Monetary and Macroprudential Policy Coordination with Biased Preferences

Pierre-Richard Agénor* and Timothy P. Jackson**

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Abstract

This paper studies the extent to which biased policy preferences, motivated by narrow institutional mandates, affect the gains from coordination between monetary policy (which may respond to financial imbalances) and macroprudential regulation (in the form of capital requirements) in responding to financial stability considerations, and whether these mandates can be set optimally. Numerical experiments show that, depending on the degree of bias in policy preferences, coordination may not entail *burden sharing* (in the sense of one policymaker reacting more, and the other less, aggressively to financial stability concerns) and may not be Pareto improving relative to the Nash equilibrium—even though it may generate significant gains for the economy as a whole. The optimal institutional mandate, based on maximizing household welfare under coordination, internalizes the impact of the cost of each policymaker's own instrument use on policy decisions. As a result, there may be an inverse relationship between the degree of bias in preferences and the instrument manipulation cost.

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*School of Social Sciences, University of Manchester; **Economics Group, University of Liverpool. We are grateful to several colleagues, participants at various seminars, and especially two anonymous reviewers for many helpful comments. The views expressed in this paper are our sole responsibility. Appendices B, C and D are available upon request.

1 Introduction

The role of monetary and macroprudential policies in achieving macroeconomic and financial stability has been the subject of an extensive debate since the global financial crisis. Two issues have dominated this debate. The first relates to the extent to which central banks should also respond to financial imbalances—in the form of an unsustainable expansion of credit or a significant and sustained deviation of asset prices from their longer-term trends—in addition to pursuing a price stability objective. The second pertains to how best to combine monetary policy and macroprudential regulation, given that both policies influence each other's transmission mechanism to the economy. Indeed, the credit and business cycle effects of macroprudential policy may influence price developments and monetary policy decisions, whereas changes in policy interest rates, motivated solely by price stability considerations, may affect systemic financial risks through their impact on the cost and availability of credit. These linkages create potential trade-offs in the use of these policies with respect to achieving simultaneously macroeconomic and financial stability.[1]

A number of contributions have attempted to examine these questions in dynamic stochastic general equilibrium (DSGE) models with financial frictions and prudential regulation. Some, including Cúrdia and Woodford (2010, 2016), Davis and Huang (2013), Hirakata et al. (2013), Gambacorta and Signoretti (2014), and Verona et al. (2017), have focused on the trade-offs that may arise between price stability and financial stability when the only instrument available is a short-term policy interest rate, set on the basis of a Taylor-type rule, augmented to lean directly against the build-up of financial imbalances—captured through an interest rate spread, fluctuations in a credit aggregate, or changes in asset prices. Some of these studies found that whether or not *leaning against the wind* has benefits (in terms of both macroeconomic and financial stability) depends, in particular, on the measure of financial imbalances included in the interest rate rule.

Others have centered on the case where standard Taylor-type rules—augmented or not—are complemented by countercyclical macroprudential rules, which respond to an operational target for financial stability, such as credit growth, the credit-to-output ratio, credit spreads, or asset prices. Beau et al. (2011), Agénor et al. (2013), Angelini et al. (2014), de Paoli and Paustian (2017), Gelain and Ilbas (2017), Kiley and Sim (2017), Leduc and Natal (2018),

[1] This conflict may also reflect the different policy horizons over which policymakers can aim to achieve their stability objective. Price stability typically focuses on inflation developments over a relatively short horizon; whereas financial stability risks often develop over a longer time frame, because financial booms and busts tend to last longer than traditional business cycles.

and Carrillo et al. (2021), for instance, study interactions between instruments and policy coordination in models where separate monetary and prudential authorities operate, with potentially different objectives. Angeloni and Faia (2009), Christensen et al. (2011), Agénor et al. (2013), Angelini et al. (2014), Rubio and Carrasco-Gallego (2016), and Aikman et al. (2019) focus more specifically on the interaction between monetary policy and countercyclical capital buffers—along the lines proposed by the Basel III Accord (see Basel Committee on Banking Supervision (2011))—whereas Rubio and Carrasco-Gallego (2014) and Funke et al. (2018) examined the interplay between monetary policy and loan-to-value ratios.[2] A common finding of this literature is that, in responding to financial shocks, countercyclical capital requirements may yield significant gains in terms of welfare or economic stability, regardless of the way monetary and capital requirements policies interact. In addition, some also conclude that when monetary policy leans against the financial cycle, significant gains can be achieved in terms of either reduced macroeconomic and financial volatility or higher social welfare.

At the same time, it has been argued—based on Tinbergen's *effective assignment principle*, or what Stein (2013) referred to as the *decoupling philosophy*—that monetary policy should remain squarely focused on macroeconomic stability whereas macroprudential policy should focus solely on financial stability. This is the view adopted by Svensson (2017) and Ajello et al. (2019), for instance. However, observers have argued that some of the assumptions underlying this line of analysis—in particular, in Svensson's analysis, the fact that the policy response does not affect the cost of financial crises, that crises occur with a given frequency, and that they do not result in permanent output losses—tend to underestimate the costs of crises and limit the potential benefits of a policy of *leaning against the wind* (Filardo and Rungcharoenkitku (2016), and Gourio et al. (2018)). The empirical evidence suggests indeed that recessions that coincide with financial crises often result in permanent output losses and persistently lower growth rates thereafter (see Claessens and Kose (2014)). Put differently, the costs and benefits of *leaning against the wind* need to be assessed over the course of full financial cycles—rather than focusing only on the occurrence of full-blown financial crises—and the impact of past policy decisions on today's and tomorrow's financial outcomes need to be accounted for. In addition, incorporating the role of asset prices, credit, and bank risk-taking may significantly alter the cost-benefit analysis of the use of monetary

[2] Other contributions include Gelain et al. (2012), Agénor and Zilberman (2015), Benes and Kumhoff (2015), Bailliu et al. (2015), Levine and Lima (2015), Collard et al. (2017), Gourio et al. (2018), and Agénor and Flamini (2021). Some of these contributions are further discussed later on.

policy to address systemic financial risks (Adrian and Liang (2018)).

The purpose of this paper is to contribute to this debate by focusing on the role of *biased preferences* among policymakers, that is, the case where policy objective functions account not only for household welfare but also for a narrow and specific institutional mandate bestowed by society to each authority (price stability for the central bank, financial stability for the regulator).[3] Using a model in which financial intermediation is subject to frictions, macroprudential regulation takes the form of bank capital requirements, instrument manipulation is costly, and the economy is subject to financial shocks, we address two key issues. First, how does the degree of bias in preferences affect the gains from cooperation, relative to either no activism or a setting where policymakers can act strategically, associated with *leaning against the wind*? Second, how should society set *optimal* institutional mandates, in the sense of determining the optimal degree of bias in the objective functions of the central bank and the regulator, and how does the optimal mandate depend on the cost of instrument manipulation?[4]

From a practical standpoint, the main reason for focusing on biased preferences is because, since the global financial crisis, there have been a number of changes in the institutional organization of financial supervision and the role played by central banks beyond their traditionally narrow mandate of price stability. These changes have led to a variety of institutional arrangements, which differ essentially in two dimensions (Calvo et al. (2018)): the first relates to the extent to which they allow synergies across different functions to be exploited, by grouping them within a specific institution, whereas the second pertains to their capacity to minimize conflicts across objectives by assigning them to different authorities. The latter is, in principle, as important as the former, given that conflicting objectives within the same authority may lead to the subordination of one to the other in a way that may be socially suboptimal. These arrangements include a *goal-integrated* mandate, in which the central bank is responsible for both monetary policy and macroprudential regulation, and

[3] To our knowledge, Bodenstein et al. (2019) were the first to consider the case of biased policy preferences, as defined here, in a setting with multiple policymakers. However, macroprudential regulation in their model takes the form of a lump-sum tax on banks, and they do not address the issue of endogeneity of biases in policy preferences.

[4] De Paoli and Paustian (2017) also addressed the issue of institutional mandates, or policy delegations, although their motivation for doing so is the lack of commitment technology for the central bank and the regulator. In their model, separate loss functions, each with two objectives (inflation and output for the central bank, output and a measure of the "effective" interest rate for the regulator), are delegated to the policy authorities. However, the relative weight on output in these functions is set equal to the one corresponding to the quadratic microfounded social loss function that they derive, that is, the weight that the social planner would choose. As is made clear later on, our approach to solving for optimal weights focuses instead directly on household welfare and accounts explicitly for the cost of instrument manipulation.

partially integrated mandates, which group responsibilities in different authorities according to different criteria, including the setting of objectives and the choice of instruments. At the same time, however, recent evidence on institutional arrangements for financial stability found that while there has been a significant increase in the number of central banks being part of an inter-agency council to address financial stability issues, they do not make the central bank the sole macroprudential authority—and in no case have their charters been explicitly changed to allow for the use of policy interest rates to respond to systemic financial risks (see Bank for International Settlements (2017)). Put differently, and despite some institutional changes observed in recent years, society continues to bestow narrow explicit mandates to central banks and regulators. Although social welfare remains a fundamental criterion for evaluating policy performance, allowing explicitly for biased preferences as defined earlier helps to assess the role of these mandates in policy decisions.

From an analytical standpoint, the issue of whether society should delegate an institutional mandate to policymakers—in the sense of setting a positive weight on each authority's specific objective, in addition to household welfare—demands also justification.[5] Since Woodford's (2003) seminal contribution, it is well established that a policy loss function, defined in terms of a narrow set of key aggregates, can be rigorously derived as an analytic, second-order approximation of a welfare function.[6] However, there are two possible reasons for considering an institutionally-motivated bias in policy preferences, alongside household welfare. First, conditional on a particular specification of financial frictions, the second-order approximation to the utility function remains model-specific and may require accounting for several wedges—and the trade-offs that they create—that have no clear counterpart in commonly-defined institutional mandates.[7] Moreover, some of these wedges often have little in common with variables (such as credit growth) that have been associated with episodes of financial volatility in empirical studies. Second, there are a number of alternative ways of modeling financial frictions; and there is no consensus yet in the profession as to which approach is the most appropriate, and under which circumstances. In fact, empirical studies suggest that a *combination* of financial frictions may be more suitable to explain business

[5] The reverse problem, the extent to which policymakers, in addition to their institutional mandate, should attach some optimal weight to household welfare, is in principle equivalent.

[6] See, for instance, De Fiore and Tristani (2012), Andrés et al. (2013), and Ferrero et al. (2018), and Laureys et al. (2020) for examples, and Debortoli et al. (2019) for a broader discussion

[7] See, for instance, Andrés et al. (2013), De Paoli and Paustian (2017), and Ferrero et al. (2018). Actually, it could be be argued that this may be a more general issue. *Any* friction, real or financial, may generate a second-order approximation that requires responding to a friction-specific wedge. See, for instance, the derivation of the loss function in Rhee and Song (2013) in a model with real wage rigidity.

and financial cycles (see Agénor (2020, chapter 1)). By implication, there is no unique correspondence between household welfare and an analytic, second-order approximation that can be systematically related to the objectives of price and financial stability commonly assigned to policymakers in the real world. It is therefore important to consider a more general—and presumably more robust—case where the policy objective function accounts not only for household welfare, that is, a strict normative perspective, but also directly for a narrow institutional mandate delegated by society. Indeed, as noted earlier, such mandates remain the norm for both central banks and macroprudential regulators. For the former, the mandate is generally formulated in terms of price stability and (less commonly) output stability, whereas for the latter, it is often in terms of an empirically-based, operational measure of financial stability, such as credit gaps, deviations in credit-to-GDP ratios, or broader measures of financial sector leverage.[8]

Our main results can be summarized as follows. First, biased preferences play a significant role in determining whether there are gains from policy coordination and how large these gains are. In particular, and somewhat counter-intuitively, household welfare is significantly higher under coordination with biased preferences. The reason essentially is that when maximizing welfare only, the instrument manipulation cost is not internalized. Second, depending again on the degree of bias in policy preferences, coordination does not entail *burden sharing* (in the sense of one policymaker reacting more, and the other less, aggressively to financial stability concerns) and may not be Pareto improving relative to the Nash equilibrium—even though it can generate significant gains for the economy as a whole. Third, the optimal institutional mandate, based solely on maximizing household welfare under coordination, internalizes the impact of each policymaker's own instrument manipulation cost on their policy decisions. As a result, there may be an inverse relationship between the preference bias parameter and the parameter that captures the cost of instrument use. In addition, each policymaker's bias parameter is independent of changes in the other policymaker's instrument cost parameter, and the bias parameter for the regulator does not depend on changes in its own instrument manipulation cost. The latter result is a reflection of the fact that, in the model, and given our parameterization, *leaning against the wind* is a more effective tool to mitigate financial volatility than countercyclical capital requirements. The key reason is that the loan rate is a weighted average of the policy interest rate and the cost of raising bank

[8] Other commonly-defined financial stability objectives, such as ensuring a smooth functioning of the financial system (avoiding disruptions in payments, and so on), are harder to capture in macroeconomic models.

capital, and the weight on the latter (which consists of the product of the capital adequacy ratio and the risk weight on investment loans) is relatively small. As a result, changes in the cost of issuing capital—unless they are very large—have more limited effects on market borrowing costs.

The remainder of the paper proceeds as follows. Section 2 sets the stage by discussing two of the key features of our analysis—the modelling of capital requirements and the link between policy preferences and the gains from coordination—relative to the existing literature. Section 3 presents the model, together with its equilibrium solution and some of the main features of its steady state. The financial frictions that are accounted for allow us to capture three key features and implications of the regulatory regime. First, as a result of monopolistic banking, the rate at which firms must borrow to finance investment can be written as a markup over a weighted average of the cost of central bank liquidity and the cost of issuing bank capital. Second, the probability of loan repayment, which also affects the cost of borrowing and is itself linked to changes in collateral values, as well as cyclical output, has a direct impact on the risk weight used to calculate required capital ratios. Third, although capital is costly, it also generates a pecuniary benefit; consequently, it is optimal for banks to hold capital in excess of the level required by the regulator.[9] Moreover, in the model, the transmission mechanisms of monetary policy and macroprudential regulation are closely intertwined, and this creates *prima facie* a case for policy complementarity.

Parameterization is discussed in section 4. Core experiments are described in section 5, to highlight the transmission mechanism with a standard interest rate rule and no countercyclical regulation. We focus on temporary financial shocks, given the broad evidence that these shocks are an important independent cause of business cycle fluctuations, and that macroprudential policies often lack effectiveness in responding to real shocks. The optimality of alternative mandates, including *leaning against the wind* (in the form of an augmented Taylor rule), is assessed in section 6. Section 7 addresses more specifically the issue of strategic gains in coordinating monetary policy and macroprudential regulation, and the role of bias in preferences in that context. While both sections 6 and 7 focus on the case where biases in policy preferences are exogenous, section 8 discusses optimal institutional mandates, that is, the determination of the optimal degree of bias in preferences. Section 9 discusses some sensitivity analysis. The last section offers some concluding remarks.

[9] The sensitivity of our results to some of the model's features is reported later on. Appendix B discussed more broadly our approach to modeling financial frictions and how it relates to the literature.

2 Background

To highlight how our analysis differs from the existing literature on the interactions between monetary and macroprudential policies, we consider, in turn, the modelling of capital requirements, as well as the implications of other model features, and biases in policy preferences, for assessing the gains from coordination.

2.1 Capital Requirements

A common approach to modelling capital requirements, followed, for instance, by de Walque et al. (2010), Gerali et al. (2010), Meh and Moran (2010), Darracq Pariès et al. (2011), Angelini et al. (2014), and others, is to assume that banks accumulate capital solely through retained earnings. However, there are several limitations to this approach. First, these models generally do not account directly for the demand for bank capital, how it depends on the cost of issuing bank liabilities, and how the latter affects banks' decisions in setting the cost of loans.[10] They do generate a positive relationship between increases in bank leverage—measured in terms of the ratio of risk-weighted assets to bank capital—and the loan spread, but only as long as leverage exceeds the target level. Second, the share of profits that banks accumulate (or, equivalently, their dividend policy) is generally exogenous, and excess capital holdings—a common characteristic of banking systems around the world, as documented, for instance, by the World Bank (2020, Figure O.4)—is not accounted for. Indeed, the cost of the leverage ratio deviating from the target value imposed by the regulator is symmetric in most of these models, implying that there are no benefits from holding excess capital. Third, assuming that capital accumulation occurs only through retained earnings is equivalent to assuming that the cost of raising equity on financial markets is prohibitively high. Although the evidence does suggest that equity is more expensive than other sources of funding (see Gambacorta and Shin (2018)), excluding it entirely is rather restrictive.

In the model presented in this paper, we assume instead that banks satisfy capital requirements by issuing debt-like instruments rather than equity *per se*. They close their operations at the end of each period and start anew at the beginning of the next, and therefore they do not accumulate capital over time. At the same time, the cost effect of issuing debt is accounted for and is shown to have a direct impact on the loan rate.[11]

[10] In addition, in Gerali et al. (2010) and Angelini et al. (2014), as well as related contributions such as Bekiros et al. (2018), the cost of managing the banks' capital position, or the depreciation rate of bank capital, is calibrated at a very high value.

[11] Ideally, what would be desirable is to have a model that accounts for both retained earnings and equity

2.2 Policy Preferences and Coordination Gains

As discussed earlier, there is a large literature focusing on the coordination of monetary policy (with or without *leaning against the wind*) and macroprudential regulation. From that perspective, two contributions that are most closely related to the analysis in this paper are Angelini et al. (2014) and De Paoli and Paustian (2017).[12] Both of them emphasize the benefits of cooperation between the central bank and the regulator (in terms of reduced macroeconomic and financial volatility in the first case, and in terms of higher welfare in the second) when macroeconomic fluctuations are driven by financial shocks.

Our modeling approach differs from the first contribution in several respects. First, we account for the direct cost effect of capital requirements, as discussed earlier. Second, risk weights in our model are sensitive to loan default risk, rather than the business cycle. Third, we focus on an adjusted measure of welfare (as discussed later on), rather than simple policy loss functions, to determine optimal policy. Finally, we calculate the gain from cooperation relative to the Nash equilibrium. The fact that we consider strategic interactions is important, because one of the key results that Angelini et al. (2014) established—in response to financial shocks, cooperation is superior relative to the case where policymakers act independently—may not hold if strategic interactions are allowed. In particular, cooperation may not be Pareto-improving.

With respect to the second contribution, we abstract from the cost channel and model macroprudential policy as a countercyclical capital buffer (as opposed to a tax, or subsidy, on banks' funding costs), which has a direct effect on the market cost of borrowing.[13] We also use a direct second-order approximation of household utility—rather than a loss function, derived as a quadratic approximation, and defined in terms of output, inflation, and other model-specific variables—and focus on simple implementable rules, rather than the optimal policy.

As in the above studies, we explicitly account for the cost of instrument manipulation. In addition, we also provide a disaggregated analysis of welfare gains, which allows us to establish whether the gains from coordination are Pareto-improving. Most importantly, to evaluate the benefits of alternative rules and the gains from coordination, we consider

(or debt-like instruments) as ways of accumulating bank capital, and to determine endogenously how banks choose among them; however, this is beyond the scope of this paper.

[12] Gelain and Ilbas (2017) and Carrillo et al. (2021) studied related issues. However, they do not address either those that we focus on.

[13] De Paoli and Paustian (2017) also considered the case where the macroprudential instrument consists of a liquidity requirement, but this did not affect their results.

policy objective functions that account not only for household welfare but also for bias in each policymaker's preferences and the cost of manipulating instruments (as in some of the contributions alluded to earlier). Specifically, we focus on the following issues. First, how do biased preferences between policymakers affect the gains from cooperation, relative to no activism, *leaning against the wind* only, and macroprudential policy response only? Second, is cooperation, relative to a setting where policymakers can act strategically, always Pareto-improving, and is this affected by the degree of bias in preferences? Finally, how can society set optimal institutional mandates, in the sense of determining the optimal weight on preference biases, and how does this decision depend on the cost of instrument manipulation?

3 The Model

Consider a closed economy populated by eight types of agents: a continuum of infinitely-lived households, a continuum of intermediate good (IG) producers, indexed by $j \in (0,1)$, a continuum of final good (FG) producers, a continuum of capital good (CG) producers indexed by $k \in (0,1)$, a continuum of commercial banks, indexed by $i \in (0,1)$, the central bank, and a financial regulator. The final good is homogeneous and can be used either for consumption or investment, although in the latter case additional costs must be incurred. Capital producers have no initial wealth and need to borrow from banks to finance investment. Households own real estate property (housing or land), which generates utility-enhancing services; they also make it available, free of charge, to the CG producer that they own, for use as collateral for bank loans.

While the deposit market is competitive, monopolistic competition prevails in the credit market—as, for instance, in Gerali et al. (2010) and Angelini et al. (2014). As a result, the loan rate set by commercial banks incorporates a premium, above and beyond the marginal cost of funding. In turn, the premium, varies inversely with the probability of loan repayment, which itself depends on collateral values (which fluctuate with real house prices) and cyclical output (which affects unit monitoring costs). Through both channels, the model captures therefore some of the financial amplification effects that figure prominently in modern-day macroeconomics.[14]

Banks satisfy capital requirements by issuing debt-like instruments rather than equity *per se*. They close their operations at the end of each period and start anew at the beginning of the next, and therefore they do not accumulate capital over time. At the same time,

[14] See, for instance, Brunnermeier et al. (2013).

the cost effect of issuing debt is accounted for and is shown to affect directly the loan rate. In addition, in the model banks hold both required regulatory capital and excess capital—a common feature of banking, as noted earlier—partly as a signal to market about the strength of their balance sheets and partly to avoid the *ex post* penalties that the regulator can impose if financial institutions violate capital adequacy ratios.

In effect, banks issue debt-like instruments to satisfy capital regulation and a portfolio-like demand function for excess capital. They also pay interest on household deposits and the liquidity that they borrow from the central bank, as well as interest on the debt that they issue. At the end of each period, banks close their books and start afresh at the beginning of the next. Thus, bank debt is redeemed at the end of each period, all their profits are distributed, and new debt is issued at the beginning of the following period. As a result, in the model there is no intrinsic distinction between issuing equity or debt from the perspective of banks; capital consists solely of "tier 2" capital, in Basel III terminology.[15]

In what follows we describe the behavior of households, commercial banks, the central bank, and the financial regulator. The production structure is fairly standard and details are relegated to Appendix A.

3.1 Households

Households consume, holds financial assets, and supply labor to IG producers. The objective of the representative household is to maximize

$$U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ \frac{C_{t+s}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} - \int_0^1 \frac{\eta_N (N_{t+s}^j)^{1+\psi_N}}{1+\psi_N} dj + \ln x_{t+s}^{\eta_x} + \ln H_{t+s}^{\eta_H} \right\}, \tag{1}$$

where C_t is the consumption bundle, N_t^j time allocated to IG firm j, x_t a composite index of real monetary assets, H_t the stock of housing, and $\Lambda \in (0,1)$ the discount factor. $\mathbb{E}_t$ is the expectation operator conditional on the information available at the beginning of period t, $\varsigma > 0$ is the constant intertemporal elasticity of substitution in consumption, $\psi_N > 0$ the inverse Frisch elasticity of labor supply, and $\eta_N, \eta_x, \eta_H > 0$ are the relative weights on the disutility of working, and the utility of holdings of monetary assets and housing, respectively.

The composite monetary asset combines real cash balances, m_t, and real bank deposits,

[15] A broader interpretation of bank debt in this model would be to view it as consisting of convertible bonds, which in practice have been used quite extensively by banks to satisfy capital requirements. See Avdjiev et al. (2017) and World Bank (2020), for instance. In fact, as documented by the World Bank (2020, Figure 3.4), the percentage of countries allowing hybrid debt capital instruments as part of Tier 1 capital has increased from 38 percent to 45 percent between 2010 and 2016.

d_t:

$$x_t = m_t^{\nu} d_t^{1-\nu}, \tag{2}$$

where $\nu \in (0, 1)$.[16]

Assuming that housing does not depreciate, the flow budget constraint of the unconstrained household is

$$\begin{aligned} & m_t + d_t + b_t + p_t^H \Delta H_t + V_t \\ = {} & w_t N_t - T_t - C_t + \frac{m_{t-1}}{1+\pi_t} + (\frac{1+i_{t-1}^D}{1+\pi_t})d_{t-1} + (\frac{1+i_{t-1}^B}{1+\pi_t})b_{t-1} \\ & + J_t^B + J_t^I + J_t^K + (\frac{1+i_{t-1}^V}{1+\pi_t})V_{t-1} - \Theta_V \frac{V_t^2}{2}, \end{aligned} \tag{3}$$

where $N_t = \int_0^1 N_t^j dj$ is total labor supply, T_t lump-sum taxes, $\pi_{t+1} = P_{t+1}/P_t - 1$ the inflation rate, J_t^I, J_t^K, J_t^B profits made by a matched IG producer, CG producer, and bank, respectively, b_t real holdings of one-period government bonds, i_t^B interest rate on those bonds, p_t^H the real price of housing services, in terms of the price of the final good, V_t real holdings of bank capital, and i_t^V the nominal interest rate on bank debt.[17] The last term, $0.5\Theta_V V_t^2$, represents transactions costs—such as costs of collecting information about banks' balance sheet—that households incur when adjusting their stock of bank capital, with $\Theta_V > 0$ the adjustment cost parameter.[18]

The representative household chooses sequences of consumption, $\{C_{t+s}\}_{s=0}^{\infty}$, labor, $\{N_{t+s}^j\}_{s=0}^{\infty}$, $j \in (0, 1)$, cash, $\{m_{t+s}\}_{s=0}^{\infty}$, deposits, $\{d_{t+s}\}_{s=0}^{\infty}$, domestic bonds, $\{b_{t+s}\}_{s=0}^{\infty}$, and holdings of bank debt, $\{V_{t+s}\}_{s=0}^{\infty}$, so as to maximize (1) subject to (2) and (3), taking interest rates (i_t^B, i_t^D, and i_t^V), as well as prices and inflation (w_t, p_t^H, and π_t), and all lump-sum transfers and taxes (J_t^B, J_t^I, J_t^K, and T_t), as given at all times. The solution of this problem gives, for $t = 0, 1, ..., \infty$:

$$C_t^{-1/\varsigma} = \Lambda \mathbb{E}_t \left\{ C_{t+1}^{-1/\varsigma} (\frac{1+i_t^B}{1+\pi_{t+1}}) \right\}, \tag{4}$$

$$N_t^j = (\frac{w_t C_t^{-1/\varsigma}}{\eta_N})^{1/\psi_N}, \qquad \forall j \in (0, 1) \tag{5}$$

$$m_t = \frac{\eta_x \nu C_t^{1/\varsigma}(1+i_t^B)}{i_t^B}, \tag{6}$$

$$d_t = \frac{\eta_x (1-\nu) C_t^{1/\varsigma}(1+i_t^B)}{i_t^B - i_t^D}, \tag{7}$$

[16] We account for both cash and deposits because, as explained in Appendix A, the equilibrium condition of the money market is used to solved for the bond rate.

[17] As noted earlier, FG producers make zero profits.

[18] The presence of adjustment costs can be viewed as reflecting asymmetric information. As in Markovic (2006), for instance, the adjustment cost is taken to be a deadweight loss for society.

$$\frac{p_t^H}{C_t^{1/\varsigma}} = \frac{\eta_H}{H_t} + \Lambda \mathbb{E}_t(\frac{p_{t+1}^H}{C_{t+1}^{1/\varsigma}}), \tag{8}$$

$$V_t^d = \Theta_V^{-1}(\frac{i_t^V - i_t^B}{1 + i_t^B}), \tag{9}$$

together with the sequence of budget constraints (3) and the relevant transversality conditions.

Conditions (4) to (8) are fairly standard. Condition (9) shows that the household demand for bank capital is positively (negatively) related to the nominal rate of return on bank debt (government bonds). Without adjustment costs ($\Theta_V = 0$) it boils down to $i_t^V = i_t^B$; households are then indifferent between holding bank capital and government bonds.

3.2 Commercial Banks

Banks are risk-neutral and hold capital, collect fully-insured deposits, and lend to CG producers to finance investment, $l_t^{K,i}$. To fund any shortfall in resources, they borrow from the central bank, $l_t^{B,i}$.

Bank i's balance sheet is thus

$$l_t^{K,i} = d_t^i + V_t^i + l_t^{B,i}, \tag{10}$$

where

$$V_t^i = V_t^{R,i} + V_t^{E,i}, \tag{11}$$

with V_t^i denoting total capital, $V_t^{R,i}$ required capital, and $V_t^{E,i}$ excess capital.

Banks are subject to risk-based capital requirements, imposed by the regulator. They must hold an amount of capital that covers an endogenous percentage of its (risky) investment loans. Thus, with σ_t^i denoting the risk weight on these loans, capital requirements are given by

$$V_t^{R,i} = \rho_t \sigma_t^i l_t^{K,i}, \tag{12}$$

where $\rho_t \in (0, 1)$ is the capital adequacy ratio, defined later.

For simplicity, the market for deposits is competitive, and deposits and central bank liquidity are perfect substitutes. This ensures therefore that, for all banks, the following no-arbitrage condition holds:

$$i_t^{D,i} = i_t^R, \tag{13}$$

where i_t^R is the refinance rate, that is, the cost of borrowing from the central bank.

By contrast, monopolistic competition prevails in the market for investment loans. The demand for these loans from bank i, $l_t^{K,i}$, is given by the downward-sloping curve

$$l_t^{K,i} = (\frac{1+i_t^{L,i}}{1+i_t^L})^{-\zeta_L} l_t^K, \tag{14}$$

where $i_t^{L,i}$ is the rate on the loan extended by bank i, $l_t^K = [\int_0^1 (l_t^{K,i})^{(\zeta_L-1)/\zeta_L} di]^{\zeta_L/(\zeta_L-1)}$ the amount borrowed by the representative CG producer (set equal to the level of investment, as shown in Appendix A), with $\zeta_L > 1$ denoting the elasticity of substitution between differentiated loans, and $1+i_t^L = [\int_0^1 (1+i_t^{L,i})^{1-\zeta_L} di]^{1/(1-\zeta_L)}$ is the aggregate loan rate.

Banks set the loan rate on investment, as well as holdings of excess capital, to maximize expected profits. In addition, banks also set optimally their monitoring effort. Specifically, each bank can affect the repayment probability on its loan to the representative CG producer, q_t^i, by expending effort; the higher the monitoring effort, the safer the loan. Thus, greater monitoring is also desirable from the borrower's perspective.[19] For simplicity, as is common in the banking literature (and as discussed in Appendix A) the probability of repayment itself, rather than monitoring effort *per se*, is taken to be the choice variable.

Because there are no retained earnings and debt is redeemed at the end of each period, this optimization problem boils down to a period-by-period problem. Formally, bank i's maximization problem is:

$$\max_{R_t^{L,i}, V_t^{E,i}, q_t^i} \mathbb{E}_t J_{t+1}^{B,i},$$

where $\mathbb{E}_t J_{t+1}^{B,i}$, expected profits, are defined as

$$\mathbb{E}_t J_{t+1}^{B,i} = q_t^i R_t^{L,i} l_t^{K,i} + (1-q_t^i)\left(\kappa^i \mathbb{E}_t p_{t+1}^H H_t\right) \tag{15}$$

$$-R_t^{D,i} d_t^i - R_t^R l_t^{B,i} - R_t^{V,i} V_t^i - \gamma_V V_t^i + \frac{\gamma_{VV}}{1-\phi_E}(V_t^{E,i})^{1-\phi_E} - x_t^{M,i},$$

with $R_t^{L,i} = 1+i_t^{L,i}$, $R_t^h = 1+i_t^h$, $h = B, R, V$, $\kappa \in (0,1)$, $\gamma_V > 0$, $\gamma_{VV} \geq 0$, and $\phi_E \in (0,1)$.

The first term on the right-hand side in (15), $q_t^i R_t^{L,i} l_t^{K,i}$, represents expected repayment if there is no default. The second term represents what bank i expects to earn in case of default, which occurs with probability $1-q_t^i$. If there is default, the bank seizes the collateral pledged by the borrower, which is given by $\kappa^i \mathbb{E}_t p_{t+1}^H H_t$. In this expression, $\mathbb{E}_t p_{t+1}^H H_t$ is the expected value of housing and $\kappa^i = \int_0^1 \kappa^{k,i} dk$, where $\kappa^{k,i} \in (0,1)$ is the fraction of the housing stock of CG producer k pledged as collateral to bank i. The third and fourth terms, $R_t^{D,i} d_t^i$ and $R_t^R l_t^{B,i}$, represent repayment to depositors and the central bank, respectively. The fifth term,

[19] See Agénor and Pereira da Silva (2017) for a more detailed discussion.

$R_t^V V_t^i$, represents the value of bank debt redeemed at the end of the period, plus interest. The linear term, $\gamma_V V_t^i$, captures the cost associated with issuing debt, which includes, for instance, underwriting costs.[20] By contrast, the term $\gamma_{VV}(1-\phi_E)^{-1}(V_t^{E,i})^{1-\phi_E}$ captures the view that maintaining a positive level of excess capital generates a pecuniary benefit—it represents a signal that the bank's financial position is strong, and reduces the intensity of regulatory scrutiny (or the degree of intrusiveness in the bank's operations), which in turn reduces the cost associated with providing the information required by the regulator.[21] The restriction $\phi_E < 1$ ensures that holding excess capital entails decreasing marginal benefits. The last term, $x_t^{M,i}$, is the pecuniary cost of monitoring investment loans faced by bank i, defined as

$$x_t^{M,i} = \Phi_t^i \frac{(q_t^i)^2}{2} l_t^{K,i}, \tag{16}$$

and Φ_t is the unit cost function, which depends negatively on bank i's collateral-investment loan ratio and cyclical output, $Y_t/\tilde{Y}$:

$$\Phi_t^i = \left(\frac{\kappa^i \mathbb{E}_t p_{t+1}^H H_t/\tilde{p}^H \tilde{H}}{l_t^{K,i}/\tilde{l}^K}\right)^{-\phi_1}\left(\frac{Y_t}{\tilde{Y}}\right)^{-\phi_2}, \tag{17}$$

with $\phi_1, \phi_2 > 0$ and a tilde ($\tilde{}$) denoting a steady-state value. A higher collateral-loan ratio mitigates moral hazard problems and induces borrowers to take less risk and exert more effort in ensuring that their investments are successful; in addition, it may induce them to be more compliant with bank monitoring requirements. In the same vein, in boom times, when profits and cash flows are high, (unit) monitoring costs tend to fall, because borrowers are more diligent and the risk of default abates.

Banks maximize (15) subject to (10) to (12), and (16), taking the value of collateral, the refinance rate, the capital ratio ρ_t, the risk weight σ_t^i, and the unit cost Φ_t^i, as given.[22] As shown in Appendix B, the solution of this problem yields, in a symmetric equilibrium, and using (17),

$$i_t^L = \frac{\zeta_L}{q_t(\zeta_L - 1)}[(1-\rho_t\sigma_t)(1+i_t^R) + \rho_t\sigma_t(1+i_t^V+\gamma_V)] - 1, \tag{18}$$

[20] The cost of issuing debt could be defined so as to account for the fact that in recessions (expansions), market funding is more expensive (cheaper). This would imply, for instance, a specification of the form $\gamma_V V_t^i (Y_t/\tilde{Y})^{-\phi_Y^V}$, where $\phi_Y^V \geq 0$.

[21] In Dib (2010), holding bank capital in excess of the required level also generates a pecuniary gain, by signaling to markets that they are well capitalized. In de Walque et al. (2010), banks keep a buffer above the required minimum in order to avoid penalties. See Agénor et al. (2012) for a more detailed discussion.

[22] Under Basel's internal ratings-based (IRB) approach, banks are allowed in principle to use their own estimated risk parameters for the purpose of calculating regulatory capital. This could be captured by assuming that banks internalize the fact that changes in the repayment probability affect the risk weight σ_t^i, as implied by (23). However, use of the IRB approach requires approval by the regulator, which we assume is given only *ex post* to mitigate moral hazard on the part of the bank. We capture this by assuming that banks take the risk weight as given when setting the loan rate to maximize expected profits.

$$V_t^E = (\frac{\gamma_{VV}}{i_t^V + \gamma_V - i_t^R})^{1/\phi_E}, \tag{19}$$

$$q_t = \varphi_0(\frac{\kappa \mathbb{E}_t p_{t+1}^H H_t / \tilde{p}^H \tilde{H}}{l_t^{K,i}/\tilde{l}^K})^{\varphi_1}(\frac{Y_t}{\tilde{Y}})^{\varphi_2}, \tag{20}$$

where $\varphi_0 > 0$ is a scale parameter and $\varphi_1, \varphi_2 > 0$. Equation (18) shows now that the lending rate depends negatively on the repayment probability and positively on a weighted average of the marginal cost of borrowing from the central bank (at the gross rate $1 + i_t^R$) and the total cost of raising bank capital, which accounts for both the gross rate of return to be paid to investors and issuing costs. Weights on each component of funding costs are measured in terms of the ratio of required capital to (risky) loans, $1 - \rho_t \sigma_t$ and $\rho_t \sigma_t$, respectively. Thus, a higher marginal cost of raising capital implies a higher loan rate. And assuming that raising funds through bank capital is more costly than borrowing from the central bank ($i_t^V + \gamma_V > i_t^R$), an increase in the capital adequacy ratio, ρ_t, or the risk weight, σ_t, also increases the cost of borrowing.

Equation (19) indicates that an increase in the direct or indirect cost of issuing debt (i_t^V or γ_V) reduces excess capital, whereas an increase in γ_{VV} raises excess capital. With $\gamma_{VV} = 0$, holding capital beyond what is required brings no benefit, so $V_t^E = 0$ for all t. A similar result holds if the fixed cost of issuing debt, γ_V, is very high. An increase in the marginal cost of borrowing from the central bank makes holding capital more attractive as a source of funding of bank operations. Finally, an increase in required capital, which raises the equilibrium cost of issuing bank debt i_t^V, has an indirect, negative effect on the desired level of excess capital. Thus, the two components of bank capital are gross substitutes.

Equation (20) shows that a higher level of cyclical output tends to increase incentives to monitor borrowers. This effect is consistent with the evidence which suggests that the business cycle, in addition to firm-specific financial variables, has a negative impact on the probability of bankruptcy of nonfinancial firms. Equation (20) also shows that an increase in the collateral-loan ratio raises the probability of repayment. As discussed in Appendix B, the collateral-loan ratio exerts conflicting effects on monitoring and the repayment probability. On the one hand, there is a negative *hedging* or *lazy bank effect*, due to the fact that by mitigating the loss that banks incur in case of default, collateral can induce them to monitor less—thereby reducing the probability of repayment. On the other, there is a positive *disciplining effect*, alluded to earlier (reduced incentives for borrowers to take risks and lower unit monitoring costs). Consistent with the evidence of a negative correlation between collateral and a borrower's risk, the disciplining effect is assumed to dominate.

3.3 Central Bank

The central bank's assets consist of loans to commercial banks, $l_t^B = \int_0^1 l_t^{B,i} di$, whereas its liabilities consist of currency in circulation. The balance sheet of the central bank is thus given by[23]

$$l_t^B = m_t^s + nw_t, \tag{21}$$

where nw_t is the central bank's net worth.

The central bank operates a standing facility and, in the base scenario the central bank sets its policy rate on the basis of a Taylor-type rule:

$$\frac{1 + i_t^R}{1 + \tilde{\imath}^R} = (\frac{1 + \pi_t}{1 + \pi^T})^{\varepsilon_1} (\frac{Y_t}{\tilde{Y}})^{\varepsilon_2}, \tag{22}$$

where $\tilde{\imath}^R$ and $\tilde{Y}$ are the steady-state values of the policy rate and output of final goods, $\pi^T \geq 0$ the central bank's inflation target, and $\varepsilon_1, \varepsilon_2 > 0$.

3.4 Financial Regulator

As noted earlier, the financial regulator sets capital requirements as a proportion of risky loans. In turn, in line with the foundation variant of the Internal Ratings Based (IRB) approach of the current Basel arrangements, the risk weight σ_t^i is negatively related to the repayment probability, which reflects perceived default risk, as in de Walque et al. (2010, p. 10) and Mendicino et al. (2018, p. 15), for instance:[24]

$$\sigma_t^i = (\frac{q_t^i}{\tilde{q}})^{-\phi_q}, \tag{23}$$

where $\phi_q \geq 0$ and $\tilde{q}$ is the steady-state value of q_t. Thus, if risk weights are insensitive to default risk (as in a Basel I-type regime), $\phi_q = 0$ and $\sigma_t^i = 1$, $\forall i$.

3.5 Equilibrium and Steady State

Equilibrium conditions for the credit, deposit, cash, labor, housing, and final goods markets are provided in Appendix A. For the housing market, in particular, the equilibrium condition is $H_t = \bar{H}$. The equilibrium condition of the market for bank debt (which determines i_t^V) is obtained by equating (9) and (11):

$$\Theta_V^{-1}(\frac{i_t^V - i_t^B}{1 + i_t^B}) = V_t^R + V_t^E, \tag{24}$$

[23] Bank borrowing from the central bank is determined residually from the aggregate balance sheet of commercial banks.

[24] For a more detailed discussion of the reduced-form, constant elasticity specification used in (23), see Darracq Pariès et al. (2010) and Agénor et al. (2012).

where V_t^R and V_t^E are given by (12) and (19).

The steady-state solution of the model is discussed in Appendix C.[25] Several of its characteristics are fairly standard and need not be elaborated upon. With respect to interest rates, it is worth noting that $\tilde{\imath}^V > \tilde{\imath}^B$ for $\Theta_V > 0$, because holding bank debt is subject to a cost. From the perspective of the representative household, the rate of return on that debt must therefore compensate for that by incorporating a premium relative to the rate of return on government bonds. We also have $\tilde{\imath}^R = \tilde{\imath}^B$, to ensure that banks have no incentives to borrow from the central bank to buy bonds. Thus, the condition $\tilde{\imath}^V > \tilde{\imath}^D$ for $\Theta_V > 0$ holds as well. By construction, the risk weight $\tilde{\sigma} = 1$ and from (12) the steady-state required capital-risky assets ratio, $\tilde{V}^R/\tilde{l}^K$, is equal to $\tilde{\rho}$.

4 Parameterization

To study the properties of the model we parameterize it using mostly standard values used in the literature. In addition, for some of the parameters that are deemed critical from the perspective of this study, sensitivity analysis is reported later on.

The discount factor, Λ, is set at 0.98, which gives a steady-state annualized real interest rate of about 2 percent. The intertemporal elasticity of substitution, ς, is 0.5, in line with the empirical evidence discussed by Braun and Nakajima (2012) and Thimme (2017). The preference parameter for leisure, η_N, is set at 25, to ensure that in the steady state households devote one third of their time endowment to market activity, a fairly common benchmark in the literature (see Christoffel and Schabert (2015), for instance). The inverse of the Frisch elasticity of labor supply, ψ_N, is set at 1.8, which implies that the elasticity itself is 0.56. The preference parameter for the composite monetary asset, η_x, is set at the low value of 0.001 (as in Christiano et al. (2010) and in line with Christoffel and Schabert (2015), for instance), to capture the common assumption in the literature that money *per se* provides little direct utility. The share parameter in the index of money holdings, ν, which corresponds in practice to the relative share of cash in broad money, is set at 0.2 to capture a significantly higher use of sight deposits in transactions. The housing preference parameter, η_H, is set at 0.1, as in Andrés et al. (2013), Rubio and Carrasco-Gallego (2014), and Mendicino et al. (2018), for instance. The portfolio adjustment cost parameter Θ_V is set at 1.9, in order to generate (together with the estimate of γ_V) a spread between the return on bank debt and

[25] We assume that policymakers have no access to lump-sum subsidies to neutralize the distortions associated with monopolistic competition and financial frictions. In that sense, the steady state is inefficient.

the government bond rate of about 4 percentage points.

The elasticity of substitution between intermediate goods, θ, is set at 6, a fairly standard value (see, for instance, Gambacorta and Signoretti (2014), and Funke et al. (2018)), which implies a 20 percent markup in the steady-state equilibrium. The share of capital in domestic output of intermediate goods, α, is set at 0.35, also a standard value; see Christiano et al. (2010), Benes and Kumhof (2015), and Chen and Columba (2016), for instance. The adjustment cost parameter for prices of domestic intermediate goods, ϕ_I, is set at 74.5 to capture a relatively high degree of nominal price flexibility. This value is within the range of values estimated by Ireland (2001). The capital depreciation rate, δ_K, is set at a quarterly rate of 0.035, which is in the span of values typically used in the literature (see, for instance, Gerali et al. (2010), Mendicino and Punzi (2014), and Mendicino et al. (2018)). The adjustment cost incurred by the CG producer for transforming investment into capital, Θ_K, is set at 14, in order to match the fact that the standard deviation of the cyclical component of investment is 3 to 4 times more volatile as GDP in high-income countries (see Uribe and Schmitt-Grohé (2017, Table 1.1).

Regarding commercial banks, the effective collateral-loan ratio, κ, is set at 0.2, to capture the relatively high costs associated with debt enforcement procedures, as documented by Djankov et al. (2008).[26] The elasticity of the repayment probability is set at $\varphi_1 = 0.05$ initially with respect to the effective collateral-loan ratio and at $\varphi_2 = 0.2$ with respect to deviations in output from its steady state. As discussed later, we perform sensitivity analysis with respect to φ_2, to assess the role of credit market imperfections. The elasticity of substitution ζ_L is set at 4.5, as in Dib (2010), for instance. This value generates a spread between the lending rate and the bond rate of the order of 6 percentage points. The parameter that determines the pecuniary benefit associated with excess capital, ϕ_E, is set at 0.5, as in Agénor et al. (2013), to ensure decreasing marginal benefits.

The response of the base policy rate to inflation and output deviations, ε_1 and ε_2, are set at 1.6 and 0.15, respectively. These values are related to those estimated by Christoffel and Schabert (2015, Table 2).

Regarding the regulatory regime, the elasticity of the risk weight with respect to the repayment probability, ϕ_q, is set at a relatively low value, 0.05, consistent with studies like Covas and Fujita (2010) and Agénor et al. (2012, 2013). Consistent also with the linear equity issuance cost estimated by Covas and Fujita (2010, p. 158), the parameter γ_V is set

[26] The results are not particularly sensitive to this value of κ.

at 0.01. The capital adequacy ratio, ρ, is set at 0.08, which corresponds to the floor value under the current Basel regime. As noted earlier, the steady-state value of the risk weight σ is equal to unity. By implication, the steady-state required capital-risky loan ratio is also 8 percent. The pecuniary benefit parameter γ_{VV} is set at 0.001, to ensure that the steady-state excess capital-loan ratio is about 4 percent, in line with the evidence reported by Fonseca et al. (2010).

Parameter values are summarized in Table 1, whereas initial steady-state values for the major variables are displayed in Table 2. In particular, the total (required and excess) capital-risk weighted assets ratio is of the order of 12 percent, consistent with the evidence.

5 Impulse Responses to Financial Shocks

To illustrate the behavior of the model, and the potential sources of gains associated with *leaning against the wind* and the coordination of monetary and macroprudential policies, we briefly describe impulse response functions (IRFs) of some key variables to two financial shocks: a positive repayment probability shock and a negative shock to the deterministic component of bank capital requirements. These shocks are implemented by introducing a multiplicative stochastic disturbance ϵ_t in (20) in the first case, and in (12) in the second. Thus, in the first case, the shock can be interpreted as a transitory reduction in perceived default risk, whereas in the second it can be construed as a temporary reduction in capital requirements.[27] In both cases, the shock is assumed to follow a first-order autoregressive process,

$$\epsilon_t = \epsilon_{t-1}^{\vartheta} \exp(\xi_t),$$

where $\vartheta \in (0, 1)$ and $\xi_t \sim \mathbf{N}(0, \sigma_\xi)$. For both shocks, we set $\vartheta = 0.8$ and $\sigma_\xi = 0.01$. In addition to some of the key variables defined earlier, the behavior of the asset-capital ratio, defined as the ratio of loans to total bank capital, l_t^K/V_t, is also examined.

Figure 1 shows the impulse response functions associated with a 1 standard deviation shock to the repayment probability. The immediate effect is a reduction in the loan rate, which stimulates investment and raises aggregate demand and marginal costs, leading to higher inflation. The refinance rate therefore increases, and this mitigates the initial drop in

[27] The repayment probability shock is similar to the markup shock implemented in Angelini et al. (2014). The bank capital shock differs from the "stock" shock implemented in Angelini et al. (2014) and De Paoli and Paustian (2017) but it is similar in spirit to the initiating disturbance in the "crisis" experiment conducted by Gertler and Karadi (2011).

the cost of bank borrowing. At the same time, both the deposit and bond rates increase.[28] The increase in the nominal bond rate exceeds the rise in the expected inflation rate, implying that the expected real bond rate also increases. This leads to a drop in current consumption (through intertemporal substitution) and to a reduction in the demand for housing.[29] As a result, house prices and collateral values fall, which mitigates the initial increase in the repayment probability and the initial downward effect on the loan rate.

The increase in the repayment probability leads to a lower risk weight which, combined with the increase in investment loans, implies lower capital requirements. The rate of return on bank debt must therefore fall to induce households to hold less of that debt, and this further amplifies the initial downward effect of the shock on the cost of bank borrowing and the initial boom in investment and output. At the same time, the reduction in the return on bank capital exceeds in magnitude the increase in the policy rate, thereby inducing banks to increase their holdings of excess capital. But because required capital and excess capital move in opposite directions, and the reduction in the former exceeds the increase in the latter, total bank capital falls. Because loans increase while bank capital falls, the bank asset-capital ratio unambiguously rises. A key feature of these results is that the presence of a risk-sensitive regulatory regime is *countercyclical* in response to a positive financial shock that has a direct impact on the cost of bank borrowing, but this effect is mitigated by the offsetting movement in excess capital held by banks.

Figure 2 shows the impulse response functions associated with a 1 standard deviation shock to bank capital. The reduction in required capital puts downward pressure on the rate of return to capital, which lowers the marginal cost of borrowing for banks. The lending rate therefore falls, and this stimulates investment and aggregate demand. Inflation also rises. The refinance rate therefore unambiguously increases, thereby mitigating the initial drop in the loan rate. The nominal bond rate increases as well and so does the expected real bond rate, because the increase in one-period ahead in inflation is relatively small. As a result, current consumption drops and the demand for, and the real price of, housing services, fall. Despite higher cyclical output, the reduction in collateral values leads to a reduction in the repayment probability, which tends again to mitigate the initial reduction in the loan rate and the expansion of credit and investment. The lower repayment probability raises the risk

[28] The deposit rate rises *pari passu* with the refinance rate and leads to an increase in household demand for deposits (a reduction in the demand for bonds), which translates into a higher bond rate. In addition, the increase in the bond rate reduces the demand for cash, which contributes also to the shift into deposits.

[29] The reduction in consumption lowers the demand for leisure and raises labor supply, which mitigates the upward pressure on wages associated with the increase in activity.

weight, which dampens (despite the increase in loans) the initial fall in capital requirements. The regulatory regime is thus *procyclical* in response to a bank capital shock; but here again, this effect is mitigated by the fact that excess capital rises in response to a lower differential between the rate of return on capital and the refinance rate. Once again, the drop in required capital exceeds the increase in excess capital, so total capital falls. Because, at the same time, investment and the supply of risky loans expand, the bank asset-capital ratio increases unambiguously. Overall therefore, except for the behavior of the repayment probability, the adjustment process is very similar for the two shocks.

Figures 1 and 2 also show the impulse response functions when excess capital is kept constant at its initial steady-state value. Qualitatively, the results are similar to those obtained when that variable is endogenous. When excess capital is constant, the drop in total capital is larger for both shocks, and so is the drop in the rate of return on bank capital. Consequently, the drop in the loan rate is magnified, and so is the expansion in investment and output—in the latter case, despite the stronger contraction in current consumption, associated with a more significant increase in the real bond rate. The reason for the latter is because with higher output, the increase in inflation is larger, and so is the rise in the refinance and deposit rates. Given the magnitude of the shocks, however, the differences in outcomes between endogenous and exogenous excess capital are not large.[30]

6 Welfare Gains under Alternative Policy Mandates

To study the optimality of alternative policy mandates, and assess the role of biased preferences, we assume that the central bank and the regulator follow simple, implementable rules. In the case of *leaning against the wind*, an augmented Taylor rule is specified:

$$\frac{1+i_t^R}{1+\tilde{\imath}^R} = (\frac{1+\pi_t}{1+\pi^T})^{\varepsilon_1}(\frac{Y_t}{\tilde{Y}})^{\varepsilon_2}(\frac{l_t^K}{l_{t-1}^K})^{\varepsilon_3}, \tag{25}$$

where $\varepsilon_3 \geq 0$. Thus, the central bank reacts to credit growth.[31] We begin by keeping ε_1 and ε_2 at their benchmark values provided earlier. Our motivation for imposing these restrictions initially is to make the analysis more transparent, and to ensure that the policy rule resembles the kind of reaction functions that broadly describes central bank decisions in

[30] We further discuss the role of excess capital for optimal policy later on. In that context, quantitative differences become more apparent.

[31] Agénor et al. (2013), Gambacorta and Signoreti (2014), and Bailliu et al. (2015) also use credit growth in the interest rate rule, whereas Agénor and Zilberman (2015) use (deviations in) credit-to-output ratios. However, as discussed next, the latter variable can be an unreliable measure of financial risks; for consistency with the macroprudential policy rule, credit growth is used in both specifications.

practice. We then consider the welfare consequences of policy rules with different coefficients for credit deviations only.[32]

To specify the policy rule of the financial regulator, we begin by decomposing the overall capital ratio, ρ_t, into a deterministic component, ρ^D, and a cyclical component, ρ_t^C:

$$\rho_t = \rho^D + \rho_t^C. \tag{26}$$

The component ρ^D can be viewed as the minimum capital adequacy ratio imposed under Basel III, whereas the component ρ_t^C can be viewed as the discretionary component, that is, the countercyclical capital buffer.

As in Agénor et al. (2013), Gelain and Ilbas (2017), and Bekiros et al. (2018), for instance, adjustment of the countercyclical component of capital requirements is also related to credit growth:

$$\frac{1+\rho_t^C}{1+\tilde{\rho}^C} = (\frac{l_t^K}{l_{t-1}^K})^{\chi_2}, \tag{27}$$

where $\chi_2 > 0$. This specification is consistent with the evidence showing that excessive credit expansion is a key predictor of financial crises, as documented by Agénor and Montiel (2015, chapter 15), Taylor (2015), Aikman et al. (2015), and Chen and Svirydzenka (2021).[33] Thus, in a sense, credit is an *operational* or *intermediate target* for financial stability. In addition, the use of credit growth is consistent with the analysis in Drehmann et al. (2010) and Drehman and Tsatsaronis (2014) with regard to the build-up phase of capital buffers under Basel III: the credit-to-output ratio can send the wrong signal in the early stages of a recession, because it may increase not because of a rise in the numerator (credit) but instead because of a fall in the denominator (activity).[34]

In addition to the base case of no activism—under which the refinance rate is set on the basis of the standard Taylor rule (22), and the regulator does not react countercyclically—we consider three alternative regimes. The first relates to *leaning against the wind* only,

[32] de Paoli and Paustian (2017) follow a similar approach, although they also consider the case where the coefficient on output deviations varies at the same time. The case of endogenous parameters is discussed later on.

[33] Some studies, including Anundsen et al. (2016), Aldasoro et al. (2018), Greenwood et al. (2020), and Krishnamurthy and Muir (2017), have found that asset prices (in particular, property prices) can also be predictors of financial crises. However, overall, the evidence appears to be less robust. Moreover, property prices and credit are often closely correlated in practice. A parsimonious rule like (27) is also more easily implementable.

[34] Contributions that have considered (deviations in) the credit-to-output ratio in countercyclical capital requirements rules include Angelini et al. (2014), Benes and Kumhof (2015), Clancy and Merola (2017), and Bekiros et al. (2018), whereas Benes and Kumhof (2015), Clerc et al. (2015), and Rubio and Carrasco-Gallego (2016) considered deviations in credit from steady state. By contrast, in Mendicino et al. (2018), capital requirements are linked directly to expected default risk.

which involves the central bank using the augmented Taylor rule (25) and solving optimally for ε_3, while the regulator doesn't react (and thus $\chi_2 = 0$). The second regime involves countercyclical *macroprudential regulation* only, that is, the rule (27), with the regulator solving optimally for χ_2, while the central bank continues to use the standard Taylor rule, given by (22), or $\varepsilon_3 = 0$. The third is the *full coordination* regime, in which policymakers solve jointly for the optimal combination of the two instruments, ε_3 and χ_2. Policies are computed under commitment, that is, under the assumption that policymakers have the ability to deliver on past promises—no matter what the current situation is today.

Under the first two mandates, each policymaker solves for the value that maximizes its social welfare function, which corresponds to the welfare the representative household, subject to some bias in their preferences, and a cost associated with instrument manipulation. Specifically, we assume that the central bank attaches some weight to inflation (as in Bodenstein et al. (2019)), as well as some weight to deviations in the policy interest rate (as in Rudebusch and Svensson (1999), Angelini et al. (2014), and Debortoli et al. (2019)):

$$W_t^C = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s u_{t+s} - \omega^C \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\pi_{t+s} - \pi^T)^2 - \varkappa^C \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (i_{t+s}^R - i_{t+s-1}^R)^2, \tag{28}$$

where $\omega^C, \varkappa^C \geq 0$ are parameters that measure the degree of bias in central bank preferences and the cost associated with changes in the policy rate, respectively, and u_t is the period utility function. Thus, the central bank is more concerned with deviations from its inflation target than the representative household, as a result of an explicit institutional mandate.

For its part, the financial regulator attaches a higher weight to financial stability, as measured by deviations in the credit-to-output ratio, as well as a cost to changes in the discretionary component of capital requirements:

$$W_t^R = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s u_{t+s} - \omega^R \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left(\frac{l_{t+s}^K}{Y_{t+s}} - \frac{\tilde{l}^K}{\tilde{Y}}\right)^2 - \varkappa^R \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s (\rho_{t+s}^C - \rho_{t+s-1}^C)^2, \tag{29}$$

where $\omega^R, \varkappa^R > 0$. Thus, in the first regime the central bank sets $\varepsilon_3 = \arg\max W_t^C$ with $\chi_2 = 0$, in the second the macroprudential regulator sets $\chi_2 = \arg\max W_t^R$ with $\varepsilon_3 = 0$, and in the third policymakers jointly determine both response parameters so as to maximize a weighted sum of each policymaker's welfare:

$$\varepsilon_3, \chi_2 = \arg\max[n W_t^C + (1-n) W_t^R], \tag{30}$$

where $n \in (0, 1)$ reflects the relative weight attached to the central bank's welfare function.

The welfare gains under each policy scenario is assessed by calculating compensating variations compared to the "no activism" benchmark. Thus, the welfare gain from the perspective of each policymaker is obtained by solving for λ^j, $j = C, R$, in the expression:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s W_t^j[(1+\lambda^j)C_{t+s}^B, Z_{t+s}^B] = \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s W_t^j(C_{t+s}^h, Z_{t+s}^h), \tag{31}$$

where Z_t^B and Z_t^h relate to all the variables other than consumption appearing in (28) and (29), $\{C_{t+s}^B, Z_{t+s}^B\}_{s=0}^{\infty}$ are solution paths in the baseline case with no activism ($\varepsilon_3 = \chi_2 = 0$), and $\{C_{t+s}^h, Z_{t+s}^h\}_{s=0}^{\infty}$ are solution paths under scenario h. Similarly, the welfare gain for the economy as a whole is calculated by solving for λ in the expression

$$\mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ nW^C[(1+\lambda)C_{t+s}^B, Z_{t+s}^B] + (1-n)W^R[(1+\lambda)C_{t+s}^B, Z_{t+s}^B] \right\} \tag{32}$$

$$= \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda^s \left\{ nW^C(C_{t+s}^h, Z_{t+s}^h) + (1-n)W^R(C_{t+s}^h, Z_{t+s}^h) \right\},$$

where λ^j, $\lambda \geq 0$ indicate a welfare gain.[35]

The results for the three mandates are shown in the upper part of Table 3, for two alternative assumptions about policy preferences. In the first, both authorities set policies with no bias in preferences, $\omega^C = \omega^R = 0$, thereby maximizing only the discounted utility of the representative household, adjusted for the cost of instrument manipulation. In the second, the central bank and the regulator have biased preferences with respect to inflation stability and financial stability, respectively, with the same weight attached to the additional objective, so $\omega^C = \omega^R = 0.5$. We also set the cost of instrument volatility at a fairly low value, $\varkappa^C = \varkappa^R = 0.01$, and assume that under coordination authorities have equal weight, so that $n = 0.5$.[36] Figures 3 and 4 also show how the optimal response parameters are determined under alternative policy scenarios, so as to maximize welfare (normalized by welfare under no activism). Grid searches over the coefficients of both the monetary and macroprudential policy rules were conducted at 3 decimal points and involve a step of 0.001.

With respect to the repayment probability shock, the results displayed in Table 3 indicate that under *leaning against the wind*, there is a welfare gain for households, both policymakers, and the economy as a whole, compared to the base case with no policy response, when

[35] Expressions (31) and (32) are evaluated using second-order approximations to both the household's period utility function and the model, conditional on the initial steady state being the deterministic steady state. See Appendix D for details.

[36] A low value of the instrument cost is sufficient to ensure that the regulator does not fully stabilize credit by setting $\chi_2 \to \infty$.

there are no biases in preferences. However, no party gains when preferences are biased. By contrast, with countercyclical capital requirements, all parties benefit from activism, whether preferences are biased or not. In addition, biased preferences induce the regulator to respond more aggressively, and the central bank not at all. The reason is that with stronger preferences for price stability, *leaning against the wind* is not optimal.

The results also indicate that full coordination of the two policies is superior to a situation where either policymaker acts alone, for all parties and the economy as a whole, when there is no bias in preferences. Moreover, independently of whether preferences are biased or not, both policymakers pursue a more aggressive policy; ε_3 and χ_2 are indeed substantially higher when policymakers cooperate. When preferences are biased, the welfare gain for the economy as a whole is also higher under full coordination than when each authority acts alone. In that sense, monetary and macroprudential policies are complements, rather than substitutes. Relative to no activism, the gain from policy intervention (under coordination or not) is higher when preferences are biased. In particular, under full coordination, the compensating variation increases from 2.8 percent to 3.0 percent for households, from 2.4 percent to a sizable 12.4 percent for the regulator, and from 2.3 percent to 3.4 percent for the economy as a whole. However, under full coordination the central bank is worse off, moving from a gain of 2.0 percent to a loss of 4.2 percent. Thus, cooperation is not Pareto-improving.

Intuitively, coordination leads to an aggressive response by the central bank because monetary policy is quite effective in terms of stabilizing the credit-to-output ratio; this effect is internalized when the two authorities choose to cooperate. However, relative to the case where it does not act, it incurs a higher cost of instrument volatility. Thus, from the perspective of the central bank, the possible gain generated by *leaning against the wind* (in terms of reduced volatility of consumption and employment, in particular) is offset by the loss associated with changes in interest rates—even when the cost of instrument manipulation is relatively small, as is the case here. Moreover, given that the central bank has no mandate for financial stability, it does not benefit directly (in contrast to the regulator) from a more aggressive response to credit fluctuations. For the financial regulator, the loss incurred as a result of instrument manipulation exists as well, but it is much less significant, even though under coordination it reacts also more aggressively. Thus the regulator is better off under full coordination—so much so that households and the economy as a whole also benefit from coordination. Because both authorities react more when they cooperate, monetary and macroprudential policies can be viewed as complements.

With respect to the bank capital shock, the results are fairly similar; the central bank is worse off (compared to no activism), whether it reacts alone or it cooperates with the regulator. The key difference is that, despite the fact that in both cases the central bank reacts less aggressively, its loss is magnified when preferences are biased. As a result, although the regulator (which again reacts more aggressively under full coordination) is better off, the gain for households and the economy as a whole is mitigated compared to the case where there is no bias in preferences.

Interestingly, is also worth noting that, for the repayment probability shock, households are better off under coordination when policy preferences are biased, that is, when policy-makers do not focus solely on household welfare. Qualitatively, a similar result obtains for *both* shocks when macroprudential regulation alone is used countercyclically. The key reason is that in all of these cases, output, and thus employment, is more stable; this creates a direct welfare benefit for the representative household. Although these numerical results cannot be construed by any means as being general in nature, they illustrate well the fact that putting more weight on a mandate-specific variable—and thus relatively less weight on household welfare—may not be detrimental to households.

7 Coordination Gains and Biased Preferences

The foregoing discussion has shown that, abstracting from strategic considerations, full coordination between policymakers is always welfare-enhancing—regardless of the origin of the shock. We now examine whether coordination brings benefits, and how large these benefits are, compared to a situation where policymakers can act strategically, in the presence of biased and unbiased preferences.

To study the gain from full coordination, we continue to assume that the central bank pursues an augmented Taylor rule as in (25), and the regulator a countercyclical capital rule as in (27). Now, as under a Nash equilibrium, in the absence of full coordination policymakers pursue independent policies and set unilaterally their instrument (or more accurately, the response parameter in the policy rules), taking as given the response of the other policymaker. In so doing, each of them seeks to maximize the welfare of the representative household, subject again possibly to some bias in their preferences, and a cost associated to instrument manipulation, as in (28) and (29).

Thus, under non-cooperation (Nash), each policymaker determines independently the optimal value of the response parameter ε_3 or χ_2 in the rules (25) and (27), denoted by ε_3^N

and χ_2^N, so that

$$\varepsilon_3^N = \arg\max W_t^C\big|_{\chi_2=\chi_2^N}\,,\ \ \chi_2^N = \arg\max W_t^R\big|_{\varepsilon_3=\varepsilon_3^N}\,. \tag{33}$$

As in de Paoli and Paustian (2017), for instance, under non-cooperation we solve for the closed-loop equilibrium: given the feedback rules (25) and (27), each regulator has full knowledge of the other regulator's reaction function; their best responses reflect therefore this knowledge. In contrast, under full coordination, policymakers once again jointly determine the optimal response parameters, denoted χ_2^O and ε_3^O, so as to maximize a weighted sum of each policymaker's welfare, as in (30). We calculate the welfare gain from full coordination using a similar method as above, that is, using equations (31) and (32), except that welfare gains are relative to Nash, rather than relative to the baseline (no activism), as in the previous calculations.

7.1 Main Results

The main results are shown in the lower part of Table 3. They indicate that both policymakers act less aggressively under Nash than under full coordination; with biased preferences, the optimal response for the central bank under Nash is actually not to respond at all to financial stability considerations. In that case, and consistent with Tinbergen's principle, *leaning against the wind* is not optimal. By contrast, it is optimal (and welfare-improving for the economy as a whole) for both policymakers to react to credit fluctuations under coordination. Yet, when preferences are biased, the central bank is worse off under coordination than under Nash—with losses of 4.5 percent and 9.9 percent, depending on the shock. Thus, because it involves *burden deepening* (both policymakers reacting more aggressively to financial stability considerations) rather than *burden sharing* (one policymaker reacting more, and the other less, aggressively), and because policy intervention is costly, full coordination is not Pareto-improving—even though, relative to Nash, households gain from full coordination, the more so when preferences are biased.

Table 4 shows the results when excess capital is exogenous. As noted earlier, in response to both financial shocks, movements in excess capital tend to mitigate the cyclical effects of the regulatory regime. The reason (in line with the results in de Walque et al. (2010), for instance) is that the impact of these shocks is dampened by the buffer that banks hold on top of the minimum capital impose by the regulator. Figures 1 and 2 showed indeed that when excess capital is kept constant at its initial steady-state value, the increase (fall) in total bank capital is magnified in response to the spread (bank capital) shock, and so is the increase (fall) in the return on bank debt. At the same time, the real effects are amplified in response to both shocks—more so for the bank capital shock. One would therefore expect that, with exogenous excess capital, policy responses (whether authorities act independently or jointly) should be essentially the same as those documented earlier in response to the repayment probability shock, and to be more aggressive in response to the bank capital shock, given that the regulatory regime in that case is procyclical. At the same time, in the latter case, given a positive cost to instrument volatility, the net effect on welfare relative to the benchmark scenario may be ambiguous—and possibly negligible. The results shown in Table 4 indicate no major differences with those reported in Table 3.

To further illustrate the gains to the economy from each regime, Figure 5 decomposes each policymaker's objective function into household welfare, the institution-specific mandate, and the instrument-specific manipulation cost.[37] The absolute difference to no activism, normalized by household welfare under no activism, is shown in each case. Positive values denote gains, in terms of reduced volatility of the relevant variable, whereas negative values indicate losses from increases in volatility. The net gains (benefits less costs) to the economy as a whole are identified by an asterisk on the same scale. The first row depicts results without biased preferences; thus, all gains are associated with household welfare and all costs with the regulatory agencies. Graphically, the weakness of the macroprudential instrument when acting alone is readily apparent.

With biased preferences, the benefits of coordination are also very clear. The figure shows that central bank losses under coordination are mainly due to increased inflation volatility, as opposed to the instrument cost. Indeed, this loss is greater than the financial regulator's gain from reduced volatility in the credit-to-output ratio. Importantly, however, household welfare is significantly higher under coordination with biased preferences, for the reasons discussed earlier—essentially the fact that biases can be used to internalize the cost of instrument manipulation.

7.2 Constrained Coordination

The fact that cooperation is not Pareto-improving when preferences are biased means that a voluntary agreement to cooperate is unlikely to be sustainable. However, suppose that society can impose a *constrained coordination* regime, which is such that neither policy authority can be worse off compared to Nash. Formally, we solve equation (30) subject to

[37] To save space, we consider only the case of endogenous excess capital; results for exogenous excess capital are similar qualitatively.

the constraint that $\lambda^j \geq 0$, for both policymakers. We calculate λ^j, $j = C, R$, using the same methodology as described earlier, that is, using equation (31), redefined with the Nash equilibrium as the benchmark regime.

The results are shown in Table 5. This regime, naturally enough, implies significant *burden sharing* between policymakers, with the central bank intervening less, and the regulator more, when preferences are biased.[38] At the same time, however, for the economy as a whole, constrained coordination is also significantly less beneficial than full coordination; compared to no activism, the gain is smaller by 69 percent for the repayment shock and by 72 percent for the capital shock. Compared to Nash, these numbers are 65 percent and 79 percent, respectively. Thus, relative to Nash, there are still significant gains to coordination both for households and the economy as a whole—especially with biased preferences, which suggests that even with the constraint of Pareto-improvement for both authorities, an institution-specific mandate can improve welfare.

7.3 Varying Changes in Bias Parameters

Figures 6 to 9 generalize the results in Table 3 by showing how—for given values of the instrument manipulation costs, $\varkappa^C$ and $\varkappa^R$—the results vary when the bias parameters ω^C and ω^R vary independently within the interval $(0, 1)$.[39] Figures 6 and 7 show, for both shocks, how the optimal policy responses for the central bank and the regulator vary under coordination and under Nash, respectively. Figures 8 and 9 show, again for both shocks, how aggressive policy responses are, and how welfare changes, under coordination relative to Nash, the upper panels in these two figures correspond therefore to the differences shown in the previous figures. As in Table 3, the three components of welfare (household, central bank, regulator) are displayed, in addition to welfare for the the economy as a whole.

The results indicate, first, that as the institutional mandate of the central bank puts greater emphasis on price stability, the central bank's response to financial stability becomes weaker, whereas when the mandate of the regulator puts greater emphasis on financial stability, the regulator's response to credit fluctuations becomes more aggressive. Second, as the bias toward financial stability in the regulator's objective function increases, *both* policy authorities respond more aggressively to credit developments, compared to when they act strategically. The reason is that in our model the policy rate is a more effective instrument to

[38] As shown in Tables 3 and 4, when there are no biases in preferences, the central bank is not worse off under coordination.

[39] Using an upper bound of 1 is sufficient for illustrative purposes.

address credit fluctuations than capital requirements and is therefore used more intensively when policy authorities cooperate. As can be seen in the loan rate equation (18), the weights on the refinance rate and the cost of raising bank capital are $1 - \rho_t \sigma_t$ and $\rho_t \sigma_t$, respectively. Because ρ_t is relatively small, this implies that changes in the cost of issuing capital, by construction, have more limited effects on the loan rate than changes of the same magnitude in the refinance rate.[40] At the same time, and again for both shocks, while the regulator and the economy as a whole always gain, the household and the central bank are worse off. Intuitively, for the regulator the benefit of a more aggressive policy always exceeds the cost of instrument manipulation, whereas for the central bank the opposite holds. In addition, for the household, a more aggressive use of policy rates translates into more volatile market rates, which translates into increased consumption volatility.

By contrast, when the bias toward price stability in the central bank's objective function increases, the policy response and the welfare gain associated with full coordination relative to Nash are *non-monotonic* for all parties—it increased at first and falls beyond a certain point. Intuitively, as the weight that the central bank attaches to price stability in its objective function increases, it responds also more aggressively to credit fluctuations, because these fluctuations have an indirect effect (through aggregate demand) on price movements. By stabilizing prices, fluctuations in the real bond rate are mitigated, and this dampens volatility in consumption. Thus, by *leaning against the wind*, the central bank not only stabilizes credit flows (the intermediate target associated with financial stability), it also contributes to greater macroeconomic stability. Beyond a certain point, however, a more aggressive interest rate policy increases volatility in the loan rate, which translates into greater volatility in investment, aggregate demand, and prices. The implication therefore is that if the goal is to maximize the welfare gain relative to Nash, there is an optimal value of the preference bias for the central bank that is positive and less than unity. At the same time, the optimal value of the preference bias for the regulator is the highest possible value that society can bestow to that policy authority.

Finally, it is worth pondering further the role played by *burden deepening* and *burden sharing* in determining whether coordination is Pareto improving. As discussed earlier, both policymakers act less aggressively under Nash than under coordination; indeed, in both Tables 3 and 4, the optimal response parameters ε_3 and χ_2 are always lower when the central

[40] In addition, through their impact on these weights, changes in the capital adequacy ratio (holding interest rates constant) have conflicting effects on the loan rate. This could mitigate the net effect of these changes on the market cost of borrowing if the refinance rate and the interest rate on bank debt move in the same direction in response to shocks.

bank and the regulator act independently—regardless of whether policy preferences are biased or not. Coordination therefore entails *burden deepening* (both policymakers reacting more aggressively to financial stability considerations) rather than *burden sharing* (one policymaker reacting more and the other less aggressively), as also noted earlier. However, in the case of biased preferences, the central bank is also worse off under coordination, despite *burden deepening*, whereas in the case of unbiased preferences, *all* parties are better off, implying that is Pareto-improving. The key reason is that with biased preferences, coordination induces the central bank to intervene proportionately more (compared to Nash) to promote *both* price and financial stability, compared to the regulator, because capital requirements (as noted earlier) are a less effective tool in the model. Consequently, the central bank incurs a higher cost of instrument manipulation.

Of course, assuming different costs of instrument use—namely, a lower cost for the central bank, which can change its policy rate overnight, compared to the high cost of changing capital requirements—could alter this result and make coordination, even with biased preferences, also Pareto-improving. But more broadly, this result illustrates the importance of accounting for the cost of instrument use when assessing not only the degree to which policymakers should respond to shocks (a fairly standard practice) but also in assessing welfare benefits across policies.

8 Optimal Institutional Mandates

In the foregoing analysis, biases in preferences were taken as given. We now discuss how these biases, or equivalently in our setting the institutional mandates that underlie them, can be set optimally. The early literature, illustrated by the conservative central banker studied by Rogoff (1985, 1989), focused on the need to address time-inconsistency problems under discretion through greater concern with inflation stabilization. With the notable exception of De Paoli and Paustian (2017), this issue has received limited attention since then.[41] As noted earlier, De Paoli and Paustian's approach is indeed motivated by the lack of a commitment technology. However, their approach is to set the relative weight on output in the delegated loss functions equal to the weight that the social planner would choose. Our analysis, by contrast, highlights the role of instrument adjustment costs and the specification of the social welfare function in the presence of these costs, when biases in preferences are endogenous

[41] Another contribution is Lazopoulos and Gabriel (2019). They emphasized, as we do, the spillovers that instruments may have on policymakers' objectives, although they do so in a very different setting.

and policy is set under commitment.

Specifically, the issue that we address is how to choose optimally the bias parameters, ω^C and ω^R. In Figures 8 and 9, we showed how (for given values of the instrument manipulation costs) these biases affect the gains from coordination relative to Nash. The criterion that we propose to determine the optimal mandates is that society should set these two parameters so as to maximize the household gain only, under coordination, relative to no activism. The rationale for doing so is that society, when it chooses to bestow a specific institutional mandate to policy authorities, ensures that it only cares about maximizing the welfare of its citizens. However, in our setting the optimal mandate also depends *indirectly* on the cost of instrument manipulation, because it does matter from the perspective of the policy authorities when they set their instruments. Therefore, the optimal bias parameters are conditional on the instrument cost that both policymakers face. In a sense, in choosing the optimal bias, society internalizes the effect of the instrument cost on the behavior of each policymaker—because, each of them does so directly when calibrating their reaction functions. Moreover, under coordination, the instrument cost faced by each authority naturally affects the behavior of the other.[42]

Figure 10 illustrates the results for the two shocks. We vary the instrument cost parameters, $\varkappa^C$ and $\varkappa^R$, between 0.01 and 0.1, and the optimal bias parameters between 0 and 1; in both cases we use a grid step of 0.01.[43] The results show that, for the repayment probability shock, the optimal bias for the central bank falls continuously with increases in its own instrument manipulation cost, whereas for the regulator the bias is at its upper bound—unless the instrument cost for the central bank is very low. These results are consistent with those established earlier for both shocks (see Figures 6 and 7): as the cost of instrument use rises, the central bank responds less to financial stability considerations. In turn, weaker incentives to *lean against the wind* constrain the central bank's ability to mitigate interest rate volatility—and, therefore, consumption volatility. To maximize household welfare, it is therefore optimal to bestow a mandate that is less focused on price stability. By contrast, under coordination the regulator responds more aggressively to movements in credit: it is optimal to rely as much as possible on macroprudential policy to address financial stability considerations.

[42] This is the reason why we focus on outcomes under cooperation, rather than Nash. Note that Bodenstein et al. (2019) also considered the cooperation solution in discussing how biased parameters should be set, but they did not discuss the role of instrument costs in that context and their implications for the optimal mandate.

[43] Again, these values are sufficient for illustrativee purposes.

When the cost of instrument manipulation rises for the regulator, the opposite occurs—society should grant the central bank as much latitude as possible to achieve price stability, whereas the regulator should not—at least beyond a certain value of the cost parameter. The optimal values are thus $\omega^C \in (0.53, 1)$ and $\omega^R \in (0.97, 1)$ as the instrument cost for the central bank varies between 0.01 and 0.1, and $\omega^C = 1$ and $\omega^R \in (0.94, 0.97)$ when the instrument cost for the regulator changes.[44] Related results hold for the capital shock, with values of $(0.25, 0.52)$ and 1 in the first case, and 1 and 0.53 in the second. Thus, at least for these two shocks, the proposed optimal institutional mandate is robust, even though specific values for the optimal bias parameters differ somewhat across shocks. Importantly, the results also suggest that, in contrast with the core illustrative experiments reported in Tables 3 and 4, preference biases do not need to be symmetric.

Intuitively, the penalty cost associated with instrument manipulation distorts policy away from the representative household's optimum because households do not care directly about instrument volatility *per se*.[45] As a result, biases in preferences have the potential to improve welfare for households: increasing the bias, while holding fixed the weights attached by the policymaker to household welfare and the instrument volatility cost, effectively reduces these weights. However, because *both* weights are affected in the objective function of each policymaker, higher biases do not imply that households are necessarily better off. For the central bank, regardless of the financial shock considered, there is indeed an inverse relationship between the own instrument manipulation cost and the preference for inflation. In addition, the bias parameter ω^C (respectively, ω^R) is independent of changes in $\varkappa^R$ (respectively, $\varkappa^C$), the other policymaker's instrument cost parameter, even though the choice of both bias parameters is based on the assumption of coordination among policy authorities. At the same time, the bias parameter for the regulator does not depend on changes in its own instrument cost. These results are a reflection of the fact that, in our model, *leaning against the wind* is (as discussed earlier) is a more effective tool to mitigate financial volatility than countercyclical capital requirements; consequently, the cost component matters a lot more (indirectly) for setting the central bank's institutional mandate, and the weight that the regulator must attach to credit fluctuations should be as high as possible.

[44] For both shocks, as can be inferred from Figure 10, the optimal value of ω^C tends to 0 as the instrument cost for the central bank continues to increase beyond 0.1.

[45] This distortion is somewhat magnified because inertia in instrument adjustment is not accounted for in the policy rules (22), (25) and (27). As a result, policymakers can reduce instrument volatility only by responding less to the underlying trigger variable.

9 Sensitivity Analysis

To assess the robustness of the above results, we performed sensitivity analysis with respect to several features of the model and its parameterization, within reasonable ranges. We considered, in turn, the case of stronger financial frictions, in the form of greater sensitivity of the repayment probability to the collateral-loan ratio and cyclical output (increases in ϕ_1 and ϕ_2); a more sensitive risk weight to the repayment probability (as measured by the coefficient φ_q), and the existence of a monitoring incentive (or *skin in the game*) effect associated with bank capital, as discussed in Agénor et al. (2012, 2013); a higher cost of holding bank debt (an increase in Θ_V), a greater marginal benefit of excess capital (a reduction in γ_{VV}); a higher deterministic component of the capital adequacy ratio (an increase in ρ^D), to reflect a permanent increase in capital requirements; and a constant risk weight (σ, normalized to unity), in line with Basel II and the existence of a leverage ratio. We also considered the case where, in our welfare calculations, the composite monetary asset is excluded from the second-order approximation of the period utility function.[46] In each case, we considered changes in the transmission mechanism, the optimal policy responses, and the optimal bias coefficients in policy preferences. While these exercises did alter somewhat the results from a quantitative standpoint, they did not change the main qualitative features of the results discussed earlier.

We also examined whether the response of the central bank to its main objective (price stability), when it acts independently or in coordination with the regulator, is mitigated when it can optimize across all parameters of its augmented interest rate rule (ε_1, ε_2, and ε_3)—as opposed to optimizing with respect to its response to credit growth only. When solving for all three parameters, the values of ε_1 and ε_2 were found to be always equal to the upper bound that we imposed.[47] Thus, in our setting, and given the shocks that we consider, it is always optimal for the central bank to react to movements in inflation and output as much as it is allowed to.[48] Again, the thrust of the previous results were not affected either. Accordingly, and given our focus in this paper on biases in policy preferences and their implications, a full discussion of these issues is omitted to save space.

[46] The rationale for doing so, as discussed in Agénor (2020, chapter 5), is the well-established functional equivalence between using money as an argument of the utility function and either entering it into liquidity costs or a shopping-time technology.

[47] Although there is no clear metric on what upper parameter bounds should be in this type of experiments, we used a value of 3, as in Bailliu et al. (2015) and others.

[48] By implication, the issue of whether the interest rate response to inflation or output is weaker when the monetary authority *leans against the wind*—an issue discussed in the literature focusing on monetary policy only—does not arise.

10 Concluding Remarks

This paper studied the extent to which biased policy preferences, motivated by narrow institutional mandates, affect the gains from coordination between monetary policy (which may respond to financial imbalances) and macroprudential regulation (in the form of risk-sensitive capital requirements) in responding to financial stability considerations, and whether these mandates can be set optimally. The analysis was based on a model with banking and financial frictions in which the transmission mechanism of monetary policy and macroprudential regulation are closely interlinked. It was assumed that the objective function of each policymaker differs from the welfare of the representative household due to biases in policy preferences and costly instrument volatility.

The main results were summarized in the introduction. To conclude, it is worth pointing out that our analysis could be extended in several directions. A fruitful area of investigation would be to endogenize risk-taking by banks, and to account for the fact that capital requirements, along with monetary policy, may affect lenders' incentives to take risk—in addition to increasing monitoring incentives, as noted earlier. Some recent contributions to the DSGE literature, including Nguyen (2014), Begenau (2015), Collard et al. (2017), and Aikman et al. (2019) have indeed explored these relationships, with a focus on solving for the welfare-maximizing optimal risk-based capital ratio. If bank risk-taking affects the composition of lending and investment efficiency, it may also affect the gains from coordinating monetary and macroprudential policies, for given biases in policy preferences.

Another extension would be to consider possible complementarities between macroprudential instruments themselves and what their implications for coordinating monetary and macroprudential policies are. So far, only a few contributions to the literature have focused on the issue of multiple instruments of macroprudential regulation, and the extent to which these instruments themselves are complements or substitutes.[49] Different instruments may affect differently market pricing of uninsured liabilities, and consequently bank funding costs and portfolio allocation. For the issue at stake, considering a range of tools—distinguishing, in particular, between those that affect borrowers and those that affect lenders—could be important because it is possible that, in response to some shocks, coordinating macroprudential instruments among themselves may generate superior welfare outcomes and be Pareto improving, compared to the coordination of any of these instruments, taken individually,

[49] Agénor and Pereira da Siva (2017), for instance, consider complementarity (or lack thereof) between loan loss provisions and reserve requirements, whereas Krueger et al. (2018) focus on the interactions between loan loss provisions and capital requirements. See also Millard et al. (2021).

with monetary policy. From the perspective of this paper, it is also possible that the impact of policy bias in preferences on the strategic gain from coordination may vary depending on the macroprudential instrument under consideration.

Appendix A
Production Side and Real Equilibrium Conditions

This Appendix describes the production of the final good, the production of intermediate goods, and the production of capital goods.

Final Good Producers

The final good, Y_t, is produced by assembling a continuum of imperfectly substitutable intermediate goods Y_t^j, with $j \in (0,1)$:

$$Y_t = \left\{ \int_0^1 (Y_t^j)^{(\theta-1)/\theta} dj \right\}^{\theta/(\theta-1)}, \tag{A1}$$

where $\theta > 1$ is the elasticity of demand for each intermediate good.

The FG producer sells its output at a perfectly competitive price. Given the intermediate-goods prices P_t^j and the final-good price P_t, it chooses the quantities of intermediate goods, Y_t^j, that maximize its profits. Thus,

$$Y_t^j = \arg\max P_t \left\{ \int_0^1 (Y_t^j)^{(\theta-1)/\theta} dj \right\}^{\theta/(\theta-1)} - \int_0^1 P_t^j Y_t^j dj.$$

The first-order conditions yield demand for each variety of good j:

$$Y_t^j = (\frac{P_t^j}{P_t})^{-\theta} Y_t, \quad \forall j \in (0,1). \tag{A2}$$

Imposing a zero-profit condition leads to the following final good price:

$$P_t = \left\{ \int_0^1 (P_t^j)^{1-\theta} dj \right\}^{1/(1-\theta)}. \tag{A3}$$

Intermediate Good Producers

Each IG firm produces (using capital and labor) a distinct, perishable good that is sold on a monopolistically competitive market. At the beginning of the period, each IG producer rents capital from a randomly matched CG producer, at a cost r_t^K.

Production of each intermediate good j, Y_t^j, requires labor and capital:

$$Y_t^j = A_t (N_t^j)^{1-\alpha} (K_t^j)^{\alpha}, \tag{A4}$$

where N_t^j is total labor hours, $\alpha \in (0,1)$, and A_t a common technology shock, which follows a first-order autoregressive process:

$$A_t = A_{t-1}^{\rho_A} \exp(\xi_t^A),$$

where $\rho_A \in (0,1)$ and $\xi_t^A \sim \mathbf{N}(0, \sigma_{\xi^A})$.

Intermediate goods are sold on a monopolistically competitive market. IG producers solve a two-stage problem. In the first stage, taking input prices as given, they rent labor and capital in perfectly competitive factor markets so as to minimize real costs. This yields the optimal capital-labor ratio:

$$\frac{K_t^j}{N_t^j} = (\frac{\alpha}{1-\alpha})(\frac{w_t}{r_t^K}), \quad \forall j \tag{A5}$$

and the unit real marginal cost:

$$mc_t = \frac{w_t^{1-\alpha}(r_t^K)^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha}A_t}. \tag{A6}$$

In the second stage, each IG producer chooses a sequence of prices P_t^j so as to maximize discounted real profits:

$$\{P_{t+s}^j\}_{s=0}^\infty = \arg\max \mathbb{E}_t \sum_{s=0}^\infty \Lambda^s \lambda_{t+s} J_{jt+s}^I,$$

where real profits at t, J_{jt}^I, are defined as

$$J_t^{I,j} = (\frac{P_t^j}{P_t})Y_t^j - mc_t Y_t^j - PAC_t^j,$$

and PAC_t^j is a Rotemberg-type price adjustment cost:

$$PAC_t^j = \frac{\phi_I}{2}[\frac{P_t^j}{(1+\tilde{\pi})P_{t-1}^j} - 1]^2 Y_t. \tag{A7}$$

In this expression, $\phi_I \geq 0$ is an adjustment cost parameter and $\tilde{\pi}$ steady-state inflation.

Taking $\{mc_{t+s}, P_{t+s}, Y_{t+s}\}_{s=0}^\infty$ as given, the first-order condition for this maximization problem is:

$$(1-\theta)\lambda_t(\frac{P_t^j}{P_t})^{-\theta}\frac{Y_t}{P_t} + \theta\lambda_t(\frac{P_t^j}{P_t})^{-\theta-1}\frac{mc_t Y_t}{P_t} - \lambda_t\phi_I\left\{[\frac{P_t^j}{(1+\tilde{\pi})P_{t-1}^j} - 1]\frac{Y_t}{(1+\tilde{\pi})P_{t-1}^j}\right\}$$

$$+\Lambda\phi_I\mathbb{E}_t\left\{\lambda_{t+1}[\frac{P_{t+1}^j}{(1+\tilde{\pi})P_t^j} - 1]Y_{t+1}[\frac{P_{t+1}^j}{(1+\tilde{\pi})(P_t^j)^2}]\right\} = 0,$$

which gives, in the symmetric equilibrium where $P_t^j = P_t$ for all j,

$$1 - \theta + \theta mc_t - \phi_I(\frac{1+\pi_t}{1+\tilde{\pi}} - 1)(\frac{1+\pi_t}{1+\tilde{\pi}}) \tag{A8}$$

$$+\Lambda\phi_I\mathbb{E}_t\left\{\frac{\lambda_{t+1}}{\lambda_t}(\frac{1+\pi_{t+1}}{1+\tilde{\pi}} - 1)(\frac{1+\pi_{t+1}}{1+\tilde{\pi}})(\frac{Y_{t+1}}{Y_t})\right\} = 0.$$

Equation (A8) determines implicitly the behavior of current-period inflation, as an increasing function of the real marginal cost and the expected, one-period ahead inflation rate.

Capital Good Producers

Capital goods are produced with a linear technology. At the beginning of the period, the representative CG producer buys a real amount I_t of the final good from the representative FG producer. These goods must be paid in advance, so investment loans are

$$l_t^K = I_t. \tag{A9}$$

The matched household makes its exogenous housing stock, $\bar{H}$, available free of charge to the (matched) CG producer, who uses it as collateral against which it borrows from banks, at the rate i_t^L. With $q_t \in (0,1)$ denoting the probability that loans are repaid in full, expected repayment is $q_t(1+i_t^L)l_t^K + (1-q_t)\kappa\mathbb{E}_t p_{t+1}^H \bar{H}$, where $(1+i_t^L)l_t^K$ is the contractual payment, and $\kappa\mathbb{E}_t p_{t+1}^H \bar{H}$ the value of collateral where $\kappa = \int_0^1 \kappa^i di$ and $\kappa^i \in (0,1)$ is the fraction of the housing stock pledged by the representative CG producer as collateral to bank i.

To produce new capital requires combining gross investment with the existing stock of capital, adjusted for depreciation and adjustment costs:

$$K_{t+1} = I_t + (1-\delta_K)K_t - \frac{\Theta_K}{2}(\frac{K_{t+1}}{K_t} - 1)^2 K_t, \tag{A10}$$

where $\delta_K \in (0,1)$ is the rate of depreciation and $\Theta_K > 0$ an adjustment cost parameter. The new capital stock is then rented to a matched IG producer at the rate r_t^K.

The representative CG producer chooses the level of the capital stock so as to maximize the value of discounted stream of dividend payments to the matched household:

$$\{K_{t+s}\}_{s=0}^{\infty} = \arg\max \sum_{s=0}^{\infty} \Lambda^s \mathbb{E}_t(\lambda_{t+s} J_{t+s+1}^K),$$

where J_{t+s+1}^K denotes real profits at the end of period $t+s$, defined as

$$J_{t+s+1}^K = r_{t+s}^K K_{t+s} - q_{t+s}(1+i_{t+s}^L)I_{t+s} - (1-q_{t+s})\kappa p_{t+s+1}^H \bar{H},$$

subject to equation (A10) and taking $\{q_{t+s}\}_{s=0}^{\infty}$, $\{p_{t+s+1}^H\}_{s=0}^{\infty}$ and $\{i_{t+s}^L\}_{s=0}^{\infty}$ as given.

The solution of this problem gives

$$\begin{aligned} \mathbb{E}_t r_{t+1}^K \simeq q_t(1+i_t^L)\mathbb{E}_t \left[\left\{ 1 + \Theta_K(\frac{K_{t+1}}{K_t} - 1) \right\} (\frac{1+i_t^B}{1+\pi_{t+1}}) \right] \\ -\mathbb{E}_t \left[q_{t+1}(1+i_{t+1}^L) \left\{ 1 - \delta_K + \frac{\Theta_K}{2}[(\frac{K_{t+2}}{K_{t+1}})^2 - 1] \right\} \right], \end{aligned} \tag{A11}$$

which relates the expected rental rate of capital is a function of the current and expected loan rates, the latter through its effect on adjustment costs in t and $t+1$.[50]

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

$$l_t^K = [\int_0^1 (l_t^{K,i})^{(\zeta_L - 1)/\zeta} di]^{\zeta_L/(\zeta_L - 1)}.$$

The demand for type-i loan, $l_t^{K,i}$, is thus given by the downward-sloping curve

$$l_t^{K,i} = (\frac{1+i_t^{L,i}}{1+i_t^L})^{-\zeta_L} l_t^K, \tag{A12}$$

[50] The derivation of equation (A11) ignores covariance terms for simplicity.

where $i_t^{L,i}$ is the rate on the loan extended by bank i and i_t^L the aggregate loan rate, defined as

$$i_t^L = [\int_0^1 (1+i_t^{L,i})^{1-\zeta_L} di]^{1/(1-\zeta_L)} - 1.$$

Government

The government purchases the final good and issues nominal riskless one-period bonds. Assuming that all central bank interest income is transferred to the government, its budget constraint in real terms is given by

$$b_t^G = G_t - T_t + (\frac{1+i_{t-1}^B}{1+\pi_t})b_{t-1}^G - \frac{i_{t-1}^R l_{t-1}^B}{1+\pi_t}, \tag{A13}$$

where $b_t^G = b_t + b_t^C$. Government purchases are a fixed fraction of output of the final good:

$$G_t = \psi_G Y_t, \tag{A14}$$

where $\psi_G \in (0,1)$.

In what follows the government is assumed to keep its real stock of debt constant and to balance its budget by adjusting lump-sum taxes.

Equilibrium Conditions

Equilibrium conditions for the credit, deposit, cash, labor, housing, and final goods markets are as follows.[51] Because the supply of loans by commercial banks, and the supply of deposits by households, are perfectly elastic at the prevailing interest rates, the markets for loans and deposits always clear. The labor market clears through flexible wages, whereas equilibrium of the goods market requires that production be equal to aggregate demand:

$$Y_t = C_t + G_t + I_t + \frac{\phi_I}{2}(\frac{1+\pi_t}{1+\tilde{\pi}} - 1)^2 Y_t, \tag{A15}$$

where the last term are price adjustment costs, as discussed earlier.

The counterpart to loans to IG and CG producers is cash, which is used instantaneously to pay wages and buy investment goods at the beginning of the period. The equilibrium condition of the market for cash is thus given by

$$m_t = m_t^s, \tag{A16}$$

where m_t is defined in (6).

Finally, the equilibrium condition of the housing market is

$$\bar{H} = H_t, \tag{A17}$$

which can be solved, using (8), to determine the dynamics of house prices. Finally, as noted in equation (24), in equilibrium the demand for bank capital, V_t^d, defined in (9) must be equal to its supply, as given by (11).

[51] By Walras' Law, the equilibrium condition of the market for government bonds can be eliminated.

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Table 1
Benchmark Parameterization: Key Parameter Values

Parameter	Value	Description
Household		
Λ	0.98	Discount factor
ς	0.5	Elasticity of intertemporal substitution
η_N	25.0	Preference parameter for leisure
η_x	0.001	Preference parameter for money holdings
η_H	0.1	Preference parameter for housing
ψ_N	1.8	Inverse of Frisch elasticity of labor supply
ν	0.2	Share parameter in index of money holdings
Θ_V	1.9	Adjustment cost parameter, bank capital
Production		
θ	6.0	Elasticity of demand, intermediate goods
α	0.35	Share of capital, domestic intermediate goods
ϕ_I	74.5	Adjustment cost parameter, IG prices
δ_K	0.035	Depreciation rate of capital
Θ_K	14	Adjustment cost parameter, investment
Commercial banks		
κ	0.2	Effective collateral-loan ratio
φ_1	0.05	Elasticity of repayment probability, collateral
φ_2	0.2	Elasticity of repayment probability, cyclical output
ζ_L	4.5	Elasticity of substitution, loans to CG producers
γ_V	0.01	Linear debt issuance cost
γ_{VV}	0.001	Pecuniary benefit of excess capital
ϕ_E	0.5	Sensitivity of pecuniary benefit to excess capital
Central bank		
ε_1	1.6	Response of policy rate to inflation deviations from target
ε_2	0.15	Response of policy rate to cyclical output
Regulator		
ρ^D	0.08	Deterministic component of capital adequacy ratio
ϕ_q	0.05	Sensitivity of risk weight to repayment probability
Other		
ϑ	0.8	Persistence parameter, financial shocks

Table 2
Initial Steady-State Values: Key Variables
(In proportion of final output, unless indicated otherwise)

Variable	Description	Value
C	Household consumption	0.650
$I = l^K$	Investment loans to IG firms	0.170
K	Capital stock	4.857
r^K	Rental rate of capital (percent)	0.056
q^L	Repayment probability, loans to IG firms (percent)	0.930
i^B, i^R	Government bond rate, refinance rate (percent)	0.020
i^D	Bank deposit rate (percent)	0.018
i^L	Loan rate, investment loans to IG firms (percent)	0.095
i^V	Rate of return on bank capital (percent)	0.060
σ	Risk weight (between 0 and 1)	1.000
V^E/l^K	Excess capital ratio (proportion of loans)	0.040
V^R/l^K	Required capital ratio (proportion of loans)	0.080
l^K/V	Asset-capital ratio (proportion of bank total capital)	8.333

Table 3

Optimal Policy Responses and Gains from Coordination: Endogenous Excess Capital

(Benchmark parameters)

	$\omega^C = \omega^R = 0.0$		$\omega^C = \omega^R = 0.5$	
	R-Shock	C-Shock	R-Shock	C-Shock
Leaning against the wind ($\varepsilon_3 \geq 0, \chi_2 = 0$)				
Optimal response parameter, ε_3	0.058	0.145	0.00	0.00
Compensating variations[1,2]				
Household	0.026	0.106	0.000	0.000
Central bank	0.018	0.075	0.000	0.000
Financial regulator	0.026	0.106	0.000	0.000
Economy[3]	0.022	0.090	0.000	0.000
Macroprudential regulation ($\varepsilon_3 = 0, \chi_2 \geq 0$)				
Optimal response parameter, χ_2	0.027	0.038	0.055	0.064
Compensating variations[1,2]				
Household	0.001	0.003	0.003	0.005
Central bank	0.001	0.003	0.003	0.005
Financial regulator	0.001	0.001	0.003	0.004
Economy[3]	0.001	0.002	0.003	0.005
Nash equilibrium ($\varepsilon_3, \chi_2 \geq 0$)				
Optimal response parameters, ε_3, χ_2	0.058, 0.029	0.145, 0.061	0.00, 0.055	0.00, 0.064
Compensating variations[1,2]				
Household	0.027	0.110	0.003	0.005
Central bank	0.019	0.079	0.003	0.005
Financial regulator	0.026	0.108	0.003	0.004
Economy[3]	0.023	0.094	0.003	0.005
Coordination ($\varepsilon_3, \chi_2 \geq 0$)				
Optimal response parameters, ε_3, χ_2	0.065, 0.062	0.163, 0.141	0.072, 0.101	0.096, 0.151
Compensating variations[1,2]				
Household	0.028	0.117	0.030	0.100
Central bank	0.020	0.084	−0.042	−0.095
Financial regulator	0.026	0.107	0.124	0.259
Economy[3]	0.023	0.096	0.034	0.053
Gain from Coordination (rel. to Nash)				
Compensating variations[1,4]				
Household	0.002	0.005	0.027	0.095
Central bank	0.001	0.004	−0.045	−0.099
Financial regulator	0.000	0.000	0.121	0.253
Economy[3]	0.000	0.002	0.031	0.048

Note: R-Shock refers to the repayment probability shock and C-Shock to the bank capital shock. [1]Compensating variations include the cost of instrument volatility and are calculated using the formulas provided in the text. [2]With respect to the equilibrium with no activism. [3]Equal weights to each policy authority. [4]With respect to the Nash equilibrium.

Table 4

Optimal Policy Responses and Gains from Coordination: Exogenous Excess Capital

(Benchmark parameters)

	$\omega^C = \omega^R = 0.0$		$\omega^C = \omega^R = 0.5$	
	R-Shock	C-Shock	R-Shock	C-Shock
Leaning against the wind ($\varepsilon_3 \geq 0, \chi_2 = 0$)				
Optimal response parameter, ε_3	0.064	0.144	0.00	0.00
Compensating variations[1,2]				
Household	0.031	0.105	0.000	0.000
Central bank	0.022	0.074	0.000	0.000
Financial regulator	0.031	0.105	0.000	0.000
Economy[3]	0.026	0.089	0.000	0.000
Macroprudential regulation ($\varepsilon_3 = 0, \chi_2 \geq 0$)				
Optimal response parameter, χ_2	0.033	0.044	0.064	0.074
Compensating variations[1,2]				
Household	0.002	0.004	0.004	0.007
Central bank	0.002	0.004	0.004	0.007
Financial regulator	0.001	0.002	0.004	0.006
Economy[3]	0.001	0.003	0.004	0.006
Nash equilibrium ($\varepsilon_3, \chi_2 \geq 0$)				
Optimal response parameters, ε_3, χ_2	0.064, 0.036	0.143, 0.071	0.000, 0.064	0.000, 0.074
Compensating variations[1,2]				
Household	0.032	0.110	0.004	0.007
Central bank	0.023	0.080	0.004	0.007
Financial regulator	0.031	0.107	0.004	0.006
Economy[3]	0.027	0.093	0.004	0.006
Coordination ($\varepsilon_3, \chi_2 \geq 0$)				
Optimal response parameters, ε_3, χ_2	0.072, 0.077	0.163, 0.164	0.074, 0.121	0.096, 0.175
Compensating variations[1,2]				
Household	0.035	0.119	0.037	0.103
Central bank	0.025	0.086	−0.046	−0.093
Financial regulator	0.031	0.106	0.136	0.258
Economy[3]	0.028	0.096	0.037	0.054
Gain from Coordination				
Compensating variations[1,4]				
Household	0.002	0.007	0.033	0.095
Central bank	0.001	0.005	−0.050	−0.099
Financial regulator	0.000	−0.001	0.131	0.250
Economy[3]	0.001	0.002	0.033	0.048

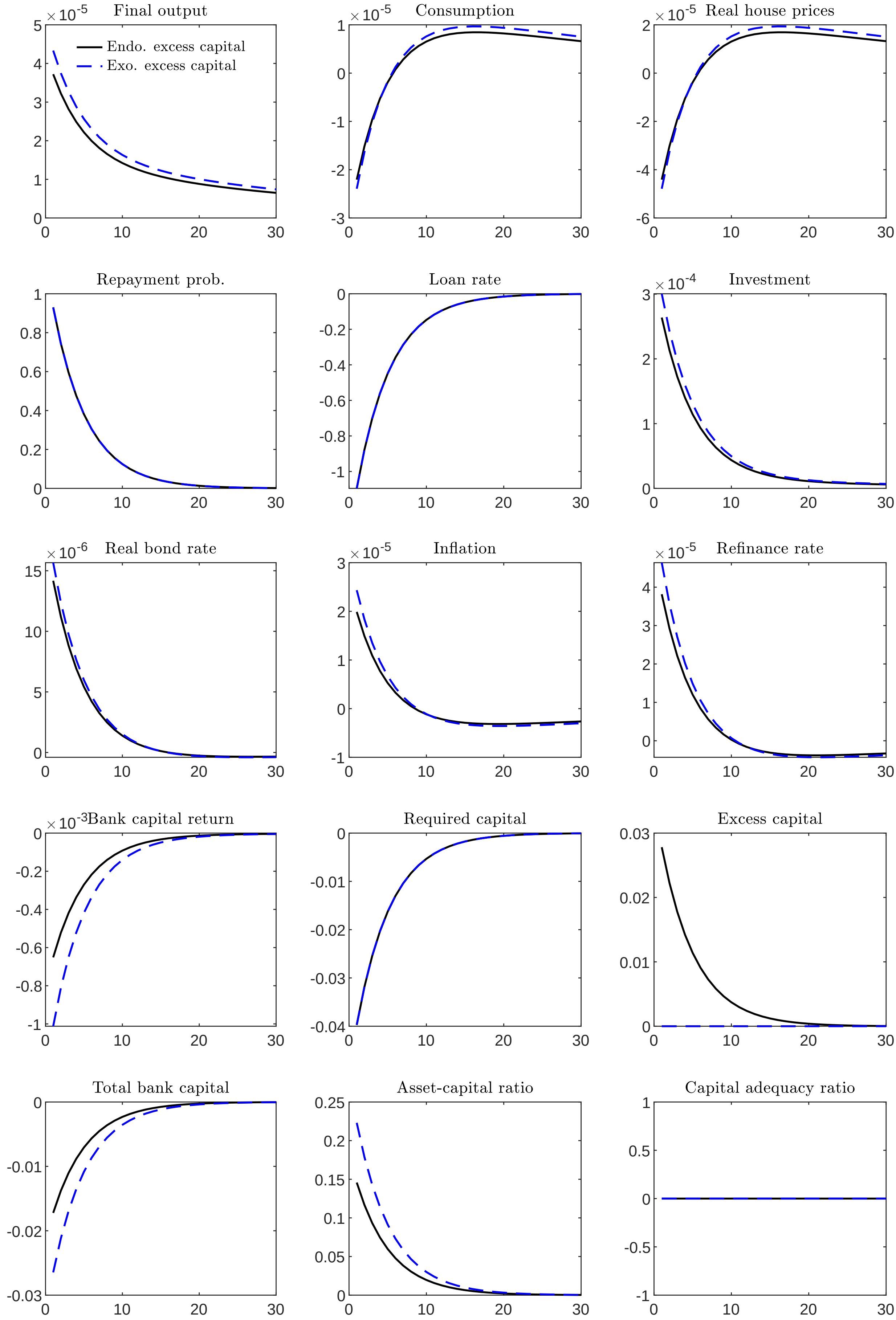
Note: See Notes to Table 3.

Table 5
Optimal Policy Responses and Gains from Constrained Coordination:
Endogenous Excess Capital
(Benchmark parameters)

	$\omega^C = \omega^R = 0.0$		$\omega^C = \omega^R = 0.5$	
	R-Shock	C-Shock	R-Shock	C-Shock
Coordination ($\varepsilon_3, \chi_2 \geq 0$)				
Optimal response parameters, ε_3, χ_2	0.065, 0.062	0.163, 0.141	0.072, 0.101	0.096, 0.151
Pareto-constrained Coordination ($\varepsilon_3, \chi_2 \geq 0$)				
Optimal response parameters, ε_3, χ_2	0.065, 0.062	0.164, 0.134	0.017, 0.179	0.013, 0.200
Gain relative to No activism				
Compensating variations[1,2]				
Household	0.028	0.117	0.019	0.033
Central bank	0.020	0.083	0.003	0.005
Financial regulator	0.026	0.108	0.025	0.025
Economy[3]	0.023	0.096	0.014	0.015
Gain relative to Nash				
Compensating variations[1,4]				
Household	0.002	0.005	0.017	0.027
Central bank	0.001	0.003	0.000	0.000
Financial regulator	0.000	0.000	0.022	0.021
Economy[3]	0.000	0.002	0.011	0.010
Gain relative to Coordination				
Compensating variations[1,5]				
Household	0.000	0.000	−0.009	−0.053
Central bank	0.000	0.000	0.047	0.116
Financial regulator	0.000	0.000	−0.076	−0.146
Economy[3]	0.000	0.000	−0.018	−0.033

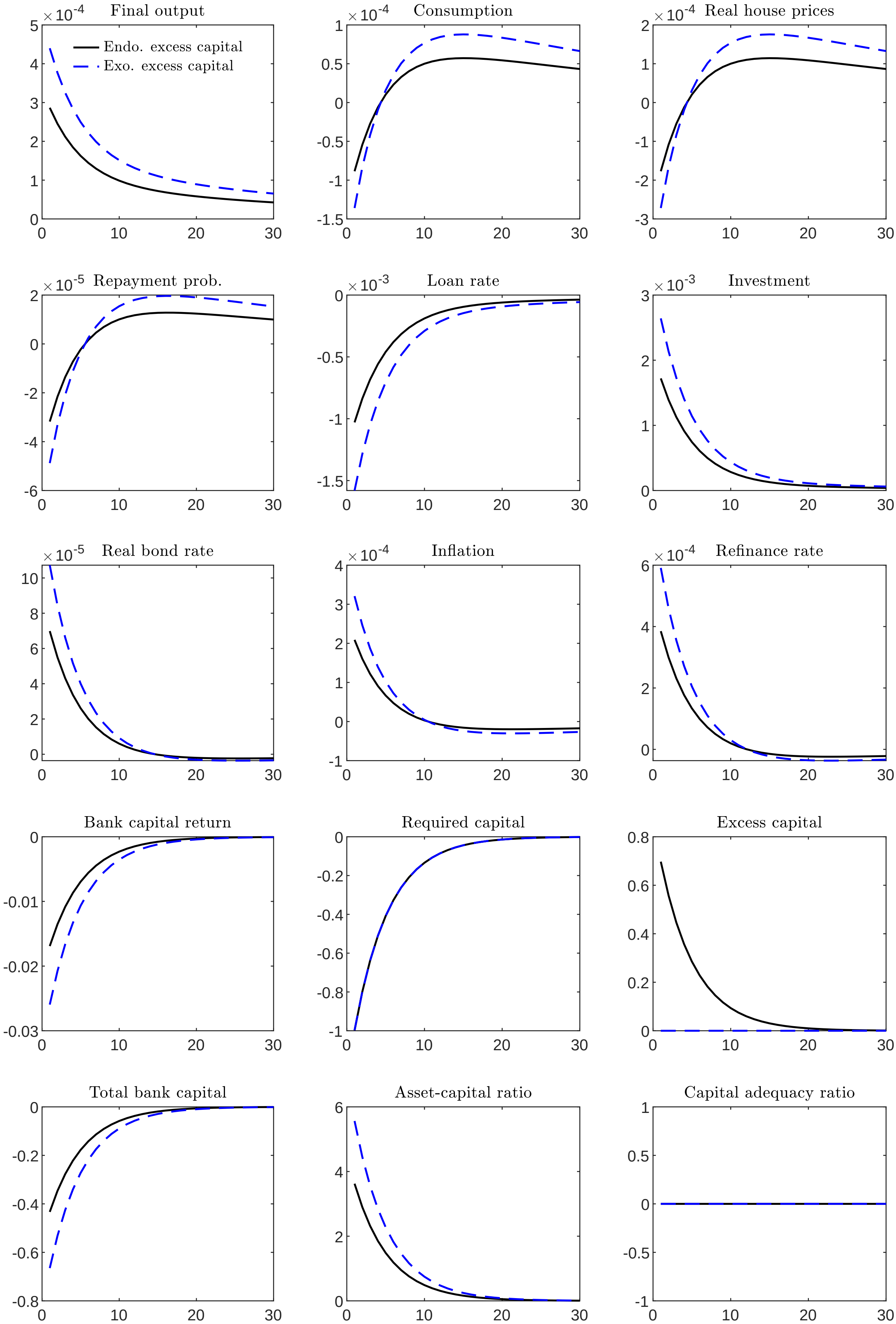
Note: See Notes to Table 3. [5]With respect to the coordination equilibrium. The optimal response parameters under coordination shown in the first line are the same as those displayed in Table 3.

Figure 1
Positive Repayment Probability Shock: Benchmark Parameters
(Deviations from steady state)



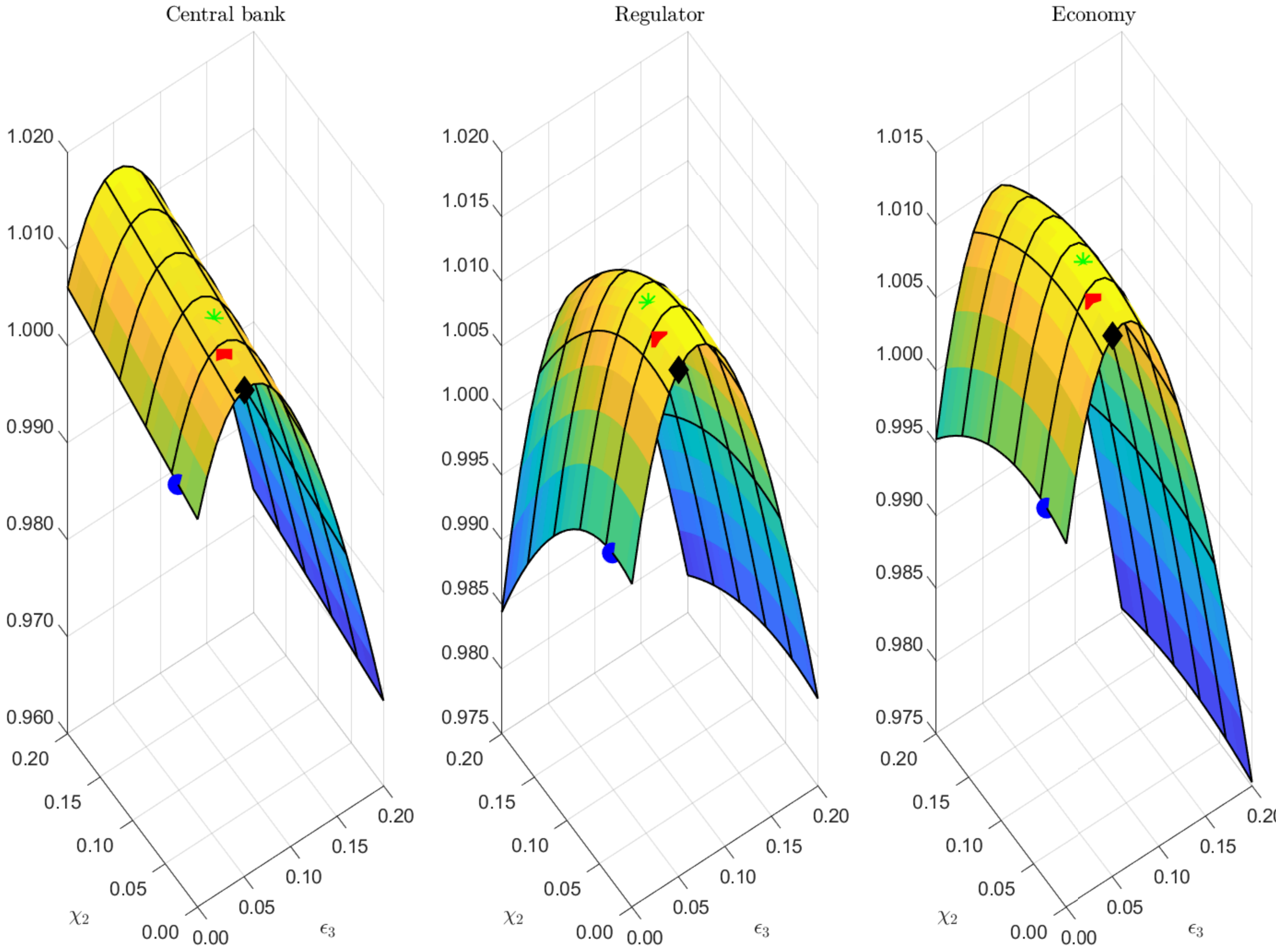
Notes: Consumption, investment, output, real house prices, and bank capital (required, excess, and total) are shown as percentage deviations from their steady-state values. The lending rate, the refinance rate, the expected real bond rate, the repayment probability, the inflation rate, the return on bank capital, the leverage ratio, and the capital adequacy ratio are absolute deviations from their steady-state values. All numbers are in percent; for instance, 0.1 represents 0.1 percent.

Figure 2
Negative Bank Capital Shock: Benchmark Parameters
(Deviations from steady state)



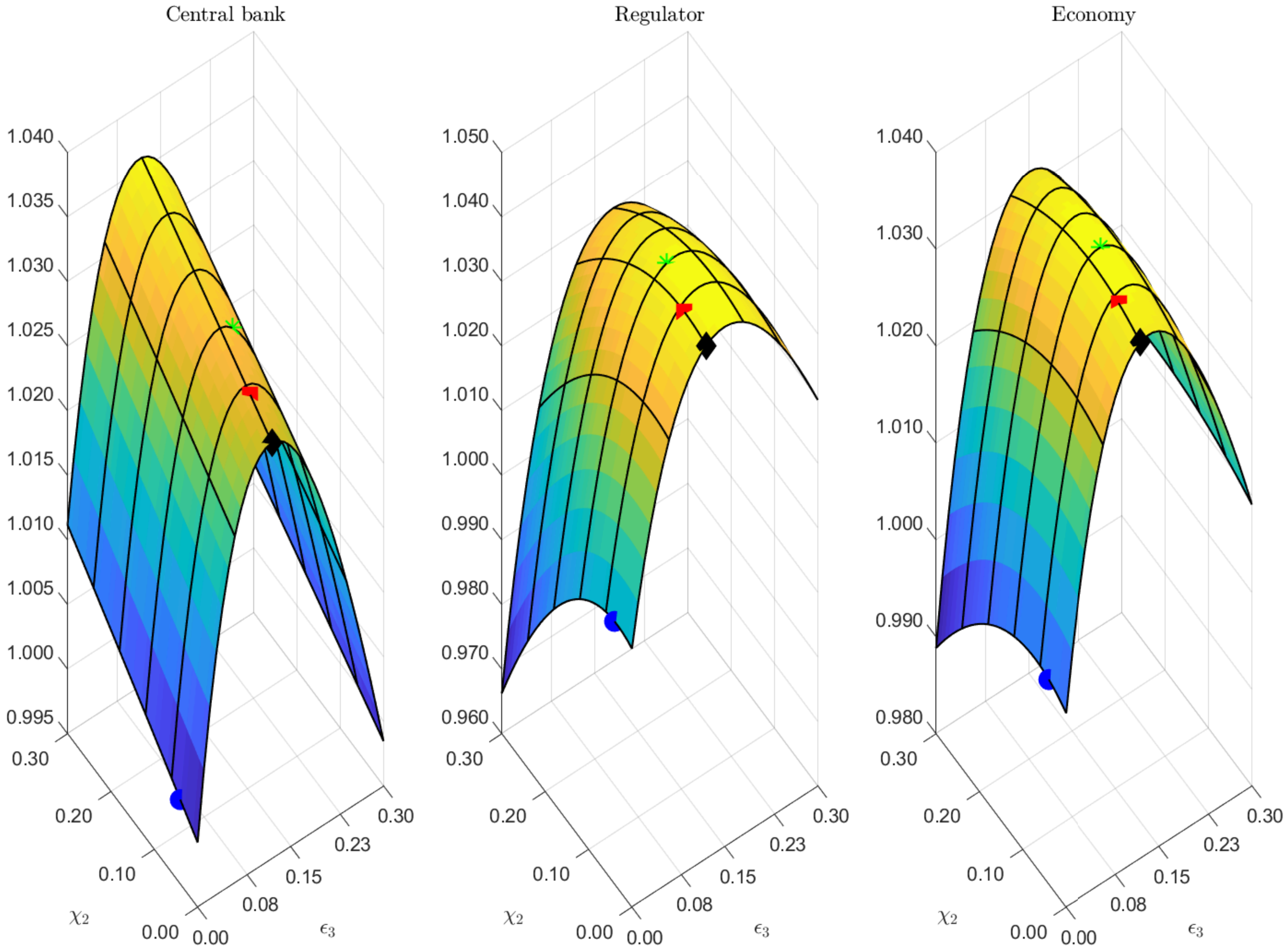
Notes: See notes to Figure 1.

Figure 3
Positive Repayment Probability Shock: Normalized Welfare and Optimal Policy Response



Note: Normalized welfare is welfare under activism divided by welfare under no activism. The black diamond corresponds to leaning against the wind only, the blue circle to macroprudential policy only, the red square to the Nash equilibrium, and the green star to coordination.

Figure 4
Negative Bank Capital Shock: Normalized Welfare and Optimal Policy Response



Note: See note to Figure 3.

Figure 5
Decomposition of Gains under Alternative Policy Regimes

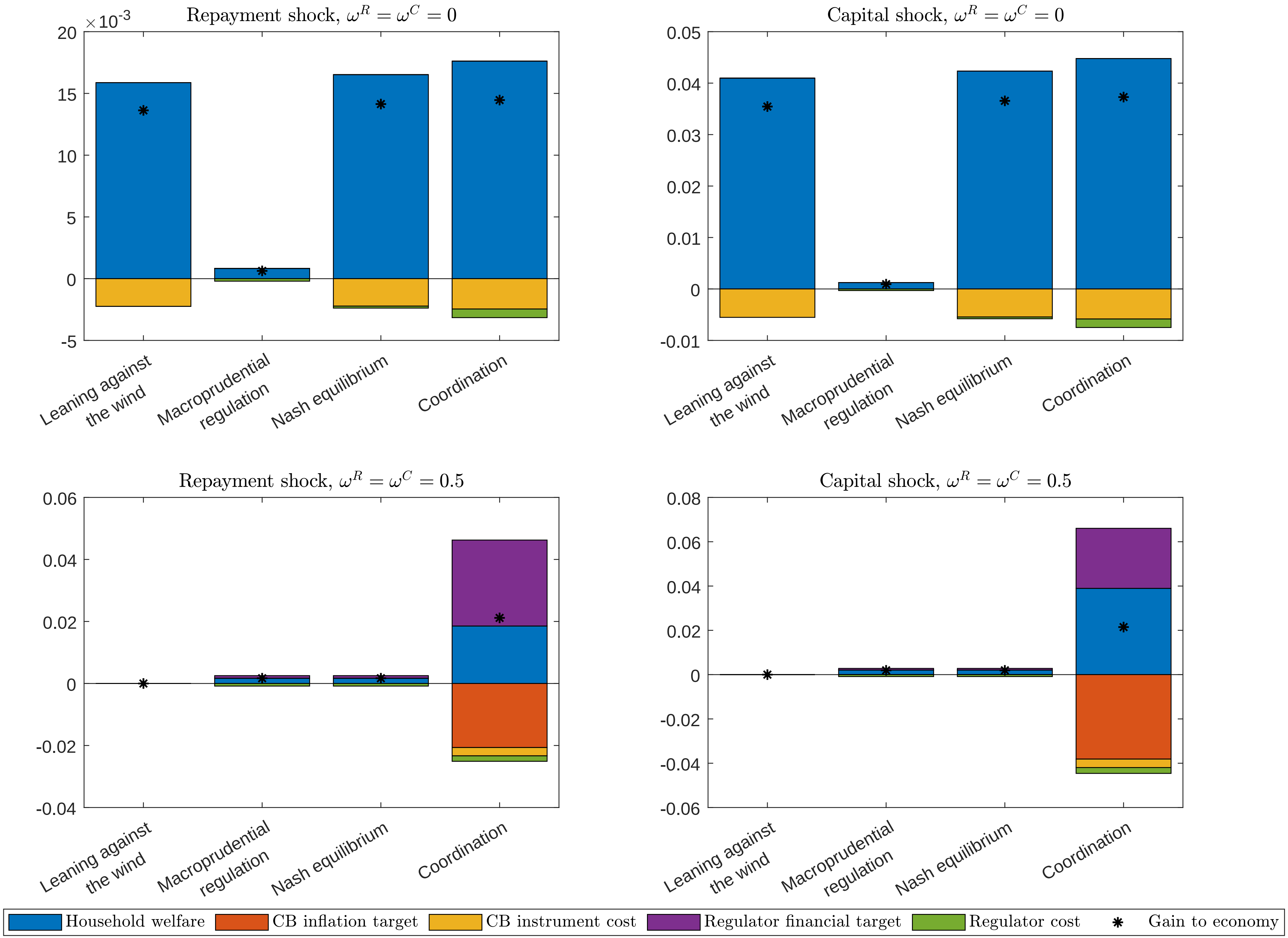


Figure 6
Repayment Probability Shock: Optimal Policy Response under Coordination and Nash

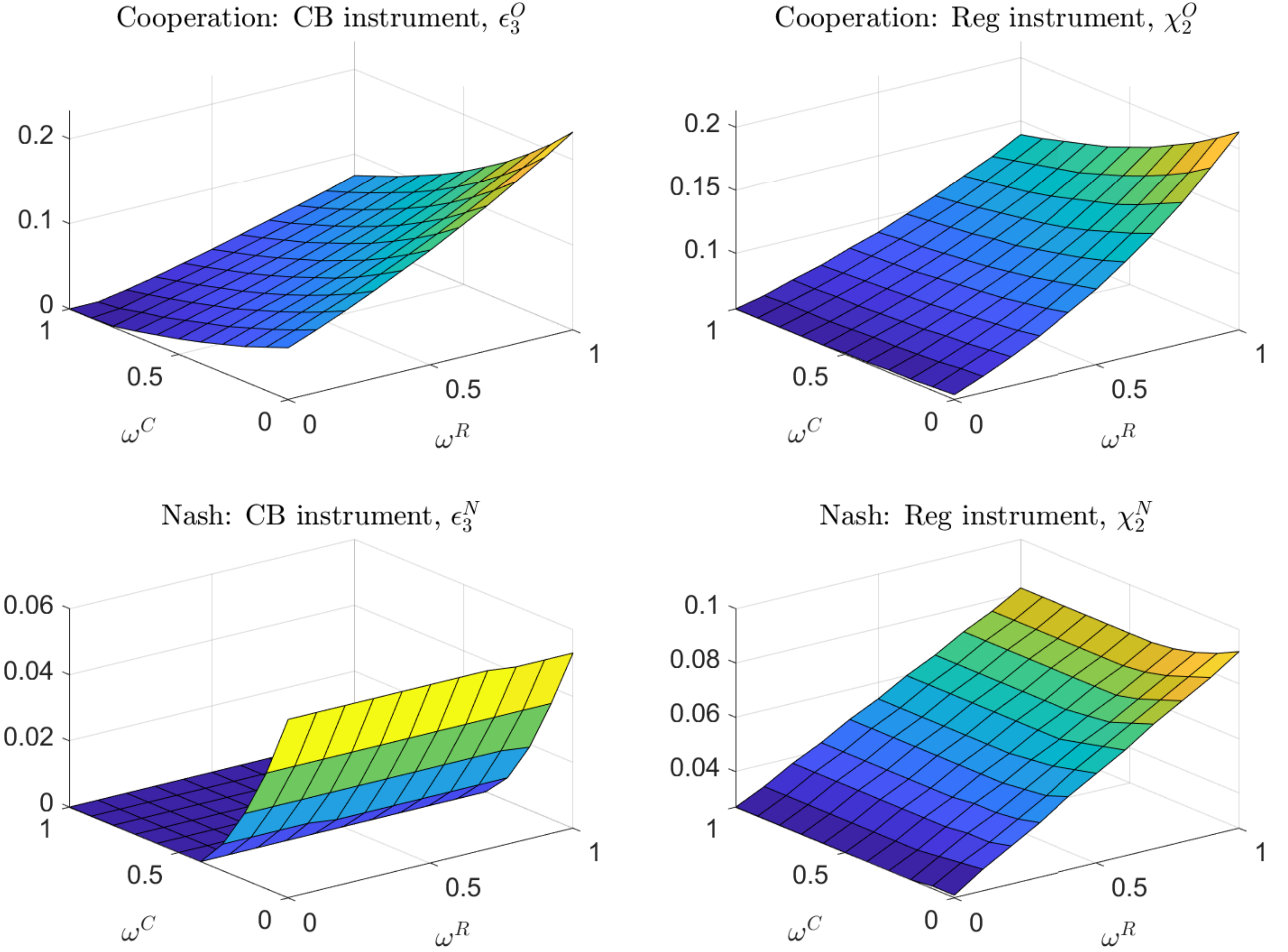


Figure 7
Bank Capital Shock: Optimal Policy Response under Coordination and Nash

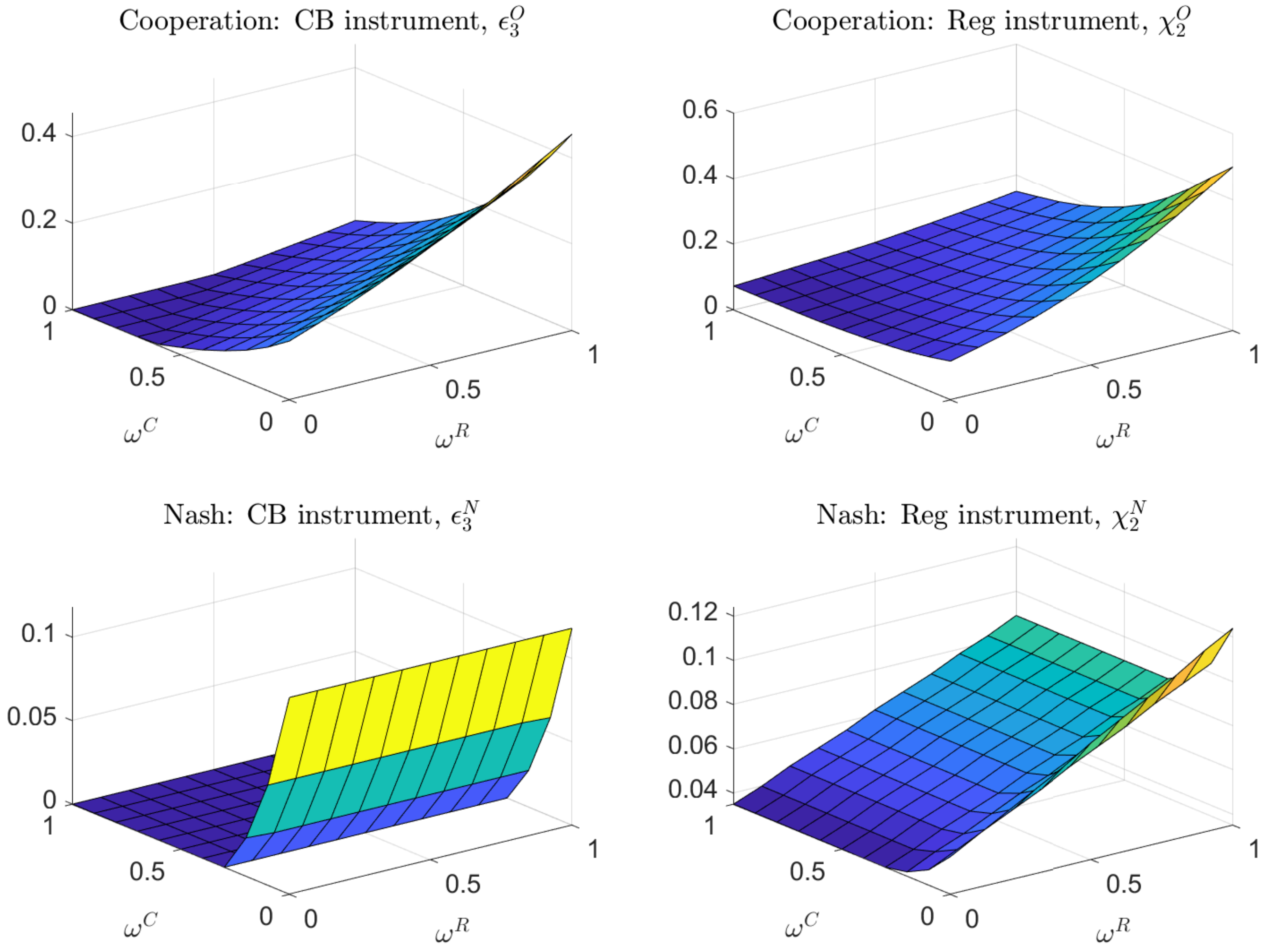
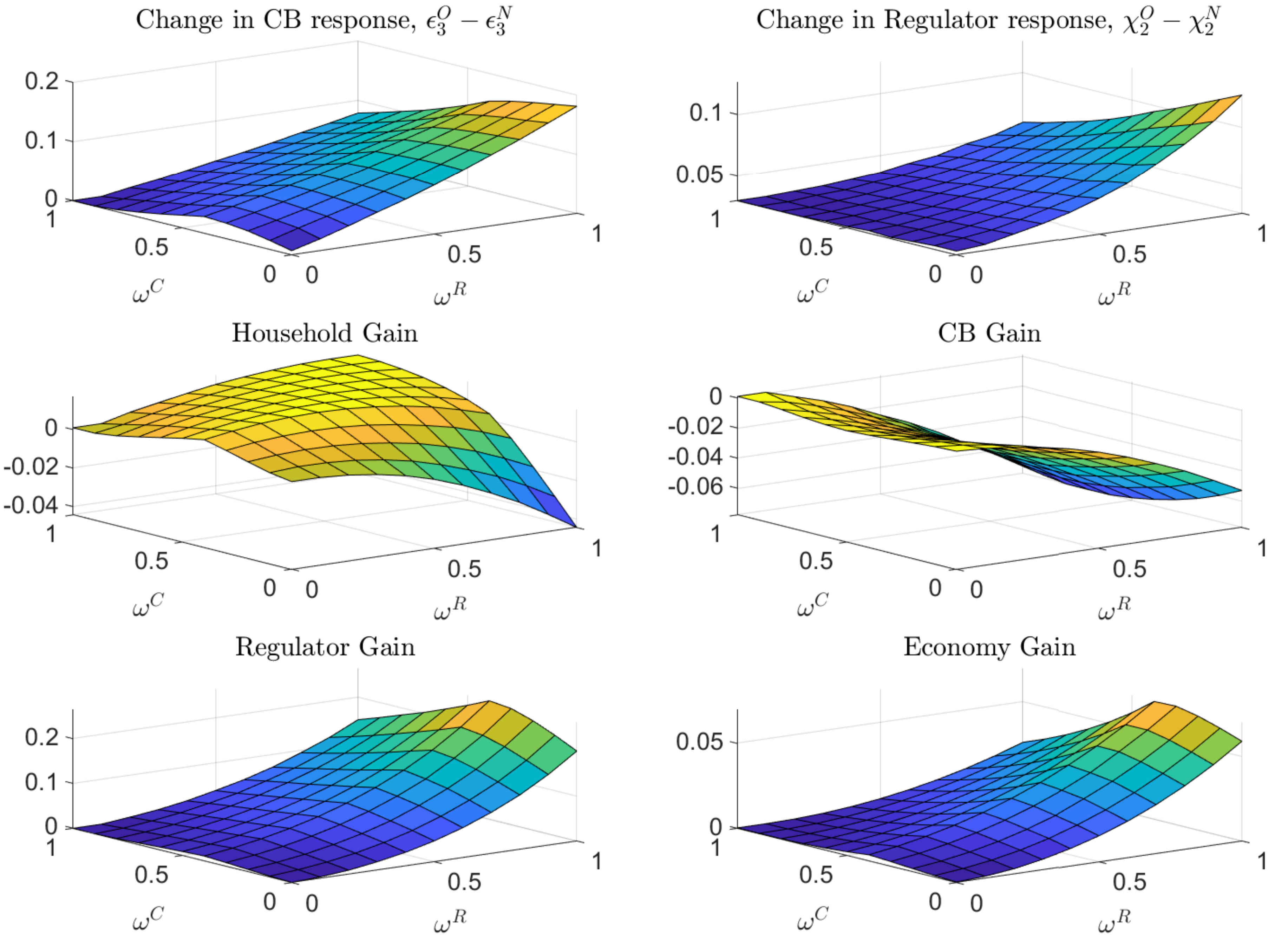
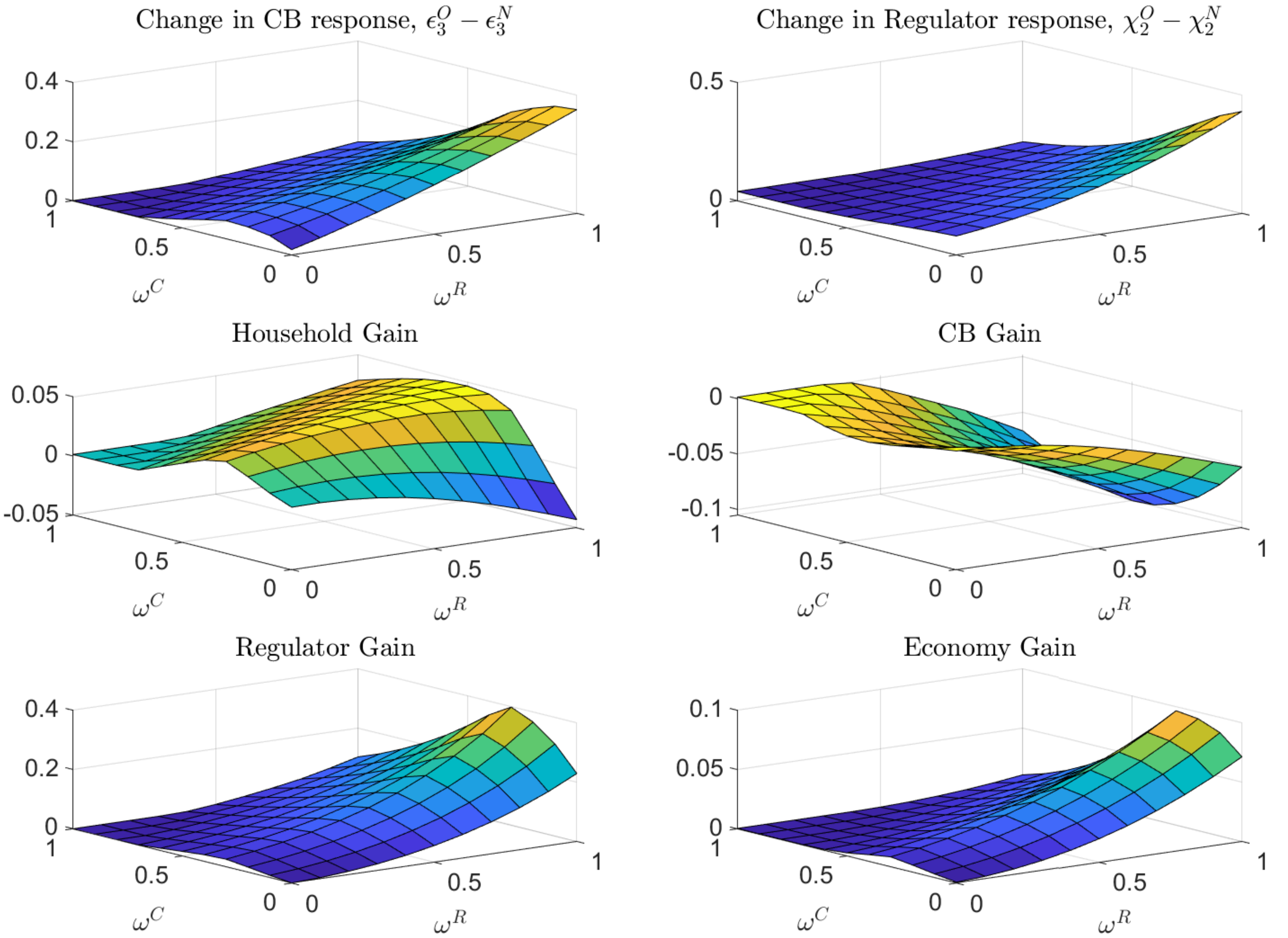


Figure 8
Repayment Probability Shock: Optimal Policy Response and Welfare Gains, Coordination vs. Nash



Note: Welfare is measured in terms of compensating variations of coordination with respect to Nash, based on the formulas in the text.

Figure 9
Bank Capital Shock: Optimal Policy Response and Welfare Gains, Coordination vs. Nash



Note: See note to Figure 7.

Figure 10
Instrument Manipulation Cost and Optimal Institutional Mandate