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Bank Leverage Regulation and Macroeconomic Dynamics

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Abstract:

This paper assesses the merits of countercyclical bank balance sheet regulation for the stabilization of financial and economic cycles and examines its interaction with monetary policy. The framework used is a dynamic stochastic general equilibrium model with banks and bank capital, in which bank capital solves an asymmetric information problem between banks and their creditors. In this economy, the lending decisions of individual banks affect the riskiness of the whole banking sector, though banks do not internalize this impact. Regulation, in the form of a constraint on bank leverage, can mitigate the impact of this externality by inducing banks to alter the intensity of their monitoring efforts. We find that countercyclical bank leverage regulation can have desirable stabilization properties, particularly when financial shocks are an important source of economic fluctuations. However, the appropriate contribution of countercyclical capital requirements to stabilization after a technology shock depends on the size of the externality and on the conduct of the monetary authority.

Keywords: Moral hazard, bank capital, countercyclical capital requirements, leverage, monetary policy

JEL Classification: E44, E52, G21

1 Introduction

The regulatory response to the crisis of 2007-08 has been sweeping and important changes in global bank regulation will become effective over the next few years. Most notably, a set of new macroprudential policies will both strengthen regulatory constraints on bank leverage and balance sheets and also make such regulation more responsive to cyclical developments. The most prominent example of the latter is the countercyclical bank capital buffer introduced as part of the Basel III banking reforms. These upcoming regulatory changes have motivated a set of important questions for policy makers worldwide: To what extent should bank leverage regulation be countercyclical– tightened during upswings in financing activity and eased during periods of banking system stress? How will the new bank leverage regulation interact with the conduct of monetary policy?

This paper develops a macroeconomic framework with banking and bank capital that can provide a quantitative assessment of these questions. To do so, we extend the model of Meh and Moran (2010), which itself builds on the double moral hazard problem of Holmstrom and Tirole (1997), on several dimensions. First, we allow banks to choose the intensity with which they undertake costly monitoring of their borrowers. As a consequence, the extent of risk-taking by a bank becomes endogenous and can depend on the economic cycle. Second, we introduce regulatory bank capital requirements. When faced with higher capital requirements, banks will tend to increase their monitoring intensity which may reduce risk-taking. Third, we allow lending decisions by banks to affect the riskiness of the banking sector. We can then examine the extent to which macroprudential policy in the form of countercyclical capital requirements can mitigate the effects of this externality. Regarding the non-financial side of the model, it is the same as in Meh and Moran (2010) and is a New Keynesian environment in the spirit of Christiano et al. (2005) and Smets and Wouters (2007). Taken together, all these features allow the study of the interaction between optimal monetary policy and countercyclical bank capital requirements.

Our simulations reveal that the effects of bank leverage regulation differ markedly depending on whether it is constant or time-varying. In response to a technology shock and a shock to bank capital, countercyclical capital regulation dampens real macroeconomic variables, bank lending, and a measure of banking sector default probability relative to the time-invariant regulation. In the case of a negative shock to bank capital, allowing higher bank leverage reduces the impact of the shock on inflation because it partly offsets the drop in demand for final goods. In the case of a technology shock, countercyclical leverage regulation dampens aggregate demand at a time when the productive capacity of the economy has increased. This puts downward pressure on inflation, requiring the monetary authorities to lower interest rates further.

A key finding is that strongly countercyclical regulatory policy improves welfare relative to time-invariant regulation when the economy faces shocks originating in the banking sector. However, the optimal degree of countercyclicality in banking regulation will vary for other, more standard, shocks to the macroeconomy. We show that, when the economy faces productivity shocks, the welfare gain from applying counter-cyclical capital regulation depends importantly on the aggressiveness of the monetary authority in responding to inflation and the size of the banking sector risk externality created by rising bank lending. This suggests that the appropriate contribution of regulatory policy to the stabilization of more standard macro shocks will depend on the authorities' assessment of the likely impact of these shocks on the emergence of financial vulnerabilities.

This paper is related to several recent papers in the literature on banking and macroeconomics. Our model of banking and bank capital is closely related to Gertler and Karadi (2011), in the sense that bank capital is motivated by financial frictions between bankers and their creditors. In their model however, the financial friction is in the form of limited commitment, while in ours it originates from asymmetric information. Moreover, our analysis focuses on bank capital requirements whereas Gertler and Karadi (2011) study unconventional monetary policy actions. Further, our modeling of endogenous banking sector risk resembles similar mechanisms in Woodford (2011a,b) and Gertler et al. (2011), in which a link exists between lending decisions and the banking sector's riskiness that are not internalized by individual banks. However, these authors address different questions: Gertler et al. (2011)'s model is real and thus cannot consider the interactions that arise between macroprudential and monetary policies; Woodford (2011a) emphasizes inflation targeting policy and Woodford (2011b) studies an alternative form of macroprudential policy to the one considered here, where time-varying reserve requirements help stabilize funding risks faced by financial intermediaries. Recent papers by Angeloni and Faia (2010) and Angelini et al. (2011) share our emphasis on the interaction between monetary and macroprudential policies, but these papers do not incorporate an externality in banking sector risk, which can motivate the presence of counter-cyclical capital requirements.[1] Other related work on bank capital regulation includes Van den Heuvel (2008) and Covas and Fujita (2010) who assess the impact of capital regulation in models of liquidity provision by banks but abstract from monetary policy's stabilization properties.

The remainder of this paper is organized as follows. Section 2 describes the model and Section 3 discusses the model's calibration. Section 4 presents our findings on the quantitative implications of bank leverage regulation for the economy's dynamic adjustment to various shocks. Section 5 studies the welfare properties of regulation, with particular emphasis on the interaction that exists between regulation and monetary policy. Section 6 provides some concluding comments.

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[1] Dib (2010) also presents an analysis of bank capital regulation and monetary policy, but does not assess counter-cyclical capital requirements.

2 The Model

This section describes the structure of the model and the optimization problem of the economy's agents. The description is organized in blocks that reflect the three key ingredients of our analysis: a financial environment that reserves a significant role for bank capital and bank capital regulation in the transmission of shocks, an endogenous link between the banking sector's leverage and its risk of distress, which provides motivation for macroprudential policies like counter-cyclical bank capital requirements, and finally the New Keynesian models in Christiano et al. (2005) and Smets and Wouters (2007), which allow a quantitative assessment of alternative macroprudential rules and their interaction with the stabilization properties of monetary policy rules.

2.1 The financial environment

Following Holmstrom and Tirole (1997) and Meh and Moran (2010), the financial environment is centered around the relationship between three classes of agents: households, entrepreneurs, and bankers, with population masses η^h, η^e and $\eta^b = 1 - \eta^h - \eta^e$, respectively. Entrepreneurs have the technology to produce capital goods but require external funds. Households provide these funds via the intermediation of banks, who alone can monitor entrepreneurs.

Two sources of moral hazard are present. The first one arises because entrepreneurs can influence their technology's probability of success and may choose projects with a low probability of success, to enjoy private benefits. Banks can monitor and mitigate this moral hazard problem, with more intense monitoring lessening moral hazard problem. Since the bank's monitoring technology is imperfect, some moral hazard always remains and as a complement to monitoring, banks require that entrepreneurs invest their own net worth in the projects they undertake. The second moral hazard problem arises because bank monitoring is private and costly. As a result, banks might be tempted to monitor entrepreneurs less than agreed to economize on costs, knowing that any resulting risk in their loan portfolio would be mostly borne by the households providing the bulk of their loanable funds. To mitigate the impact of this second source of moral hazard, banks are compelled to invest their own net worth (their capital) in entrepreneurs' projects.

We depart from Holmstrom and Tirole (1997) and Meh and Moran (2010) by introducing an authority that regulates bank leverage, the ratio of the size of banks' balance sheets to their capital, and modifying the structure of the financial contract between the three agents to take this regulation into account. We consider two regulatory scenarios: *Time-invariant* regulation, with a constant regulatory leverage ratio, and *counter-cyclical* requirements, which direct banks to decrease their leverage in times when credit is accelerating and allows them to increase it when credit weakens.

Overall, the double moral hazard framework present in our paper implies that through the business cycle, the dynamics of bank capital affects how much banks can lend and the dynamics of entrepreneurial net worth affects how much entrepreneurs can borrow. In addition, and in contrast with the earlier contributions of Holmstrom and Tirole (1997) and Meh and Moran (2010), the banks' monitoring intensity and the actions of the regulatory authority impact the strength of these two channels. The next subsections describe in detail the conditions under which production of the capital good is organized, how the financial contract that links the three type of agents is set, and the impact of the regulatory authority on that contract.

2.1.1 Capital good production

Entrepreneur have access to a technology that produces capital goods. The technology is subject to idiosyncratic shocks: an investment of i_t units of final goods returns Ri_t $(R > 1)$ units of capital if the project succeeds, and zero units if it fails. The project scale i_t is variable and determined by the financial contract linking the entrepreneur and the bank. Returns from entrepreneurial projects are publicly observable.

The first moral hazard problem is formalized by assuming that entrepreneurs can choose from two classes of projects. First, the *no private benefit* project involves a high probability of success (denoted α) and zero private benefits. Second, there exists a continuum of projects with private benefits. Projects from this class all have a common, lower probability of success $\alpha - \Delta\alpha$, but differ in the amount of private benefits they deliver to the entrepreneurs. The private benefit probabilities are denoted by $b\, i_t$, where i_t is the size of an entrepreneur's project and $b \in [\underline{B}, \overline{B}]$. Among those, an entrepreneur will thus prefer the project with the highest private benefit b possible, since they all produce the same low probability of success.[2]

Bank monitoring can reduce the private benefits associated with projects, ie. limit the ability of entrepreneurs to divert resources.[3] A bank monitoring at intensity μ_t limits the ability of an entrepreneur to divert resources to $b(\mu_t)$, where $b(0) = \overline{B}$, $b(\infty) = \underline{B}$,

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[2] Throughout the analysis, it is assumed that only the project with no private benefit is economically productive, in that

$$q_t \alpha R i_t - R^d_t i_t > 0 > q_t(\alpha - \Delta\alpha) R i_t - R^d_t i_t + \overline{B} i_t,$$

where q_t is the price of the capital goods produced by the entrepreneur's technology and R^d_t is the opportunity costs of the funds engaged in projects. A sufficient condition for this to hold is that $\overline{B} \leq \Delta\alpha R$; intuitively, even the biggest private benefit generated by the second class of projects has a smaller value than the social cost it imposes in the form of a lower probability of success.

[3] In this framework, bank monitoring is interpreted as the inspection of cash flows and balance sheets, or the verification that firms conform with loan covenants, as in Holmstrom and Tirole (1997). This is in contrast with the costly state verification (CSV) literature, where bank monitoring is associated with bankruptcy-related activities.

$b'(\cdot) < 0$ and $b''(\cdot) > 0$. Figure 1 illustrates the relationship between bank monitoring and entrepreneurial private benefits: a higher monitoring intensity, akin to a tighter bank-entrepreneur relationship, produces more information about the entrepreneur and thus reduces his ability to divert resources. By contrast, a lower monitoring intensity – a more "arms-lengths" relationship– generates less information and thus more severe moral hazard on the entrepreneur side. Note, however, that bank monitoring remains imperfect: even when monitored by his bank at intensity μ_t, an entrepreneur may still choose to run a project with private benefit $b(\mu_t)$. A key component of the financial contract discussed below ensures that the entrepreneur has the incentive to choose the no-private benefit project instead.

Monitoring an entrepreneur operating at investment scale of i_t with intensity μ_t entails a total resource cost equal to $\mu_t i_t$. Since monitoring is not publicly observable, a second moral hazard problem emerges in our environment, between banks and the investors providing banks with loanable funds. A bank that invests its own capital in entrepreneurial projects mitigates the severity of this problem, because this bank now has a private incentive to monitor as agreed the borrowing entrepreneurs. This reassures investors and allows the bank to attract more loanable funds.

Finally, we assume that the returns in the projects funded by each bank are perfectly correlated. Correlated projects can arise because banks specialize (across sectors, regions or debt instruments) to become efficient monitors. The assumption of perfect correlation improves the model's tractability, but could be relaxed at the cost of additional computational requirements.

2.1.2 The Financial contract

An entrepreneur with net worth n_t undertaking a project of size $i_t > n_t$ needs external financing (a bank loan) worth $i_t - n_t$. The bank provides this funding with a mix of deposits it collects from investors (d_t) as well as its own net worth (capital) a_t. Considering the costs of monitoring the project ($\mu_t i_t$), the bank thus lends an amount $a_t + d_t - \mu_t i_t$.

We concentrate on equilibria where the financial contract leads all entrepreneurs to undertake the project with no private benefits; as a result, α represents the probability of success of all projects. We also assume the presence of inter-period anonymity, which restricts the analysis to one-period contracts.

The financial contract is set in real terms and has the following structure. It determines an investment size (i_t), contributions to the financing from the bank (a_t) and the bank's investors (d_t), and how the project's return is shared among the entrepreneur ($R^e_t > 0$), the bank ($R^b_t > 0$) and the investors ($R^h_t > 0$). The contract also specifies the intensity μ_t at which banks agree to monitor, to which corresponds an ability to divert resources $b(\mu_t)$ on the entrepreneur side. Limited liability ensures that no agent earns a negative return.

The contract's objective is to maximize the entrepreneur's expected share of the return $q_t \alpha R_t^e i_t$ subject to a number of constraints. These constraints ensure that entrepreneurs and bankers have the incentive to behave as agreed, that the funds contributed by the banker and the household earn (market-determined) required rates of return, and that the loan size respects the maximum leverage imposed by the regulatory authority.

Formally, the contract is represented by the following optimization problem:

$$\max_{\{i_t, R_t^e, R_t^b, R_t^h, a_t, d_t, \mu_t\}} q_t \alpha R_t^e i_t, \tag{1}$$

subject to

$$\begin{aligned} R &= R_t^e + R_t^h + R_t^b; && (2)\\ q_t \alpha R_t^b i_t - \mu_t i_t &\geq q_t(\alpha - \Delta\alpha) R_t^b i_t; && (3)\\ q_t \alpha R_t^e i_t &\geq q_t(\alpha - \Delta\alpha) R_t^e i_t + q_t b(\mu_t) i_t; && (4)\\ q_t \alpha R_t^b i_t &\geq (1 + r_t^a) a_t; && (5)\\ q_t \alpha R_t^h i_t &\geq (1 + r_t^d) d_t; && (6)\\ a_t + d_t - \mu_t i_t &\geq i_t - n_t. && (7)\\ i_t - n_t &\leq \gamma_t^g a_t. && (8) \end{aligned}$$

Equation (2) states that the shares promised to the three different agents must add up to the total return. Equation (3) is the incentive compatibility constraint for bankers, which must be satisfied in order for monitoring to occur at intensity μ_t, as agreed. It states that the expected return to the banker, net of the monitoring costs, must be at least as high as the expected return with no monitoring, a situation in which entrepreneurs would choose a project with the lower probability of success. Equation (4) is the incentive compatibility constraint of entrepreneurs: given that bankers monitor at intensity μ_t, entrepreneurs can at most choose the project that gives them private benefits $b(\mu_t)$. The constraint then ensures that they have an incentive to choose instead the project with no-private benefits and high probability of success. Equations (5) and (6) are the participation constraints of bankers and households, respectively. They state that these agents, when engaging their bank capital a_t and deposits d_t, are promised a return that covers the (market-determined) required rates (r_t^a and r_t^d, respectively). Equation (7) indicates that the loanable funds available to a banker (its own capital and the deposits it attracted), net of the monitoring costs, are sufficient to cover the loan given to the entrepreneur. Finally, (8) specifies that the loan arranged by the bank cannot be bigger than a regulated leverage $\gamma_t^g > 1$ over the capital the bank engages into the loan.

Imposing that the incentive-compatibility constraints (3) and (4), as well as the budget constraint (2) hold with equality, we have

$$R_t^e = \frac{b(\mu_t)}{\Delta\alpha}; \tag{9}$$

$$R_t^b = \frac{\mu_t}{q_t\Delta\alpha}; \tag{10}$$

$$R_t^h = R - \frac{b(\mu_t)}{\Delta\alpha} - \frac{\mu_t}{q_t\Delta\alpha}. \tag{11}$$

Note from (9) and (10) that the shares allocated to the banker and the entrepreneur are affected by the severity of the two moral hazard problems, themselves linked to bank monitoring intensity. An increase in μ_t, say, reduces the per-unit project share R_t^e that must be promised to entrepreneurs, because it reduces their ability to divert resources ($b(\mu_t)$ decreases). However, this increase R_t^b, the per-unit share of project return that must be allocated to bankers in order for them to find it profitable to monitor as intensively as promised. Overall, (11) shows that the per-unit share of project return that can be credibly promised to investors supplying loanable funds is linked to these two moral hazard problems and dependent on the efficiency of the monitoring technology of banks, as measured by the schedule $b(\mu_t)$.

Introducing (11) in the participation constraint of households (6) holding with equality leads to the following:

$$d_t = \frac{q_t\alpha}{1+r_t^d}\left(R - \frac{b(\mu_t)}{\Delta\alpha} - \frac{\mu_t}{q_t\Delta\alpha}\right)i_t. \tag{12}$$

This expression states that the importance of investors' deposits d_t in financing a given-size project is governed by two macroeconomic factors, the price of investment goods q_t and the cost of loanable funds r_t^d. Favorable conditions, when the price of capital goods q_t are high or financing costs for banks r_t^d are low, thus make it possible for banks to attract more loanable funds and lend more. In addition, the overall extent of moral hazard in the financial market, represented by $b(\mu_t)$ and μ_t, also affect the ability of banks to attract loanable funds and lend.

Next, (5) and (10) together can be used to deliver

$$a_t = \frac{\alpha\mu_t}{(1+r_t^a)\Delta\alpha}i_t, \tag{13}$$

which states that banks promising to monitor more intensively (high μ_t) will be required to invest more of their own capital in a given-size project, in order to limit moral hazard. Said otherwise, in this model a greater capital participation of banks in a given-sized project (more "skin in the game") is associated with more intense monitoring, a key link to understand the impact of regulatory capital requirements on the transmission of shocks. Expression (13) also shows that an increase in the required rate of return on bank equity

r_t^a (reflecting a worsening of the aggregate availability of bank capital for example) reduces the capital participation of banks in given-size projects.

Next, assume that the regulation constraint (8) binds. Using (7), it becomes

$$a_t + d_t - \mu_t i_t = \gamma_t^g a_t. \tag{14}$$

Using (12) and (13) to eliminate a_t and d_t from this expression yields a relation between the regulated leverage γ_t^g and the monitoring intensity μ_t needed to achieve it while respecting all incentive and participation constraints:

$$\gamma_t^g = 1 + \left(\frac{q_t(1+r_t^a)}{1+r_t^d}\right)\left(\frac{\Delta\alpha R - b(\mu_t) - \mu_t/q_t}{\mu_t}\right) - \frac{(1+r_t^a)\Delta\alpha}{\alpha}. \tag{15}$$

Expression (15) provides intuition about the way banks adjust their monitoring intensity μ_t to comply with the regulatory requirements. The left-hand side of the expression is the leverage imposed by the regulator, while the right-hand side shows how the monitoring decisions of banks help achieve it. Consider first a bank monitoring at very low intensity, with $\mu_t \to 0$. Moral hazard on the entrepreneurial side worsens but eventually reaches its maximum extent $\overline{B}$. Meanwhile, the very low monitoring intensity μ_t decreases the moral hazard problem on the bank side considerably, reducing dramatically the bank capital that must be engaged into lending. As a result, the ratio of outside funds to bank capital, d_t/a_t rises. In effect banks are lending very little, but investing even less of their own capital in the projects, so that leverage is very high. As the intensity of bank monitoring increases, moral hazard on the entrepreneurial side, captured by $b(\mu_t)$, decreases so that attracting loanable funds becomes easier and the ability of banks to lend increases. However, moral hazard on the bank side increases and outside investors now require that banks contribute an increasing portion of each financed project with their own capital. As a consequence, bank leverage decreases. The assumed properties on the schedule $b(\mu_t)$ ensure that a single value of μ_t exists that achieves the regulated leverage. Figure 2 illustrates the situation by graphing regulated and achieved leverage as a function of μ_t, as well as the resulting choice for monitoring intensity.

2.1.3 The Regulatory Authority

As seen above, leverage regulation constrains the choices of banks by compelling them to follow specific targets for the leverage of assets over capital they achieve. We operationalize these requirements by assuming that regulated leverage γ_t^g evolves according to

$$\gamma_t^g = \gamma^g + \omega x_t, \tag{16}$$

where γ^g is the steady-state leverage ratio allowed and x_t represents an economic variable that regulation might respond to (with ω measuring the strength of this response).

The regulation rule (16) is specified at a general level to accommodate a series of different scenarios about regulation. In this paper we analyze two such scenarios. First we study *Time-invariant* regulation in which required leverage is constant regardless of any economic outcome; this corresponds to setting $\omega = 0$ for all economic variables. Second, we also study *counter-cyclical* regulation that compels banks to lower their leverage in an upswing and allows them to raise it in a downturn. We implement this rule by specifying x_t to be the ratio of bank credit to GDP, and setting $\omega < 0$. This is consistent with the evidence linking the pace of financial intermediation relative to economic activity to banking sector risk (Borio and Lowe, 2002; Borio and Drehmann, 2009). It is also coherent with the fact that under Basel III, all countries will be required to publish a credit-to-GDP ratio as guidance for the operation of the countercyclical capital buffer. In practical terms, such a counter-cyclical policy requires banks to accumulate extra capital buffers when the economy is booming and allows them to draw down their capital levels as the economy deteriorates.[4]

2.2 Endogenous riskiness of the banking sector

Because of the linear specification in the production function for capital goods, the private benefits accruing to entrepreneurs, and the monitoring costs facing banks, the distributions of bank capital across banks and of entrepreneurial net worth across entrepreneurs have no effects on the investment and monitoring intensity decisions of banks in equilibrium. This is an interesting feature of our model because tracking aggregate bank capital provides a well-defined notion of the economy-wide lending capacity of the banking sector. This is in line with the macroprudential approach of banking sector regulation that policymakers are undertaking recently under Basel III. Another interesting feature of our model is that, in equilibrium, the probability of default of the banking sector is given by $1 - \alpha$ and this measures the riskiness of the banking sector. In principal, the risk of banking sector distress may be endogenous, depending on economic conditions and the behavior of banks themselves.

A large and growing body of empirical work suggests that the banking system plays a critical role in this endogeneous build-up of risk. For example, Kaminsky and Reinhart (1999) and Borio and Lowe (2002) find that the strong pace of bank credit growth relative to economic activity provides an important signal of impending banking crises. In addition, periods of strongly rising credit and leverage are frequently associated with subsequent recessions (Crowe et al., 2011). Furthermore, recessions tend to be more severe when bank credit tightens sharply (Claessens et al., 2011). This evidence suggests that the risks to the banking sector are rising in the upswing, a time when traditional measures of individual

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[4] The analysis of macroprudential policies in Angelini et al. (2011) also features a prominent role for the ratio of bank credit to GDP as indicator of banking sector risk.

bank risk are low (Crockett, 2000).[5]

Modelling endogenous banking sector riskiness, especially in a macroeconomic environment, is a complex task and is the subject of ongoing research. In our quantitative exercise, we simply assume that the probability of banking sector stress depends on endogenous aggregate variables. A similar approach has also been employed in Woodford (2011a) and Gertler et al. (2011). Since each bank is atomistic it does not take into account its own impact on the riskiness of the banking sector when choosing its individual leverage.[6] We examine how accounting for a such a relationship between the probability of default of the banking sector and aggregate endogenous variables would affect optimal stabilization policies and the interaction between macroprudential and monetary policies. If one believes that a relationship of this type is important, as the data suggests, analysis based on this simple approach may be more useful than one that ignores the endogenous build-up of banking sector risk.

Specifically, to capture endogenous banking sector distress in the model presented here, we assume that the probability of default of the banking sector increases as the banking sector credit-to-GDP ratio rises above its trend—that is, the larger is this ratio, the higher is the risk of banking sector distress (systemic risk). The endogenous probability of the banking sector distress is given by the following functional form:

$$1-\alpha_t \quad = \quad (1-\alpha_{ss}) + \left(\frac{I_t - N_t}{Y_t} - \frac{I_{ss} - N_{ss}}{Y_{ss}}\right)^{\varsigma} \tag{17}$$

where I_t is the aggregate investment at time t, N_t is the time-t aggregate entrepreneurial net worth, $I_t - N_t$ is the time-t aggregate bank credit, Y_t is the time-t aggregate output. I_{ss}, N_{ss}, and Y_{ss} are the corresponding steady state variables. The parameter ς captures the strength of this endogenous link between aggregate leverage and the default probability of the banking sector, or said otherwise, the strength of the externality imposed by individual bank actions on the riskiness of the whole banking system. A potential interpretation of ς is the degree of interconnectedness in the banking sector where higher a degree of interconnectedness corresponds to a higher value of ς. The interconnectedness in the financial system is seen by many observers as an important contributor to the severity of

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[5] Theories of systemic externalities in financial systems provide a number of possible mechanisms that generate bank behaviour in an upswing that raises the risk of greater banking system distress in the downturn (see Brunnermeier et al. (2009)). These include information contagion, where investors extrapolate bad news reported by one bank to other similar banks, or the possibility that banks facing stress will engage in asset fire sales that lower the value of assets held by other banks. Another example is that deleveraging by banks through more restrictive lending will lower output and the prices of goods and assets. This can increase the probability of default for all private firms worsening the state of bank balance sheets and leading to further credit restrictions.

[6] Therefore, α is taken as a parameter when each bank solves its individual problem.

the recent financial crisis. As we will see, this parameter will play an important role in the quantitative analysis described below.

2.3 Non-Financial Side of the Model

Our financial environment with bank capital, bank capital requirements and endogenous banking distress is now embedded in a version of the New Keynesian paradigm in the spirit of Christiano et al. (2005) and Smets and Wouters (2007). Accordingly, we assume that final goods are assembled by competitive firms using intermediate goods as inputs, intermediate goods are produced by monopolistically competitive firms facing nominal rigidities, households face nominal wage ridigities when maximizing their intertemporal utility and, finally, monetary authorities conduct monetary policy using an interest rate-targeting rule. The next subsections review these model characteristics.

2.3.1 Final good production

Competitive firms produce the final good by combining a continuum of intermediate goods indexed by $j \in (0, 1)$ using the standard Dixit-Stiglitz aggregator:

$$Y_t = \left(\int_0^1 y_{jt}^{\frac{\xi_p - 1}{\xi_p}} dj \right)^{\frac{\xi_p}{\xi_p - 1}}, \qquad \xi_p > 1, \tag{18}$$

with y_{jt} the time-t input of intermediate good j and ξ_p the constant elasticity of substitution between intermediate goods.

The following first-order condition for the choice of y_{jt} obtains:

$$y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\xi_p} Y_t, \tag{19}$$

and expresses the demand for good j as a function of its relative price P_{jt}/P_t and of overall production Y_t. The usual zero-profit condition leads to the final-good price index P_t being defined as

$$P_t = \left(\int_0^1 P_{jt}{}^{1-\xi_p} dj \right)^{\frac{1}{1-\xi_p}}. \tag{20}$$

2.3.2 Intermediate good production

Intermediate goods are produced under monopolistic competition and nominal rigidities in price setting. The firm producing good j operates the technology

$$y_{jt} = \begin{cases} z_t k_{jt}^{\theta_k} h_{jt}^{\theta_h} - \Theta & \text{if } z_t k_{jt}^{\theta_k} h_{jt}^{\theta_h} \geq \Theta \\ 0 & \text{otherwise} \end{cases} \tag{21}$$

where k_{jt} and h_{jt} are the amount of capital and labor services, respectively, used by firm j at time t.[7] The parameter $\Theta > 0$ represents the fixed cost of production and z_t is an aggregate technology shock that follows the autoregressive process

$$\log z_t = \rho_z \log z_{t-1} + \varepsilon_{zt}, \tag{22}$$

where $\rho_z \in (0,1)$ and ε_{zt} is *i.i.d.* with mean 0 and standard deviation σ_z.

Minimizing production costs for a given demand leads to the following first-order conditions for k_{jt} and h_{jt}:

$$r_t = s_t z_t \theta_k k_{jt}^{\theta_k - 1} h_{jt}^{\theta_h} {h_{jt}^{e}}^{\theta_e} {h_{jt}^{b}}^{\theta_b}; \tag{23}$$

$$w_t = s_t z_t \theta_h k_{jt}^{\theta_k} h_{jt}^{\theta_h - 1} {h_{jt}^{e}}^{\theta_e} {h_{jt}^{b}}^{\theta_b}; \tag{24}$$

In these conditions, r_t represents the (real) rental rate of capital services, while w_t represents the real household wage. Further, s_t is the Lagrange multiplier on the production function (21) and represents marginal costs. Combining these conditions, one can show that total production costs, net of fixed costs, are $s_t y_{jt}$.

The price-setting environment is as follows. Each period, a firm receives the signal to reoptimize its price with probability $1 - \phi_p$; with probability ϕ_p, the firm simply indexes its price to steady-state inflation. After k periods with no reoptimizing, a firm's price would therefore be

$$P_{jt+k} = \pi^{k-1}\, P_{jt}, \tag{25}$$

where $\pi_t \equiv P_t / P_{t-1}$ defines the aggregate (gross) rate of price inflation and π is its steady-state value.

A reoptimizing firm chooses $\widetilde{P_{jt}}$ in order to maximize expected profits until the next reoptimizing signal is received. The profit maximizing problem is thus

$$\max_{\widetilde{P}_{jt}} E_t \sum_{k=0}^{\infty} (\beta\phi_p)^k \lambda_{t+k} \left[\frac{P_{jt+k}\, y_{jt+k}}{P_{t+k}} - s_{t+k}\, y_{jt+k} \right], \tag{26}$$

subject to (19) and (25).

The first-order condition for $\widetilde{P}_{jt}$ leads to

$$\widetilde{P}_t = P_{t-1}\, \frac{\xi_p}{\xi_p - 1}\, \frac{E_t \sum_{k=0}^{\infty} (\beta\phi_p \pi^{-\xi_p})^k \lambda_{t+k} s_{t+k} Y_{t+k} \prod_{s=0}^{k} \pi_{t+s}^{\xi_p}}{E_t \sum_{k=0}^{\infty} (\beta\phi_p \pi^{1-\xi_p})^k \lambda_{t+k} Y_{t+k} \prod_{s=0}^{k} \pi_{t+s}^{\xi_p - 1}}. \tag{27}$$

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[7] Following Carlstrom and Fuerst (1997), we also include labor services from entrepreneurs and bankers in the production function so that these agents always have non-zero wealth to pledge in the financial contract described above. The calibrated values of θ_e and θ_b are small enough to make the influence of these labor services on the model's dynamics negligible and thus the description abstracts from their presence. See Meh and Moran (2010) for details.

2.3.3 Households

Households consume, allocate money holdings between currency and bank deposits, supply units of specialized labor, choose a capital utilization rate, and purchase capital goods.[8]

Lifetime expected utility of household i is

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^h - \gamma c_{t-1}^h, l_{it}, M_t^c / P_t),$$

where c_t^h is consumption in period t, γ measures the importance of habit formation in consumption, l_{it} is hours worked, and M_t^c/P_t denotes the real value of currency held.[9]

The household begins period t with money holdings M_t and receives a lump-sum money transfer X_t from the monetary authority. These monetary assets are allocated between funds invested at a bank (deposits) D_t and currency held M_t^c so that $M_t + X_t = D_t + M_t^c$. In making this decision, households weigh the tradeoff between the utility obtained from holding currency and the return from bank deposits, the risk-free rate $1 + r_t^d$.[10]

As in Christiano et al. (2005), households also make a capital utilization decision. At the start of period t, a representative household owns capital stock k_t^h and can provide capital services $u_t k_t^h$ with u_t the utilization rate. Rental income from capital is thus $r_t u_t k_t^h$, while utilization costs are $\upsilon(u_t) k_t^h$, with $\upsilon(.)$ a convex function whose calibration is discussed below. Household i also receives labor earnings $(W_{it}/P_t)\, l_{it}$, as well as dividends Π_t from firms producing intermediate goods.

Income from these sources is used to purchase consumption, new capital goods (priced at q_t), and money balances carried into the next period M_{t+1}, subject to the constraint

$$c_t^h + q_t i_t^h + \frac{M_{t+1}}{P_t} = (1 + r_t^d) \frac{D_t}{P_t} + r_t u_t k_t^h - \upsilon(u_t) k_t^h + \frac{W_{it}}{P_t} l_{it} + \Pi_t + \frac{M_t^c}{P_t}, \qquad (28)$$

with the associated Lagrangian λ_t representing the marginal utility of income. The capital stock evolves according to the standard accumulation equation:

$$k_{t+1}^h = (1 - \delta) k_t^h + i_t^h. \qquad (29)$$

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[8] Households are indexed by i and distributed along the continuum $\in (0, \eta^h)$.

[9] Note that the nominal wage rigidities described below imply that hours worked and labor earnings are different across households. We abstract from this heterogeneity by referring to the results in Erceg et al. (2000) who show, in a similar environment, that the existence of state-contingent securities makes households homogenous with respect to consumption and saving decisions. We assume the existence of these securities and our notation reflects their presence with consumption and asset holdings not contingent on household type i.

[10] To be consistent with the presence of idiosyncratic risk at the bank level, we follow Carlstrom and Fuerst (1997) and Bernanke et al. (1999) and assume that households deposit money at a large mutual fund, which in turn invests in a cross-section of banks and diversifies away bank-level risk.

The first-order conditions associated with the choice of c_t^h, M_t^c, u_t, M_{t+1}, and k_{t+1}^h are:

$$U_1(\cdot_t) - \beta\gamma E_t U_1(\cdot_{t+1}) = \lambda_t; \tag{30}$$

$$U_3(\cdot_t) = r_t^d \lambda_t; \tag{31}$$

$$r_t = \upsilon'(u_t); \tag{32}$$

$$\lambda_t = \beta E_t \left\{ \lambda_{t+1}(1 + r_{t+1}^d)\left(P_t / P_{t+1}\right) \right\}; \tag{33}$$

$$\lambda_t q_t = \beta E_t \left\{ \lambda_{t+1}\left[q_{t+1}(1-\delta) + r_{t+1}u_{t+1} - \upsilon(u_{t+1}) \right] \right\}, \tag{34}$$

where $U_j(\cdot_t)$ represents the derivative of the utility function with respect to its j^{th} argument in period t.

Wage Setting

We follow Erceg et al. (2000) and Christiano et al. (2005) and assume that household $i \in (0, \eta^h)$ supplies a specialized labor type l_{it}, while competitive labor packers assemble all types into one composite labour input using the technology

$$H_t \equiv \left(\int_0^{\eta^h} l_{it}^{\frac{\xi_w - 1}{\xi_w}} i \right)^{\frac{\xi_w}{\xi_w - 1}}, \qquad \xi_w > 1.$$

The demand for each labor type coming from the packers is thus

$$l_{it} = \left(\frac{W_{i,t}}{W_t} \right)^{-\xi_w} H_t, \tag{35}$$

where W_t is the aggregate wage (the price of one unit of composite labor input H_t). Labor packers are competitive and make zero profits, which leads to the following economy-wide aggregate wage:

$$W_t = \left(\int_0^{\eta^h} {W_{it}}^{1-\xi_w} i \right)^{\frac{1}{1-\xi_w}}. \tag{36}$$

Households set wages as follows. Each period, household i receives the signal to reoptimize its nominal wage with probability $1 - \phi_w$, while with probability ϕ_w the household indexes its wage to steady-state inflation, so that $W_{i,t} = \pi \, W_{i,t-1}$. A reoptimizing worker takes into account the evolution of its wage and the demand for its labor (35) during the expected period with no reoptimization. The resulting first-order condition for wage-setting when reoptimizing $(\widetilde{W}_{it})$ yields

$$\widetilde{W}_t = P_{t-1} \frac{\xi_w}{\xi_w - 1} \frac{E_t \sum_{k=0}^{\infty} (\beta\phi_w \pi^{-\xi_w})^k (-U_2(\cdot_{t+k})) H_{t+k} w_{t+k}^{\xi_w} \prod_{s=0}^{k} \pi_{t+s}^{\xi_w}}{E_t \sum_{k=0}^{\infty} (\beta\phi_w \pi^{1-\xi_w})^k \lambda_{t+k} H_{t+k} w_{t+k}^{\xi_w} \prod_{s=0}^{k} \pi_{t+s}^{\xi_w - 1}},$$

where $w_t \equiv W_t/P_t$ is the real aggregate wage and $-U_2(\cdot_t)$ is the derivative of the utility function with respect to hours worked and represents the marginal (utility) cost of providing work effort l_{it}. Once the household's wage is set, actual hours worked l_{it} are determined by (35).

2.3.4 Monetary Policy

Monetary policy sets r_t^d, the short-term nominal interest rate, according to the following rule:

$$r_t^d = (1-\rho_r)r^d + \rho_r r_{t-1}^d + (1-\rho_r)\left[\rho_\pi(\pi_t - \overline{\pi}) + \rho_y \hat{y}_t\right] + \epsilon_t^{mp}, \tag{37}$$

where r^d is the steady-state rate, $\overline{\pi}$ is the monetary authority's inflation target, $\hat{y}_t$ represents output deviations from steady state, and ϵ_t^{mp} is an *i.i.d* monetary policy shock with standard deviation σ^{mp}.

2.3.5 Entrepreneurs and Bankers

There is a continuum of risk neutral entrepreneurs $\in (0, \eta^e)$ and bankers $\in (0, \eta^b)$. Each period, a fraction $1-\tau^e$ of entrepreneurs and $1-\tau^b$ of bankers exit the economy at the end of the period's activities.[11] Exiting agents are replaced by new ones with zero assets.

Entrepreneurs and bankers solve similar optimization problems: in the first part of each period, they accumulate net worth, which they invest in entrepreneurial projects later in that period. Exiting agents consume accumulated wealth while surviving agents save. These agents differ, however, with regards to their technological endowments: as discussed above, entrepreneurs have access to the technology producing capital goods, while bankers have the capacity to monitor entrepreneurs.

A typical entrepreneur starts period t with holdings k_t^e in capital goods, which are rented to intermediate-good producers. The corresponding rental income, combined with the value of the undepreciated capital and the small wage received from intermediate-good producers, constitute the net worth n_t available to an entrepreneur:

$$n_t = (r_t + q_t(1-\delta))\, k_t^e + w_t^e. \tag{38}$$

Each entrepreneur then undertakes a capital-good producing project and invests all available net worth n_t in the project. An entrepreneur whose project is successful receives earnings $R_t^e i_t$ in capital goods and unsuccessful projects have zero return. As described above, the entrepreneur's earnings $R_t^e i_t$ depend on the monitoring intensity of its bank. At

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[11] This follows Bernanke et al. (1999). Because of financing constraints, entrepreneurs and bankers have an incentive to delay consumption and accumulate net worth until they no longer need financial markets. Assuming a constant probability of death reduces this accumulation process and ensures that a steady state with operative financing constraints exists.

the end of the period, entrepreneurs associated with successful projects but having received the signal to exit the economy use their earnings to consume final goods. Successful and surviving entrepreneurs save their entire earnings, which become their real asset holdings at the beginning of the subsequent period. We thus have

$$k_{t+1}^e = \begin{cases} R_t^e i_t, & \text{if surviving and successful} \\ 0 \;, & \text{otherwise.} \end{cases} \tag{39}$$

Saving entire earnings is an optimal choice for surviving entrepreneurs because of risk neutrality and the high internal rate of return. Unsuccessful entrepreneurs neither consume nor save.

A typical banker starts period t with holdings of k_t^b capital goods (retained earnings from previous periods) that are offered as capital services to firms producing intermediate goods. We assume that the value of these retained earnings, the net worth of the bank, may be affected by an exogenous shock to its value, denoted κ_t. The presence of this shock loosens the otherwise tight link between retained bank earnings at time $t-1$ and bank net worth at time t, and is meant to represent episodes during which sudden deteriorations in the balance sheets of banks, caused by loan losses and asset writedowns, suddenly reduce bank equity and net worth.[12] Inclusive of the valuation shock, a bank thus receives the income a_t during the first part of the period

$$a_t = \kappa_t \left(r_t + q_t(1-\delta)\right) k_t^b + w_t^b, \tag{40}$$

which defines how much net worth can be pledged when financing entrepreneurs. The valuation shock κ_t follows the AR(1) process

$$\log \kappa_t = \rho_\kappa \log \kappa_{t-1} + \varepsilon_t^\kappa, \tag{41}$$

where $\rho_\kappa \in (0,1)$ and ε_t^κ is *i.i.d.* with mean 0 and standard deviation σ_κ.

The bank then invests its own net worth a_t in the projects of entrepreneurs it finances, in addition to the funds d_t invested by outside investors depositing at the bank. A bank associated with successful projects but having received the signal to exit the economy consumes final goods, whereas successful and surviving banks retain all their earnings, so that their real assets at the start of the subsequent period are

$$k_{t+1}^b = \begin{cases} R_t^b i_t, & \text{if surviving and successful} \\ 0 \;, & \text{otherwise.} \end{cases} \tag{42}$$

Table 2 below illustrates the sequence of events. The value of aggregate shocks are revealed at the beginning of the period. Intermediate goods are then produced, using

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[12] Similar valuation shocks to the financial position of banking or entrepreneurial sectors are analyzed in Goodfriend and McCallum (2007), Christiano et al. (2010) and Gertler and Karadi (2011), among others.

Table 1: Timing of Events

- The productivity (z_t) and banking (ε_t^κ) shocks are realized.
- Intermediate goods are produced, using capital and labor services; final goods are produced, using intermediates.
- Households deposit savings in banks, who use these funds as well as their own net worth to finance entrepreneur projects i_t.
- Entrepreneurs choose which project to undertake; bankers choose their intensity of monitoring.
- Successful projects return $R\,i_t$ units of new capital, shared between the three agents according to terms of financial contract. Failed projects return nothing.
- Exiting agents sell their capital for consumption goods, surviving agents buy this capital as part of their consumption-savings decision.
- All markets close.

capital and labor, and then final goods are produced, using the intermediates. Next, the production of capital goods occurs: households deposit funds in banks, who meet with entrepreneurs to arrange financing. Once financed, entrepreneurs choose projects to undertake and monitor at an intensity compatible with the double moral hazard problem described above. Successful projects return new units of capital goods that are distributed to households, banks and entrepreneurs according to the terms of the financial contract. Exiting banks and entrepreneurs sell their share of capital good in exchange for consumption and households and surviving banks and entrepreneurs make their consumption-savings decisions.

2.4 Aggregation

As we discussed earlier, the distribution of net worth across entrepreneurs and bank capital across banks has no effects on bank's decisions about their monitoring intensity μ_t and investment. We thus focus on the behavior of the aggregate levels of bank capital and entrepreneurial net worth.

Aggregate investment I_t is given by the sum of individual projects i_t from (8):

$$I_t = \gamma_t^g A_t + N_t, \tag{43}$$

where A_t and N_t denote the aggregate levels of bank capital and entrepreneurial net worth, respectively, and aggregate bank lending is represented by $I_t - N_t$. A_t and N_t are found by summing (38) and (40) across all agents:

$$A_t = \kappa_t \left[r_t + q_t(1-\delta) \right] K_t^b + \eta^b w_t^b; \tag{44}$$

$$N_t = \left[r_t + q_t(1-\delta)\right] K_t^e + \eta^e w_t^e, \tag{45}$$

where K_t^b and K_t^e denote the aggregate wealth of banks and entrepreneurs at the beginning of period t. Recalling that η^e and η^b represent the population masses of entrepreneurs and banks, these are

$$K_t^b = \eta^b k_t^b; \;\; K_t^e = \eta^e k_t^e.$$

As described above, banks and entrepreneurs survive to the next period with probability τ^b and τ^e, respectively; surviving agents save all their wealth because of risk-neutral preferences and the high return on internal funds. Aggregate wealth at the beginning-of-period $t+1$ is thus

$$K_{t+1}^b = \tau^b \alpha R_t^b I_t; \tag{46}$$

$$K_{t+1}^e = \tau^e \alpha R_t^e I_t. \tag{47}$$

Combining (43)-(47) yields the following laws of motion for A_t and N_t:

$$A_{t+1} = \kappa_{t+1}\left[r_{t+1} + q_{t+1}(1-\delta)\right] \tau^b \alpha R_t^b \left(\gamma_t^g A_t + N_t\right) + w_{t+1}^b \eta^b; \tag{48}$$

$$N_{t+1} = \left[r_{t+1} + q_{t+1}(1-\delta)\right] \tau^e \alpha R_t^e \left(\gamma_t^g A_t + N_t\right) + w_{t+1}^e \eta^e. \tag{49}$$

Equation (48) illustrates the bank capital channel that is at play in the model: all things equal, an increase in aggregate investment I_t increases earnings for the banking sector, and through a retained earnings mechanism serves to increase bank capital and thus further increases in lending and investment in the subsequent periods, which themselves increase bank earnings and bank capital, etc. This mechanism helps to propagate the effects of the initial shock several periods into the future. Further, one can see from (48)-(49) that bank capital A_t, through its effect on aggregate investment, also affects the evolution of net worth of entrepreneurs, in an interrelated manner where entrepreneurial net worth N_t itself has an impact on future levels of bank capital.

Exiting banks and entrepreneurs consume the value of their available wealth. This implies the following for aggregate consumption of entrepreneurs and banks:

$$C_t^b = (1-\tau^b) q_t \alpha R_t^b I_t, \tag{50}$$

$$C_t^e = (1-\tau^e) q_t \alpha R_t^e I_t. \tag{51}$$

Finally, aggregate household consumption and capital holdings are

$$C_t^h = \eta^h c_t^h; \;\; K_t^h = \eta^h k_t^h, \tag{52}$$

and the economy-wide equivalent to the participation constraint of banks (5) defines the aggregate equilibrium return on bank net worth:

$$1 + r_t^a = \frac{q_t \alpha R_t^b I_t}{A_t}. \tag{53}$$

2.5 The competitive equilibrium

A competitive equilibrium for the economy consists of (i) decision rules for c_t^h, i_t^h, W_{it}, k_{t+1}^h, u_t, M_t^c, D_t, and M_{t+1} that solve the maximization problem of the household, (ii) decision rules for $\widetilde{p_{jt}}$ as well as input demands k_{jt}, and h_{jt} that solve the profit maximization problem of firms producing intermediate goods in (26), (iii) decision rules for i_t, R_t^e, R_t^b, R_t^h, a_t and d_t that solve the maximization problem associated with the financial contract, (iv) saving and consumption decision rules for entrepreneurs and banks, and (v) the following market-clearing conditions:

$$\begin{aligned}
K_t &= K_t^h + K_t^e + K_t^b; &(54)\\
u_t K_t^h + K_t^e + K_t^b; &= \int_0^1 k_{jt} dj; &(55)\\
H_t &= \int_0^1 h_{jt} dj; &(56)\\
Y_t &= C_t^h + C_t^e + C_t^b + I_t + \mu_t I_t; &(57)\\
K_{t+1} &= (1-\delta) K_t + \alpha\Big((I_t - N_t)/Y_t\Big) R I_t; &(58)\\
\eta^b d_t &= \eta^h \frac{D_t}{P_t}; &(59)\\
\overline{M}_t &= \eta^h M_t. &(60)
\end{aligned}$$

Equation (54) defines the total capital stock as the holdings of households, entrepreneurs and banks. Next, (55) states that total capital services (which depend on the utilization rate chosen by households) equals total demand by intermediate-good producers. Equation (56) requires that the total supply of the composite labor input produced according to (35) equals total demand by intermediate-good producers. The aggregate resource constraint is in (57) and (58) is the law of motion for aggregate capital. Finally, (59) equates the aggregate demand of deposits by banks to the supply of deposits by households, and (60) requires the total supply of money $\overline{M}_t$ to be equal to money holdings by households.

3 Calibration

This section describes our model calibration. The household sector of our model, as well as its final good and intermediary good production sectors, are similar to those in leading New Keynesian models such as those in Christiano et al. (2005) and Smets and Wouters (2007). Accordingly, our calibration of those parameters is conventional.

First, the utility function of households is specified as

$$U(c_t^h - \gamma c_{t-1}^h, l_{i,t}, M_t^c/P_t) = log(c_t^h - \gamma c_{t-1}^h) - \psi \frac{{l_{it}^h}^{1+\eta}}{1+\eta} + \zeta log(M_t^c/P_t).$$

The weight on leisure ψ is set in order that steady-state work effort by households be equal to 0.3. One model period corresponds to a quarter, so the discount factor β is set at 0.99. Following Christiano et al. (2005), the parameter governing habits, γ, is fixed at 0.65, ζ is set to 0.0018 and η is set to 1. To parameterize households' capital utilization decision, we first require that $u = 1$ in the steady-state, and set $v(1) = 0$. This makes steady state computations independent of $v(.)$. Next, we set $\sigma_u \equiv v''(u)(u)/v'(u) = 0.5$ for $u = 1$.

Next, on the production side, the share of capital in the production function of intermediate-good producers, θ^k, is set to the standard value of 0.36. Since we want to reserve a small role in production for the hours worked by entrepreneurs and bankers, we fix the share of the labor input θ^h to 0.6399 instead of $1 - 0.36 = 0.64$. The parameter governing the extent of fixed costs, Θ, is chosen so that steady-state profits of the monopolists producing intermediate goods are zero. Following Meh and Moran (2010), the persistence of the technology shock, ρ_z, and its standard deviation, σ_z, are set to 0.95 and 0.005, respectively, which are standard values in the literature. Finally, we set $\delta = 0.02$.

Price and wage-setting parameters are set following results in Christiano et al. (2005). The elasticity of substitution between intermediate goods (ξ_p) and the elasticity of substitution between labor types (ξ_w) are set to 6 and 21, which ensures that the steady-state markups are 20% in the goods market and 5% in the labor market. The probability of not reoptimizing for price setters (ϕ_p) is 0.60 while for wage setters (ϕ_w), it is 0.64.

Finally, in our benchmark specification, the monetary policy rule (37) is calibrated to standard values, based on estimates such as those in Clarida et al. (2000): we thus have $\rho_\pi = 1.5$, $\rho_r = 0.8$ and $\rho_y = 0.1$. Our welfare analysis will assess whether this standard rule can be improved. The target rate of inflation $\overline{\pi}$ is 1.005, or 2% on a net, annualized basis.

The regulation policies we analyze in this version of the model are either a *time-invariant* policy that sets the parameter $\omega = 0$ in (16), or a *counter-cyclical* policy which sets $\omega = -5$, so that regulators limit the growth of bank credit in good times. Setting the parameter $\omega = -5.0$ leads to volatility in the regulated capital-asset ratios of banks that are in line with the recently adopted provisions of the Basel III accord, which specify that the counter-cyclical capital buffers will have a range of 2.5 percentage points.

The remaining parameters are related to the banking and entrepreneurial sector. To guide us in calibrating them, we appeal when possible to the related literature emphasizing models of financial frictions and also use targets for some of the steady-state properties of the model.

Table 2: Baseline Parameter Calibration

Household Preferences and Wage Setting

γ	ζ	ψ	η	β	ξ_w	ϕ_w
0.65	0.0018	9.05	1.0	0.99	21	0.64

Final Good Production

θ_k	θ_h	ρ_z	ξ_p	ϕ_p
0.36	0.6399	0.95	6	0.6

Capital Good Production and Financing

$\underline{B}$	$\overline{B}$	α	R	τ_e	τ_b	$\Delta\alpha$	χ	ε_b
0	0.1575	0.99	1.05	0.7	0.9	0.35	15.0	10.0

The production parameters in the entrepreneurial sector are α and R. We set α to 0.99, so that the (quarterly) failure rate of entrepreneurs is 1%, as in Carlstrom and Fuerst (1997), and $R = 1.05$, so that the steady-state (relative) price of capital is within a reasonable range. Next, the parameters $\Delta\alpha$, τ^e and τ^b are related to the extent of the moral hazard problem in financial markets and the scarcity of net worth. The parameter τ^b controls the rate of return on bank capital (bank equity) and is set to 0.9. The remaining parameters are $\Delta\alpha = 0.35$ and $\tau^e = 0.7$.

The schedule linking bank monitoring intensity μ_t and moral hazard on the entrepreneurial size $b(\mu_t)$ is specified as follows:

$$b(\mu_t) = \overline{B}\,(1 + \chi\mu_t)^{-\varepsilon^b} ,$$

where we set $\overline{B} = 0.9\,\Delta\alpha R$, $\chi = 15$, and $\varepsilon^b = 10$. $\overline{B}$, the maximum private benefits from shirking, is set below the gain in return from choosing good project. χ was chosen to match equilibrium monitoring costs to average bank operating costs in the data. Operating costs calculated using Bank Holding Company Data available from the Federal Reserve Bank of Chicago are in the range of 3 to 5 per cent of assets. ε^b is linked to shirking and the premium paid by entrepreneers. $\varepsilon^b = 10$ results in a premium of 300 basis points over the deposit rate. Business loan interest rate spreads of this magnitude are reported in Gerali et al (2010) and Angeloni and Faia (2010).

Finally, the link between aggregate bank lending and the endogenous riskiness of the banking sector, the parameter ς in (17), is set to 0.1. This value implies that the probability of failure increases by 0.2% after a standard macroeconomic shock like the disturbance to technology analyzed in Figure 3 below. This sensitivity is intended to be a conservative value. Picking a value for this parameter is challenging, since it governs the response of unobserved endogenous risk to the banking system that is rising when traditional measured default probabilities (e.g. based on asset price returns and volatility) are low. Our welfare analysis will study the sensitivity of our results to the value of this parameter, Table 2 summarizes the numerical values of the model parameters.

4 Business Cycle Implications of Countercyclical Bank Capital Regulation

This section analyzes the business-cycle implications of bank capital regulation, by studying the dynamic response of the economy to various shocks, with and without countercyclical regulation. It shows that this type of macroprudential policy can help stabilize economic fluctuations, but that they also have implications for the dynamics of prices and inflation.

Technology shocks

Figure 3 presents the effects of a one-standard deviation, positive technology shock on two economies. The first economy features the *Time-invariant Regulation* (i.e. $\omega = 0$) environment and its responses to the shock are in solid lines. The second economy is one where leverage regulation is counter-cyclical ($\omega = -5$) and its responses to the shock are displayed in dashed lines. Figure 3 shows that the macroeconomic impact of the technology shock is markedly different in the two economies: while output and investment increase briskly under the *Time-invariant* solution, they experience more subdued fluctuations under a policy of counter-cyclical bank capital requirements. However, the reaction of the price of investment goods q_t, as well as those of inflation and interest rates, are more volatile under the counter-cyclical regulatory solution.

These contrasting responses of quantities and prices across the two types of regulation arise as follows. In both economies, the favorable technology shock raises the expected return from physical capital in future periods. A positive shift in the demand for capital goods puts upwards pressure on q_t, the relative price of these goods. The upward pressure on q_t has the important effect of mitigating moral hazard in financial markets. To see this, recall expression (12) arising from the financial contract. Expressed with economy-wide variables, it reads:

$$D_t = \frac{q_t\alpha}{1+r_t^d} R_t^h I_t = \frac{q_t\alpha}{1+r_t^d}\left(R - \frac{b(\mu_t)}{\Delta\alpha} - \frac{z\mu_t}{q_t\Delta\alpha}\right) I_t. \tag{61}$$

As discussed above, this expression states that the reliance on outside funds D_t in the financing of a given-size investment project is limited by the double moral hazard problem:

banks need to credibly promise a sufficient return to outside investors. But the technology shock has created upward pressure on q_t, which attenuates moral hazard, because it increases the value of R_t^h, the share of project return set aside for outside investors. It is now easier for banks to attract loanable funds and, absent regulation, banks would take advantage of the easier access to funds to increase their leverage with no commensurate increase in their monitoring and screening intensity, possibly leading to the development of serious financial imbalances, represented here by sharp increases in the riskiness of the banking sector (probability of default).

Banking sector regulation, aimed at limiting the development of these financial imbalances, now intervenes to play a key role in banks' choices of leverage and monitoring. First, under the time-invariant solution (solid lines) banks must keep their leverage unchanged even with the favourable financing conditions, which results in a noticeable increase in bank monitoring intensity. Under the counter-cyclical capital requirements environment (dashed lines) the impact on the banking sector is more pronounced, because complying with the regulation implies that leverage must fall on impact and remain low throughout the episode. In effect, counter-cyclical capital regulation leads banks to accumulate buffers of bank capital following the favourable shock which they would then be able to draw down if bad times materialize later. The policy leads banks to increase considerably their capital involvement in a given-sized project relative to what would occur under time-invariant regulation. This higher capital involvement is accompanied by an important and sustained increase in the monitoring efforts of banks.

Figure 3 shows that this counter-cyclical capital requirement succeeds in keeping the development of financial imbalances in check: the sustained increase in the banks' monitoring and screening intensity moderates significantly the increase in the riskiness of the banking sector. But what impact does this policy have on aggregate economic activity and inflation? To see this, recall first that since bank capital is comprised of retained bank earnings from past periods, its ability to change immediately at the onset of a shock is limited. In such circumstances, the banking sector's only possible adjustment to the counter-cyclical capital regulation, which requires more bank capital per unit of lending, is to limit the response of bank lending itself to the shock. As a result, a much more subdued response of bank lending obtains relative to the time-invariant solution, which also limits the increase in aggregate investment. From that point on, the bank capital channel described in Meh and Moran (2010) is responsible for the difference in the dynamic paths across the two economies: the muted response of investment in the economy with counter-cyclical capital requirements translates into smaller increases in bank earnings and thus lower levels of bank capital in subsequent periods. The second-round positive effects on bank lending and investment (with higher bank capital further facilitating the ability of banks to attract loanable funds and fund projects) thus have a more muted impact.

The counter-cyclical capital regulation also has implications for prices and interest rates. By limiting the increase in bank lending and, as a result the production of new capital goods, following the favourable supply shock, counter-cyclical regulation makes the price of investment goods q_t increase more than under time-invariant regulation. Further the subdued expansion in general economic activity, at a time when the productive capacity of the economy has improved, means that inflation will decrease more, requiring the monetary authority to lower interest rates to a greater extent.

Overall therefore, favourable technology shocks are associated with easier access to outside loanable funds. However, counter-cyclical capital regulation limits the ability of banks to tap these outside funds and instead requires them to increase their capital position in lending. This leads to subdued fluctuations in real activity and limits the development of financial imbalances, but it also implies higher volatility for inflation. These model responses suggest that policymakers face a tradeoff between mitigating financial imbalances with counter-cyclical regulation and inflation performance. We explore this further when we conduct a welfare analysis of monetary and regulatory regimes below.

Shocks to Bank Capital

We now consider the effects of shocks that lead to sudden declines in bank capital. As described above, we study 'valuation' shocks which deteriorate the value of retained earnings and cause sharp declines in the capital position of banks. Figure 4 depicts the effects of such a negative shock to bank capital, contrasting the responses of the *Time-invariant Regulation* economy (in solid lines) to the economy with *Counter-cyclical* capital requirements (dashed lines). The size of the shock has been chosen to set the initial decrease in bank capital at around 5%, a magnitude that is in line with recent evidence on the likely effects of financial distress episodes.[13]

The decline in aggregate bank capital makes it more scarce. The efficient response to such scarcity would be to economize on bank capital when arranging financing and thus to increase leverage. However, this is not permitted under the *Time-invariant* economy, as leverage must remain fixed throughout the episode. Figure 4 shows that as a result, the *time-invariant regulation* economy experiences a deep downturn following the shock.

This results because banks are prevented from reducing their participation in the financing of a given-size project (increasing their leverage) and must instead continue investing their own capital in bank lending. This continued involvement is associated with an important increase in monitoring intensity. Of course, without the ability to increase leverage, and at a time when bank capital has suffered a significant decline at the aggregate

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[13] Following other authors analyzing shocks to net worth of the entrepreneurial or banking sectors (Goodfriend and McCallum, 2007; Christiano et al., 2010; Gertler and Karadi, 2011) we assume bank capital shocks have moderate to high serial correlation. We thus set the autocorrelation ρ_κ to 0.9.

level, bank lending must go down importantly to adjust, and it does so in a pronounced manner, declining by more than 4% on impact. In subsequent periods, the depressed levels of investment lead to decreases in bank earnings and thus in bank capital. As a consequence, bank lending and economic activity experience further decreases, through the bank capital channel of propagation. The low levels of bank credit throughout the episode lead to a sharp drop in the banking sector probability of default.

By contrast, in the economy with counter-cyclical capital regulation, the banking sector is allowed to increase its leverage as a response to the shock, which enables banks to alleviate somewhat the sudden scarcity of bank capital. As a result, the decrease in bank lending is under 2%, much less than it was under time-invariant regulation, and the economic downturn is not as pronounced. Counter-cyclical regulation therefore shields the economy from the worst of the negative effects following bank capital shocks. Because credit has not declined as much as under the time-invariant regulation, the decrease in bank riskiness is correspondingly not as pronounced.

Notice further that because of the procyclical response of inflation following the shocks to bank capital, there is no trade-off between stabilizing the riskiness of the banking sector, the purview of macroprudential policies, and stabilizing inflation, as in the monetary policy's mandate. Because inflation decreases following the shock, the response of monetary policy is to lower rates. Such a monetary action is unlikely to lead to the development of financial imbalances, as credit is already low. Likewise, the actions of the counter-cyclical capital regulation, by shielding the economy from the worst effects of the decline in economic activity, also help stabilize inflation.

Notice that under the buffer stock interpretation of bank regulation, the onset of this shock to bank capital is an instance where the capital buffer is allowed to be drawn down. As a result, the downturn in bank lending, investment and output are mitigated and inflation is stabilized. The riskiness of bank failure, however, is allowed to be somewhat higher than it would have been under time-invariant regulation (Hanson et al., 2011). Figure 4 helps to preview some of the welfare results we present in the next section. According to the dynamic responses depicted in the figure, counter-cyclical requirements on bank capital allow the banking sector to efficiently react to the shock, in the context of the sudden scarcity of aggregate bank capital. Relative to the time-invariant regulation environment, both output and inflation volatilities are stabilized, with potentially important welfare consequences which we study quantitatively below.

5 Welfare Analysis

The results presented above show that macroprudential policies like counter-cyclical bank capital regulation can have stabilizing effects on economic activity and the risk of banking sector stress. However, such policies also affect prices and inflation and thus create a connection between capital regulation and the conduct of monetary policy. Consequently, correctly evaluating macroprudential rules requires a careful assessment of their impact on both real activity and prices, as well as taking into account their interaction with monetary policy.

To address these issues, this section presents a welfare analysis of the monetary and regulation policy regimes. Specifically, we use our model to quantitatively evaluate alternative specifications of the monetary policy rule (37) and the regulation rule (16), measuring the welfare performance of each policy combination with the unconditional expectation of household utility it implies.[14] To this end, a second-order approximate solution of the model around the non-stochastic steady state is employed, in order to avoid well-known problems with policy evaluation using first-order solutions (Kim and Kim, 2003). We measure welfare over a range between 0 and -10 for ω (with increments of 0.25) and a range between 1 and 3 for the values of ρ_π, with increments of 0.1.[15]

Our welfare analysis is designed to identify the optimal degree of countercyclicality in bank capital regulation and to measure its contribution to welfare. We identify the best regulation policy under different scenarios regarding the monetary policy rule, to take into account its influence on the economic environment in which regulation policy operates. In addition, we explore the welfare consequences of the monetary policy and regulatory regimes by conditioning on the source of shocks, as well as assessing them when all shocks are present. This allows us to explore the possibility that following certain types of disturbances, the relative importance of each policy regime might differ according to the type of disturbance that is affecting the economy.[16]

Table 3 presents our results. For each type of shock analyzed, the table displays the policy mix considered in the first two columns. First, a benchmark for comparison is established in case (i), by computing the welfare consequences of the calibrated specification for the monetary policy rule (37) with time-invariant regulation, which sets $\omega = 0$ in (16). Next, keeping monetary policy unchanged at this calibrated specification, optimized

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[14] Since entrepreneurs and bankers are risk neutral the alternative rule specifications we consider have no impact on these agents' average levels of consumption and thus the welfare rankings we obtain are robust to including the utility of entrepreneur and bankers in the welfare computations (Faia and Monacelli, 2007).

[15] The range examined for ω is guided by the specifics of the counter-cyclical buffers envisioned in the Basel III accord. These buffers will increase bank capital requirements by up to 2.5 percentage points. A range between 0 and -10 for ω ensures that the fluctuations in the capital-asset ratio of banks always respect the Basel III specifications. The range examined for ρ_π follows the spirit of Schmitt-Groh and Uribe (2007), who argue that the monetary policy specifications evaluated should be *implementable*, which requires policy parameters like ρ_π to be within a reasonable numerical range as to allow efficient communication of policy goals. They argue that a range between 1.0 and around 3.0 is appropriate.

[16] Our welfare analysis abstract from the presence of monetary policy shocks, to focus on the systematic part of monetary policy represented in the rule (37).

counter-cyclical regulation is identified by searching for the value of ω that maximizes household welfare (case *ii*). The next policy combination analyzed has monetary policy respond more aggressively to inflationary pressures, and regulation is again optimized, to reflect this new economic environment (case *iii*). Continuing, case (*iv*) reports a situation where monetary and regulation policies are determined jointly, to maximize the coordination of their effects. Finally, case (*v*) evaluates the impact on welfare when the optimal degree of countercyclicality is implemented, but monetary policy reverts back to its calibrated specification. In the following two columns of Table 3, the policy coefficients that obtain are reported. Next, the welfare level achieved by the policy combination is depicted and, finally, the welfare achieved by the policy *relative* to the one implied by the benchmark with calibrated monetary policy and time-invariant regulation is reported.[17]

Table 3 shows that in all cases considered, a significant degree of countercyclicality in bank capital regulation is beneficial. The table also reveals that the optimal degree of countercyclicality depends in important ways both on the source of shocks and on the conduct of monetary policy, which we discuss in turn.

First, *Panel A* studies an environment where technology shocks are the main source of economic fluctuations. Case (*ii*) shows that optimal counter-cyclical regulation sets $\omega = -3.0$ when monetary policy follows the calibrated specification, which delivers a welfare gain of 0.06% relative to the situation where time-invariant capital regulation is present. Next, case (*iii*) shows that as monetary policy gets more aggressive in its response to inflation, the optimal degree of countercyclicality in capital requirements also increases, to reach $\omega = -9.75$ when $\rho_\pi = 2.0$ and up to $\omega = -10$, when $\rho_\pi = 2.9$, and the welfare gain that these policy regimes generate reaches 0.3%. This result suggests that the interaction between monetary policy and counter-cyclical capital regulation can produce superior welfare outcomes when well coordinated. This interdependence between the two policies occurs as follows. A positive shock to technology, say, initiates downward pressures on inflation, which lead monetary authorities to decrease rates and thus stimulate bank lending and credit. Absent counter-cyclical capital regulation, the resulting boom in credit might lead financial imbalances to start developing, which would increase the probability of bank failure, an unfavorable spillover from the monetary policy actions. By contrast, the presence of the countercyclical capital buffers limits the formation of these imbalances and keeps the riskiness of the banking sector in check, which allows monetary policy to more efficiently stabilize the economy. In short, the presence of counter-cyclical regulation facilitates the implementation of an effective monetary policy, by preventing the build-up of financial imbalances following monetary policy actions. Conversely, case (*v*) suggests that a successful policy of countercyclical capital buffers requires the appropriate

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[17] The relative welfare gain is the percentage consumption increase that a household living in the economy represented by the policy regime of case (*i*) would need to obtain a level of welfare equivalent to the one enjoyed by a household living in the alternative policy regime considered.

monetary policy to be fully efficient, since otherwise inflation might be destabilized: by reacting too little to inflation when capital regulation is aggressive the welfare gain over the benchmark is diminished. As presented here, this interaction between the conduct of monetary policy and the effects of counter-cyclical capital requirements relies on the assumption that increases in bank lending and credit are likely to contribute to the build up of financial imbalances and increase the risk of bank failure. In a situation where such build-ups are unlikely to accompany credit booms, we would expect this interaction between monetary policy and capital regulation to be less active; we analyze this conjecture below.

The second panel of Table 3 studies an environment where shocks to bank capital are the primary source of economic fluctuations. As was the case in the environment with technology shocks, significant degrees of countercyclicality in bank capital requirements continue to be beneficial to the economy and provide important welfare gains. When monetary policy follows the benchmark specification, the optimal value for ω is found to be very high, at -10. Further, the welfare improvement that such a policy offers over its time-invariant counterpart is 0.062%, a higher gain than the one that was achieved in the corresponding experiment with technology shocks in Panel A. Shocks originating from the banking sector thus make counter-cyclical capital regulation both more active and more beneficial to the economy. In addition the interaction between monetary policy and bank capital regulation is also modified, because of the procyclical impact of these shocks on inflation. Recall that a negative shock to bank capital, say, will decrease output and credit availability at the same time as it decreases inflation. Counter-cyclical regulation on bank capital helps shield the economy from the worst extent of the shock by allowing bank leverage to increase thus mitigating the decrease in credit. The response of monetary policy to the same shock is to lower interest rates in order to stabilize the falling rate of inflation and stimulate output, but this time without fears of fueling excessive credit growth and increasing bank riskiness, because the easing is occurring at a time where credit is low. Using two different instruments, the actions of monetary policy and counter-cyclical regulation thus reinforce each other. Because the two policies work in the same direction, capital regulation may not need to be as active if monetary policy increases its responsiveness, as cases (*iii*) and (*iv*) show: as the coefficient on inflation ρ_π increases from 1.5 to 2.0 and then 3.0, the optimal degree of countercyclicality remains high but decreases slightly, to -9.75 (case *iii*) and -8.75 (case *iv*). Specifying a vigourous degree of countercyclicality in bank capital regulation remains very important for welfare, however, as illustrated in case (*v*): with the optimal value of ω in place, the welfare gain achieved remains strong even if monetary policy reverts back to its benchmark specification. This is in contrast with the situation in Panel A, where the welfare gain achieved by the correct counter-cyclical policy was reduced somewhat when monetary policy was not chosen optimally in tandem. This indicates that following shocks to bank capital, the natural first line of defence to stabilize fluctuations is a correctly calibrated policy of countercyclical bank capital requirements, with monetary policy playing a secondary supporting role.

Finally, Panel C of Table 3 analyzes an environment where both types of shocks are present. Interestingly, the optimal degree of countercyclicality in bank capital requirements remains high and its numerical value lies between those obtained in Panel A and Panel B of the table. The welfare gain achieved by this policy over its time-invariant counterpart is now 0.12%, a higher gain than under each type of shock alone, suggesting that counter-cyclical bank capital requirements continue to be welfare improving. The interactions between monetary and regulation policy suggest that the influence of broad-based shocks, like the disturbances to technology, dominate the analysis and thus that these two policies work well in tandem. For example, in Panel A of the table the optimal value for ω increases as monetary policy's responsiveness to inflation, ρ_π, increases (cases *iii* and *iv*) and this pattern is repeated in Panel C. Similarly to Panel B, however, Panel C also shows the importance of correctly setting the degree of countercyclicality in bank capital requirements.

5.1 The importance of an endogenous riskiness of the banking sector

The connections identified above between monetary policy and counter-cyclical bank regulation relied in large part on the endogenous riskiness of the banking sector, as specified in (17). As this endogeneity becomes weaker, one would expect these interactions to be modified. To analyze this conjecture, Table 4 reports the results of simulations that mirror those conducted for Table 3, but in an environment with a significantly weaker endogenous link between aggregate credit and the riskiness of the banking sector.[18] Such an experiment could be interpreted as reflecting an economy in which the shocks affecting aggregate fluctuations are not expected to contribute importantly to the build-up of financial imbalances and thus do not pose a strong threat to the riskiness of the banking sector.

Table 4 reveals that some degree of countercyclicality in leverage regulation continues to be beneficial for welfare. However, the weaker link between credit and financial imbalances modifies the optimal degree of countercyclicality. In an environment with only technology shocks, for example, the optimal coefficient for ω is now -0.75, rising in absolute value to 1.5 as monetary policy increases its responsiveness to inflationary pressures. It is still the case that by limiting the development of financial imbalances following interest rate actions by monetary authorities, counter-cyclical leverage regulation allows a more efficient, welfare-improving, stabilization of the economy; however, since their potential

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[18] This is achieved by setting the parameter ς to 0.01 in (17), one tenth of its calibrated value.

impact on the riskiness of the banking sector are muted, the degree of countercyclicality needed is much reduced and the welfare gain it delivers is much more modest.

Panel B of the table shows the welfare analysis for the environment with shocks only to bank capital. Tuning down the endogeneity of the banking sector's riskiness does not have as much of an impact on the optimal degree of countercyclicality in this environment: the optimal values for ω continue to be high, although slightly diminished from Table 5, and the welfare gain achieved by pursuing the correct policy is of the same order of magnitude. This suggests that counter-cyclical capital regulation is ideally suited to stabilize the economy following shocks to the banking sector, and that this statement remains true whether the bank capital impairments are thought to develop into financial imbalances or not. By contrast, the contribution of counter-cyclical capital requirements in stabilizing the economy following the more standard shocks like the disturbances to technology depends on the authorities' assessment of the likely impact of these shocks on the creation of financial imbalances.

6 Conclusion

Recent changes in global banking regulation have put counter-cyclical regulatory policy in the toolkit of public authorities seeking to mitigate risks to the functioning of the financial system. These changes have raised a new set of questions for policy makers worldwide regarding the extent to which bank leverage regulation should be countercyclical and how the new bank leverage regulation will interact with the conduct of monetary policy.

This paper presents a macroeconomic framework that can be used to study the impact of different configurations of bank leverage regulation and how they might interact with monetary policy. The model emphasizes the role of bank capital in mitigating moral hazard between banks and theirs suppliers of loanable funds as in Meh and Moran (2010). In addition, the lending decisions of individual banks affect the riskiness of the banking sector, though banks do not internalize this impact. Leverage regulation mitigates the impact of this externality by inducing banks to alter the intensity of their monitoring efforts.

We find that countercyclical bank leverage regulation is likely to have beneficial stabilization properties, particularly when shocks to bank capital are a significant source of economic fluctuations. Further, we find that strong interactions between monetary policy and bank regulation policy may exist. The stabilization benefits of countercyclical capital requirements for a standard productivity shock depends on the policy response taken by the monetary authority.

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Table 3. Welfare Analysis of Monetary and Regulation Regimes

Case	Policy Mix		Policy Coefficients		Welfare	Welfare Gain
	Monetary Policy	Regulation Policy	ρ_π	ω	Level	Relative to case (i) (%)
	Panel A: Technology Shocks					
(i)	Calibrated	Time-Invariant	1.5	0	-1.6592	0.0000
(ii)	Calibrated	Optimized	1.5	-3	-1.6586	0.0596
(iii)	Aggressive	Optimized	2	-9.75	-1.6567	0.2479
(iv)	Optimized	Optimized	2.9	-10	-1.6562	0.2993
(v)	Calibrated	Optimized	1.5	-10	-1.6586	0.0527
	Panel B: Shocks to Bank Capital					
(i)	Calibrated	Time-Invariant	1.5	0	-1.6551	0.0000
(ii)	Calibrated	Optimized	1.5	-10	-1.6545	0.0617
(iii)	Aggressive	Optimized	2	-9.75	-1.6544	0.0631
(iv)	Optimized	Optimized	3	-8.25	-1.6544	0.0640
(v)	Calibrated	Optimized	1.5	-8.25	-1.6545	0.0615
	Panel C: Both Types of Shocks					
(i)	Calibrated	Time-Invariant	1.5	0	-1.6598	0.0000
(ii)	Calibrated	Optimized	1.5	-4.5	-1.6586	0.1169
(iii)	Aggressive	Optimized	2	-9.75	-1.6567	0.3112
(iv)	Optimized	Optimized	2.9	-10	-1.6562	0.3633
(v)	Calibrated	Optimized	1.5	-10	-1.6587	0.1145

Note: Calibrated monetary policy sets $\rho_\pi = 1.5$, $\rho_r = 0.8$ and $\rho_y = 0.1$.

Table 4. Welfare Analysis of Monetary and Regulation Regimes

Low Endogeneity of Banking Sector's Riskiness

Case	Policy Mix		Policy Coefficients		Welfare	Welfare Gain
	Monetary Policy	Regulation Policy	ρ_π	ω	Level	Relative to case (i) (%)
Panel A: Technology Shocks						
(i)	Calibrated	Time-Invariant	1.5	0	-1.6579	0.0000
(ii)	Calibrated	Optimized	1.5	-0.75	-1.6578	0.0046
(iii)	Aggressive	Optimized	2	-1.5	-1.6562	0.1629
(iv)	Optimized	Optimized	2.7	-1.5	-1.6559	0.1921
(v)	Calibrated	Optimized	1.5	-1.5	-1.6579	-0.0005
Panel B: Shocks to Bank Capital						
(i)	Calibrated	Time-Invariant	1.5	0	-1.6550	0.0000
(ii)	Calibrated	Optimized	1.5	-7.5	-1.6544	0.0588
(iii)	Aggressive	Optimized	2	-6.25	-1.6544	0.0607
(iv)	Optimized	Optimized	3	-5.25	-1.6544	0.0631
(v)	Calibrated	Optimized	1.5	-5.25	-1.6544	0.0583
Panel C: Both Types of Shocks						
(i)	Calibrated	Time-Invariant	1.5	0	-1.6584	0.0000
(ii)	Calibrated	Optimized	1.5	-2	-1.6580	0.0451
(iii)	Aggressive	Optimized	2	-1.5	-1.6563	0.2127
(iv)	Optimized	Optimized	2.7	-1.5	-1.6560	0.2462
(v)	Calibrated	Optimized	1.5	-1.5	-1.6580	0.0431

Notes: Calibrated monetary policy sets $\rho_\pi = 1.5$, $\rho_r = 0.8$ and $\rho_y = 0.1$.

Figure 1. Bank Monitoring and Entrepreneurs' Private Benefits

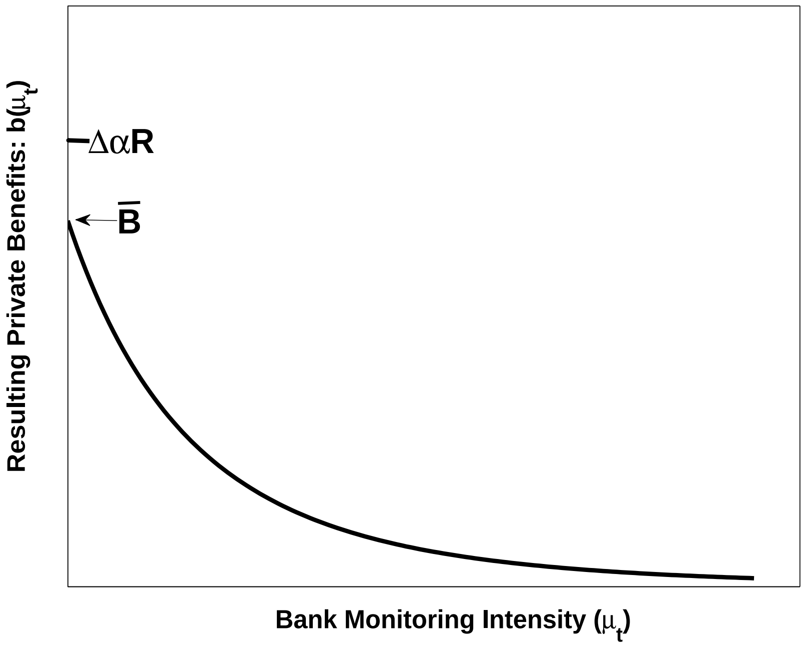

Figure 2. Choice of monitoring intensity μ_t under the Regulation Solution

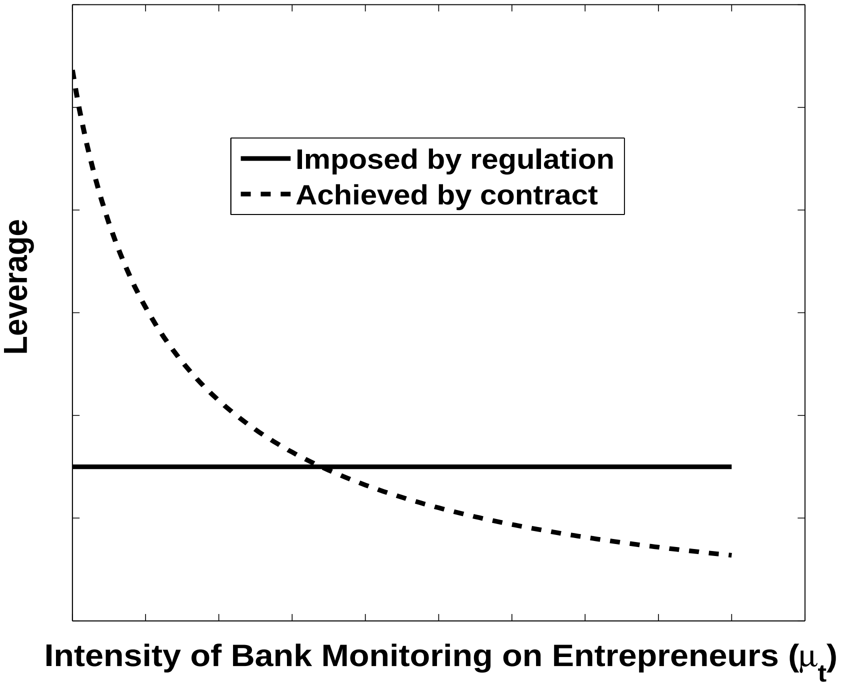

Figure 3. Responses to a Positive Technology Shock
Time-invariant versus Counter-cyclical Regulation

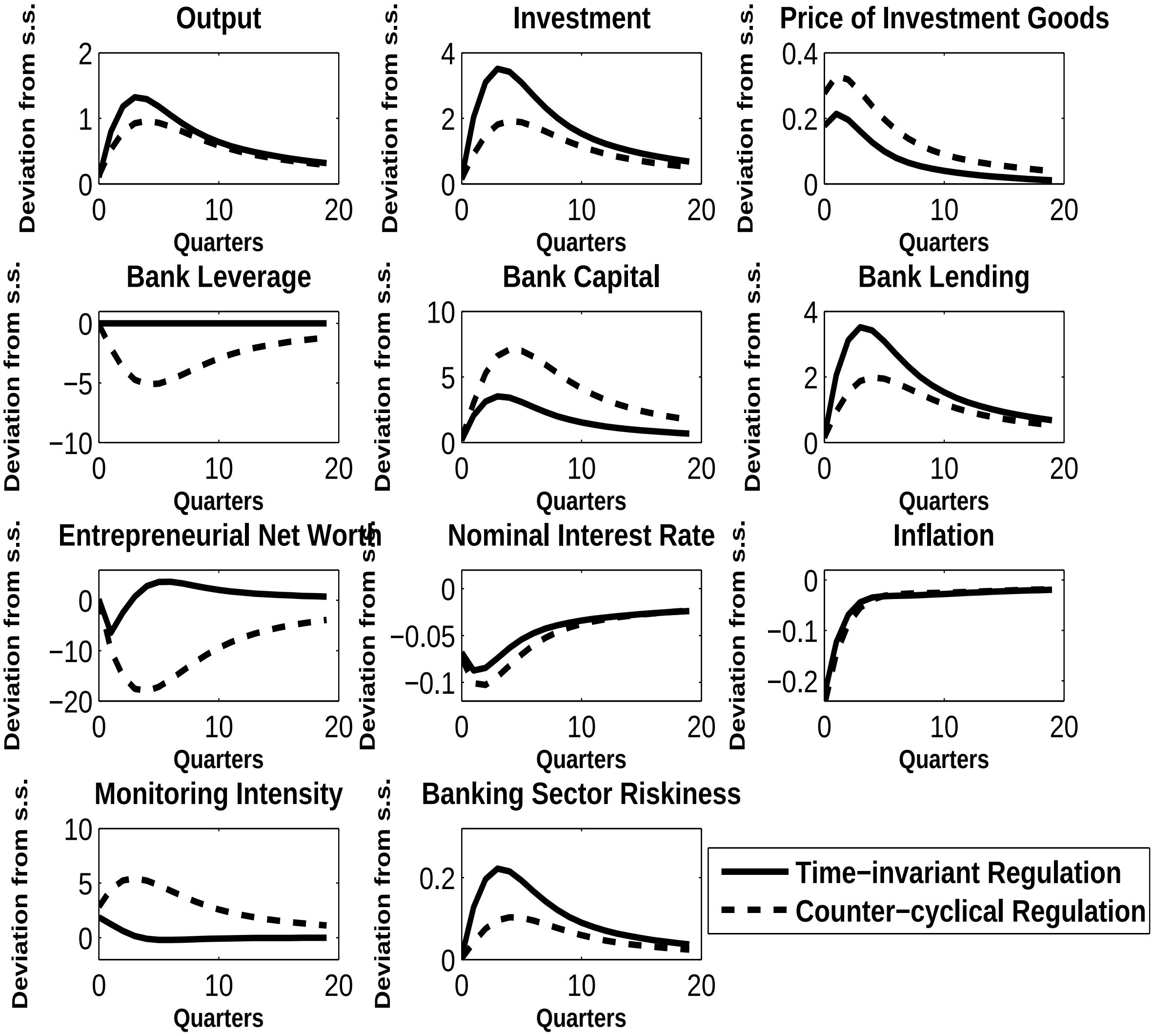

Figure 4. Responses to a Negative Shock to Bank Capital
Time-invariant Regulation versus Counter-cyclical Regulation