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Abstract

We examine the interplay between monetary policy, bank risk-taking, and financial stability in a quantitative macroeconomic model with endogenous risk-taking by banks and systemic crises. Banks' access to leverage depends on their charter value, which is itself affected by movements in the real interest rate. We find that permanent shifts in the long-term real interest rate have a significant impact on banks' leverage and on their investments in systemically risky assets, while transitory movements have a more limited impact. We show that in the presence of systemic risk-taking, the systemic component of monetary policy faces a trade-off between price stability and financial stability. A moderate reaction to inflation deviations from the target is optimal, as it sustains banks' equity value after financial crises. Seeking price stability reduces inflation volatility but leads to increased systemic risk-taking and more severe financial recessions. The optimal central bank policy combination involves an increase in regulatory bank capital requirements coupled with a moderate reaction of monetary policy to inflation.

Keywords: financial intermediation, monetary policy, systemic risk, macroprudential policy.

JEL classification: E44, E52, E58, G21.

Resumen

Este trabajo analiza la interacción entre la política monetaria y la estabilidad financiera en un modelo macroeconómico con toma de riesgo endógena por parte de los bancos. Tanto el apalancamiento como la toma de riesgo dependen del valor de la franquicia bancaria, que se ve afectado, a su vez, por las tasas de interés reales. Los cambios permanentes en dichas tasas a largo plazo tienen un impacto significativo en el apalancamiento bancario y las inversiones más arriesgadas, mientras que los movimientos transitorios tienen un impacto limitado. El componente sistémico de la política monetaria afronta un dilema entre la estabilidad financiera y la de precios. La combinación óptima de las políticas monetaria y macroprudencial implica un aumento de los requisitos mínimos de capital junto con una reacción moderada de la política monetaria ante la inflación, lo que ayuda a sostener los niveles de capital bancario tras el impacto de las crisis financieras.

Palabras clave: intermediación financiera, política monetaria, riesgo sistémico, política macroprudencial.

Códigos JEL: E44, E52, E58, G21.

1. Introduction

The interaction between monetary policy and financial stability has become very important in the aftermath of the Global Financial Crisis (GFC), a period characterized by low interest rates, elevated asset prices, and a widespread search for yield throughout various segments of the financial system. While such risk-taking behavior was often associated with loose monetary policy in popular discourse, the persistently low inflation rates throughout the 2010s suggest that a decline in the natural real interest rate may have been a significant underlying driver of low interest rates and risk-taking in the financial system.

Our paper contributes to the ongoing debate on monetary-macroprudential policy interactions by investigating the inter-dependencies between natural real interest rates, monetary policy and bank risk-taking. More specifically, the paper addresses three main questions. First, we examine how long-term real interest rates and monetary policy affect banks' systemic risk-taking. Second, we explore the normative question of how monetary policy should be conducted in the presence of endogenous systemic risk. We ask whether the monetary authority faces a trade-off between price stability and financial stability and whether there are potential benefits of bringing inflation to target in a more gradual fashion in order to safeguard financial stability. Third, we investigate how bank capital regulation interacts with monetary policy.

Our findings are consistent with the view that financial stability risks arise mainly from low long-term real interest rates. In addition, macroprudential policy is by far the most effective policy instrument in mitigating banks' tendency to take excessive risks. In contrast, monetary policy plays a relatively less prominent role in the determination of banks' holdings of risky assets. However, because bank capital requirements are costly in our framework, their optimal level does leave some bank risk-taking in equilibrium and monetary policy remains a useful policy tool in dealing with financial crises and in discouraging banks' risky asset holdings. The use of monetary policy in this way does require a tolerance of moderate inflation volatility around the target.

To investigate the questions in our paper, we build a New Keynesian macroeconomic model with endogenous bank risk-taking and systemic crisis, drawing on the work of Martinez-Miera and Suarez (2012) and Abad et al. (2024). In our model, financial intermediaries are the most efficient holders of the capital stock but face a choice in how to invest their capital holdings. They can hold non-systemic assets, which deliver a safe return in all states of the world, or systemic assets, which pay a premium in normal times but incur losses during financial crises. Banks operate with leverage and under limited liability, introducing a motive to invest in assets with volatile returns in order to profit from the upside in normal times while passing on the costs of crises to uninsured debt-holders and the deposit insurance agency. Following Gertler and Kiyotaki (2010), bank leverage is endogenously determined by the charter value of the bank, introducing a link between movements in real interest rates and bank risk-taking decisions. We generate real effects from monetary policy through two mechanisms: first, by assuming that deposits are nominal, so inflation affects their real value, and second, by incorporating nominal rigidities à la Rotemberg (1982).

In our economy, banks have the option to invest in safe capital goods with a conventional depreciation rate and in risky capital goods which are more productive in normal times but which are exposed to exogenous systemic events that partially destroy the risky capital goods. When a large number of banks choose the risky investments, the systemic event leads to widespread equity losses for banks, creating a cascade of effects throughout the economy. Hence, while the shocks themselves are exogenous, the severity of the resulting crises is endogenously determined by banks' choice of their exposure to systemic assets. Our paper focuses on the link between this exposure and the evolution of real interest rates as driven by real and monetary factors.

First, we compare the way monetary policy shocks and shocks to the discount factor of the representative household affect long-term interest rates and bank leverage and risk-taking decisions. In the Gertler and Kiyotaki (2010) framework we use, banks' equity values determine their ability to obtain leverage. Banks are profitable and enjoy an intermediation spread between the rate of return on bank assets and the real deposit rate due to the scarcity of aggregate bank equity introduced by binding leverage constraints. Banks' equity values are equal to the net present value of these intermediation profits. A lower discount rate, other things equal, makes bank equity more valuable, increasing the charter value of the bank and its leverage limit. Under higher leverage, the limited liability distortion leads the bank to choose a larger share of systemically risky assets.

We find that permanent declines in the real rate (driven by a higher household discount factor) boost bank equity values and leverage very strongly, leading to a large increase in risk-taking. Transitory (but persistent) changes in the real rate have qualitatively similar effects but are quantitatively much smaller, with the magnitude of the impact and the effects on bank risk taking diminishing as the shock becomes less persistent. Interestingly, expansionary monetary policy shocks–direct shocks to the Taylor rule– actually decrease bank risk taking. This is mainly due to the way the inflationary impact of expansionary monetary policy shocks reduces the real value of bank liabilities, increasing bank equity values, and reducing leverage, therefore reducing risk-taking incentives. Overall, these findings suggest that the long-term level of real interest rates has a more significant impact on bank risk-taking behavior than short-term monetary policy actions, highlighting the importance of considering secular trends in interest rates when assessing financial stability risks.

Second, we examine how the systematic component of monetary policy affects bank risk-taking. We find that responding moderately to inflation deviations from target in the Taylor rule leads to lower levels of bank risk-taking. This channel primarily operates through the way that monetary policy revalues banks' nominal deposits in response to shocks. For instance, when a crisis destroys the value of systemic assets on banks' balance sheets, it reduces aggregate supply and generates inflation on impact. Aggressively seeking to maintain price stability in this scenario deepens the financial crisis. As bank equity declines sharply, bank leverage increases, further increasing risk-taking. These dynamics create periods of strong systemic risk-taking and large downside risks for the real economy. Therefore, when the central bank responds moderately to inflation deviations from target, it tends to stabilize bank equity during crises, leading to less pronounced increases in risk-taking and helping to avoid more extreme outcomes.

Finally, we consider the joint optimal setting of bank capital requirements and the systematic reaction of monetary policy to inflation. We find that the optimal combination consists of a moderate reaction to inflation and a 10.75% regulatory capital requirement. Regulatory limits to leverage prove to be the most powerful tool in reducing systemic exposure and risk-taking and, therefore, the cost of financial crises. As capital requirements increase and effectively limit these factors, the role of systematic monetary policy becomes less relevant for welfare. However, because capital is costlier than debt for financial institutions, the optimal capital requirements do not eliminate all risk, and banks' systemic exposure and risk-taking remain quantitatively significant. Consequently, monetary policy also needs to help with financial stability concerns and the optimum is achieved with a moderate reaction to inflation that stabilizes bank equity during crises, complementing the macroprudential approach to financial stability.

Related Literature. Our work is related to a number of strands in the literature. Most closely related to our paper is Martinez-Miera and Suarez (2012); Abad et al. (2024) who build a model of bank systemic risk-taking to study optimal capital requirements. We extend and modify their framework in order to study how bank risk-taking evolves in response to persistent changes in natural real interest rates and the conduct of monetary policy. Also related is Aoki and Nikolov (2015) who develop a rational bubble framework to investigate whether banks or ordinary savers hold the bubble in the stochastic steady state of the model economy. The rational bubble plays the role of the systemically risky asset which is held by banks when leverage is high and supervision is lax. In this paper, leverage will also be important for the extent to which banks invest in the systemic asset, but our emphasis will be on how leverage is determined by monetary policy and shocks to the natural real interest rate.

Our paper contributes to the literature on the link between monetary policy and banks' risk-taking. Dell'Ariccia et al. (2014) show, in a partial equilibrium framework, that when the risk-free interest rate declines, banks increase leverage and the riskiness of their loans. Abbate and Thaler (2019) embed this mechanism in a DSGE model and estimate it on US data while Abbate and Thaler (2023) show that the model implies an optimal policy that allows some inflation volatility in order to prevent bank risk-taking during periods of low interest rates. Martinez-Miera and Repullo (2017) use a similar framework in general equilibrium to show that lower real interest rates caused by a greater supply of savings can cause an increase in bank risk-taking as well as an expansion of riskier market-based financing. Our paper also generates higher bank leverage under lower real interest rates, although our mechanism works through a higher borrowing capacity when the bank's market value increases.

There is also a large theoretical literature on the interactions of monetary policy and financial stability in frameworks that emphasize pecuniary fire sale externalities. This literature - surveyed in Martin et al. (2021) and Ajello et al. (2022) - emphasizes bank risk taking through excessive leverage. Van der Ghote (2021) investigates the jointly optimal setting of monetary and macroprudential policy in a continuous time Gertler and Karadi (2011) framework in which monetary or macroprudential policies can restrict excessive leverage in good times. Ikeda (2022) uses a framework with asset price bubbles to investigate a *"leaning against the wind"* policy using monetary policy. In his model, marginal cost depends on the interest rate on bank borrowing, so a credit boom that reduces lending spreads may actually lead to low inflation in the short term. It is therefore not optimal to stabilize inflation by cutting interest rates for fear of amplifying the boom even further.

In contrast to this literature where excessive risk-taking takes the form of high bank leverage, we emphasize excessive risk-taking on the asset side through investments in a systemic asset which can inflict large aggregate losses on the banking system in a crisis. We also find that –through the inflation effects on the value of bank liabilities– *leaning against the wind* is optimal in order to stabilize bank risk-taking and the costs of systemic crisis over the cycle.

Our paper is also consistent with the findings in Bianchi (2016) who argue that what they call "systemic bailouts" do not lead to moral hazard by encouraging higher ex ante risk taking. Monetary policy works precisely as a "systemic bailout" in our framework: it boosts bank capital during a crisis without rewarding banks that have taken risks in the past. As a result, ex post monetary policy interventions do not lead to moral hazard.

There is also a large body of empirical evidence on the linkages between monetary policy and financial stability, as surveyed by Boyarchenko et al. (2022). Jiménez et al. (2014) and Jiménez et al. (2017) use credit register data and show a strong effect between monetary policy and lending to riskier borrowers at the individual bank level. Maddaloni and Peydró (2011) have similar findings using the ECB's Bank Lending Survey. Dell'Ariccia et al. (2017) show that banks increase the riskiness of new loans following a reduction in interest rates. The effect is weaker for poorly capitalized banks and during times of financial distress. Heider et al. (2021) and Ampudia and Van den Heuvel (2022) find that negative interest rates in particular cause higher risk-taking by banks that rely a lot on retail deposits whose interest rates are 'sticky' at zero.

The literature has also examined the broader effects of monetary policy on risk in the financial system. Bekaert et al. (2013) have VAR evidence that monetary policy affects the market price of risk, thus moving not just risk-free rates but also risk premia in a persistent fashion. Adrian et al. (2019) use a quantile VAR framework to show that looser monetary policy increases the conditional mean of GDP growth in the short term while increasing its variance and downward skewness in the medium term.

Our model is consistent with empirical evidence on the link between real interest rates and financial system risk more broadly. In the model, bank risk-taking increases following lower interest rates. As a result, lower real interest rates boost real activity in the short term while increasing medium-term risks due to higher systemic risk in the financial sector.

Outline. Section 2 describes the model. Section 3 outlines the equilibrium conditions and the solution method. Section 4 is devoted to the quantitative analysis. Section 5 concludes.

2. The Model

The baseline model is a standard production economy with nominal rigidities and financial intermediation. Following Gertler and Karadi (2011), banks' borrowing capacity depends on their equity value, generating a link between real interest rates and bank leverage. Systemic risk taking will be introduced as in Martinez-Miera and Suarez (2012) and Abad et al. (2024). Limited liability then encourages banks to invest in systemic assets that fail simultaneously when an exogenous systemic event occurs.

2.1. Households

There is an infinitely lived aggregate household whose members derive utility from consumption and disutility from labor supply. As in Gertler and Kiyotaki (2010), we assume that in each period some household members become bankers - special agents who are able to place equity into banks. The rest of the household's members remain workers. Bankers receive an initial endowment from the aggregate household and face a constant probability of retiring and returning their accumulated net worth to the rest of the household. The aggregate household provides full consumption insurance to its members so all households have the same consumption level.

The aggregate household chooses consumption C_t, labor L_t, holdings of nominal bank deposits D_t, risk-free nominal bonds B_t, and physical capital K_t^H to maximize the following recursive formulation of lifetime welfare:

$$V_t^H = \max_{C_t, L_t, D_t, B_t, K_t^H} \left\{ \log(C_t) - \kappa \frac{L_t^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}} + \beta_t E_t[V_{t+1}^H] \right\} \tag{1}$$

where β_t is the discount factor, κ captures the relative disutility of working and ν represents the inverse of the Frisch elasticity. The household maximizes (1) subject to the intertemporal budget constraint:

$$C_t + (1+s_t)K_t^H + D_t + B_t = w_t L_t + R_t^K K_{t-1}^H + \frac{\widetilde{R}_t^D}{\pi_t} D_{t-1} + \frac{R_{t-1}}{\pi_t} B_{t-1} + \Pi_t - T_t. \tag{2}$$

The household is able to invest directly in capital K_t^H and obtain the market return R_t^K only by paying a management fee s_t.[1] The household is also able to invest in nominal bonds B_{t-1} with a real rate of return of R_{t-1}/π_t.[2] Moreover, the household can also invest in bank debt in the form of deposits D_t and get $\widetilde{R}_t^D$, which is the ex-post nominal return on a diversified portfolio of partially insured bank debt. For the labor supplied, the household receives a wage w_t. The household receives profits Π_t from the ownership of banks, capital management firms and final goods producers. Finally, the household pays taxes T_t to finance the Deposit Insurance Scheme (DIS).

In order to generate movements in real interest rates we assume β_t follows an AR(1) stochastic process

$$\beta_t = (1-\rho_\beta)\overline{\beta} + \rho_\beta \beta_{t-1} + u_t, \tag{3}$$

where $\overline{\beta}$ is the non-stochastic steady state discount factor determining the long-run natural interest rate.

2.2. Bankers

Bankers are special households who participate in the market for bank equity. Each active banker faces a constant probability of retiring (1 - η) in each period. Upon

[1] This is how non-bank financial intermediation (NBFI) is captured in the model. Banks will not face a management cost which gives them an efficiency advantage as capital holders.

[2] Nominal bonds are assumed to be in zero net supply and the central bank sets their interest rate.

retirement, he pays his entire net worth back to the household and becomes a worker. Simultaneously, the same measure of households switches from being workers to being bankers and begins investing the initial endowment given to them by the aggregate household. Hence, the measure of households that are bankers is constant over time.

Let $V_t^B(n_t)$ denote the value of a continuing banker with n_t of accumulated wealth. The banker chooses how much of his wealth to invest in bank equity e_t as well as the share of this equity that goes to systemic banks $x_t \in [0,1]$. Hence, bankers solve:

$$V_t^B(n_t) = \max_{e_t, x_t, div_t} div_t + E_t \Lambda_{t+1} \left[(1-\eta) n_{t+1} + \eta V_{t+1}^B(n_{t+1}) \right], \tag{4}$$

where $\Lambda_{t+1} = \beta_t \frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic discount factor of the household which will be fully defined subsequently.

The banker faces a current budget constraint stating that his wealth is either used to invest into the equity of banks or is paid out as dividends:

$$n_t = e_t + div_t. \tag{5}$$

We assume that bankers are subject to a dividend non-negativity constraint:

$$div_t \geq 0. \tag{6}$$

The law of motion for the evolution of bankers' wealth is given by

$$n_{t+1} = [\rho_{t+1}(z_t = 1) x_t + \rho_{t+1}(z_t = 0)(1 - x_t)] e_t, \tag{7}$$

where $\rho_{t+1}(z_t)$ is the type-dependent rate of return on equity where $z_t = 0$ and $z_t = 1$ denote, respectively, systemic and non-systemic banks. We follow Gertler and Kiyotaki (2010) and guess that the value function is linear in wealth

$$V_t^B(n_t) = \phi_t n_t, \tag{8}$$

with ϕ_t being the shadow value of one unit of bankers' wealth. In equilibrium, as long as $\phi_t > 1$, bankers will strictly prefer to accumulate wealth rather than paying it out as dividends to the household.[3] This implies $div_t = 0$ and $n_t = e_t$. Substituting (8) into the value function and imposing $div_t = 0$, we find that the shadow value of a unit of bankers' wealth satisfies the following functional equation

$$\phi_t = E_t \left[\Lambda_{t,t+1}^B \frac{n_{t+1}}{n_t} \right], \tag{9}$$

[3]We verify that this is the case in our quantitative exercises.

where $\Lambda^B_{t,t+1} = \Lambda_{t,t+1}(1-\eta+\eta\phi_{t+1})$ is the stochastic discount factor of the banker which also takes the evolution of the shadow value of bankers' wealth into account.

2.3. Banks

Banks are one-period-lived intermediaries which raise equity e_t from bankers and deposits d_t from households to buy capital goods k^B_t subject to a balance sheet constraint

$$k^B_t = e_t + d_t. \tag{10}$$

As in Gertler and Kiyotaki (2010) the bank faces a moral hazard problem. Its shareholders are able to abscond with a $(1-\theta)$ fraction of the bank's assets at the cost of losing the charter value of the bank. This implies that the amount of resources the bank can raise must satisfy the following incentive compatibility constraint:

$$V^B_t(n_t) \geq (1-\theta)k^B_t. \tag{11}$$

In other words, the charter value of the bank must always exceed the value of absconding with the assets. Using (8) we can see how this mechanism will act as the bank's market-imposed capital constraint. The bank also faces a standard regulatory constraint that requires its equity capital ratio to be at least γ. Actual leverage is determined by the tighter of the two constraints:

$$\frac{e_t}{k^B_t} = \max\left\{\frac{(1-\theta)}{\phi_t},\ \gamma\right\}. \tag{12}$$

Banks enjoy limited liability and choose their asset investments, how much equity to raise from bankers and how much nominal deposits to raise from households in order to maximize their net present value (NPV)[4]

$$\max NPV^B_t = \mathbb{E}_t\left\{\Lambda^B_{t+1}\max\left[\Xi_{t+1}\widetilde{R}^K_{t+1}k^B_t - \frac{R^D_t}{\pi_t}d_t, 0\right] - \phi_t e_t\right\}, \tag{13}$$

where $\widetilde{R}^K_{t+1}$ is the gross return on assets, R^D_t is the contractual deposit rate and subject to (10) and (12).

Endogenous systemic risk taking by banks is introduced as in Martinez-Miera and Suarez (2012) and Abad et al. (2024). Let $z_t = \{0,1\}$ be a variable that indicates the bank's type. Non-systemic (*safe*) banks ($z_t = 0$) are not exposed to a systemic

[4]The assumption of a bank holding nominal deposits and real assets implies a financial institution that lends mostly variable rate to NFCs and a large share of "sticky" insured deposits which have a higher effective duration because they are held by households which are insensitive to the interest rate they pay.

event, whereas systemic (*risky*) banks ($z_t = 1$) are specialized in risky assets.[5] A bank investing in k_t^B units of capital obtains a gross return of $\widetilde{R}_t^K = R_{t+1}^K \Xi_{t+1}(z_t)$ where

$$R_{t+1}^K = r_{t+1}^K + 1 - \delta \tag{14}$$

is the rate of return on capital, r_{t+1}^K is the rental rate of capital, and δ is the depreciation rate. The term $\Xi_{t+1}(z_t)$ captures the differential exposure of each type of bank to an aggregate systemic event. Let ι_t be an indicator for the systemic event such that

$$\iota_{t+1} = \begin{cases} 0 & \text{with probability } 1 - \ , \\ 1 & \text{with probability } \ , \end{cases} \tag{15}$$

with being the probability of a systemic event taking place. Next, we define the type-specific return premium

$$\Xi_{t+1}(z_t) = \begin{cases} 1 + \mu^+ z_t & \text{if} \quad \iota_{t+1} = 0, \\ 1 - \mu^- z_t & \text{if} \quad \iota_{t+1} = 1. \end{cases} \tag{16}$$

In other words, the risky asset delivers a premium, $\mu^+ > 0$, in normal times at the expense of suffering losses $\mu^- \in (0, 1]$ when a systemic event takes place.

Following the risk-shifting literature, we assume that the safe bank is the efficient one in the sense that it generates a higher expected return on assets:

$$1 > (1 - \ )(1 + \mu^+) + \ (1 - \mu^+). \tag{17}$$

Note that, conditional on the crisis not taking place, systemic banks yield higher expected returns than non-systemic banks. This implies that, in the presence of limited liability, bankers will have incentives to invest in systemic assets.

2.4. Other Agents

Capital management firms. There is a measure-one continuum of firms managing households' direct capital investments K_t^H at a fee s_t maximizing

$$\Pi_t^S = \max_{K_t^H} \quad s_t K_t^H - \frac{\zeta}{2}(K_t^H / K_t)^2 K_t. \tag{18}$$

As in Gertler et al. (2020), these firms face a convex cost of managing assets and pay any profits back to the household.

Intermediate good producers and retailers. In the final good sectors, a continuum of monopolistically competitive intermediate good firms indexed by i, produce

[5] Bank specialization is an efficient equilibrium outcome product of the limited liability distortion (Repullo and Suarez 2004).

differentiated varieties that are combined into a final good composite. Formally, final output Y_t is produced by combining the $y_t(i)$ intermediate varieties according to

$$Y_t = \left[\int_0^1 y_t(i)^{\frac{\ -1}{}} di \right]^{\frac{}{\ -1}}, \tag{19}$$

where is the elasticity of substitution among varieties.

Intermediate good producers transform capital and labor inputs into varieties according to a constant returns to scale technology

$$y_t = AK_t^{\alpha} L_t^{1-\alpha}, \tag{20}$$

where A it the total factor productivity and α the capital share in production.

Nominal rigidities are introduced as follows. Producers choose $(p_t(i), y_t(i))$ to maximize the expected discounted value of profits

$$E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(\frac{p_t(i)}{P_t} - MC_t \right) y_t(i) - \frac{\xi}{2} \left(\frac{p_t(i)}{p_{t-1}(i)} - 1 \right)^2 Y_t \right] \right\}, \tag{21}$$

where MC_t is the marginal costs, ξ is the price adjustment cost à la Rotemberg (1982), and $\Lambda_{0,t}$ is the stochastic discount factor of the representative households.

Aggregate firm profits, Π_t^F, in the symmetric equilibrium $(p_t(i) = P_t)$ are paid out to the household every period and given by

$$\Pi_t^F = (1 - MC_t) Y_t - \frac{\xi}{2} (\pi_t - 1)^2 Y_t. \tag{22}$$

where $\pi_t = \frac{P_{t-1}}{P_t}$ is the inflation rate.

2.5. Monetary Policy

We assume that the central bank has a zero inflation target and follows a simple Taylor rule where ψ_π is the response coefficient on inflation deviations from target [6]

$$R_t = \beta_t^{-1} \pi_t^{\psi_\pi}. \tag{23}$$

3. Equilibrium

3.1. Households

The first order conditions of the household problem are given below. The Lagrange multiplier on the household budget constraint is

[6] We allow the rule's intercept to vary with shocks to the households time discount factor. This is done in order to focus the analysis of monetary policy on its role in managing financial stability risks and not on the impact of misperceptions of the natural real interest rate.

$$\lambda_t = C_t^{-1}. \tag{24}$$

The first order condition with respect to labor supply solves

$$\lambda_t w_t = \kappa L_t^{\frac{1}{\nu}}. \tag{25}$$

Define the households' stochastic discount factor as $\Lambda_{t,t+1} = \beta_t \frac{\lambda_{t+1}}{\lambda_t}$. The first order condition with respect to the risk-free nominal bond gives

$$E_t\left(\Lambda_{t,t+1}\frac{R_t}{\pi_{t+1}}\right) = 1. \tag{26}$$

and the first order condition with respect to nominal deposits is

$$E_t\left(\Lambda_{t,t+1}\frac{\widetilde{R}^D_{t+1}}{\pi_{t+1}}\right) = 1, \tag{27}$$

where $\widetilde{R}^D_{t+1}$ is the return on a diversified portfolio of partially insured bank deposits that may experience some default losses. The equilibrium expression for $\widetilde{R}^D_{t+1}$ will be derived in detail in the next section.

Finally, we have the first order condition with respect to directly held capital

$$E_t\left(\Lambda_{t,t+1}\frac{R^K_{t+1}}{1+s_t}\right) = 1. \tag{28}$$

3.2. Bankers and Banks

From the expression for banks' profits at time $t+1$ (13) , we get the following expression for the rate of return on equity invested

$$\rho_{t+1}(z_t) = \max\left\{\Xi_{t+1}(z_t)R^K_{t+1}\frac{k^B_t}{e_t} - \frac{R^D_t}{\pi_{t+1}}\frac{d_t}{e_t},\ 0\right\}. \tag{29}$$

Bankers choose how much equity to place into systemic and non-systemic banks. In order to have positive investment in both types of assets, a no-arbitrage condition implies that the value bankers obtain from both types of banks should be the same in equilibrium

$$E_t\left[\Lambda^B_{t,t+1}\rho_{t+1}(z_t=0)\right] = E_t\left[\Lambda^B_{t,t+1}\rho_{t+1}(z_t=1)\right]. \tag{30}$$

Non-systemic banks are safe and always pay back deposits in full. However, systemic banks can default on their liability repayments depending on the state of the world. Following Mendicino et al. (2020) we assume that a share τ of their deposits is insured and always pay back the contractual deposit rate. The remaining deposits are uninsured and when banks default, uninsured debt holders recover only the value of the bank's assets minus an asset repossession cost. Let $\overline{R}^D_{t+1}(z_t)$ denote the ex-post realized nominal return on the deposits of an individual bank of type z_t, which is given by

$$\overline{R}^D_{t+1}(z_t) = \tau R^D_t + (1-\tau)\min\left\{R^D_t,\ \pi_{t+1}\Xi_{t+1}(z_t)R^K_{t+1}\frac{d_t}{e_t}\right\}. \tag{31}$$

Depositors receive the full contractual return when the bank is safe ($z_t = 0$). When the bank is risky ($z_t = 1$) due to its systemic exposure, insured deposits (τ fraction of the total) pay out the full contractual return while uninsured deposits ($1-\tau$ fraction of the total) pay out the contractual return in normal times or the recovery value of the bank when it fails during a systemic event. The realized return on a diversified portfolio of bank deposits is determined by x_t - the share of systemic investment over total bank capital.

$$\widetilde{R}^D_{t+1} = x_t\overline{R}^D_{t+1}(z_t = 1) + (1-x_t)\overline{R}^D_{t+1}(z_t = 0). \tag{32}$$

Finally, the Deposit Insurance Scheme experiences losses from systemic banks with a real value equal to

$$DIS_t = \tau\max\left\{0,\ x_t\left[\frac{R^D_t}{\pi_{t+1}} - \Xi_{t+1}(z_t = 1)R^K_{t+1}\frac{d_t}{e_t}\right]\right\}. \tag{33}$$

Notice that we are implicitly assuming that the economy is in a pooling equilibrium where all banks choose identical leverage. Different banks are then indistinguishable to depositors who compute expected returns using the equilibrium level of banks' systemic exposure.[7]

3.3. Other Agents

Capital management firms. Profit maximization of (18) delivers an expression for the equilibrium capital management fee charged per unit of households' capital direct investment

$$s_t = \zeta(K^H_t/K_t). \tag{34}$$

Intermediate good producers and retailers. From cost minimization, final good producers set input prices according to:

$$W_t = MC_t(1-\alpha)\frac{Y_t}{L_t}, \tag{35}$$

$$r^K_t = MC_t\alpha\frac{Y_t}{K_t}. \tag{36}$$

[7] For further discussion on the role of deposit insurance in a separating equilibrium see Abad et al. (2024).

Each monopolistically competitive retailer chooses its price $p_t(z)$ to maximize the NPV of profits. From the first order condition with respect to $p_t(z)$, evaluated at the symmetric equilibrium ($p_t(z) = P_t$), we obtain

$$(\pi_t - 1)\pi_t = \frac{1}{\xi}(\quad MC_t + 1 - \quad) + E_t\left[\Lambda_{t,t+1}\frac{y_{t+1}}{y_t}\pi_{t+1}(\pi_{t+1} - 1)\right], \tag{37}$$

which defines the New Keynesian Phillips curve (NKPC) in the model.

3.4. Aggregation and market clearing

From this section and in the rest of the paper we use capital letters to denote aggregate quantities.

Capital market. Total capital invested by banks is equal to the sum of capital invested in systemic and non-systemic assets. When systemic projects collapse due to a crisis, the capital invested in them is partially destroyed. The available capital stock within a period $\widetilde{K}^B_{t+1}$ therefore depends on the realized return on the systemic technology $\Xi_{t+1}(z_t)$ and on the share of systemic exposure over total bank assets x_t

$$\widetilde{K}^B_{t+1} = [x_t\Xi_{t+1}(z_t = 1) + (1 - x_t)\Xi_{t+1}(z_t = 0)]K^B_t. \tag{38}$$

Total capital available for production within a period is the sum of bank capital and household capital

$$K_t = \widetilde{K}^B_t + K^H_t. \tag{39}$$

Finally, investment is given by the difference between new bank and household capital demand and effective capital carried over from the last period:

$$I_t = K^H_t + K^B_t - (1 - \delta)K_{t-1}. \tag{40}$$

Bank equity market. Bankers' wealth before transfers $\widetilde{N}_{t+1}$ and after the realization of aggregate shocks (captured by $\widetilde{K}^B_{t+1}$ in (38)) evolves according to

$$\widetilde{N}_{t+1} = R^K_{t+1}\widetilde{K}^B_t - \frac{R^D_t}{\pi_{t+1}}D_t, \tag{41}$$

Adding up the wealth of continuing bankers and newborn ones, we obtain the final law of motion for bankers' wealth

$$N_{t+1} = [\eta + \chi(1 - \eta)]\widetilde{N}_{t+1}, \tag{42}$$

where χ is the proportion of retiring bankers' wealth that is transferred from the household to the newborn bankers as a start-up fund.

Deposit Insurance Scheme. The government collects taxes to finance the Deposit Insurance Scheme

$$T_t = DIS_t. \tag{43}$$

Goods market. Demand for final goods consists of household consumption, investment, inflation costs, and capital management costs. Therefore, the goods market clearing condition at time t is given by

$$Y_t = C_t + I_t + \frac{\xi}{2}(\pi_t - 1)^2 Y_t + \frac{\zeta}{2}(K_t^H / K_t)^2 K_t. \tag{44}$$

4. Quantitative Analysis

In this section, we first detail the calibration used in our benchmark economy and then explore the quantitative properties of the model. In order to capture all the non-linear reactions implied by the presence of systemic events we rely on global solution methods. The Online Appendix details the algorithm.

4.1. Calibration

The model is calibrated to a quarterly frequency. We set some parameters to standard values in the literature, while others are set to match key moments of the simulated economy and its reaction to a systemic crisis from the economy's stochastic steady state (SSS).[8] Table 1 summarizes the values of the parameters.

Pre-set parameters. The long-run household discount factor ($\overline{\beta}$) is set to 0.99 to match a 4% annual risk-free rate. The share of capital in production (α) is set to a standard value of 0.33. The capital depreciation rate (δ) is set to match an annual rate of 10%. The Frisch elasticity of labor supply (ν) is equal to 5 in line with Gertler and Karadi (2011).[9] The elasticity of substitution between different intermediate goods varieties ( ) is set to 11 implying a 10% steady state mark-up of price over marginal cost. The scale parameter in the quadratic cost of changing prices (ξ) is set to 116.5 which (to a linear approximation) implies an equivalent New Keynesian Phillips curve slope to that obtained in the Calvo (1983) framework by assuming that prices are rigid on average for a year. ψ_π is set to 2.5 implying a moderate reaction to inflation in the Taylor rule. The probability of systemic events ( ) is set to 1% quarterly (Schularick and Taylor 2012), which implies that a crisis occurs on average every 25 years. Finally, we assume $\mu^- = 0.45$ consistent with a 45% loss given default.

[8] Similarly to Abad et al. (2024) we define the stochastic steady state (SSS) as the invariant equilibrium allocation attained after sufficiently many periods without a systemic event taking place. In our environment, shocks to the discount factor generate an additional source of aggregate uncertainty. Therefore, we keep the value of the discount factor at its long-term average.

[9] This choice implies a Frisch elasticity that is higher than the ones suggested by the micro evidence but this is appropriate for calibrating a model which abstracts from modelling nominal rigidities in wage setting.

TABLE 1. Calibration

Description	Parameter	Value	Source/Target
Discount factor	$\overline{\beta}$	0.99	4% annual risk-free rate
Capital share	α	0.33	Standard
Depreciation rate	δ	0.025	10% annual rate
Risky asset loss	μ^-	0.45	BCBS (2004)
Share of insured deposits	τ	0.54	Demirgüç-Kunt et al. (2015)
Minimum capital requirement	γ	0.08	BCBS (2004)
Bankers start-up transfer	χ	0.001	Gertler and Kiyotaki (2010)
Frisch elasticity	ν	5	Gertler and Kiyotaki (2010)
Dissutility of hours	κ	1	Normalization
Elasticity of substitution between varieties		11	10% mark-up
Probability of crisis		0.01	Schularick and Taylor (2012)
Sticky prices	ξ	116.5	Calvo (1983) probability of 75%
Taylor rule inflation coefficient	ψ_π	2.5	Standard
Persistence of β shock	ρ_β	0.95	Standard
Risky asset premium	μ^+	0.0019	Fall in bank capital in crisis
Absconding rate	θ	0.725	Bank leverage
Banker's survival rate	η	0.975	Return on bank equity
Capital management cost	ζ	0.0055	NBFI share
Std. dev. of β process	σ_β	0.005	GDP volatility

TABLE 2. Model fit

Moment	Model	Target	Source
Real return on equity	11.4%	12%	US banks 2000-2020
CET1 ratio	10.9%	10%	US banks 2000-2020
NBFI share	38.7%	40%	FSB (2023)
Fall in bank equity	-32.2%	-30%	Baron et al. (2020)
Std. dev. of $\log(GDP)$	0.013	0.014	US 2000-2020

Note: Targets for the real return on equity, capital ratio and NBFI share correspond to stochastic means of the full model economy. Fall in bank equity targets the impact reaction to a crisis when the economy is at the SSS. The standard deviation of log(GDP) targets the volatility of GDP in the absence of banking crisis.

Calibrated parameters. There are five remaining parameters: the survival rate of bankers (η), the share of divertable assets (θ), the scale parameter on the quadratic capital management cost for households (ζ), the risk-taking gains (μ^+) and the volatility of the shock to the discount factor (σ_β). These parameters are jointly calibrated in order to match the model's counterparts on the return on bank equity, capital ratio, the share of capital held by households, the impact fall in bank capital after a systemic banking crisis, and the volatility of GDP.

We target average values for the US economy during the period 2000-2020. Bankers' survival rate is set to 0.975 to match a 10% average annual real return on equity for US banks. We target an average CET1 ratio of 11%.[10] The share of non-bank financial intermediation over total bank assets is targeted at 40% as reported for the US by the Financial Stability Board (2023). The standard deviation of the cyclical component of log(GDP) is targeted at 0.014. Finally, following Baron et al. (2020), we target a 30% fall in bank equity when a systemic crisis occurs. Table 2 reports the fit of the model.

4.2. Decision rules and economy's reaction to systemic crisis

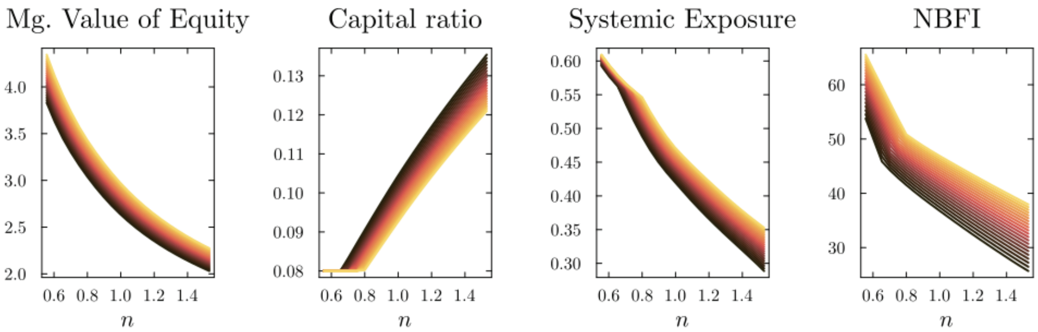

FIGURE 1. Equilibrium decision rules

Note: The figure shows policy functions given bankers' wealth (n_t) for the marginal value of bank equity (ϕ_t), the capital ratio (n_t/k_t^B), systemic exposure (x_t) and share of non-bank financial intermediation (K_t^H/K_t)

Figure 1 shows the equilibrium decision rules for the marginal value of bank equity (ϕ), the bank capital ratio (the inverse of leverage), the share of systemic exposure (risk-taking) and the share of capital directly intermediated by the household as a proxy for non-bank financial intermediation (NBFI).

Notice that in this set-up, where leverage depends on the charter value of the bank, higher bankers' wealth leads to lower leverage. As bankers' wealth becomes more abundant, its marginal value decreases and this lowers the bank's equity value and hence its leverage limit. Everything else equal, lower leverage leads to lower risk-taking due to the reduced limited liability distortion. Moreover, more abundant bankers' wealth leads to higher capital investment by the banks and a larger aggregate capital stock. As a result, the return to capital falls and directly held capital by the household (NBFI) decreases.

Figure 2 describes the impact of a crisis in the model. The capital invested in risky (systemic) assets suffers a loss and the resulting reduction in the aggregate capital stock leads to a deep fall in output and consumption.[11] Bank equity falls even more sharply –around 30% (Baron et al. 2020)– due to the effects of leverage, reducing banks' ability to intermediate. Due to households' convex cost of holding capital

[10]Data on the return on equity for US banks is available at FRED. Data on the CET1 ratio is reported by the FED.

[11]This resembles the *capital quality shock* in Gertler and Karadi (2011).

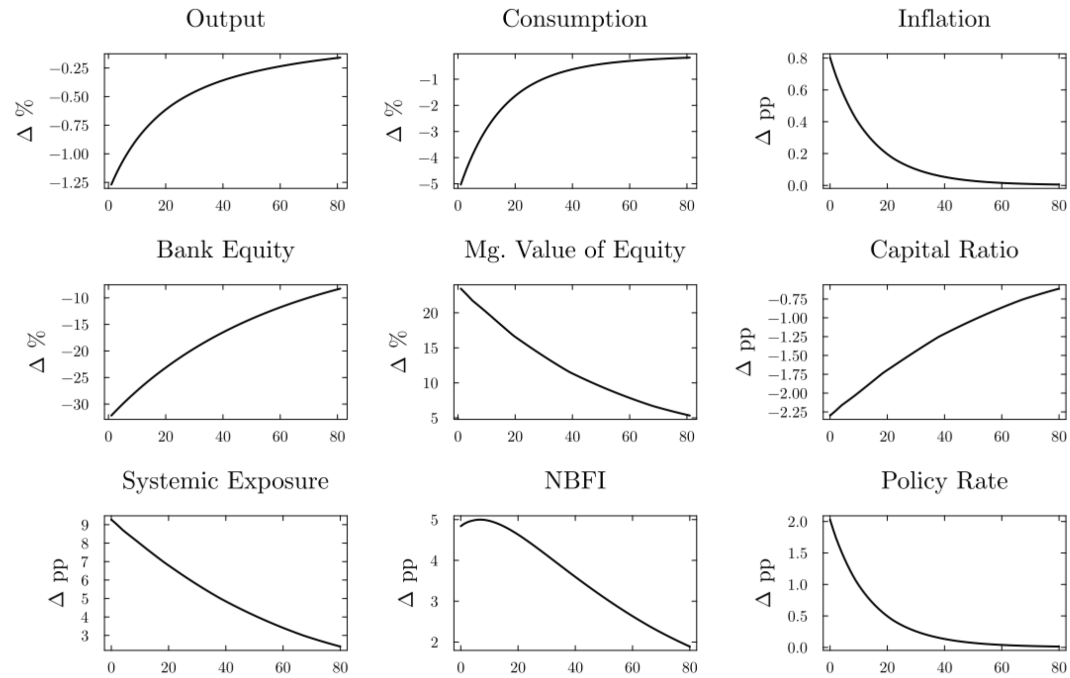

FIGURE 2. Reaction to a systemic crisis

Note: The figure shows impulse response functions to a systemic event taking place when the benchmark economy is at its SSS.

directly, their capacity to absorb capital is limited and requires an increase in its expected rate of return. As a result, bank capital ratios decline, driven by higher bank charter values due to the higher expected return to capital. This helps to cushion the blow to bank credit supply to some extent but it has the side effect of boosting leverage and bank risk taking. The fall in the capital stock leads to a significant decline in aggregate supply causing an increase in inflation which the Taylor rule stabilizes through an increase in the policy rate.[12]

4.3. Interest rates and bank risk-taking

Next, we examine the model's implications for the link between real interest rates and bank risk-taking. First, we consider the impact of the long-term interest rate (implemented via a comparative statics exercise with respect to the discount factor of the representative household). Second, we examine the impact of monetary policy.

4.3.1. Comparative statics with respect to the long-term real interest rate

We start by looking at the impact of steady state real interest rates — which in our model is determined by the average degree of households' time discounting such

[12]Systemic crisis events in the model destroy a part of capital and act as supply shocks, moving output and inflation in different directions. During the GFC, the enormous loss of confidence for both firms and households acted as large negative demand shocks which reduced inflation. However, empirical evidence on financial shocks more generally (Abbate et al. 2023) and on other worldwide banking crisis episodes (Kaehler and Weber 2023) has shown that they create inflationary pressure and lead to trade-offs for monetary authorities.

that $r^* = 1/\beta - 1$. Figure 3 displays the comparative statics of a number of macro-financial variables in our economy with respect to the steady state real interest rate, a key variable to determine agents' investing opportunities.

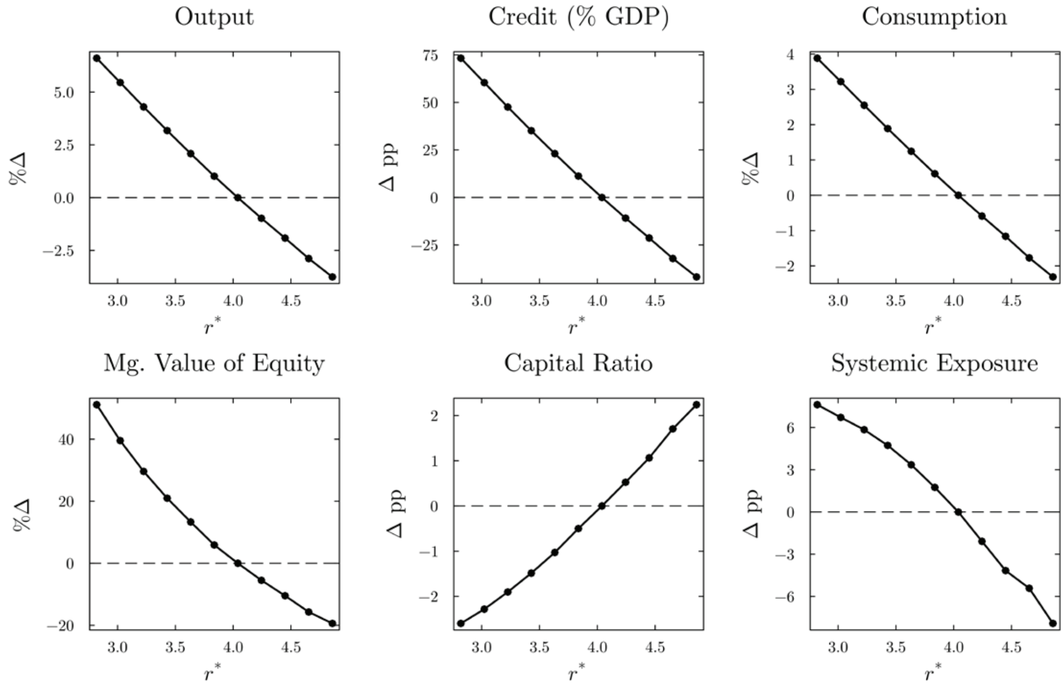

FIGURE 3. Comparative statics with respect to the steady state real interest rate

Note: The figure shows the stochastic means of key variables of the model under different values of the steady state real interest rate.

We immediately observe that the economy with a lower steady state real interest rate – i.e. with more patient households – features more capital (credit) and a higher level of GDP but also more levered banks and much higher holdings of risky assets. We see that banks' capital ratios fall by 2 pp and exposure to the systemic asset rises more than 5 pp as the real rate decreases by 100 bp. This is driven by the impact of lower risk-free rates on the market value of a unit of bank capital. Due to the presence of limits to bank leverage, an intermediation spread arises between the rate of return on bank assets and the real deposit rate. Hence, banks in the model make profits whose net present value depends on the long-run real interest rate. A lower real rate, other things equal, makes bank capital more valuable and, because the bank's leverage constraint depends on the value of the bank, it also increases the leverage the bank can obtain from debt holders. Under higher leverage, the limited liability distortion has a larger effect and the bank chooses to hold a larger share of risky assets.

4.3.2. Transitory and persistent changes in real interest rates

Next, in Figure 4 we examine how the economy responds to a temporary but persistent shock to the household's discount factor. This leads to a long-lived (but transient) fall in the long-term real interest rate and an increase in the value of bank capital – the NPV of future bank profits per unit of wealth. Through the same mechanism described in the previous section, this leads to higher leverage and bank risk-taking.

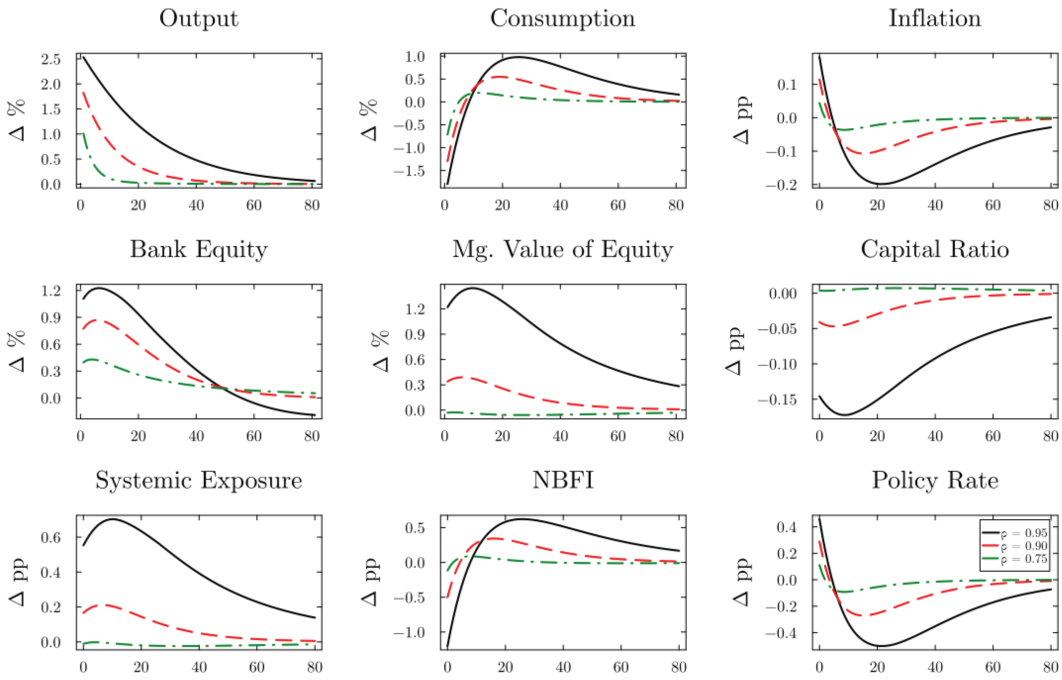

FIGURE 4. Effects of transitory positive change in the discount factor

Note: The figure shows impulse response functions, under different levels of persistence, to a positive shock to the discount factor β lowering the long-run risk-free rate by 100 bp.

Two key points are worth stressing. First, the quantitative magnitude of the move in leverage and risk-taking is much smaller than the impact of permanent changes in the previous section. Even the highly persistent shock with $\rho_\beta = 0.95$ delivers less than a 1 pp increase in systemic exposure. This highlights the significant difference between the way temporary and permanent shocks change net present value calculations such as the one behind the market value of bank equity. Second, as the shock becomes less persistent, the effect diminishes until the point where these temporary shocks have no sizable effect on bank risk-taking.

4.3.3. Transitory and persistent monetary policy shocks

We have seen that highly persistent changes in the time discount factor of households have an effect on bank risk-taking by affecting their leverage. We now examine whether pure monetary policy changes are able to achieve a similar effect. In order to examine this, we need to modify the Taylor rule in (23) as follows [13]

$$R_t = \frac{m_t}{\overline{\beta}} \pi_t^{\psi_\pi}, \tag{45}$$

where m_t represents a monetary policy shock following an AR(1) process

$$m_t = (1 - \rho_{MP}) + \rho_{MP} m_{t-1} + v_t. \tag{46}$$

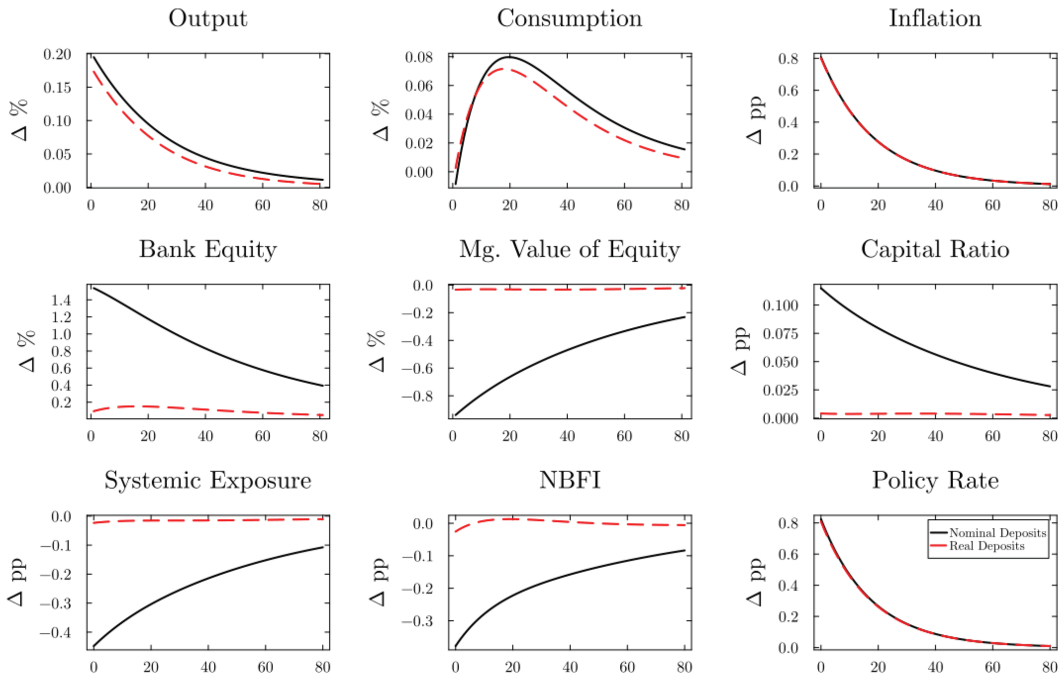

FIGURE 5. Effects of a transitory expansionary monetary policy shock

Note: The figure shows impulse response functions to a direct monetary policy shock in the Taylor rule lowering the target long-run risk-free rate by 100 bp. The solid line shows the reaction in the baseline case with nominal bank deposits, whereas the dash line shows the reaction in an economy where bank liabilities are real.

Figure 5 compares the economy's response to a persistent monetary policy shock. In order to understand the effect of monetary policy shocks on bank risk-taking decisions, we plot impulse response functions under a baseline case where bank deposits are nominal and an alternative economy where they are real (i.e. their nominal value is indexed to the realized inflation rate).

Focusing on the baseline case with nominal deposits (solid line) we observe that an expansionary monetary policy shock has the standard effects on the real economy, boosting output and inflation. The nominal policy rate is subject to two opposing forces. The policy shock itself reduces interest rates but the higher inflation

[13] In this version of the Taylor rule, the long-term intercept is constant at $\overline{\beta}^{-1}$ because we only consider monetary policy shocks and not shocks to the household's time discount rate.

increases interest rates as prescribed by the Taylor rule. The net effect is a higher nominal interest rate but a lower real rate, which stimulates the economy.

On the financial side, we observe how reductions in the monetary policy rate actually decrease bank risk-taking. This is mainly due to the way that the inflationary impact of monetary policy shocks reduces the real value of bank liabilities, increasing bankers' wealth. This raises bank capital ratios, reducing the bank's risk-taking incentive. We confirm this mechanism by showing that, when deposits are real, monetary policy is essentially unable to affect bank risk-taking decisions.

4.4. The role of systematic monetary policy

In this section, we examine how the systematic component of monetary policy (the central bank's response to inflation deviations from target) affects bank risk-taking and overall economic outcomes. We explore this through a series of exercises that highlight the potential trade-offs faced by monetary authorities in the presence of systemic risk.

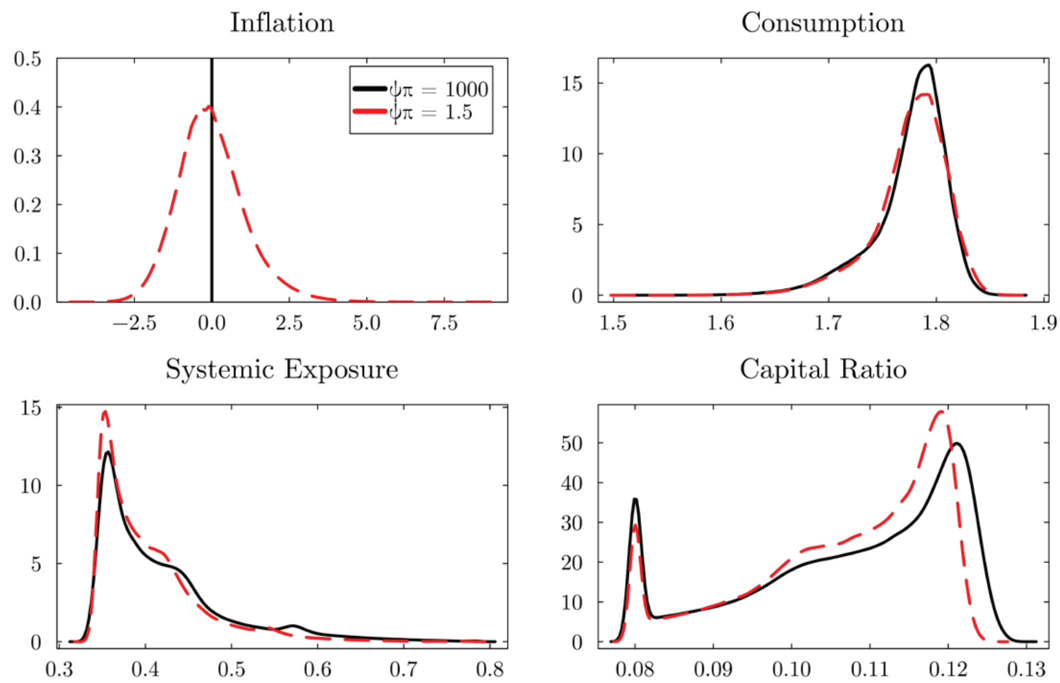

FIGURE 6. Equilibrium distributions and systematic monetary policy

Note: Kernel density functions of the ergodic distribution obtained from a simulation of length 1,000,000 of the economy. Under price stability ($\psi = 1000$) inflation is always on target.

In Figure 6, we start by exploring how the shape of the ergodic distributions of the key macro-financial variables evolves under two different coefficients of reaction to inflation $\psi_\pi \in \{1.5, 1000\}$. A very large coefficient approximately implements price stability at all times, while values closer to one imply a weaker response to inflation deviations from the target. We observe how a more moderate reaction to inflation tends to stabilize bank leverage since the distribution is less skewed and the regulatory limit is hit less often. As a consequence, we also observe fewer tail events of very high systemic exposure and elevated risk-taking. This comes at the cost of having positive inflation volatility, which is fully eliminated under the price stability regime ($\psi_\pi = 1000$).

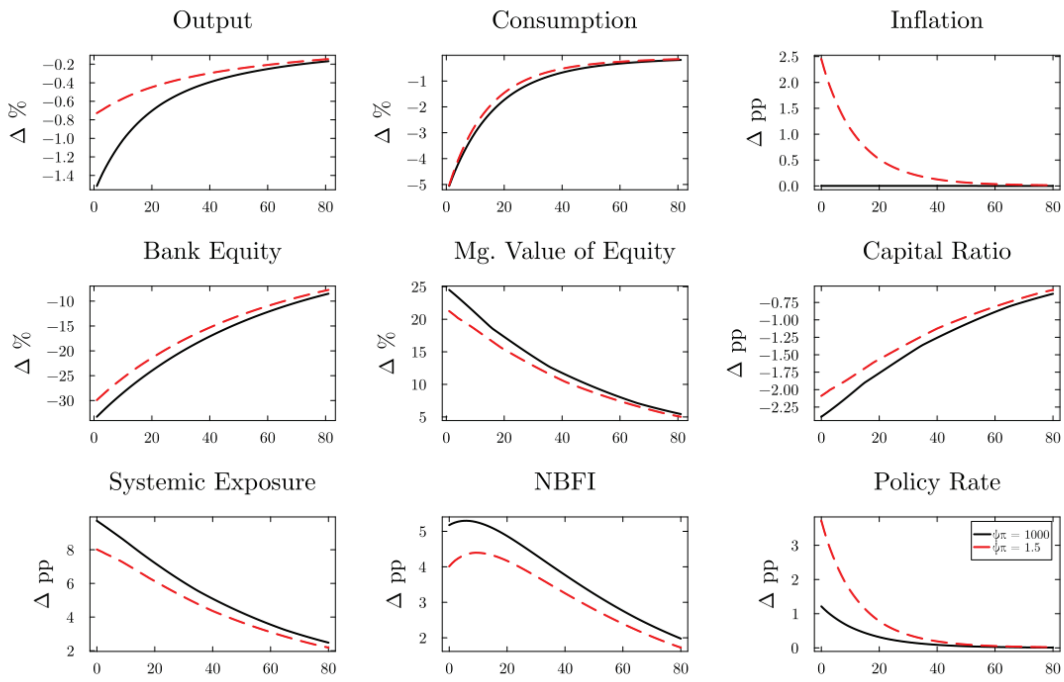

FIGURE 7. Reaction to crisis under different responses to inflation

Note: The figure shows impulse response functions to a systemic event taking place when economies under different systematic monetary policy regimes are at their respective stochastic steady states (i.e. the point at which the system settles following a period of no shocks but when shocks had been expected)

To gain a deeper understanding of the way ψ_π affects economic outcomes, we plot in Figure 7 the economy's non-linear impulse response to a banking crisis under different Taylor rule response coefficients to inflation deviations from target. Yet again, price stability ($\psi_\pi = 1000$ - the solid line in the Figure) ensures that inflation does not move in the crisis. Recall that the fall in the capital stock leads to a significant fall in aggregate supply, causing an increase in inflation, which the Taylor rule stabilizes through an increase in the policy rate. On the banking side, bank equity falls sharply as a result of the collapse of the systemic asset. Consequently, intermediation spreads and hence bank leverage increases, encouraging banks to raise their risk-taking via greater holdings of the systemic asset.

Under a more moderate reaction ($\psi_\pi = 1.5$ - the dashed line in the Figure), the real interest rate rises by less compared to the price stability policy and inflation increases on impact. This reduces the real value of nominal deposits, allowing bank net worth to recover some of its losses. As a result, bank credit supply falls less and intermediation spreads and hence bank leverage rises by a smaller amount. This in turn mitigates the increase in the share of risky assets on banks' balance sheets.

All the previous analysis points towards the monetary authority facing a potential trade-off. On the one hand, allowing some inflation reduces the value of nominal bank liabilities, reducing the fall in bank equity during a crisis. Therefore, inflation has a stabilizing effect on bank equity, allowing the economy to spend less time in states in which bank equity is very scarce and in which bank leverage and bank risk-taking are elevated. This helps to shrink somewhat average holdings of systemic assets and all the associated inefficiencies associated with investing in these negative NPV assets. On the other hand, we have the standard cost of inflation in a model with nominal rigidities: more resources are wasted in changing prices when inflation is allowed to rise.

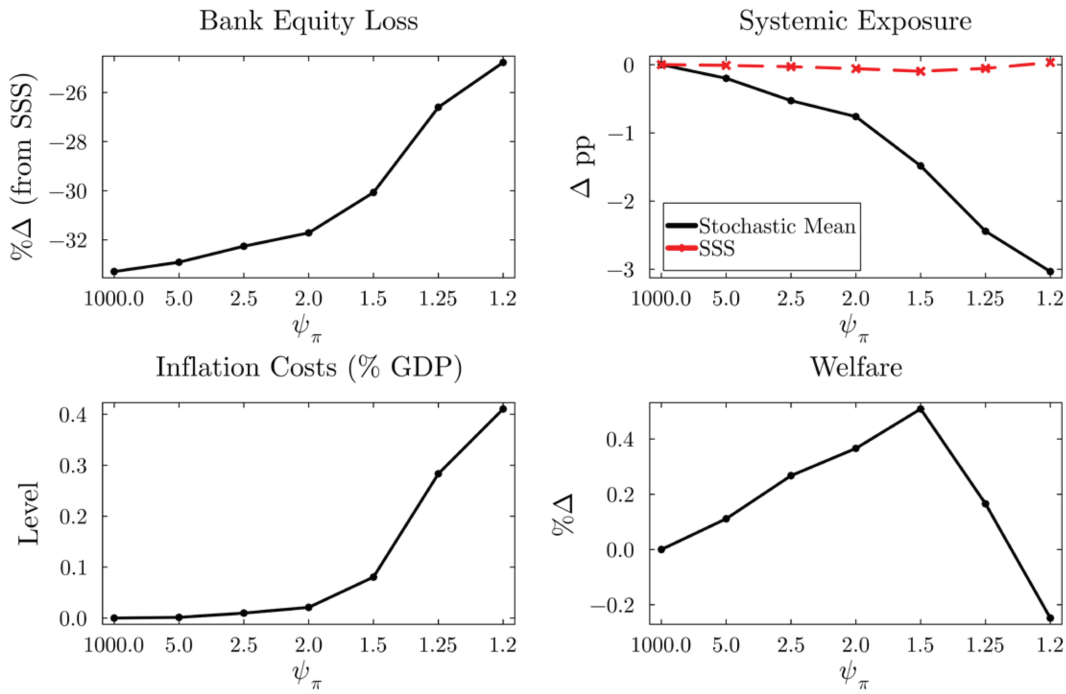

FIGURE 8. Stochastic means under different responses to inflation

Note: The figure shows stochastic first moments (solid line) and stochastic steady state values (dashed line which is displayed only for Systemic Exposure) of key variables under different systematic monetary policy regimes. The stochastic steady state (SSS) is the point at which the system settles following a long period of no shocks but when shocks had been expected.

Figure 8 quantifies the key underlying determinants of this trade-off. It depicts first moments of the ergodic distribution (solid lines) for different key variables. We observe how deviating from price stability increases the deadweight costs of inflation (bottom left panel). This increase is highly non-linear and the costs of inflation (expressed as a percent of GDP) rise sharply as the response coefficient in the Taylor rule approaches unity. At the same time, inflation mitigates the crisis impact on bank equity (top left panel). Ultimately, this implies lower average levels of systemic exposure and risk-taking (top right panel) which carry their own deadweight costs. Aggregate household welfare (the bottom right panel) is a summary measure of this trade-off. It exhibits an inverse U-shape, peaking at a value of approximately ψ_π = 1.5. It turns out that a moderate (and empirically plausible) response to inflation maximizes welfare in the face of the conflicting objectives of stabilizing bank equity following a systemic event and reducing inflation volatility.

This optimal response of monetary policy to inflation allows some state contingency in the real value of bank deposits. Inflation erodes the real value of debt at precisely the time when bank equity is most needed and is most socially and privately valuable. Since banks are more efficient at holding capital than households, the higher capital accumulation can be done either by transferring additional equity to banks or by banks expanding their leverage. Higher bank equity is the socially preferred way of expanding banks' balance sheets in a crisis compared to increasing leverage. This achieves higher credit supply to the real economy without increasing limited liability distortions and boosting inefficient investments in risky assets. Although explicit state-contingent transfers between households and banks are ruled out, inflation can achieve the necessary redistribution. The immediate cost of this state contingency through inflation is the resources wasted due to nominal rigidities. This explains why a moderate response to inflation is optimal rather than implementing price stability.

Another cost of allowing state contingency in the real value of nominal deposits through inflation comes from the potential moral hazard that it creates. Jeanne and Korinek (2020) have shown that while ex post interventions soften the negative impact of a crisis, they also encourage greater risk taking ex ante. The dashed line in the top right panel of Figure 8 shows, for each value of ψ_π, the share of risky assets in banks' portfolios after a very long period without any shocks when the economy has converged to the stochastic steady state (SSS). This measure sheds light on what happens to bank ex ante risk taking in normal times and we see that it is barely affected by systematic monetary policy. A moderate response to inflation in crises helps to reduce ex post bank leverage and risk taking (shown in the solid line) without creating moral hazard.

The above result obtains because a moderate monetary policy response to inflation creates two offsetting effects on the incentive to invest in risky assets ex ante. On the one hand, by boosting bank capital during crisis periods, it weakens the 'last bank standing effect' of Perotti and Suarez (2002). More bank capital following a crisis reduces lending spreads and makes it less profitable to be a surviving bank in such a state of the world. This increases ex ante risk taking, other things equal. On the other hand, inflation reduces the real value of bank liabilities and works in a way similar to the 'systemic bailout' in Bianchi (2016): it does not directly subsidize loss-making investments but boosts aggregate bank capital and supports lending. In addition, inflation increases the ex post return on equity for surviving banks which had invested in safe assets, further tipping the balance in favor of safe assets. The dashed line in the top right panel of Figure 8 shows that these two effects broadly offset each other without a large impact on bank risk taking in either direction.

4.5. Interaction between macroprudential and monetary policy

In the preceding section, we examined the impact of monetary policy on bank risk-taking without varying minimum bank capital requirements. That analysis focused on the risk-taking mechanism and its response to monetary policy. However, setting limits to bank leverage is the most direct tool available to central banks and prudential authorities to mitigate banks' tendency to take excessive risk due to limited liability. In this section, we explore the optimal joint selection of minimum bank capital requirements and systematic monetary policy responses to inflation that maximize aggregate household welfare.

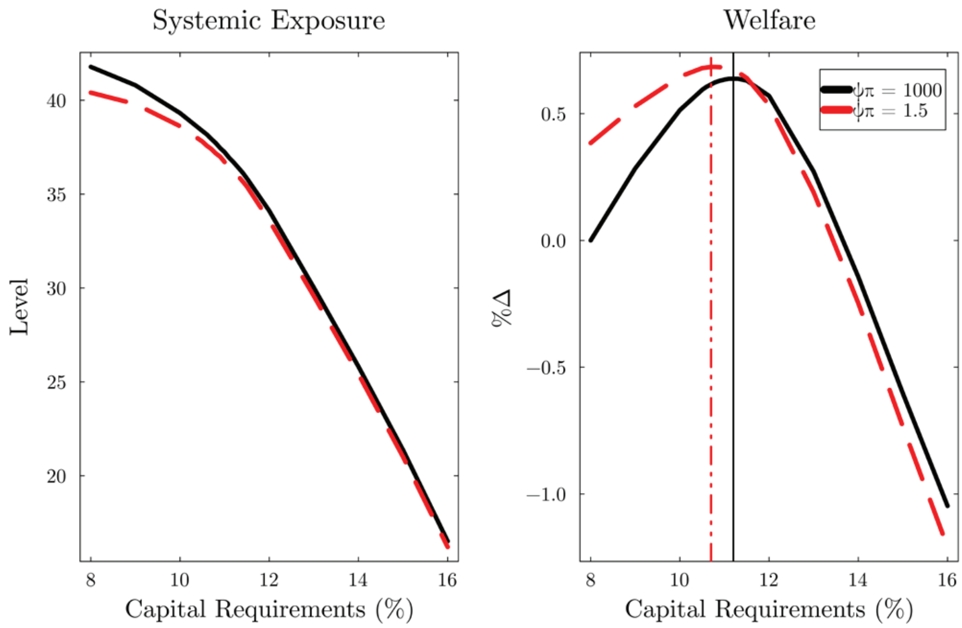

FIGURE 9. Optimal macroprudential-monetary interaction

Note: Welfare is computed through simulation and represented as % deviations from the case with $\gamma = 8\%$ and $\psi_\pi = 1000$

The right panel of Figure 9 plots household welfare as a function of the regulatory minimum capital requirement (γ) imposed on banks in the economy. There are two lines in the figure corresponding to different monetary policy responses to inflation deviation from target: the solid line is computed for $\psi_\pi = 1000$ while the dashed line is computed for $\psi_\pi = 1.5$. The figure illustrates the value of macroprudential policy as well as its interactions with monetary policy.

First, we see that, regardless of the conduct of monetary policy, welfare is hump-shaped in the minimum capital requirement when we start from the baseline value of 8% (the right panel). Higher capital requirements mitigate the limited liability distortion and reduce the incentive to invest in systemic assets. The left panel of the figure shows that risk taking halves when we increase the minimum capital requirement to 14% from the baseline. This avoids deadweight costs from negative NPV investments and makes crises less severe, increasing household welfare. However, the fact that only bankers can invest in bank equity makes equity more expensive than bank debt. Forcing banks to fund more with this expensive source of finance eventually starts to discourage investment and reduce welfare.

Second, we see that the dashed line (a moderate response to inflation in the Taylor rule) lies above the solid line (strict inflation targeting) for low capital requirements but the ranking reverses for high capital requirements. This is due to the beneficial effects of responding moderately to inflation that we discussed in the previous sections of the paper. A small amount of inflation in a crisis helps to recapitalize banks and limits the rise in bank leverage and risk-taking that takes place in the aftermath of the collapse of the risky technology. We can see from the left panel of the figure that the dashed line lies below the solid line: in other words, average holdings of risky assets are lower when monetary policy responds to inflation more moderately. However, we can also see that, for higher capital requirements (above 12%), the effect of monetary policy on bank risk-taking becomes quantitatively small. This is the point when the costs of inflation start to dominate and price stability becomes optimal.

Third, we see that the conduct of monetary policy affects the optimal capital requirement. Under strict inflation, it is optimal to have an 11.25% minimum capital requirement. Under $\psi_\pi = 1.5$, the optimal capital falls to 10.75%. This is still 275 bp above the benchmark value, but the more moderate reaction to inflation implies less of a need for very large equity buffers ex ante.

These results show an important and quantitatively significant interaction between monetary and macroprudential policy in the presence of systemic risk. Bank capital requirements are the most direct and effective means of discouraging excessive risk taking by banks. In contrast, monetary policy has a more marginal effect on banks. Therefore, if bank capital were costless, it would be optimal to lift capital requirements to levels that drive systemic asset investments to zero and then use monetary policy to keep prices stable. However, when bank capital is more expensive than debt, driving bank risk taking to zero becomes excessively costly. In such a world, monetary policy faces a trade-off and price stability is no longer optimal as long as inflation can help with bank solvency ex post. The global optimum in the model is to have moderate bank capital requirements and a moderate response to inflation. If the monetary authority focuses exclusively on price stability, higher bank capital levels would be necessary.

5. Concluding Remarks

In this paper, we examine the relationship between monetary policy, bank risk-taking, and financial stability using a quantitative macroeconomic model with endogenous bank risk-taking and systemic crises. Our model incorporates key features such as banks' limited liability, endogenous leverage determination based on charter value, and nominal deposits, allowing us to explore the interplay between real interest rates, monetary policy, and financial stability.

Our analysis yields several important findings. First, we demonstrate that permanent declines in the natural real interest rate significantly increase bank risk-taking by boosting bank equity values and leverage. This effect is driven by the impact of lower risk-free rates on the market value of bank capital and the resulting increase in leverage. In contrast, transitory changes in the real rate have qualitatively similar but quantitatively smaller effects. Interestingly, we find that expansionary monetary policy shocks actually decrease bank risk-taking, primarily due to the inflationary revaluation of bank liabilities.

Second, we show that the systematic component of monetary policy plays a crucial role in affecting bank risk-taking behavior. A moderate response to inflation deviations from the target in the Taylor Rule leads to lower levels of bank risk-taking, particularly during crises. This occurs because a less aggressive approach to maintaining price stability helps stabilize bank equity during economic downturns, mitigating increases in risk-taking and avoiding more extreme negative outcomes.

Finally, our examination of the joint optimal setting of bank capital requirements and monetary policy reaction to inflation reveals that a combination of moderately increased regulatory capital requirements and a moderate reaction to inflation maximizes welfare. Our paper underscores the importance of coordinating monetary and macroprudential policies to maintain financial and price stability, especially in an environment of low interest rates.

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