendix.

4.4.1 Price stickiness & financial sector parameters

Appendix B.3 reports the results for four parameterizations: (a) *"stickier" prices* ($\vartheta = 0.85$ v. 0.74 in the baseline), so that firms reset prices every two years on average rather than once a year, (b) *larger monitoring costs* ($\mu = 0.30$ v. 0.12 in the baseline), which increases monitoring costs to nearly a third of the entrepreneurs' gross returns, (c) *riskier entrepreneurs* ($\bar{\sigma}_\omega = 0.40$ v. 0.27 in the baseline), which nearly doubles the average variability of the entrepreneurs' profits, and (d) *zero steady-state financial subsidy* ($\tau_f = 0$ v. 0.96% in the baseline), which allows costly state verification to distort the deterministic stationary equilibrium and makes the financial rule more likely to fluctuate between subsidies and taxes. For each scenario, we re-compute the optimized rule elasticities that minimize welfare costs under the STR, ATR, and DRR regimes, and solve for the cooperative and non-cooperative equilibria.

Tinbergen rule is quantitatively relevant in all four cases. The DRR delivers welfare gains of roughly 1% and 2% relative to ATR and STR, respectively. Strategic interaction delivers results that echo the baseline findings, with some variations worth noting. For instance, as in the baseline, the monetary reaction function shifts from strategic complements to substitutes in the choice of a_π as a_{rr} changes when $\bar{\sigma}_\omega = 0.40$ and $\tau_f = 0$, while it displays only strategic complementarity when $\vartheta = 0.85$ and $\mu = 0.30$. In contrast, the financial reaction curves always display a shift from strategic complements to substitutes as in the baseline. In all cases, the Nash equilibrium yields a tight-money, tight-credit regime with respect to the best-policy and cooperative outcomes. In turn, the latter is a tight-money regime with respect to the best policy regime when $\vartheta = 0.85$, $\bar{\sigma}_\omega = 0.40$, and $\tau_f = 0$, but it is a loose-money regime when $\mu = 0.30$. The credit policy of the cooperative equilibrium does not display a clear pattern with respect to the best policy case. It is a tight-credit regime when $\tau_f = 0$, slightly tighter when $\vartheta = 0.85$, and looser when $\mu = 0.30$ and $\bar{\sigma}_\omega = 0.40$.

In case (a), with a higher degree of price stickiness, the central bank responds more aggressively, particularly when the financial authority is relatively passive (i.e. for low a_{rr}). As documented in Appendix B.3, the best response of the monetary rule elasticity features larger complementarities with the financial rule elasticity, so that monetary authority finds optimal to increase a_π more aggressively than in the baseline as a_{rr} decreases, and more so when a_{rr} is low.

In cases (b) and (c), stronger financial frictions increase the variability of efp and π, which implies that the policy rules of all three regimes have to respond to larger deviations from their targets. If the variance of efp increases more than that of π, we should expect a more aggressive reaction by the financial authority, reflected in an upward shift of its reaction function relative to the baseline (i.e. a shift towards easier credit policy). In contrast, if the variance of π rises more than that of efp, we should observe a rightward shift in the monetary reaction function relative to the baseline (i.e. a shift towards tighter monetary policy). In Appendix B.3, we show that when $\mu = 0.30$, efp becomes much more volatile than π, and thus we find a shift towards easier credit policy by the financial authority in comparison to the baseline, while monetary policy increases its strategic complementarity with financial policy. As a result, the policy regime is loose-money, loose-credit v. the baseline. In the case with $\bar{\sigma}_\omega = 0.40$, the variances of efp and π increase in a similar manner, and so we find just a slight shift towards a regime of tighter-money, tighter-credit with respect to the baseline, with only moderate shifts in the reaction curves.

In case (d) (i.e. removing the steady-state financial subsidy), Nash yields a slightly tighter financial policy rule (lower a_{rr}) and a much tighter monetary policy rule (higher a_π) than in the baseline Nash case and in the cooperative and best-policy equilibria with $\tau_f = 0$. The curvature of the reaction curves is similar to that in the baseline, but the monetary (financial) authority's reaction curve shifts rightward (downward). Hence, the policy spillovers reflected in the curvature of reaction curves are similar with and without the steady-state financial subsidy, but the optimal elasticity of one authority's rule changes when the other authority's elasticity is set to its lowest level.[22]

The monetary authority sets a_π higher when $a_{rr} = 0$ in the case with $\tau_f = 0$ than in the baseline, because with both $a_{rr} = 0$ and $\tau_f = 0$ there is no financial policy. Since in the neighborhood of $a_{rr} = 0$ the two policy rule elasticities are strategic complements, when financial policy is removed the central bank cannot benefit from the effect of the financial policy response to risk shocks on inflation, and thus it chooses a higher Taylor rule elasticity. The financial reaction curve shifts because of an analogous effect. The financial authority sets a_{rr} lower (i.e. tightens financial policy) when a_π is close to 1 in the case with $\tau_f = 0$ than in the baseline, because when $a_\pi \to 1$ the monetary policy reacts passively to inflation deviations. Since in the neighborhood of $a_\pi \to 1$ the two elasticities are strategic complements, when the monetary policy becomes less responsive to inflation, the financial authority cannot benefit from the effect of the monetary policy response to risk shocks on efp, and thus it responds more aggressively by choosing a lower a_{rr}.

4.4.2 Monetary rules responding to output gap

Appendix B.4 documents results showing that, using monetary rules that include the output gap with an elasticity a_y, setting $a_y = 0$ always yields the lowest welfare costs. Hence, our quantitative findings on Tinbergen rule are identical to those obtained with the baseline model. This finding holds for two specifications of output: one consistent with the resource constraint (2.17), so that output equals aggregate demand plus monitoring costs ($y_t = c_t + c_t^e + i_t + g + \mu G(\bar{\omega}_t) r_t^k q_{t-1} k_{t-1}$), and one that matches the definition of output in the national accounts, so that output equals aggregate demand only ($\tilde{y}_t = y_t - \mu G(\bar{\omega}_t) r_t^k q_{t-1} k_{t-1}$). To find the optimized elasticities, we perform a two-dimensional search over a_π and a_y for the STR regime, and three-dimensional searches over a_π, $\breve{a}_{rr}$, and a_y for the ATR regime and over a_π, a_{rr}, and a_y for the DRR regime.

The result that welfare costs are minimized with $a_y = 0$ in the STR regime may seem puzzling, because one may think that by responding to the output gap the central bank could address some of the real effects caused by efp fluctuations. This is akin to replacing the spreads in the ATR regime with the output gap. The question is then whether augmenting the STR rule with the output gap could do as well as the ATR rule. In the model we proposed, the answer is no, since setting $a_y = 0$ yields the smallest welfare cost in the STR regime. This result echoes Schmitt-Grohé and

[22] Setting $\tau_f = 0$ also reduces the long-run investment- and capital-output ratios because of the efficiency losses due to costly monitoring, as we explained earlier (see Table 2), but with the local solution method these effects do not alter significantly the cylical tradeoffs that determine the curvature of reaction curves.

Uribe (2007), who find that interest-rate rules with $a_y > 0$ can lead to large welfare losses, because inflation volatility tends to increase with $a_y > 0$ and this makes the inefficiencies due to price dispersion larger. The answer would be different if the central bank does not focus on welfare but instead minimizes a loss function that includes the variance of the output gap. In this case, the central bank may find optimal to set $a_y > 0$, even if social welfare is lower. See Appendix B.4 for an analysis of the effects of varying a_y on output variability.

4.4.3 Determinants of welfare costs

The results of robustness experiments showing how changes in parameters values affect the welfare analysis are detailed in Appendix B.5. We vary the habit parameter h in the interval $[0, 0.95]$, the monitoring costs parameter μ in the interval $[0, 0.50]$, and the Calvo pricing parameter ϑ in the interval $[0, 0.90]$. These changes are introduced one at a time, keeping the rest of the parameters at their baseline calibration values.

The total welfare cost of risk shocks, ce, is always large and varies non-linearly in all these experiments, with regions in which it is nearly invariant to parameter variations and regions in which it rises sharply. ce rises sharply as μ starts to rise from zero, reaching roughly 4%, 5%, and 6% when $\mu = 0.05$ in the DRR, ATR, and STR regimes respectively. As μ rises above 0.05, ce increases at a much slower pace and eventually becomes slightly decreasing in μ. The opposite is observed for h and ϑ. The value of ce is nearly unchanged as these parameters rise from zero, until eventually ce becomes a very steep function of both. For ϑ, there is an intermediate region in which ce is slightly negatively-sloped, but as ϑ rises above 0.8 the value of ce increases rapidly with ϑ. The highest costs are roughly 5%, 7% and 8% when ϑ is about 0.9 in the DRR, ATR, and STR regimes respectively. For h, ce becomes a steep, increasing function of h for $h > 0.7$, with vertical asymptotes as h approaches 1. For $h = 0.9$ (higher than the 0.85 baseline value), the costs reach about 5%, 7.5%, and 10% in the DRR, ATR, and STR regimes respectively. This high sensitivity of welfare costs to high degrees of habit formation is in line with Campbell (1999), who argues that consumers with strong habits can be viewed as less able to make short-term adjustments in consumption to adjust to shocks, which implies that fluctuations are costlier.

DRR always dominates ATR and STR, and this is because it yields consumption processes with higher averages and lower variances. For instance, in the baseline case, mean consumption under DRR is 1.5% and 2.2% higher than under ATR and STR, respectively. In turn, the standard deviation of consumption under ATR (STR) is 2.5 (3.1) times higher than under DRR.

Appendix B.5 also provides a detailed analysis showing that, in line with the baseline results, the large welfare costs of risk shocks in all the experiments are due to changes in the long-run averages of consumption and lifetime utility relative to the deterministic steady state. In turn, costly state verficiation, via its effect on mean efp and resources used up in monitoring costs account for a large fraction of welfare costs. The contribution of cyclical volatility is small and comparable to the negligible costs of business cycles found by Lucas (1987). Across all three policy regimes and all parameter variations considered, the overall welfare cost of risk shocks ranges between 1.54% and 7.95%, and the *mean effect* accounts for at least 90% of these costs. The cost of business cycles ranges between 0.01% and 0.68%.

4.4.4 Introducing additional shocks

We study next the implications of adding shocks to government expenditures, TFP, and price markups (see Appendix B.6 for details). First we study replacing risk shocks with one of the other shocks one at a time. In sharp contrast with the baseline results, using the ATR is suboptimal for all of these alternative shocks (i.e. the welfare costs are minimized when $\breve{a}_{rr} = 0$). In the model, if business cycles are driven by fiscal, TFP, or markup shocks, the central bank does best by setting the interest rate focusing only on inflation targeting, ignoring efp. Hence, for these alternative shocks STR and ATR are equivalent, so we refer to them jointly as the STR/ATR regime.

For the DRR regime, we find again that for government expenditure and TFP shocks there is no role for financial policy in the model, since the optimized elasticity is $a_{rr} = 0$. Hence, for these shocks DRR is also equivalent to the STR. A Taylor rule with an inflation elasticity of about 2.3 (2) for government expenditure (TFP) shocks yields the best welfare outcome. For markup shocks, however, the optimized a_{rr} is positive, and hence the DRR regime differs from the STR/ATR regime. In the STR/ATR regime, the optimized elasticity of the Taylor rule is $a_{\pi} = 2.1$ (and $\breve{a}_{rr} = 0$), while in the DRR regime the optimized elasticities of the separate rules are $a_{\pi} = 2.2$ and $a_{rr} = 2.4$. Thus, monetary policy is about as tight in the STR/ATR as in the DRR regime, but financial policy is much tighter. Tinbergen rule is again quantitatively relevant: welfare is 1% higher under DRR than under STR/ATR (i.e. welfare costs of markup shocks are roughly 1% smaller).

The irrelevance of financial policy with either TFP or government expenditure shocks follows from differences in the way the shocks interact with the financial accelerator. Risk shocks have first-order effects on efp, and the resulting changes in the variability and long-run average of efp have strong effects on allocations, prices and welfare via the financial accelerator. Hence, it is natural that financial policy is relevant with risk shocks. For the other shocks, however, we need to examine further how they interact with the financial sector in order to understand why financial policy is relevant with markup shocks but not with TFP and government expenditure shocks.

One reason for financial policy to be weaker with the alternative shocks is methodological: Perturbation methods used to solve New Keynesian models do not capture fully the non-linear effects of the financial accelerator. The external finance premium is a convex function of net worth, and to the extent that shocks cause large changes in net worth the local methods underestimate efp and its real effects. This is less of a problem for risk shocks because they have first-order effects on efp.

There are also features of the model's financial transmission mechanism that weaken the interaction of the financial accelerator with TFP and government expenditure shocks but not with markup shocks. Appendix B.6 provides impulse response functions for positive shocks to government expenditures and markups and a negative TFP shock. The results explain why financial transmission is weak for shocks to government expenditures and TFP. These shocks result in higher inflation and declines in consumption, investment and the price of capital.[23] The shock to govern-

[23] Shocks to government expenditures have opposing effects on inflation. On the one hand, higher government expenditures increase aggregate demand and hence push for higher inflation. On the other hand, since agents in the model are Ricardian, government expenditures crowd out private expenditures, weakening aggregate demand. Inflation still rises with government expenditures, but by less than a one-to-one effect.

ment expenditures has a positive effect on output, while the other two have a negative effect. But for financial transmission the key difference across these shocks is in the response of input producers and their effect on credit spreads. With shocks to government expenditures or TFP, input producers increase demand for labor and capital, as they aim to meet the excess demand in the final good market. As a result, the rental rate of capital increases, which increases capital returns and the entrepreneurs' net worth, counteracting the downward pressure on these variables that the fall in the price of capital exerted, and thus weakening the financial accelerator. efp rises around 2 basis points after the shock to government spending and 5 basis point after the shock to TFP (8 and 20 basis points in annual terms, respectively), while investment falls 0.5% and 0.8% in each case.[24] In contrast, an increase in markups strengthens the monopolistic distortions affecting the inputs market, causing input producers to reduce their factor demands, so that wages and the rental rate of capital fall. The latter intensifies the fall in entrepreneurs' net worth, strengthening the financial accelerator. In this case, efp rises 10 basis points (40 in annual terms) under the STR/ATR policy, and investment and output fall 1.5% and 0.4%, respectively.

In the setup with markup shocks, when financial policy is active under the DRR, the initial rise in efp moderates to just 2 basis points (8 in annual terms), and investment and output fall only 0.9% and 0.3%. There is a short-term cost in consumption, however, due to the increase in lump-sum taxes to pay for the financial subsidy (see Section 4.2). Still, in the long-run consumption attains a higher mean under DRR than under the STR/ATR (about 2.2% higher) and welfare costs are 100 basis points lower. Examining strategic interaction, we found again that reaction curves are nonlinear and that the Nash equilibrium yields a tight-money, tight-credit regime, with a welfare cost 1.23 percentage points higher than with the Best Policy (DRR) outcome.

We consider next a scenario in which all four shocks enter the model. We calibrate the shocks following Christiano *et al.* (2014).[25] Our main results continue to hold. Tinbergen rule is again quantitatively relevant: Welfare in the STR regime is 254 basis points lower than in the DRR regime. In addition, the gains derived from coordinating financial and monetary policies are of the same order of magnitude as in the baseline case with only risk shocks. Welfare is 37 basis points higher under DRR than under Nash. The rationale behind these results is Christiano *et al.* (2014)'s finding that risk shocks are the most important source of output fluctuations. Therefore, adding other shocks to the model does not alter our findings much. See Appendix B.7 for further details.

Table 6 compares optimized elasticities and welfare costs for DRR, ATR, and STR with the four shocks, and the outcome of Nash and Cooperative equilibria against the DRR regime. The Table shows that Nash and STR are tight-money regimes in comparison to the DRR regime. In turn, ATR is a loose-money rule in comparison to the DRR regime, while the welfare-maximizing cooperative equilibrium has a similar inflation elasticity than the DRR regime. In turn, all of the regimes, with the exception of the symmetric cooperative equilibria, are tight-credit rules in comparison to the DRR regime.

[24]These numbers are consistent with results showing that the financial accelerator accounts for a small share of business cycles in standard BGG models with shocks to TFP or government expenditures.

[25]They included a larger set of shocks than these four, but these four contribute about 80% of the variance of output in their model.

Table 6: Comparison of Policy Regimes and Strategic Interaction with Multiple Shocks

Regime	Optimized Elasticities			ce v. DRR	Decomposition of ce		
	a_π	a_{rr}	$\breve{a}_{rr}$		Full ce	Mean eff.	SD eff.
Dual rules (Best Policy)	1.55	2.05	0	-	5.68%	5.20%	0.48%
Augmented Taylor rule	1.38	0	0.34	157bp	7.25%	6.55%	0.70%
Simple Taylor rule	1.78	0	0	254bp	8.22%	7.34%	0.88%
Nash	2.91	1.79	-	37bp	6.05%	5.55%	0.50%
Cooperative ($\varphi = 0.5$)	2.05	2.56	-	11bp	5.79%	5.39%	0.48%
Cooperative ($\varphi^* = 0.27$)	1.55	1.97	-	1bp	5.68%	5.20%	0.48%

Note: "Optimized Elasticities" are those from the sets used in constructing Figure 2 that produce the lowest welfare cost under each regime. ce v. DRR is the difference in ce under ATR or STR relative to DRR in basis points. "Full ce" is the welfare cost defined in equation (2.19). Full ce is decomposed into an effect due to changes in long-run averages ("Mean eff. Total") and an effect due to fluctuations ("SD eff."). Mean eff. Total is computed as in equation (2.19) but replacing $\mathbb{W}\left(a_\pi, a_{rr}; \varrho\right)$ with $\mathcal{U}\left(E[c], E[\ell^h], E[C]\right)/(1-\beta)$, where $E[c], E[\ell^h], E[C]$ are long-run averages under each policy regime. "Mean eff. Net" removes the long-run average of monitoring costs from the Mean eff. calculation, by treating monitoring costs as private consumption in the resource constraint.

4.4.5 Alternative financial policy rules

Two financial policy rules targeting variables other than spreads are equivalent, up to a first-order approximation, to the baseline rule. One rule targets leverage and the variability of entrepreneurs' profits, the other targets the ratio of debt to net worth and again the dispersion of profits. These rules yield the same impulse response functions as the baseline (see Appendix B.8 for details).

Using the optimality conditions of intermediaries, we can prove that the baseline financial rule in eq. (2.15) is equivalent, up to a first-order approximation, to a rule that sets the financial subsidy to respond to deviations of leverage and the standard-deviation of entrepreneurs' profits from their steady-state levels, with elasticities set to particular values. The alternative financial rule is:

$$1 + \tau_{f,t} = (1 + \tau_f) \times \left(\frac{x_t}{x}\right)^{a_x} \left(\frac{\sigma_{\omega,t}}{\bar{\sigma}_\omega}\right)^{a_\sigma}, \tag{4.2}$$

where $a_x, a_\sigma > 0$ are the elasticities with respect to leverage and the variability of profits. Intuitively, an increase in leverage or in the dispersion of profits raises the probability of default of entrepreneurs, and thus efp, and hence a rule that reacts to these variables is akin to one that targets efp. First-order equivalence is obtained by setting $a_b = \chi_x a_{rr}/(1+a_{rr})$ and $a_\sigma = \chi_\sigma a_{rr}/(1+a_{rr})$, where $\chi_x, \chi_\sigma > 0$ are reduced-form coefficients that depend on the model's parameters. [26]

[26] A first-order approximation to the first-order conditions of the optimal financial contract yields: $\widehat{\mathrm{efp}}_t + \hat{\tau}_{f,t} = \chi_x \hat{x}_t + \chi_\sigma \hat{\sigma}_{\omega,t}$. Combining this result with the first-order approximation of the baseline financial rule ($\hat{\tau}_{f,t} = a_{rr}\widehat{\mathrm{efp}}_t$), we obtain $\widehat{\mathrm{efp}}_t = (\chi_x \hat{x}_t + \chi_\sigma \hat{\sigma}_{\omega,t})/(1 + a_{rr})$. From here, it is straightforward to see that an alternative financial rule that reacts to x_t and $\sigma_{\omega,t}$, of the form $\hat{\tau}_{f,t} = a_x \hat{x}_t + a_\sigma \hat{\sigma}_{\omega,t}$, can be constructed to be equivalent to the baseline financial rule. Making the two rules equivalent requires $\chi_x - a_x = \chi_x/(1 + a_{rr})$ and $\chi_\sigma - a_\sigma = \chi_\sigma/(1 + a_{rr})$.

For the second rule, the balance sheet of entrepreneurs implies that there is a close relationship between an entrepreneur's debt, its leverage, and its net worth, since $x_{e,t} \equiv q_t k_{e,t}/n_{e,t} = 1 + b_{e,t}/n_{e,t}$ (see Section 2.2). Hence, a financial rule that reacts to efp is also equivalent, up to a first-order approximation, to a rule setting the financial subsidy to respond to changes in aggregate private debt, aggregate net worth, and the dispersion of entrepreneurs' profits:

$$1 + \tau_{f,t} = (1 + \tau_f) \times \left(\frac{b_t/n_t}{b/n} \right)^{a_b} \left(\frac{\sigma_{\omega,t}}{\bar{\sigma}_\omega} \right)^{a_\sigma}, \tag{4.3}$$

where $a_b > 0$ is the elasticity of with respect to b_t/n_t. This rule is equivalent (up to a first-order approximation) to the baseline rule if we set $a_b = \chi_b \upsilon_b a_{rr}/(1 + a_{rr})$ where $\upsilon_b \equiv (x - 1)/x$.[27]

5 Conclusions

This paper undertakes a quantitative study of coordination failure in the implementation of monetary and financial policies using a New Keynesian model with the Bernanke-Gertler financial accelerator and risk shocks. Price stickiness and costly monitoring of borrowers cause risk shocks to produce inefficient economic fluctuations and long-run efficiency losses. Monetary and financial policies face two forms of coordination failure when used to tackle these distortions. First, violations of Tinbergen rule, because a regime in which monetary policy alone tackles *both* distortions is inferior to one in which separate monetary and financial policy rules targets them separately. Second, strategic interaction between monetary and financial authorities, because the equilibrium determination of each authority's target depends on the instruments controlled by both authorities, and these spillovers incentivize strategic behavior.

The quantitative analysis yields four key results: 1) Welfare costs of risk shocks are large, ranging from 3.8 to 6.5% across the various policy regimes examined, because risk shocks increase the long-run average of the external finance premium causing large efficiency losses in investment and payments for monitoring costs. 2) The costs of violating Tinbergen rule are large. The standard Taylor rule (STR) and an ATR regime in which the Taylor rule is augmented to target credit spreads produce lower welfare and larger fluctuations in response to risk shocks than a dual-rules-regime (DRR). In the DRR, monetary policy follows a Taylor rule setting the nominal interest rate to target inflation and a financial policy rule sets a subsidy on financial intermediation to target spreads. Moreover, STR and ATR yield tight money-tight credit regimes in which the interest rate rises too much when inflation rises and does not fall enough when spreads widens. 3) Reaction curves for the optimal choice of policy rule elasticities of the monetary and financial authorities are convex, switching from strategic complements to substitutes in the adjustment of those elasticities. 4) Standard quadratic payoff functions yield a Nash equilibrium significantly inferior to cooperative equilibria and to a welfare-maximizing DRR regime, and both the Nash and the cooperative equilibria are also tight money-tight credit regimes. Still, even the Nash equilibrium dominates the STR and ATR regimes.

[27] A linear approximation to the aggregate balance sheet of entrepreneurs yields $\hat{x}_t = \upsilon_x(\hat{b}_t - \hat{\eta}_t)$. Hence, a financial rule that responds to b_t, n_t, and $\sigma_{\omega,t}$, so that $\hat{\tau}_{f,t} = a_b(\hat{b}_t - \hat{n}_t) + a_\sigma \hat{\sigma}_{\omega,t}$ is equivalent to the linearized baseline rule if we set $a_b = \chi_x \upsilon_x a_{rr}/(1 + a_{rr})$ and $a_\sigma = \chi_\sigma a_{rr}/(1 + a_{rr})$.

Our findings are robust to important parameter variations, including the degree of price stickiness, the severity of financial frictions, and the persistence of habits. The results are also robust to modifications adding the output gap to monetary rules, introducing shocks to TFP, govenrment expenditures and price markups, and modifying the financial policy rule to target leverage or the debt-net worth ratio and the variability of entrepreneurs' profits instead of spreads. Financial policy is relevant only if risk shocks and/or markup shocks are present, otherwise if there are only shocks to government expenditures or TFP the financial accelerator is too weak and a policy regime with a standard Taylor rule dominates.

This analysis raises two important issues for further research. First, for tractability, we used perturbation methods to quantify the amplification effects of risk shocks in the Bernanke-Gertler financial accelerator. As Mendoza (2016) explained, these methods underestimate the magnitude of the financial amplification and hence of the distortions that the financial subsidy should address. Second, our analysis included only the costly monitoring features of financial intermediation embodied in the Bernanke-Gertler setup. This setup abstracts from other important features of actual financial systems, such as securitization, systemic risk, and balance sheet leveraging, and abstracts also from informational frictions other that costly state verification.

References

Andreasen, M. M., Fernández-Villaverde, J. and Rubio-Ramírez, J. (2017) The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications, *The Review of Economic Studies*, **85**, 1–49.

Angelini, P., Neri, S. and Panetta, F. (2014) The Interaction between Capital Requirements and Monetary Policy, *Journal of Money, Credit and Banking*, **46**, 1073–1112.

Angeloni, I. and Faia, E. (2013) Capital regulation and monetary policy with fragile banks, *Journal of Monetary Economics*, **60**, 311–324.

Aoki, K., Benigno, G. and Kiyotaki, N. (2015) Monetary and Financial Policies in Emerging Markets, Mimeo.

Bernanke, B. and Gertler, M. (1989) Agency Costs, Net Worth, and Business Fluctuations, *American Economic Review*, **79**, 14–31.

Bernanke, B., Gertler, M. and Gilchrist, S. (1999) The Financial Accelerator in a Quantitative Business Cycle Framework, in *Handbook of Macroeconomics* (Eds.) J. B. Taylor and M. Woodford, Elsevier, vol. 1 of *Handbook of Macroeconomics*, chap. 21, pp. 1341–1393.

Bianchi, J. and Mendoza, E. G. (2018) Optimal, Time-Consistent Macroprudential Policy, *Journal of Political Economy*, p. forthcoming.

Bodenstein, M., Guerrieri, L. and LaBriola, J. (2014) Macroeconomic Policy Games, Finance and Economics Discussion Series 2014-87, Board of Governors of the Federal Reserve System (U.S.).

Calvo, G. A. (1983) Staggered Prices in a Utility-Maximizing Framework, *Journal of Monetary Economics*, **12**, 383–398.

Campbell, J. Y. (1999) Chapter 19 asset prices, consumption, and the business cycle, *Handbook of Macroeconomics*, **1**, 1231 – 1303.

Christiano, L. J., Eichenbaum, M. and Evans, C. L. (2005) Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy, *Journal of Political Economy*, **113**, 1–45.

Christiano, L. J., Motto, R. and Rostagno, M. (2014) Risk Shocks, *American Economic Review*, **104**, 27–65.

Cúrdia, V. and Woodford, M. (2010) Credit Spreads and Monetary Policy, *Journal of Money, Credit and Banking*, **42**, 3–35.

De Paoli, B. and Paustian, M. (2017) Coordinating Monetary and Macroprudential Policies, *Journal of Money, Credit and Banking*, **49**, 319–349.

Dixit, A. and Lambertini, L. (2003) Interactions of Commitment and Discretion in Monetary and Fiscal Policies, *American Economic Review*, **93**, 1522–1542.

Eichengreen, B., Prasad, E. and Rajan, R. (2011) Rethinking Central Banking, Tech. rep., VOX, CEPR's Policy Portal, http://www.voxeu.org/article/rethinkingcentralbanking.

Galati, G. and Moessner, R. (2013) Macroprudential Policy – A Literature Review, *Journal of Economic Surveys*, **27**, 846–878.

IMF (2013) The Interaction of Monetary and Macroprudential Policies, Tech. rep., IMF.

Kannan, P., Rabanal, P. and Alasdair, S. (2012) Monetary and Macroprudential Policy Rules in a Model with House Price Booms, *The B.E. Journal of Macroeconomics*, **12**, 1–44.

Lambertini, L., Nuguer, V. and Uysal, P. (2017) Mortgage default in an estimated model of the U.S. housing market, *Journal of Economic Dynamics and Control*, **76**, 171 – 201.

Lucas, R. E., Jr. (1987) *Models of Business Cycles*, Basil Blackwell, New York.

Mendoza, E. G. (2016) Macroprudential policy: Promise and challenges, Working Paper 22868, National Bureau of Economic Research.

Mendoza, E. G. and Tesar, L. L. (2005) Why Hasn't Tax Competition Triggered a Race to the Bottom? Some Quantitative Lessons from the EU, *Journal of Monetary Economics*, **52**, 163–204.

Quint, D. and Rabanal, P. (2014) Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area, *International Journal of Central Banking*, **10**, 169–236.

Rudebusch, G. D. (2006) Monetary Policy Inertia: Fact or Fiction?, *Int. Journal of Central Banking*, **2**.

Schmitt-Grohé, S. and Uribe, M. (2004) Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function, *Journal of Economic Dynamics and Control*, **28**, 755–775.

Schmitt-Grohé, S. and Uribe, M. (2005) Optimal fiscal and monetary policy in a medium-scale macroeconomic model: Expanded version, Working Paper 11417, National Bureau of Economic Research.

Schmitt-Grohé, S. and Uribe, M. (2007) Optimal simple and implementable monetary and fiscal rules, *Journal of Monetary Economics*, **54**, 1702–1725.

Schmitt-Grohé, S. and Uribe, M. (2008) What's news in business cycles, Working Paper 14215, National Bureau of Economic Research.

Smets, F. (2014) Financial Stability and Monetary Policy: How Closely Interlinked?, *International Journal of Central Banking*, **10**, 263–300.

Svensson, L. (2014) Inflation Targeting and "Leaning against the Wind", *International Journal of Central Banking*, **10**, 103–114.

Svensson, L. (2015) Monetary Policy and Macroprudential Policy: Different and Separate, Tech. rep., Stockholm School of Economics and IMF.

Taylor, J. and Williams, J. (2010) Simple and Robust Rules for Monetary Policy, in *Handbook of Monetary Economics* (Eds.) B. M. Friedman and M. Woodford, Elsevier, vol. 3, chap. 15, pp. 829–859, 1 edn.

Van der Ghote, A. (2016) Coordinating Monetary and Financial Regulatory Policies, Tech. rep., Princeton University.

Williams, J. C. (2010) Monetary Policy in a Low Inflation Economy with Learning, *Economic Review*, pp. 1–12.

Woodford, M. (2003) *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.

Woodford, M. (2010) Optimal Monetary Stabilization Policy, in *Handbook of Monetary Economics* (Eds.) B. M. Friedman and M. Woodford, Elsevier, vol. 3, chap. 14, pp. 723–828.

Yellen, J. (2014) Monetary Policy and Financial Stability, Tech. rep., Board of Goverments of the Federal Reserve System.

Yun, T. (1996) Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles, *Journal of Monetary Economics*, **37**, 345 – 370.