Financial Crises, Bank Risk Exposure and Government Financial Policy

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N.Y.U. and Princeton

September 2010

Abstract

We develop a macroeconomic model with financial intermediation that allow the intermediaries (banks) to issue outside equity as well as short term debt. This makes bank risk exposure an endogenous choice. The goal is to have a model that can not only capture a crisis when banks are highly vulnerable to risk, but can also account for why banks adopt such a risky portfolio structure in the first place. We use the model to assess quantitatively how perceptions of fundamental risk and of government credit policy in a crisis affect the vulnerability of the financial system ex ante. We also study the quantitative effects of macro-prudential policies designed to offset the incentives for risk-taking.

1 Introduction

A distinguishing of the recent U.S. recession - known now as the Great Recession - was the significant disruption of financial intermediation.[1] The meltdown of the shadow banking system along with the associated strain placed on the entire financial system led to an extraordinary increase in credit costs. This increase in credit costs, which peaked in the wake of the Lehman brothers collapse was considered as a major factor in the collapse of durable goods spending in the fall of 2008 that in turn triggered the extraordinary contraction in output and employment.

The challenge for macroeconomists has been to build models that cannot only capture this phenomenon but also be used to analyze the variety of unconventional measures pursued by the monetary and the fiscal authorities to stabilize credit markets. In this regard, there has been a rapidly growing literature that attempts to incorporate financial factors within the quantitative macroeconomic frameworks that had been the work horses for monetary and fiscal policy analysis up until this point.[2] Much of this work is surveyed in Gertler and Kiyotaki (2010). A common feature of these approaches has been to extend the basic financial accelerator mechanism developed by Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) to financial intermediaries in order to capture the disruption of intermediation. Overall, this literature has made progress capturing in a broad brush way the basic real/financial interactions over the crisis.

Key to motivating a crisis within these frameworks is the heavy reliance of financial intermediaries (broad banks) on short term debt. This feature makes these institutions highly exposed to the risk of adverse returns to their balance sheet in way that is consistent with recent experience. Within these frameworks and most others in this class, however, by assumption the only way banks can obtain external funds is by issuing short term debt.[3] Thus, in their present form, these model are not equipped to address how the

[1] For descriptions, see Bernanke (2009) and Gorton (2010).

[2] Examples of the work horse framework includes Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007).

[3] Some quantitative macro models with financial sectors include: Bernanke, Gertler and Gilchrist (1999), Brunnermeier and Sannikov (2009), Carlstrom and Fuerst (1997), Christiano, Motto and Rostagno (2009), Mendoza (2010) and Jermann and Quadrini (2009). Only the latter consider both debt and equity finance, though they restrict attention to borrowing constraints faced by non-financial firms.

financial system found itself so vulnerable in the first place. This question is of critical importance for designing policies to ensure the economy does not wind up in this position again. For example, as we discuss below, a number of authors have suggested that such a risky bank liability structure was ultimately the product of expectations the government will intervene to stabilize financial markets in a crisis, just as it just did recently. With the existing macroeconomic frameworks it is not possible to address this issue.

In this paper we develop a macroeconomic model with an intermediation sector that allow banks to issue outside equity as well as short term debt. This makes bank risk exposure an endogenous choice. Here the goal is to have a model that can not only capture a crisis when financial institutions are highly vulnerable to risk, but also account for why these institutions adopt such a risky portfolio structure in the first place. The basic framework builds on Gertler and Karadi (2010) and Gertler and Kiyotaki (2010). It extends the agency problem between banks and borrowers within these frameworks to allow intermediaries a meaningful trade-off between short term debt and equity. Ultimately, a bank's decision over its liability structure depends on its perceptions of risk, which will in turn depend on the fundamental disturbances and expectations about government policy.

We first use the model to analyze how different degrees of fundamental risk in the economy affect the liability structure of banks and the aggregate equilibrium. We then analyze the vulnerability of the economy to a crisis in each kind of risk environment. When perceptions of risk are low, banks opt for greater leverage. But this has the effect of making the economy more vulnerable to a crisis.

We next turn to analyzing credit policy during a crisis. Following Gertler and Karadi (2010) and Gertler and Kiyotaki (2010), we analyze large scale asset purchases of the type the Federal Reserve used to help stabilize financial markets following the Lehman collapse. Within these frameworks, this kind of credit policy is effective in mitigating a crisis even if the central bank is less efficient in acquiring assets than is private sector. The advantage the central bank has during a crisis is that it can easily obtain funds by issuing short term government debt, in contrast to private intermediaries that are constrained by the weakness of their respective balance sheets.

What is new in the present framework is that it is possible to capture the side effects of the credit market to cause moral hazard. In particular, as we show, the anticipated credit policy will induce banks to adopt a riskier liability structure, which will in turn require a larger scale credit market

intervention during a crisis. This sets the stage for an analysis of macro-prudential policy designed to offset the effects of anticipated credit policy on the incentives for bank risk-taking.

To be sure, there is lengthy theoretical literature that examines the sources of vulnerability of a financial system. For example, Fostel and Geanokoplos (2009) stress the role of investor optimism in encouraging risk taking. Others such as Diamond and Rajan (2009), Fahri and Tirole (2009) and Chari and Kehoe (2009) stress moral hazard consequences of bailouts and other credit market interventions. Our paper differences mainly by couching the analysis within a full blown macroeconomic model to provide a step toward assessing the quantitative implications.

There is as well a related literature that analyzes macro-prudential policy. Again, much of it is qualitative (e.g. Lorenzoni, 2009, Korinek, 2009, and Stein 2010). However, there are also quantitative frameworks, e.,g., Bianchi (2009) and Nikolov (2010). Our framework differs by exploring the interaction between credit policies used to stabilize the economy ex post and macro-prudential policy used to mitigate risk taking ex ante, taking into account the endogenous financial market friction.

Finally relevant are the literatures on international risk sharing and on asset pricing and business cycles.[4] Conventional quantitative models used for policy evaluation typically examine linear dynamics within a local neighborhood of a deterministic steady state. In doing so they abstract from an explicit consideration of uncertainty. Because bank liability structure will depend on perceptions of risk, however, accounting for uncertainty is critical. Here we borrow insights from these literatures by considering second order approximations to pin down determinate bank liability shares.

Section 2 develops the model. Section 3 uses the model to analyze crises and policy. Concluding remarks are in sections 4.

2 The Baseline Model

Our approach to incorporating financial frictions within a business cycle model is a variation of Gertler and Kiyotaki (2010) and Gertler and Karadi

[4]See, for example, Devereux and Sutherland (2009) and Tille and Van Wincoop (2007) for examples of the former and Campbell (1993) and Lettau (2003) for examples of the latter.

(2010).[5] As in these frameworks financial intermediaries face endogenous balance sheet constraints because of the moral hazard problem described shortly. One important difference is that we allow intermediaries to issue state-contingent debt (outside equity) as well as non-contingent short term debt. This gives intermediaries more meaningful flexibility over their risk exposure. We can then use the model to analyze how perceptions of asset return risk as well as government policy interventions influence the degree of risk exposure that intermediaries choose. This in turn sets the stage for an analysis of macro-prudential policies.

As in our earlier work we keep the core model simple enough to see clearly the role of financial intermediation, but rich enough to allow for rough quantitative analysis. As in Gertler and Kiyotaki (2010), we restrict attention to a purely real model but abstract from bank liquidity risk, which was a central feature of that analysis. Adding this consideration back in is straightforward, as would be including nominal rigidities and money, following Gertler and Karadi (2010).[6]

We begin with the basic physical environment and then turn to the behavior of households, intermediaries and nonfinancial firms.

2.1 Physical Setup

Before introducing financial frictions, we present the basic physical environment.

There are a continuum of firms of mass of unity. Each firm produces output using an identical constant returns to scale Cobb-Douglas production function with capital and labor as inputs. We can express aggregate output Y_t as a function of aggregate capital K_t and aggregate labor hours L_t as:

$$Y_t = A_t {K_t}^{\alpha} L_t^{1-\alpha}, \quad 0 < \alpha < 1, \tag{1}$$

[5] Some other recent monetary DSGE models that incorporate financial factors include Christiano, Motto, and Rostagno (2009) and Gilchrist, Ortiz and Zakresjek (2009).

[6] Much of the insight into how credit market frictions may affect real activity and how various credit policies may work can be obtained from studying a purely real model. There are, however, several insights that monetary models add, however. First, if the zero lower bound on the nominal interest is binding, the financial market disruptions will have a larger effect than otherwise. This is because the central bank is not free to further reduce the nominal rate to offset the crisis. Second, to the extent there are nominal price and/or wage rigidities that induce countercyclical markups, the effect of the credit market disruption and aggregate activity is amplified. See, e.g., Gertler and Karadi (2010) and Del Negro, Ferrero, Eggertsson and Kiyotaki (2010) for an illustration of both of these points.

where A_t is aggregate productivity, which follows a stationary Markov process.

Let K_t be the aggregate capital stock at t and S_t denote the aggregate capital stock "in process" for period $t+1$. Capital in process at t for $t+1$ is the sum of current investment I_t and the stock of undepreciated capital, $(1-\delta)K_t$.

$$S_t = (1-\delta)K_t + I_t. \tag{2}$$

Capital in process for period t, S_{t-1} is transformed into capital after the realization of a multiplicative shock to capital quality, ψ_t.

$$K_t = \psi_t S_{t-1} \tag{3}$$

Following the finance literature (e.g., Merton (1973)), we introduce the capital quality shock as a simple way to introduce an exogenous source of variation in the value of capital. As will become clear later, the market price of capital will be endogenous within our framework. In this regard, the capital quality shock will serve as an exogenous trigger of asset price dynamics. The random variable ψ_{t+1} is best thought of as capturing some form of economic obsolescence, as opposed to physical depreciation.[7] We assume the capital quality shock ψ_{t+1} also follows a Markov process, with an unconditional mean of unity. In addition, we allow for occasional disasters in the form of sharp contractions in quality, as describe later. These disaster shocks serve to instigate financial crises.[8]

Firms acquire new capital from capital goods producers. There are convex adjustment costs in the gross rate of change in investment for capital goods producers. Aggregate output is divided between household consumption C_t, investment expenditures, and government consumption G_t,

$$Y_t = C_t + [1 + f(\frac{I_t}{I_{t-1}})]I_t + G_t \tag{4}$$

[7] One way to motivate this disturbance is to assume that final output is a C.E.S. composite of a continuum of intermediate goods that are in turn produced by employing capital and labor in a Cobb-Douglas production technology. Suppose that, once capital is installed, capital is good-specific and that each period a random fraction of goods become obsolete and are replaced by new goods. The capital used to produced the obsolete goods is now worthless and the capital for the new goods is not fully on line. The aggregate capital stock will then evolve according to equation. (3).

[8] Other recent papers that make use of this kind of disturbance include, Gertler and Karadi (2010), Brunnermeier and Sannikov (2009) and Gourio (2009). An alternative (but more cumbersome) approach would be to introduce a "news" shock that affects current asset values. Gertler and Karadi (2010) illustrate the similarities between the two approaches.

where $f(\frac{I_t}{I_{t-1}})I_t$ reflects physical adjustment costs, with $f(1) = f'(1) = 0$ and $f''(I_t/I_{t-1}) > 0$. Thus the aggregate production function of capital goods producers is decreasing returns to scale in the short-run and is constant returns to scale in the long-run.

Next we turn to preferences. Our exact specification follows Miao and Wang (2010), which is in turn based on Guvenen (2009) and Greenwood, Hercowitz and Huffman (GHH, 1988):

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{1}{1-\gamma} \left(C_\tau - hC_{\tau-1} - \frac{\chi}{1+\varphi} L_\tau^{1+\varphi} \right)^{1-\gamma} \tag{5}$$

where E_t is the expectation operator conditional on date t information and $\gamma > 0$. The preference specification allows for both habit formation and GHH preferences over hours: The latter, of course, eliminates wealth effects from labor supply. As will become clear, these features improve the ability for the model to capture business cycle dynamics despite the absence of labor market frictions. At the same time, they permit introducing reasonable degrees of risk aversion to examine asset pricing and portfolio structure.

We abstract from many frictions in the conventional DSGE framework (e.g. nominal price and wage rigidities, variable capital utilization, etc.).[9] However, we allow both habit formation of consumption and adjustment costs of investment because, as the DSGE literature has found, these features are helpful for reasonable quantitative performance and because they can be kept in the model at minimal cost of additional complexity.

If there were no financial frictions, the competitive equilibrium would correspond to a solution of the planner's problem that involves choosing aggregate quantities $(Y_t, L_t, C_t, I_t, S_t)$ as a function of the aggregate state $(C_{t-1}, I_{t-1}, S_{t-1}, A_t, \psi_t)$ in order to maximize the expected discounted utility of the representative household subject to the resource constraints. This frictionless economy will serve as a benchmark to which we may compare the implications of the financial frictions.

In what follows we will introduce banks that intermediate funds between households and nonfinancial firms. We will also introduce financial frictions that may impede credit flows. A new feature of the model is that banks can offer households state-contingent liabilities as well as non-contingent liabilities. We will then study the consequences for real activity and also analyze the implications for government policy.

[9] See, e.g.,Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007).

2.2 Households

In our economy with credit frictions, households lend to nonfinancial firms via financial intermediaries. Following Gertler and Karadi (2009) and Gertler and Kiyotaki (2010), we formulate the household sector in way that permits maintaining the tractability of the representative agent approach.

In particular, there is a representative household with a continuum of members of measure unity. Within the household there are $1-f$ "workers" and f "bankers". Workers supply labor and return their wages to the household. Each banker manages a financial intermediary (which we will call a "bank") and transfers nonnegative dividends back to household subject to its flow of fund constraint. Within the family there is perfect consumption insurance.

Households do not acquire capital nor do they provide funds directly to nonfinancial firms. Rather, they supply funds to banks. (It may be best to think of them as providing funds to banks other than the ones they own). Banks offer two types of liabilities to households: non-contingent riskless short term debt (deposits) and equity, which may be thought of as perfectly state contingent debt. We refer to equity issued by banks and held by households as "outside" equity. This contrasts with the accumulated retained earnings of a banker who manages an intermediary and is involved in the operation. We refer to the latter as "inside" equity. The distinction between outside and inside equity will become important later since banks will face constraints in obtaining external funds.

In addition, households may acquire short term riskless government debt. Both intermediary deposits and government debt are one period real bonds that pay the gross real return R_t from $t-1$ to t. In the equilibrium we consider, the instruments are both riskless and are thus perfect substitutes. Thus, we impose this condition from the outset. As will be clear later, it will not matter in our model whether households hold government debt directly or do so indirectly via financial intermediaries (who in turn issue deposits to households.)

We normalize the units of outside equity so that each equity is a claim to the future returns of one unit of the asset that the bank holds. Let Z_t be the flow returns at t generated by one unit of the bank's assets and q_t the price of the outside equity at t. Then the payoff at t for a share of outside equity acquired at $t-1$ equals $[Z_t + (1-\delta)q_t]\,\psi_t$. Note that the payoff is adjusted for both the physical depreciation and the quality adjustment of the capital

that underlies bank assets.

The household chooses consumption, labor supply, riskless debt, and outside equity $(C_t, L_t, D_{ht}, \overline{e}_t)$ to maximize expected discounted utility (5) subject to the flow of funds constraint,

$$C_t + D_{ht} + q_t \overline{e}_t = W_t L_t + \Pi_t - T_t + R_t D_{ht-1} + [Z_t + (1-\delta) q_t] \psi_t \overline{e}_{t-1}. \quad (6)$$

Here W_t is the wage rate, T_t is lump sum taxes, and Π_t is net distributions from ownership of both banks and nonfinancial firms. Let u_{Ct} denote the marginal utility of consumption and $\Lambda_{t,t+1}$ the household's stochastic discount factor. Then the household's first order conditions for labor supply and consumption/saving are given by

$$E_t u_{Ct} W_t = \chi L_t^{\varphi} (C_t - hC_{t-1} - \frac{\chi}{1+\varphi} L_t^{1+\varphi})^{-\gamma}, \quad (7)$$

$$E_t \left(\Lambda_{t,t+1} \right) R_{t+1} = 1, \quad (8)$$

$$E_t (\Lambda_{t,t+1} R_{et+1}) = 1 \quad (9)$$

with

$$u_{Ct} \equiv (C_t - hC_{t-1} - \frac{\chi}{1+\varphi} L_t^{1+\varphi})^{-\gamma} - \beta h (C_{t+1} - hC_t \frac{\chi}{1+\varphi} L_{t+1}^{1+\varphi})^{-\gamma}$$

$$\Lambda_{t,\tau} \equiv \beta^{\tau - t} \frac{u_{C\tau}}{u_{Ct}}.$$

$$R_{et+1} = \frac{[Z_{t+1} + (1-\delta) q_{t+1}] \psi_{t+1}}{q_t}$$

Because banks may be financially constrained, bankers will retain earnings to accumulate assets. Absent some motive for paying dividends, they may find it optimal to accumulate to the point where the financial constraint they face is no longer binding. In order to limit bankers' ability to save to overcome financial constraints, we allow for turnover between bankers and workers. In particular, we assume that with i.i.d. probability $1-\sigma$, a banker exits next period, (which gives an average survival time $= \frac{1}{1-\sigma}$). Upon exiting, a banker transfers retained earnings to the household and becomes a worker. Note that the expected survival time may be quite long (in our

baseline calibration it is eight years.) It is critical, however, that the expected horizon is finite, in order to motivate payouts while the financial constraints are still binding.

Each period, $(1-\sigma)f$ workers randomly become bankers, keeping the number in each occupation constant. Finally, because in equilibrium bankers will not be able to operate without any financial resources, each new banker receives a "start up" transfer from the family as a small constant fraction of the total assets of entrepreneurs. Accordingly, Π_t is net funds transferred to the household, i.e., funds transferred from exiting bankers minus the funds transferred to new bankers (aside from small profits of capital goods producers).

An alternative to our approach of having a consolidated family of workers and bankers would be to have the two groups as distinct sets of agents, without any consumption insurance between the two groups. It is unlikely, however, that the key results of our paper would change qualitatively. By sticking with complete consumption insurance, we are able to have lending and borrowing in equilibrium and still maintain the tractability of the representative household approach.

2.3 Nonfinancial Firms

There are two types of nonfinancial firms: goods producers and capital producers.

2.3.1 Goods Producers

Competitive goods producers operate a constant returns to scale technology with capital and labor inputs, given by equation (1). Firms choose labor to satisfy

$$W_t = (1-\alpha)\frac{Y_t}{L_t} \tag{10}$$

It follows that we may express gross profits per unit of capital Z_t as follows:

$$Z_t = \frac{Y_t - W_t L_t}{K_t} = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha}. \tag{11}$$

A goods producer does not face any financial frictions in obtaining funds from banks and can commit to pay all the future gross profits to the creditor

bank. In particular, we suppose that the bank is efficient at evaluating and monitoring nonfinancial firms and also at enforcing contractual obligations with these borrowers. That is why these borrowers rely exclusively on banks to obtain funds. A goods producer with an opportunity to invest obtains funds from a bank by issuing new state-contingent securities at the price Q_t. The producer then uses the funds to buy new capital goods from capital goods producers. Each unit of the security is a state-contingent claim to the future returns from one unit of investment:

$$\psi_{t+1}Z_{t+1}, (1-\delta)\psi_{t+1}\psi_{t+2}Z_{t+2}, (1-\delta)^2\psi_{t+1}\psi_{t+2}\psi_{t+3}Z_{t+3}, \ldots .$$

Through perfect competition, the price of new capital goods is equal to Q_t, and goods producers earn zero profits state-by-state.

2.3.2 Capital Goods Producers

Capital producers make new capital using input of final output and subject to adjustment costs, as described in section 2.2. They sell new capital to firms at the price Q_t. Given that households own capital producers, the objective of a capital producer is to choose I_t to solve:

$$\max E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\}$$

From profit maximization, the price of capital goods is equal to the marginal cost of investment goods production as follows,

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'(\frac{I_t}{I_{t-1}}) - E_t\Lambda_{t,t+1}(\frac{I_{t+1}}{I_t})^2 f'(\frac{I_{t+1}}{I_t}) \qquad (12)$$

Profits (which arise only outside of steady state), are redistributed lump sum to households.

2.4 Banks

To provide funds to goods producers in each period, banks raise funds both internally from retained earnings and externally from households. At the beginning of the period each bank raises deposits d_t and outside equity e_t from households. In addition the bank has its own net worth, n_t accumulated

from retained earnings. We refer to n_t as inside equity. The bank then uses all its available funds to make loans to nonfinancial firms.

Financial frictions affect real activity in our framework via the impact on funds available to banks. As noted earlier, however, there is no friction in transferring funds between a bank and nonfinancial firms: Given its supply of available funds, a bank can lend frictionlessly to nonfinancial firms against their future profits. In this regard, firms are able to offer banks a perfectly state-contingent security.

Along with raising funds via deposits and outside equity issues from households, a bank decides the volume of loans s_t to make to nonfinancial firms. Q_t is the price of a state-contingent security (or "asset") - i.e. the market price of the bank's claim on the future returns from one unit of a nonfinancial firm's capital at the end of period t (i.e. capital at t in process for $t+1$).

For an individual bank, the flow-of-funds constraint implies the value of loans funded within a given period, $Q_t s_t$, must equal the sum of bank net worth n_t, and funds raised from households, consisting of outside equity $q_t e_t$ and deposits d_t.

$$Q_t s_t = n_t + q_t e_t + d_t. \tag{13}$$

Note that in general, Q_t need not equal q_t. As will become clear, when the bank is financially constrained, the price of outside equity, q_t, will in general exceed the value of a bank's claim on a unit of capital of nonfinancial firm, Q_t, given that only banks can provide funds costlessly to goods producers.

While banks may issue new outside equity, they raise inside equity only through retained earnings.[10] Since inside equity involves management and control of the firm's assets, we suppose it is prohibitively costly for the existing insiders to bring in new ones with sufficient wealth. In particular, the bank's net worth n_t at t is the gross payoff from assets funded at $t-1$, net of returns to outside equity holders and depositors, as follows:

$$n_t = [Z_t + (1-\delta)Q_t]\,\psi_t s_{t-1} - [Z_t + (1-\delta)q_t]\,\psi_t e_{t-1} - R_t d_{t-1} \tag{14}$$

where, as before, Z_t is the dividend payment at t on the loans the bank funds at $t-1$. Observe that outside equity permits the bank to hedge risks

[10] As a crude first pass, it might be useful to think of inside equity as common equity and outside equity as preferred equity. Insiders in a firm are more likely to hold the former and outsiders the latter. This is because common equity holders are the firm's ultimate residual claimants, while preferred equity holders receive a smoother stream of returns. In general, common equity is thought to be more costly to issue than preferred equity.

associated with shocks to both Z_t and the asset quality shock ψ_t. It is this hedging value that makes it attractive to the bank to issue outside equity.

When the bank is financial constrained, it finds it optimal to accumulate retained earnings until the time it exits. Accordingly, given that the bank pays dividends only when it exits (which occurs with a constant probability), the objective of the bank at the *end* of period t is the expected present value of future terminal dividend payout, as follows

$$V_t = E_t \left[\sum_{\tau=t+1}^{\infty} (1-\sigma)\, \sigma^{\tau-t-1} \Lambda_{t,\tau} n_\tau \right] \tag{15}$$

To motivate an endogenous constraint on the bank's ability to obtain funds, we introduce the following simple agency problem: We assume that after a bank obtains funds, the banker managing the bank may transfer a fraction of assets to his or her family. It is the recognition of this possibility that has households limit the funds they lend to banks.

In addition, we assume that the fraction of funds the bank may divert, further, depends on the composition of its liabilities. In particular, we assume that at the margin it is more difficult to divert assets funded by short term deposits than by outside equity. Short term deposits require the bank to continuously meet a non-contingent payment. Dividend payments, in contrast, are tied to the performance of the bank's assets, which is difficult for outsiders to monitor. By giving banks less discretion over payouts, short term deposits offer more discipline over bank managers than outside equity.[11]

Let x_t denote the fraction of bank assets funded by outside equity, as follows:

$$x_t = \frac{q_t e_t}{Q_t s_t} \tag{16}$$

Then we assume that after the bank has obtained funds it may divert the fraction $\Theta(x_t)$ of assets, where $\Theta(x_t)$ is the following convex function of x_t:

$$\Theta(x_t) = \theta \left(1 + \varepsilon x_t + \frac{\kappa}{2} x_t^2 \right) \tag{17}$$

We allow for the possibility that there could be some efficiency gains in monitoring the bank from having at least a bit of outside equity participation in funding the bank (i.e. ε can be negative). However, we restrict attention to

[11] The idea that short term debt serves as a disciplining devices over banks is due to Calomiris and Kahn (1991).

calibrations where the bank's ability to divert assets increases when outside equity replaces deposits for funding at the margin, i.e., $\theta(\varepsilon + \kappa x_t)$ is positive. Finally, we assume that the banker's decision over whether to divert funds must be made at the end of the period t but before the realization of aggregate uncertainty in the following period. Here the idea is that if the banker is going to divert funds, it takes time to position assets and this must be done between the periods (e.g., during the night).

If a bank diverts assets for its personal gain, it defaults on its debt and is shut down. The creditors may re-claim the remaining fraction $1 - \Theta(x_t)$ of funds. Because its creditors recognize the bank's incentive to divert funds, they will restrict the amount they lend. In this way a borrowing constraint may arise.

Let $V_t(s_t, e_t, d_t)$ be the maximized value of the bank's objective V_t, given an asset and liability configuration (s_t, e_t, d_t) at the *end* of period t. Then in order to ensure the bank does not divert funds, the following incentive constraint must hold:

$$V_t \geq \Theta(x_t) Q_t s_t, \tag{18}$$

Equation (18) states simply that for households to be willing to supply funds to a bank, the bank's franchise value V_t must be at least as large as its gain from diverting funds.

In general the franchise value of the bank at the end of period $t-1$ satisfies the Bellman equation

$$\begin{aligned} & V_{t-1}(s_{t-1}, e_{t-1}, d_{t-1}) & (19) \\ = \; & E_{t-1}\Lambda_{t-1,t}\{(1-\sigma)n_t + \sigma \underset{s_t, e_t . d_t}{Max}[V_t(s_t, e_t, d_t)]\}. & (20) \end{aligned}$$

where the right side takes into account that the bank exits with probability $1 - \sigma$ and continues with probability σ.

To solve the decision problem, we first guess that the value function is linear in the bank portfolio structure as follows:

$$V_t(s_t, e_t, d_t) = \nu_{st} s_t - \nu_{et} e_t - \nu_t d_t \tag{21}$$

where ν_{st} is the shadow value to the bank of a unit of assets, ν_{et} is the shadow cost of a unit of outside equity and ν_t is the shadow cost of a unit deposits. Next, let μ_{st} be the excess value of a unit of bank assets over deposits and

μ_{et} the excess value per unit from switching from deposits to outside equity finance, as follows:

$$\mu_{st} \equiv \frac{\nu_{st}}{Q_t} - \nu_t, \tag{22}$$
$$\mu_{et} \equiv \nu_t - \frac{\nu_{et}}{q_t}.$$

Then combining the flow of funds constraint (13) with equation (21) allows us to write the conjectured solution for V_t in terms of excess values, as follows:

$$V_t(s_t, e_t, d_t) = \mu_{st} Q_t s_t + \mu_{et} q_t e_t + \nu_t n_t \tag{23}$$

Now insert the conjectured solution (23) for $V_t(s_t, e_t, d_t)$ into the Bellman equation (19) and use the relation $x_t = q_t e_t / Q_t s_t$ to eliminate e_t. Then maximize this objective with respect to the to the incentive constraint (18). Given that λ_t is the Lagrangian multiplier with respect to the incentive constraint, the first order necessary conditions for x_t, s_t and λ_t yield:

$$(1 + \lambda_t)\, \mu_{et} = \lambda_t \theta (\varepsilon + \kappa x_t), \tag{24}$$

$$(1 + \lambda_t)\, (\mu_{st} + x_t \mu_{et}) = \lambda_t \theta \left(1 + \varepsilon x_t + \frac{\kappa}{2} x_t^2\right), \tag{25}$$

$$(\mu_{st} + x_t \mu_{et}) Q_t s_t + \nu_t n_t = \Theta(x_t) Q_t s_t. \tag{26}$$

The left side of equation (24) is the marginal benefit to the bank from substituting outside equity finance for unit of short term debt. The right side is the marginal cost, equal to the increase in the fraction of assets the bank can divert times the shadow value of the incentive constraint λ_t.

The first order condition for Equation (25) implies that the marginal benefit from increasing asset s_t adjusted for additional equity finance, $\mu_{st} + x_t \mu_{et}$ is equal to the marginal cost of tightening the incentive constraint by $\theta \left(1 + \varepsilon x_t + \frac{\kappa}{2} x_t^2\right)$.

Finally, the first order condition for λ_t yields the incentive constraint. From (25), we learn that the incentive constraint binds (λ is positive) only if the adjusted excess value of bank assets $\mu_{st} + x_t \mu_{et}$ is positive.

Combing equations $(24, 25)$ yields a relation for x_t the is increasing in the ratio of excess values μ_{et} / μ_{st} :

$$
\begin{aligned}
x_t &= -(\frac{\mu_{et}}{\mu_{st}})^{-1} + \sqrt{(\frac{\mu_{et}}{\mu_{st}})^{-2} + \frac{2}{\kappa}(1 - \varepsilon(\frac{\mu_{et}}{\mu_{st}})^{-1})} \qquad (27) \\
&\equiv x\left(\frac{\mu_{et}}{\mu_{st}}\right), \text{ where } x' > 0 \text{ given } \kappa > \frac{1}{2}\varepsilon^2.
\end{aligned}
$$

Next, let ϕ_t be the maximum ratio of bank assets to net worth to satisfies the incentive constraint. Then rearranging the incentive constraint yields the following relation between $Q_t s_t$ and n_t.

$$
Q_t s_t = \phi_t n_t \qquad (28)
$$

with

$$
\phi_t = \frac{\nu_t}{\Theta(x_t) - (\mu_{st} + x_t \mu_{et})}. \qquad (29)
$$

Equation (28) is a key relation of the banking sector: It indicates that when the borrowing constraint binds, the total quantity of private assets that a bank can intermediate is limited by its net worth, n_t.The relation is fairly intuitive: the leverage ratio ϕ_t is increasing in the adjusted excess value of banks assets $(\mu_{st} + x_t \mu_{et})$ and the marginal cost of deposit ν_t (which can be saved by an additional net worth). Both these factors raise the franchise value of bank in (23), which reduces the banks incentive to divert funds. This makes creditors willing to fund more assets for a given level of bank net worth. Conversely, ϕ_t is decreasing in $\Theta(x_t)$, the fraction of funds banks are able to divert.

Next, insert the conjectured value function back into the Bellman to solve for the undetermined coefficients. Then the solutions for the undetermined coefficients $(\nu_t, \mu_{st}, \mu_{et})$ are given by,

$$
\nu_t = E_t(\Lambda_{t,t+1}\Omega_{t+1})R_{t+1}, \qquad (30)
$$

$$
\mu_{st} = E_t[\Lambda_{t,t+1}\Omega_{t+1}(R_{kt+1} - R_{t+1})] \qquad (31)
$$

$$
\mu_{et} = E_t[\Lambda_{t,t+1}\Omega_{t+1}(R_{t+1} - R_{et+1})] \qquad (32)
$$

with

$$
\Omega_{t+1} = 1 - \sigma + \sigma[\nu_{t+1} + \phi_{t+1}(\mu_{st+1} + x_{t+1}\mu_{et+1})] \qquad (33)
$$

$$
R_{kt+1} = \frac{[Z_{t+1} + (1-\delta)Q_{t+1}]\,\psi_{t+1}}{Q_t} \qquad (34)
$$

and where the return on outside equity R_{et+1} is given by equation (9). R_{kt+1} is the rate of return on asset held from t to $t+1$ and Ω_{t+1} denotes the shadow value of a unit of net worth to the bank.

Note first that the shadow value of net worth for next period, Ω_{t+1} is the probability weighted average of the marginal values for exiting and for continuing banks. For an exiting bank, the marginal value is unity - i.e., equivalent to an additional unit of consumption goods. For a continuing bank it is the sum of the saving on deposits ν_{t+1} and the payoff from being able to hold more assets: the product of the leverage ratio ϕ_{t+1} and the adjusted excess value $\mu_{st} + x_t \mu_{et}$. Since both the leverage ratio and excess returns vary countercyclically, so too will the shadow value of net worth. Put differently, because the bank's incentive constraint is tighter in recessions than in booms, an additional unit of net worth is more valuable in bad times than in good times.

Let us define the "augmented stochastic discount factor" as the household stochastic discount factor $\Lambda_{t,t+1}$ multiplied by the stochastic marginal value of net worth Ω_{t+1}. Since both Ω_{t+1} and $\Lambda_{t,t+1}$ are counter-cyclical, the augmented stochastic discount factor is more volatile than the household stochastic discount factor. According to (30), the cost of deposits per unit to the bank ν_t is the expected product of the augmented stochastic discount factor and the deposit rate R_{t+1}.

From (31), the excess value of assets per unit, μ_{st}, is the expected value of the product of the augmented stochastic discount factor and the excess return $R_{kt+1} - R_{t+1}$. Note that since the excess return to assets $R_{kt+1} - R_{t+1}$ tends to be procyclical while Ω_{t+1} is counter-cyclical, the volatility in the shadow value of net worth has the effect of reducing the continuation value of the bank, and thus the leverage ratio ϕ_t. In this way, uncertainty affects the bank's ability to obtain funds.

From (32), the excess value of outside equity issue is the expected value of the product of the augmented stochastic discount factor and the difference in the rate of returns on deposit and outside equity $R_{t+1} - R_{et+1}$. From the household's portfolio decision, we learn the arbitrage relation between the deposit rate and the return on outside equity:

$$E_t[\Lambda_{t,t+1}(R_{t+1} - R_{et+1})] = 0 \tag{35}$$

Observe that the household discounts the returns by the stochastic factor $\Lambda_{t,t+1}$ while the banker uses a discount factor $\Lambda_{t,t+1}\Omega_{t+1}$, which fluctuates

more counter-cyclically. As a consequence, the bank obtains hedging value by switching from deposits to outside equity: The excess value of outside equity issue $\mu_{et} = E_t[\Lambda_{t,t+1}\Omega_{t+1}(R_{t+1} - R_{et+1})]$ is positive.

Absent any cost of issuing state-contingent liabilities, the bank would move to one hundred percent outside equity finance. However, increasing the fraction of outside equity enhances the incentive problem by making it easier for bankers to divert funds, as equation (18) suggests. Thus the bank faces a trade-off in issuing outside equity. In general, there will be an interior solution for outside equity finance. Later we explore whether or not the decentralized solution is socially optimal.

While outside equity improves banks' ability to hedge fluctuations in net worth, what matters for the overall outside credit they can obtain is their internal equity, or net worth, along with the maximum feasible leverage ratio ϕ_t. Since ϕ_t does not depend on bank-specific factors, we can aggregate equation (28) to obtain a relation between the aggregate demand for securities by banks S_{pt} and aggregate net worth in the banking sector N_t.

$$Q_t S_{pt} = \phi_t N_t \tag{36}$$

The evolution of N_t accordingly plays an important role in the dynamics of the model economy. We turn to this issue next.

2.5 Evolution of Aggregate Bank Net Worth

Total net worth in the banking sector banks, N_t, equal the sum of the net worth of existing entrepreneurs N_{ot} (o for old) and of entering entrepreneurs N_{yt} (y for young):

$$N_t = N_{ot} + N_{yt}. \tag{37}$$

Net worth of existing entrepreneurs equals earnings on assets held in the previous period net the cost of outside equity finance and the cost of deposit finance, multiplied by the fraction that survive until the current period, σ:

$$N_{ot} = \sigma\{[Z_t + (1-\delta)Q_t]\psi_t S_{t-1} - [Z_t + (1-\delta)q_t]\,\psi_t \overline{e}_{t-1} - R_t D_{t-1}\}. \tag{38}$$

Since new bankers cannot operate without any net worth, we assume that the family transfers to each one the fraction $\xi/(1-\sigma)$ of the total value assets of exiting entrepreneurs, where ξ is a small number. This implies:

$$N_{yt} = \xi[Z_t + (1-\delta)Q_t]\psi_t S_{t-1}. \tag{39}$$

In the calibration that follows, we choose ξ so that in steady state, the ratio of bank assets to net worth is approximately equal to the observation in the US. Note that the functional form of the transfer is chosen for technical convenience.

$$N_t = (\sigma + \xi)\left[Z_t + (1-\delta)Q_t\right]\psi_t S_{t-1} - \sigma\left[Z_t + (1-\delta)q_t\right]\psi_t \overline{e}_{t-1} - \sigma R_t D_{t-1} \tag{40}$$

Observe that the evolution of net worth depends on fluctuations in the return to assets. Further, the higher the leverage of the bank is, the larger will be the percentage impact of return fluctuations on net worth. The use of outside equity, however, reduces the impact of return fluctuations on net worth.

Note finally that a deterioration of capital quality (a decline in ψ_t) directly reduces net worth. As we will show, there will also be a second round effect, as the decline in net worth induces a fire sale of assets, depressing asset prices and thus further depressing bank net worth.[12]

2.6 Credit Policy

Earlier we characterized how the total value of privately intermediated assets, $Q_t S_{pt}$, is determined. We now suppose that the central bank is willing to facilitate lending. As we discussed earlier, this kind of credit policy corresponds to the central bank's large scale purchase of high grade private securities, which was at the center of its attempt to stabilize credit markets during the peak of the financial crisis.[13] Let $Q_t S_{gt}$ be the value of assets intermediated via government assistance and let $Q_t S_t$ be the total value of intermediated assets:

[12] According to the profit distribution, the net profit transfer from banks and capital goods producers to the representative household is

$$\begin{aligned}\Pi_t &= Q_t I_t - I_t\left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] - \xi[Z_t + (1-\delta)Q_t]\psi_t S_{t-1} \\ &\quad + (1-\sigma)\left\{[Z_t + (1-\delta)Q_t]\psi_t S_{t-1} - [Z_t + (1-\delta)q_t]\psi_t \overline{e}_{t-1} - R_t D_{t-1}\right\}.\end{aligned}$$

[13] Accordingly, this analysis concentrates on the central bank's direct lending programs which we think were the most important dimension of its balance sheet activities. See Gertler and Kiyotaki (2010) for a formal characterization of the different types of credit market interventions that the Federal Reserve and Treasury pursued in the current crisis.

$$Q_t S_t = Q_t S_{pt} + Q_t S_{gt} \tag{41}$$

To conduct credit policy, the central bank issues government debt to households that pays the riskless rate R_{t+1} and then lends the funds to non-financial firms at the market lending rate R_{kt+1}. We suppose that government intermediation involves efficiency costs: in particular, the central bank credit involves an efficiency cost of τ per unit supplied. This deadweight loss could reflect the administrative costs of raising funds via government debt. It might also reflect costs to the central bank of identifying preferred private sector investments. On the other hand, the government always honors its debt: thus, unlike the case with private financial institutions there is no agency conflict than inhibits the government from obtaining funds from households. Put differently, unlike private financial intermediation, government intermediation is not balance sheet constrained.[14]

Accordingly, suppose the central bank is willing to fund the fraction ζ_t of intermediated assets: i.e.,

$$S_{gt} = \zeta_t S_t \tag{42}$$

As we show, by increasing ζ_t the central bank can reduce the excess return $\mu_{st} = E_t[\Lambda_{t,t+1}\Omega_{t+1}(R_{kt+1} - R_{t+1})]$. In this way credit policy can reduce the cost of capital, thus stimulating investing. Later we describe how the central bank may choose the path of ζ_t to combat a financial crisis.

Finally, to fund its asset purchases the central bank can issue government debt D_{gt} equal to $\zeta_t Q_t S_t$. Its net earnings from intermediation in any period t thus equals $(R_{kt+1} - R_{t+1})D_{gt}$. These net earnings provide a source of government revenue and must be accounted for in the budget constraint, as we discuss next.

[14] An equivalent formulation of credit policy has the central bank issue government debt to financial intermediaries. Intermediaries in turn fund their government debt holdings by issuing deposits to households that are perfect substitutes. Assuming the agency problem applies only to the private assets it holds, a financial intermediary is not constrained in financing its government debt holdings. Thus, only the funding of private assets by financial institutions is balance sheet constrained. As in the baseline scenario, the central bank is able to elastically issue government debt to fund private assets. It is straightforward to show that the equilibrium conditions in the scenario are identical to those in the baseline case. (The identical intermediary balance sheet constraint on private assets holds). One virture of this scenario is that the intermediary holdings of government debt are interpretable as interest bearing reserves, which is how the central bank has funded its assets in practice.

2.7 Government Budget Constraint

Government expenditures consist of government consumption G, which we hold fixed, and monitoring costs from central bank intermediation:

$$G_t = G + \tau S_{gt}, \tag{43}$$

The government budget constraint, in turn is

$$G_t + Q_t S_{gt} + R_t D_{gt-1} = T_t + [Z_t + (1-\delta)Q_t]\, \psi_t S_{gt-1} + D_{gt}, \tag{44}$$

where T_t is lump-sum taxes on the household.

2.8 Equilibrium

To close the model, we require market clearing in both the market for bank securities S_t, outside equity, $\overline{e}_t$, and deposits D_t.

Market clearing for bank securities requires that the total supply of securities given by equation (2) net government security purchases, must equal private demand S_{pt} given by equations (36) and (29). This implies,

$$Q_t(S_t - S_{gt}) = \frac{\nu_t}{\theta(1+\varepsilon x_t + x_t^2) - (\mu_{st} + x_t \mu_{et})} N_t, \tag{45}$$

Similarly in the market equilibrium for outside equity, the demand by households $\overline{e}_t$ equals the supply by banks e_t

$$q_t \overline{e}_t = x_t \cdot Q_t S_{pt}, \tag{46}$$

where the fraction of total assets funded by outside equity x_t is given by equation (27). Finally, given the flow of funds constraint, equilibrium deposits must equal aggregate bank assets net outside equity and net worth:

$$D_t = D_{ht} - D_{gt} = (1-x_t)Q_t S_{pt} - N_t. \tag{47}$$

The final equilibrium condition is that labor demand equals labor supply, which requires

$$(1-\alpha)\frac{Y_t}{L_t} \cdot E_t \left[\frac{u_{Ct}}{(C_t - hC_{t-1} - \frac{\chi}{1+\varphi} L_t^{1+\varphi})^{-\gamma}} \right] = \chi L_t^{\varphi} \tag{48}$$

To close the model we need to describe the exogenous processes for the productivity shock A_t and the capital quality shock ψ_t. Since we wish to concentrate on the impact of the capital quality shock, we simply fix A_t to a constant value A,

$$A_t = A \tag{49}$$

The capital quality shock, in contrast, follows a AR(1) process that allows for the possibility of infrequent "disasters". In particular: ψ_t is the product of a process that evolves in normal times, $\widetilde{\psi}_t$, and one that arises in "disasters" $\widetilde{\psi}_t^D$

$$\psi_t = \widetilde{\psi}_t \widetilde{\psi}_t^D$$

with

$$\log \widetilde{\psi}_t = \rho_{0\psi} + \rho_\psi \log \widetilde{\psi}_{t-1} + \sigma \epsilon_{\psi t} \tag{50}$$

$$\log \widetilde{\psi}_t^D = \rho_\psi \log \widetilde{\psi}_{t-1}^D + \eta_t \tag{51}$$

where $\epsilon_{\psi t}$ is distributed $N(0,1)$, and η_t is distributed binomial:

$$\eta_t = \begin{Bmatrix} -(1-\pi)\Delta & \text{with prob. } \pi \\ \pi\Delta & \text{with prob } 1-\pi \end{Bmatrix}$$

where Δ is a positive number, implying the disaster innovation $-(1-\pi)\Delta$ is negative. We normalize the process so that the mean of η_t is zero and the variance is:

$$\mathbb{E}(\eta_t^2) = \pi(1-\pi)\Delta^2; \tag{52}$$

In practice, assuming the disaster shock Δ is not too large, we will be able to capture risk with a second order approximation of the model. In this instance, what will matter for capturing risk is the overall standard deviation of the combined ψ_t shock. We introduce the disaster formulation to enrich the economic interpretation of the model.

The equations $(1, 2, 3, 4, 6, 8, 9, 11, 12, 27, 30, 31, 32, 40, 45, 46, 47, 48)$ determine the seventeen endogenous variables $(Y_t, K_t, S_t, C_t, I_t, L_t, Z_t, R_{t+1}, q_t,$ $\nu_{t,}\mu_{st}, \mu_{et}, x_t, Q_t, N_t, \overline{e}_t, D_t)$ as a function of the state variables $(S_{t-1}, C_{t-1}, I_{t-1},$ $\overline{e}_{t-1}, R_t D_{t-1}, R_t D_{gt-1}, S_{gt-1}, A_t, \psi_t)$, together with the exogenous stochastic

process of (A_t, ψ_t) and the government policy vector of $(G_t, T_t, S_{gt}, D_{gt})$. One of these eighteen equations is not independent by Walras Law.

Absent credit market frictions, the model reduces to a real business cycle framework modified with habit formation and flow investment adjustment costs. With the credit market frictions, however, balance sheet constraints on banks may limit real investment spending, affecting aggregate real activity. A crisis is possible where weakening of bank balance sheets significantly disrupts credit flows, depressing real activity.

3 Crisis Simulations and Policy Experiments

In this section we present several numerical experiments designed to illustrate how the model may capture some key features of a financial crisis and also how credit policy and also macro-prudential policy might work to mitigate the crisis. The analysis is meant only to be suggestive. As in our earlier work, we illustrate with quantitative examples how the financial system works to propagate the effects of a disturbance to asset values. Within our new framework, however, we are also able to characterize how, in the first place, banks might adopt a portfolio structure that is highly vulnerable to these disturbances. In particular, we are able to also generate quantitative examples of how both risk perceptions and perceptions of government intervention influence banks' liabilities structures, which in turn affect the vulnerability of the financial system. We then characterize how macro-prudential policy could work to mitigate some of the effects on bank risk taking.

3.1 Calibration

Not including the standard deviations of the exogenous disturbances, there are thirteen parameters for which we need to assign values. Eight are standard preference and technology parameters. These include the discount factor β, the coefficient of relative risk aversion γ, the habit parameter h, the utility weight on labor χ, the inverse of the Frisch elasticity of labor supply φ, the capital share parameter α, the depreciation rate δ and the elasticity of the price of capital with respect to investment η. For these parameters we use reasonably conventional values, as reported in Table 1.

The five additional parameters are specific to our model: σ the quarterly survival probability of bankers; ξ the transfer parameter for new bankers,

and the three parameters that help determine the fraction of gross assets that banker can divert: θ, ε and κ. We set $\sigma = 0.968$, implying that bankers survive for eight years on average.

Finally, we choose ξ, θ, ε and κ to hit four targets. The first three involve characteristics of the low risk economy: an average credit spread of ninety basis points per year, an economy-wide leverage ratio of four, and a ratio of outside to inside equity of one half. The last target is having the fraction of assets financed by outside equity increase by fifty percent as the economy moves from low risk to high risk. The choice of a leverage ratio of four reflects a crude first pass attempt to average across sectors with vastly different financial structures. For example, before the beginning of the crisis, most housing finance was intermediated by financial institutions with leverage ratios between twenty (commercial banks) and thirty (investment banks.) The total housing stock, however, was only about a third of the overall capital stock. Leverage ratios are clearly smaller in other sectors of the economy. We base the steady state target for the spread on the pre-2007 spreads as a rough average of the following spreads: mortgage rates versus government bond rates, BAA corporate bond rates versus government bonds, and commercial paper rates versus T-Bill rates. The two targets for outside equity are arbitrary and meant only for the purpose of illustration.

The standard deviations of the shock processes are picked so that standard deviation of annual output growth in the low risk case corresponds roughly to that in the Great Moderation period. In the high risk case, we double the size of the shock.

A key feature of the model is that the bank liability structure (i.e. the mix between outside equity and short term debt) depends on risk perceptions. It is thus important to take account of risk in the computation of the model. To do so, we borrow insights from the literature on international risk sharing (e.g., Devereux and Sutherland (2009) and Tille and Van Wincoop (2007)) and on asset pricing and business cycles (e.g. Campbell (1993,1994) Lettau (2003)) by working with second order approximations of the equations where risk perceptions matter. We then construct a "risk-adjusted" steady state, where given agents perceptions of second moments, variables remain unchanged if the realization of the (mean-zero) exogenous disturbance is zero. The risk-adjusted steady state differs from the non-stochastic state only by terms that are second order. These second order terms, which depend on variances and covariances of the endogenous variables pin down bank liability structure. To analyze model dynamics, we then look at a first

order log-linear approximation around the risk-adjusted steady state.

To calculate the relevant second moments we use an iterative procedure. We first log-linearize the model around the non-stochastic steady state. We then use the second moments calculated from this exercise to compute the risk-adjusted steady state. We repeat the exercise, this time calculating the moments from the risk-adjusted steady state. We keep iterating until the moments generated by the first order dynamics around the risk-adjusted steady state are consistent with the moments used to construct it.

One point to note about our model is that banks' outside equity will depend not only on second moments (the hedging value of outside equity) but also first moments, due to the cost stemming from the tightening of the incentive constraint (which is increasing in the excess return to capital). Thus, though we treat the second moment effect as constant, the first order effect will lead to cyclical variation in the use of outside equity.

3.1.1 No Policy Response

We begin by considering the behavior of the model economy without any kind of policy response both for the case of low risk and of high risk. We first examine the risk adjusted steady state in each case. Then we consider a crisis under each scenario. The crisis in each instance is initiated by a large decline in capital quality.

Table 2 shows the relevant statistics for the risk adjusted steady state both for the low and high risk economies. Note first that outside equity as a share of total bank liabilities, x, is nearly fifty percent greater in the high risk case than in the low risk case: It increases from roughly eight percent to nearly twelve percent. This occurs, of course, because equity has greater hedging value in the high risk case. The primary leverage ratio ϕ (capital to inside equity) declines as risk increases. This occurs for two reasons: First, the more extensive use of outside equity tightens the banks' borrowing constraint by intensifying the agency problem. Second, the excess return to bank assets, μ_{st}, falls as the covariance of the excess return on banks assets, $R_{kt+1} - R_{t+1}$, with the augmented stochastic discount factor, $\Lambda_{t,t+1}\Omega_{t+1}$, becomes more negative. This also tightens the banks borrowing constraint by reducing its franchise value (and thus increasing its incentive to divert assets.).

The net effect of the increase in outside equity x_t and the decline in bank asset-net worth ratio ϕ_t is that the leverage ratio, measured by the ratio of capital to total equity (inside plus outside) declines as risk increases.

This inverse relation between risk and leverage is consistent with conventional wisdom and has been stressed by a number of others (e.g., Fostel and Geanakoplos, 2009). Further, because it affects the ability of banks to intermediate funds, this behavior of the leverage ratio has consequences for the real equilibrium. In the risk-adjusted steady state, the capital stock is roughly eight percent lower in the high risk case. As a consequence, output and consumption are roughly four and a half percent lower.

The sensitivity of the leverage ratio to risk perceptions also has consequences for the dynamics outside the steady state and, in particular, for the response to a crisis. We illustrate this point next.

In particular, suppose the economy is hit by a decline in capital quality by five percent of the existing stock. (The shock is i.i.d., as we noted earlier). We fix the size of the shock simply to produce a downturn of roughly similar magnitude to the one observed over the past year. Within the model economy, the initial exogenous decline is then magnified in two ways. First, because banks are leveraged, the effect of decline in assets values on bank net worth is enhanced by a factor equal to the leverage ratio. Second, the drop in net worth tightens the banks' borrowing constraint inducing effectively a fire sale of assets that further depresses asset values. The crisis then feeds into real activity as the decline in asset values leads to a fall in investment.

Figure 1 displays the responses of the key variables for both the low and high risk cases. For comparison we also plot the response of a frictionless economy (denoted RBC for "real business cycle."). Note that the contraction in real activity is greatest in the low risk case. The reason is straightforward: The perception of low risk induces banks to make more extensive use of short term debt to finance assets and rely less heavily on outside equity. The high leverage ratio in the low risk case makes banks' inside equity highly susceptible to the declines in asset values initiated by the disturbance to capital quality. As a consequence, in the wake of the shock, the spread jumps roughly six hundred basis points. This in turn increases the cost of capital, which leads to a sharp contraction in investment, output and employment. Note the contraction in output in the low risk economy is at the peak of the trough nearly fifty percent greater than in the case of the model without financial frictions. The difference of course is due to the sharp widening of the spread that arises in the model with financial frictions. The spread further is slow to return to its norm as it takes time for banks to rebuild their stocks of inside equity. In the frictionless model, by contrast, the excess return is fixed at zero.

In the high risk economy the output contraction is more modest than in the low risk case. The anticipation of high risk induces banks to substitute outside equity for short term debt. Outside equity then acts as a buffer in two ways. First, it moderates the drop in inside equity induced by the decline in assets values. Second, as the crisis unfolds after the initiating disturbance, banks are able to relax their borrowing constraint a bit by shortening their maturity structure by substituting short term debt for outside equity. (Recall that short term debt permits creditors greater discipline over bankers). While outside equity moderates the downturn, it is not a perfect buffer. There is a modest increase in the spread of one hundred basis points, which is far less than what occurs in the low risk economy. Nonetheless, it is sufficient to induce a noticeably larger contraction than in the frictionless economy.

3.1.2 Credit Policy Response

Here we analyze the impact of direct central bank lending as a means to mitigate the impact of the crisis. Symptomatic of the financial distress in the simulated crisis is a large increase in the spread between the expected return on capital and the riskless interest rate. In practice, further, it was the appearance of abnormally large credit spreads in various markets that induced the central bank to intervene with credit policy. Accordingly we suppose that the Fed adjusts the fraction of private credit it intermediates, ζ_t, to the difference between spread $(E_t R_{kt+1} - R_{t+1})$, and its steady state value $(ER_k - R)$, as:

$$\zeta_t = \upsilon_g[(E_t R_{kt+1} - R_{t+1}) - (ER_k - R)] \tag{53}$$

We first examine the impact of the policy rule on the steady states for the low and high risk cases. To illustrate the impact of credit policy. We set the policy parameter υ_g equal to 100. Figure 2 reports the response of the economy to a crisis shock for the low risk case. In the low risk case, credit policy has a significant stabilizing effect on the economy. The increase in central bank credit significantly reduces the rise in the spread, which in turn reduces the overall drop in investment. At its peak, central bank credit increases to slightly over fifteen percent of the capital stock.

Figure 3 reports the impact of credit policy for the high risk case. The gain from credit policy is small in the high risk case. In order to understand why, Table 3 reports how the anticipation of government intervention affects the stochastic steady state of the low risk and high risk economies.

The anticipation of government intervention leads to a reduction in risk perceptions. Banks thus rely more heavily on short term debt, relative to the case with no policy. The effect is most dramatic in the high risk case, as the anticipation of policy intervention leads to a reduction in outside equity issuances of nearly thirty percent, as compared to only three percent in the low risk case. Note that in each case there is a positive first order effect on the quantity variables. This is due to the combined effect of reduced outside equity issuance and reduced risk perceived by the private sector, which work to relax bank borrowing constraints.

The gains from the credit policy is limited in the high risk case because, absent credit policy, banks hold a greater buffer of outside equity to absorb the disturbance. The anticipation of policy induces a kind of moral hazard effect, as banks rely less on their capital structure and more on public credit policy to absorb risks. Interestingly, even though gain in output stabilization is relatively modest, the size of the credit market intervention is roughly the same as in the low risk economy, as comparison of Figures 2 and 3 makes clear. Again, the reason is that anticipated policy intervention crowds out outside equity issuance in favor of short term debt. This necessitates a more intense credit policy intervention to stabilize credit spreads.

Another way to see the issue is to suppose the private sector does not anticipate credit policy. Then consider how intense an unanticipated credit policy would need to be, as measured by the feedback parameter, υ_g, to provide the same degree of stabilization as an anticipated policy of the same intensity as our baseline policy of $\upsilon_g = 100$. As Figure 4 illustrates, if the policy is unanticipated, a significantly more modest intervention will provide the same degree of stabilization. In this case an unanticipated intervention with $\upsilon_g = 20$ would provide identical stabilization to the anticipated baseline policy. As the figure shows, in this instance, the fraction of credit the central bank needs to intermediate is only a quarter of its value under perfectly anticipated policy.

The problem is that absent some form of commitment, it is not credible for the central bank to claim that it will not intervene during a crisis. Further, the ex post benefits to intervention are clearly greater the more highly leveraged is the banking sector, which increases the incentives of the central bank to intervene. Thus, it is rational for banks to anticipate credit policy intervention in a crisis, leading banks to raise their risk exposure.

We emphasize that how much moral hazard may reduce the net effectiveness of credit policy is a quantitative issue. In the low risk case, for example,

outside equity issuance is low because of risk perceptions and not because of anticipated policy. Because the likelihood of crises is low, anticipated interventions during crises do not have much impact on private capital structure decisions.

3.2 Macro-prudential Policy

Within our framework there are two related motives for a macro-prudential policy that encourages banks to use outside equity and discourages the use of short term debt. First, due to the role of asset prices in affecting borrowing constraints, there exists a pecuniary externality which banks do not properly internalize when deciding their respective liability structure. In particular, individual banks do not take account of the fact that if they were to issue outside equity in concert, they would make the banking sector better hedged against risk, thus dampening fluctuations in asset prices and economic activity. A number of papers have emphasized how, to counter its distortionary effects, this kind of externality might induce the need for some form of ex ante regulation or, equivalently Pigouvian taxation and/or subsidies. Examples include Lorenzoni (2009), Korinek (2009), Bianchi (2009) and Stein (2010).

Second, as we noted in the previous section, the anticipation of credit market interventions during a crisis may induce banks to hedge by less than they otherwise would, tilting their liability structure toward short term debt. How this factor might introduce a need for ex ante macro-prudential policy has also been emphasized in the literature. Recent examples that emphasize this kind of time consistency problem include Diamond and Rajan (2009), Fahri and Tirole (2010), and Chari and Kehoe (2009).

We now proceed to use our model to illustrate the impact of macro-prudential policy that works to offset banks' incentive to tilt their liability structure toward short term debt. In particular we suppose that the government offers banks a subsidy τ_t^s per unit of outside equity issued and finances the subsidy with a tax τ_t on total assets.[15] The flow of funds constraint for a bank is now given by

$$(1+\tau_t^s)\,Q_t s_t = n_t + (1+\tau_t^s) q_t e_t + d_t \tag{54}$$

[15] We restrict attention to policies that affect the incentive for banks to raise outside equity since within our framework inside equity can be raised only through retained earnings. In later work we plan to allow for a richer specification of inside equity accumulation.

where the bank takes τ_t^s and τ_t as given. In equilibrium the tax is set to make the subsidy revenue neutral, so that the net impact on bank revenues is zero. However, the subsidy will clearly raise the relative attractiveness to the bank of issuing outside equity.

In addition we suppose that the subsidy is set to make the net gain to outside equity from reducing deposits constant in terms of consumption goods. Hence we set τ_t^s equal to a constant τ^s divided by the shadow cost of deposits ν_t, as follows

$$\tau_t^s = \frac{\tau^s}{\nu_t} \tag{55}$$

We can then easily show that the first order condition for the outside equity share x_t with the subsidy present is given by

$$\mu_{et} + \tau^s = \frac{\lambda_t}{1+\lambda_t}\theta(\varepsilon + \kappa x_t) \tag{56}$$

The marginal benefit to the bank from issuing equity (the left hand side) is now the sum of the excess return from issuing equity and the subsidy τ^s.

The subsidy/tax scheme we propose has the flavor of a countercyclical capital requirement (for outside equity issue). The subsidy increases the steady state level of x_t: In this respect it is a capital requirement. At the same time, x_t will vary countercyclically as it does in the decentralized equilibrium, given that the shadow value of the incentive constraint λ_t is countercyclical.

We consider a subsidy that raises the steady state outside share to 0.15 for both the low and risk cases with credit policy. This approximately doubles the steady state value of x in each instance.

Figure 5 then illustrates the effect of a crisis in the high risk economy when the macro-prudential policy is in place. The key point to note is that in this instance a more modest intervention by credit policy can achieve a similar degree of stabilization of the economy. At the peak the fraction of government lending in the crisis is only a third of its level in the case with macro-prudential policy. Intuitively, the extra cushion of outside equity required by the macro-prudential policy reduces the need for central bank lending during the crisis. In addition, the two policies combined appear to offer slightly greater stabilization: The contraction of output is persistently smaller by roughly a quarter percent per year.

In the low risk economy anticipated credit policy does not have much effect on bank risk taking ex ante. As we noted earlier, short term debt

is high because perceptions of risk are low. Nonetheless, macro-prudential policy is still potentially useful given the pecuniary externality that leads banks to not properly internalize the aggregate effects of their individual leverage decisions. Figure 6 considers a crisis in the low risk economy where credit policy is not available as a stabilizing tool, either because it is too costly or not a politically viable option. As the figure illustrates, the macro-prudential policy by itself leads to a considerable stabilization of the economy during the crisis. Again, the high initial buffer of outside equity provides the stabilizing mechanism.

Finally, we examine the net benefits from macro-prudential policy more formally considering the welfare effects under different scenarios. The welfare criterion we consider is the unconditional lifetime utility of the representative agent, given by

$$E_u\{\sum_{\tau=t}^{\infty}\beta^{\tau-t}\frac{1}{1-\gamma}\left(C_\tau - hC_{\tau-1} - \frac{\chi}{1+\varphi}L_\tau^{1+\varphi}\right)^{1-\gamma}\} \tag{57}$$

We consider a second order approximation of this function around the steady state and then evaluate welfare under different policy scenarios. We restrict attention to the high risk case, since it is in this instance that the potential benefits from macro-prudential policy are highest.

Table 4 presents measures of welfare gains in consumption equivalents under various different policy scenarios. In particular, we compute the percent increase in consumption per period needed for the household in the regime with no policy to be indifferent with being in the regime with the policy under consideration. In addition, because we have little direct information about the efficiency costs of credit policy, we consider a variety of different values. In particular, as mentioned in section 2, we suppose that the efficiency costs are proportionate to the scale of central bank lending and show up in the government budget constraint as deadweight expenditures. The percent costs are measured in annual basis points. So, for example, a cost of 100 annual basis points means a deadweight loss equal to one percent of government credit supplied over the year. In the crisis scenarios with credit policy studied in figure 2 and 3, accordingly, the implied efficiency cost over the first year of the intervention would equal roughly 0.12 percent of the capital stock, given that government lending averages roughly twelve percent of the capital stock over the course of the first year.

The table considers values ranging from 50 annual basis points to 800 annual basis points. To be clear, these costs are meant to reflect the total costs

of the variety of different credit market interventions used in practice. For some programs, such as the large scale asset purchases of commercial paper and mortgage-backed securities, the efficiency costs were probably quite low and likely well less than 50 basis points. The equity injections under the Troubled Asset Relief Program likely involved much higher costs, particularly when one takes account the redistributive effects (which is beyond the scope of this model.)[16]

The first row of Table 4 considers the welfare gains from the credit policy studied in the previous section under different assumption about efficiency costs. Under no costs, there is a welfare gain equal 0.86 percent of steady state consumption per period. This gain declines monotonically as efficiency costs increase, falling to 0.30 as efficiency costs reach 800 basis points.

The next row considers macro-prudential policy in the absence of credit policy. Despite the fact that the policy reduces volatility, the net welfare gain is negligible. There are two reasons for this. First, as we noted earlier, absent credit policy banks will hold a high buffer of outside equity. This dampens the gain in risk reduction from the policy. Second, there is a first order effect that works in the opposite direction. Outside equity is effectively more expensive for a bank to issue than short term debt since substituting the former for the latter tightens its borrowing constraint. Thus, while the macro-prudential policy makes bank portfolios safer than under laissez-faire, it also imposes on banks the expense of additional equity issue. Nikolov (2010) also emphasizes this trade-off.

In designing macro-prudential policy, one way to offset the first order effect on the cost of capital is to compensate with tax incentives that encourage investment. In our case, a relatively small subsidy to capital, equal to eight basis points annually (0.08 percent) is sufficient to offset the first order distortion. In the third row of the table, accordingly, we again examine macro-prudential policy absent credit policy, this time allowing for the compensating subsidy. Under this regime, the benefits of the macro-prudential policy for risk reduction are insulated from the added costs of additional equity issuance. The welfare gain thus increases from virtually zero to 0.25 percent of steady state consumption per period under laissez-faire.

In the last row we examine credit policy in conjunction with macro-prudential policy adjusted with the compensating subsidy to capital. Note

[16] See, for example, Veronisi and Zinagales (2010) for an analysis of the costs of the TARP.

that in this case, the macro-prudential policy reduces the size of the effective credit market intervention during a crisis. Thus the welfare gains relative to the case with credit policy only increase with the efficiency cost of the credit policy. With no costs to credit policy, there is a welfare gain of 0.96 percent of steady state consumption, as compared to 0.86 for credit policy alone. As the efficiency costs of credit policy increase to 800 basis points only, the gains become 0.62 percent in the case of the combined policy, versus 0.30 percent with credit policy alone.

Finally, we note that the gains from policy come from gains in risk reduction. We have employed relatively modest degrees of risk aversion and risk in the analysis. By raising either risk aversion or risk, we would expect the measured gains from policy to increase.

4 Conclusion

We have developed a macroeconomic framework with an intermediation sector where the severity of a financial crises depends on the riskiness of banks' liability structure, which is endogenous. It is possible to use the model to assess quantitatively how perceptions of fundamental risk and government credit policy affect the vulnerability of the financial system. It is also possible to study the quantitative effects of macro-prudential policies designed to offset the incentives for risk-taking.

As with recent theoretical literature, we find that the incentive effects for risk taking may reduce the net benefits of credit policies that stabilize financial markets. However, by how much the benefits are reduced is ultimately a quantitative issue. Within our framework it is possible to produce examples where the moral hazard costs are not consequential to the overall benefits from credit policy. Of course, one can also do the reverse. In addition, an appropriately designed macro-prudential policy can also mitigate moral hazard costs. Clearly, more work on pinning down the relevant quantitative considerations is a priority for future research.

References

[1] Angeloni, Ignazio and Ester Faia, 2009. "A Tale of Two Policies: Prudential Regulation and Monetary Policy with Fragile Banks," mimeo, European Central Bank.

[2] Bagehot, Walter, 1873, *Lombard Street: A Description of the Money Market,* London: H. S. King.

[3] Bernanke, Ben, (2009), "The Crisis and the Policy Response," Jan. 13 speech...."

[4] Bernanke, Ben and Mark Gertler, 1989, "Agency Costs, Net Worth and Business Fluctuations," *American Economic Review*: 14-31.

[5] Bernanke, Ben, Mark Gertler, and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," *Handbook of Macroeconomics,* John Taylor and Michael Woodford editors.

[6] Bianchi, Javier, 2009, "Overborrowing and Systematic Externalities in the Business Cycle," mimeo, Atlanta Fed..

[7] Brunnermeier, Markus K. and Yuliy Sannikov, 2009, "A Macroeconomic Model with a Financial Sector", mimeo, Princeton University.

[8] Calomiris, Charles, and Charles Kahn, 1991, "The Role of Demandable Debt in Structuring Banking Arrangements, *American Economic Review,* (81) June: 497-513.

[9] Campbell, John, 1993. "Asset Pricing without Consumption Data," *American Economic Review,* (83): 487-512.

[10] Campbell, John, 1994. "Inspecting the Mechanism," *Journal of Monetary Economics,* (33): 463-506.

[11] Carlstrom, Charles and Timothy Fuerst, 1997, "Agency Costs, Net Worth and Business Fluctuations: A Computable General Equilibrium Analysis", *American Economic Review.*

[12] Chari. V.V., and Patrick Kehoe, 2010, "Bailouts, Time Consistency and Optimal Regulation," mimeo, University of Minnesota.

[13] Christiano, Lawrence, Martin Eichenbaum and Charles Evans, 2005, "Nominal Rigidities and the Dynamics Effects of a Shock to Monetary Policy,", *Journal of Political Economy.*

[14] Christiano, Lawrence, Roberto Motto and Massimo Rostagno, 2009, "Financial Factors in Business Fluctuations," mimeo, Northwestern University.

[15] Curdia, Vasco and Michael Woodford, 2009b,. "Conventional and Unconventional Monetary Policy," mimeo, Federal Reserve Bank of New York and Columbia University.

[16] Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero and Nobuhiro Kiyotaki 2010. "The Great Escape?" mimeo, Federal Reserve Bank of New York and Princeton University.

[17] Devereux and Sutherland, 2009, "Country Portfolios in Open Economy Macro Models", mimeo, University of British Columbia

[18] Diamond, Douglas and Ragu Rajan, 2009, "Illiquidity and Interest Rate Policy," mimeo

[19] Fahri, Emmanuel and Jean Tirole, 2009, "Collective Moral Hazard, Systematic Risk and Bailouts." mimeo, Harvard University and University of Toulouse.

[20] Fostel Ana and Geanakoplos, John and 2009, "Leverage Cycles and the Anxious Economy," *American Economic Review*

[21] Gertler, Mark and Peter Karadi, 2009, "A Model of Unconventional.Monetary Policy," mimeo, New York University.

[22] Gilchrist, Simon, Vladimir Yankov and Egon Zakrasjek, 2009, "Credit Market Shocks and Economic Fluctuations: Evidence from Corporate Bond and Stock Markets," mimeo, Boston University.

[23] Gilchrist, Simon, and John Leahy.2002 "Monetary Policy and Asset Prices", *Journal of Monetary Economics.*

[24] Goodfriend Marvin and Bennett McCallum, 2007, "Banking and Interest Rates in Monetary Policy Analysis," *Journal of Monetary Economics.*

[25] Gorton, Gary, 2010, *Slapped in the Face by the Invisible Hand: The Panic of 2007*, Oxford: Oxford University Press.

[26] Gourio, Francois. 2009, "Disaster Risk and Business Cycles," mimeo, Boston University.

[27] Greenwood, Jeremy, Zvi Hercowitz and Gregory W. Huffman, 19888, "Investment, Capacity Utilization, and the Real Business Cycle", *American Economic Review,* (78) June: 402-417

[28] Guvenen, Fatih, 2009, "A Parsimonious Macroeconomic Model for Asset Pricing", *Econometrica* 1711-1750

[29] Holmstrom, Bengt and Jean Tirole,1997. "Financial Intermediation, Loanable Funds and the Real Sector," *Quarterly Journal of Economics.*

[30] Holmstrom, Bengt and Jean Tirole,1998. "Private and Public Supply of Liquidity," *Journal of Political Economy.*

[31] He, Zhiguo and Arvind Krishnamurthy, 2008. "Intermediary Asset Pricing," Northwestern University.

[32] Jermann, Urban, and Vincenzo Quadrini, 2009. "Macroeconomic Effects of Financial Shocks," mimeo, University of Pennsylvania and University of Southern California.

[33] Justiniano, Alejandro, Giorgio Primiceri and Andrea Tambalotti 2009, "Investment Shocks and Business Cycles," mimeo, Northwestern University.

[34] Kehoe, Timothy, and David Levine, 1994. "Debt-Constrained Economy," *Review of Economic Studies.*

[35] Kiyotaki, Nobuhiro and John Moore, 1997, "Credit Cycles," *Journal of Political Economy.*

[36] Kiyotaki, Nobuhiro and John Moore, 2008, "Liquidity, Business Cycles and Monetary Policy," mimeo, Princeton University and LSE.

[37] Korinek, Anton, 2009, "Systematic Risk-Taking Amplification Effects, Externalities and Regulatory Responses," mimeo, University of Maryland.

[38] La'O, Jennifer, 2010. "Collateral Constraints and Noisy Fluctuations," mimeo, MIT.

[39] Lettau, Martin, 2003, "Inspecting the Mechanism: Closed-Form Solutions for Asset Prices in Real Business Cycle Models", *Economic Journal* (113) 550-575

[40] Lorenzoni, Guido, 2008, "Inefficient Credit Booms," *Review of Economic Studies*: 809-833.

[41] Mendoza, Enrique, 2008, "Sudden Stops, Financial Crises and Leverage: A Fisherian Deflation of Tobin's Q," mimeo, University of Maryland.

[42] Merton, Robert, 1973, "An Intertemporal Capital Asset Pricing Model," *Econometrica.*

[43] Miao, Jianjun and Pengfei Wang, 2010, "Credit Risk and Business Cycles", mimeo, Boston University

[44] Nikolov, Kalin, 2009. "Is Private Leverage Excessive?" mimeo, LSE.

[45] Reinhart, Carmen M., and Kenneth Rogoff, 2009, *This Time is Different: Eight Centuries of Financial Folly,* Princeton: Princeton University Press.

[46] Reis, Ricardo, 2009. "Where Should Liquidity Be Injected During a Financial Crisis?" mimeo, Columbia University.

[47] Sargent, Thomas J., and Neil Wallace, 1983, "The Real Bills Doctrine versus the Quantity Theory of Money," *Journal of Political Economy*

[48] Shleifer, Andrei and Rob Vishny, 2010, "Asset Fire Sales and Credit Easing," mimeo, Harvard University.

[49] Smets, Frank and Raf Wouters, 2007, "Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach," *American Economic Review*

[50] Stein, Jeremy C., 2010, "Monetary Policy as Financial-Stability Regulation", mimeo, Harvard University.

[51] Tille, Cedric and Eric Von Wincoop, 2010, "International Capital Flows", *Journal of International Economics,* (80) 157-175

[52] Wallace, Neil, 1980. "A Modigliani-Miller Theorem for Open Market Operations", *American Economic Review..*

Table 1: Parameter Values

γ	2	Risk aversion
β	0.99	Discount factor
α	0.33	Capital share
δ	0.02	Depreciation rate
χ	0.25	Utility weight of labor
φ	1/3	Inverse Frisch elasticity of labor supply
If''/f'	1	Inverse elasticity of investment to the price of capital
h	0.75	Habit parameter
σ	0.9685	Survival rate of bankers
ξ	0.0482	Transfer to entering bankers
		Asset diversion parameters:
θ	0.2640	
ϵ	-1.8594	
κ	25	

Table 2: Steady States for Low and High Risk Economies

Variable	Low Risk	High Risk
Output	24.16	23.07
C	18.81	18.08
L	8.25	7.97
K	214.03	199.55
N	35.62	41.36
R	1.01	1.01
Spread (%)	0.86	1.23
x (%)	7.88	11.70
ν	1.46	1.21
μ_e(%)	0.03	0.11
μ_s(%)	0.24	0.09
ϕ	6.01	4.82
$QK/(N + xQK)$	4.08	3.08
SD shock (%)	0.54	1.05
SD output growth (%)	0.90	01.25

Table 3: Steady States with Credit Policy

	Low Risk		**High Risk**	
	Value	% change from no policy	Value	% change from no policy
Output	24.42	1.08	24.09	4.45
C	18.99	0.92	18.77	3.81
L	8.32	0.81	8.23	3.32
K	217.52	1.63	213.06	6.77
N	34.22	-3.93	36.20	-12.47
R	1.01	0.00	1.01	0.00
Spread (%)	0.78	-0.08	0.90	-0.33
x (%)	7.63	-3.13	8.39	-28.31
ν	1.54	5.64	1.43	18.66
μ_e (%)	0.01	-49.87	0.06	-48.72
μ_s (%)	0.27	14.35	0.22	152.62
ϕ	6.36	5.81	5.88	22.04
$QK/(N + xQK)$	4.28	4.95	3.94	27.76
SD shock (%)	0.54		1.05	
SD output growth (%)	0.66	-24.27	1.26	0.73

Table 4: Welfare Effects of Policy

	Welfare gain from no policy in consumption equivalents (%)					
Efficiency cost of credit policy (bps)	0	50	100	200	400	800
Credit Policy	0.863	0.831	0.797	0.720	0.528	0.297
Macroprudential Policy	0.007	0.007	0.007	0.007	0.007	0.007
Macroprudential Policy with subsidy on R_k	0.253	0.253	0.253	0.253	0.253	0.253
Macroprudential and Credit Policy	0.964	0.945	0.926	0.886	0.801	0.623

Figure 1. Crisis Experiment: Low Risk vs. High Risk Economy

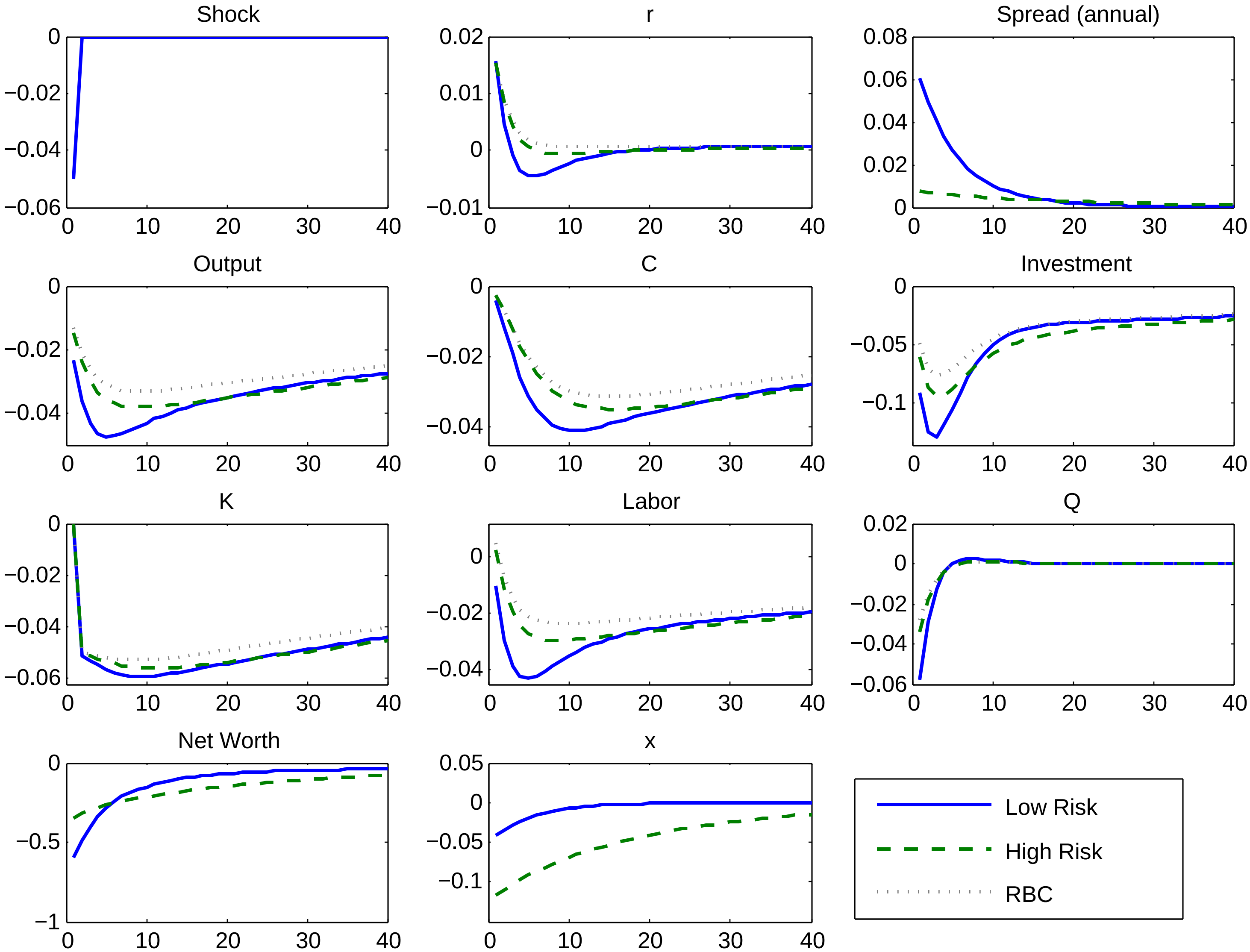

Figure 2. Credit Policy Response to Crisis: Low Risk Economy

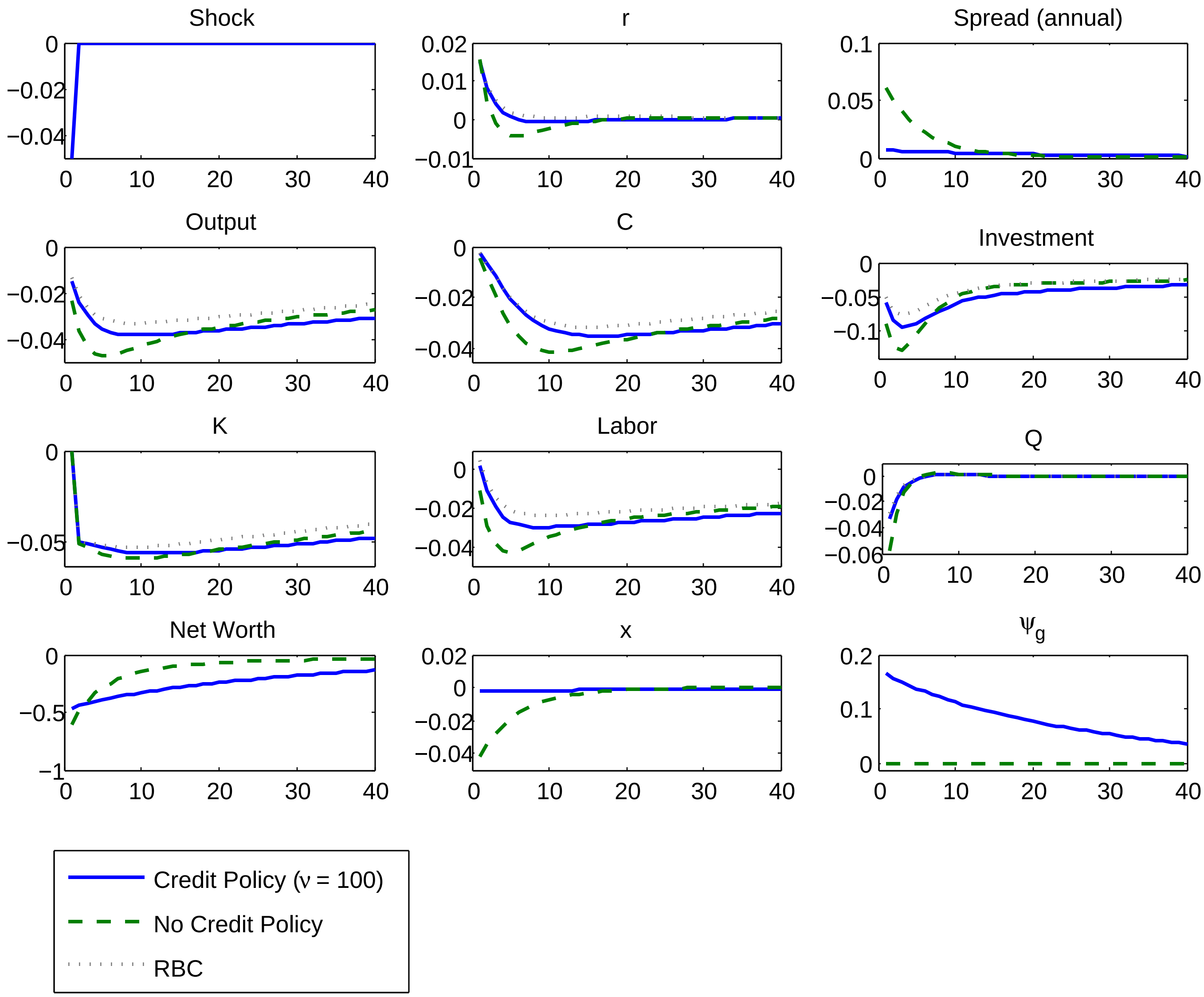

Figure 3. Credit Policy Response to Crisis: High Risk Economy

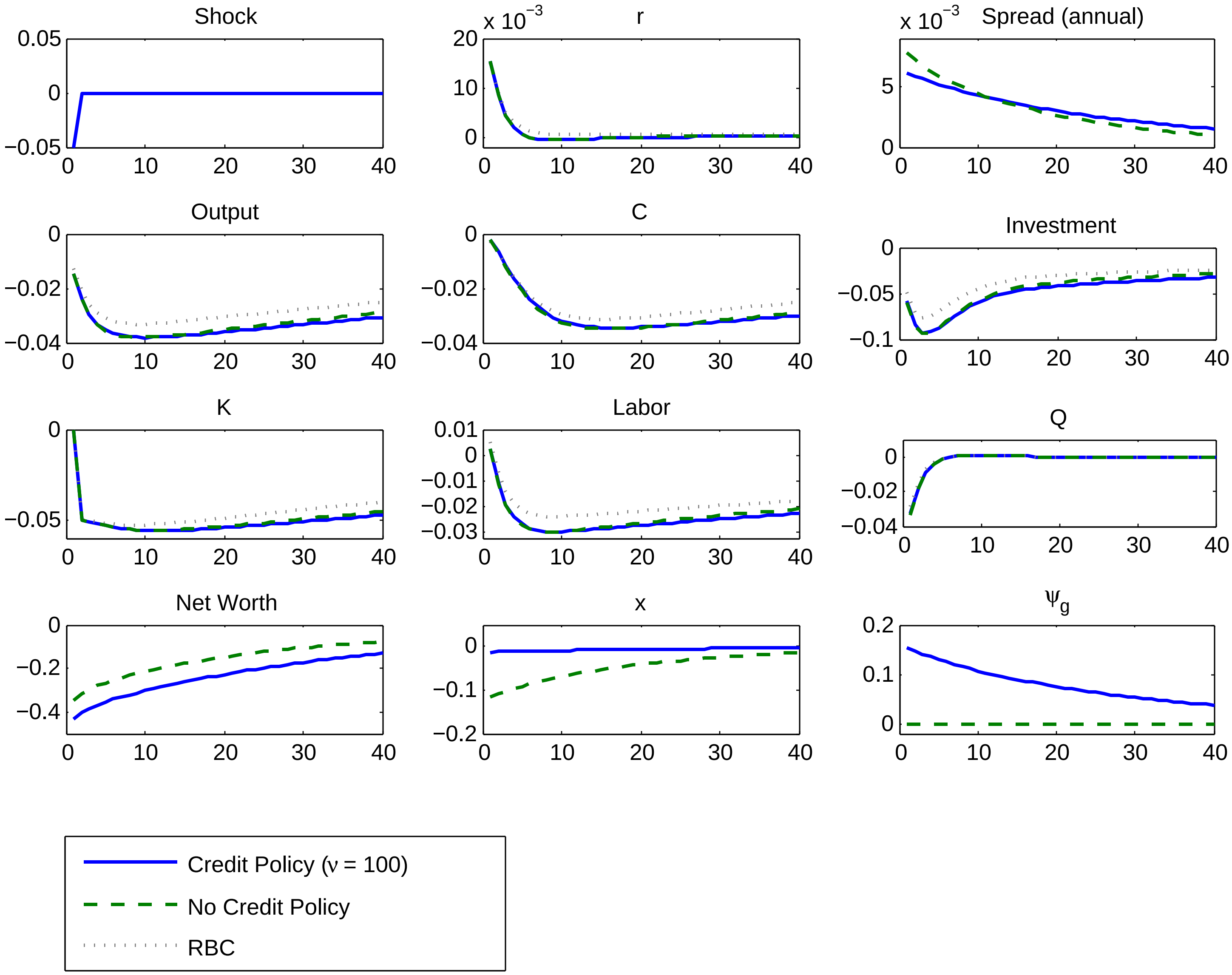

Figure 4: Anticipated vs. Unanticipated Credit Policy in High Risk Economy

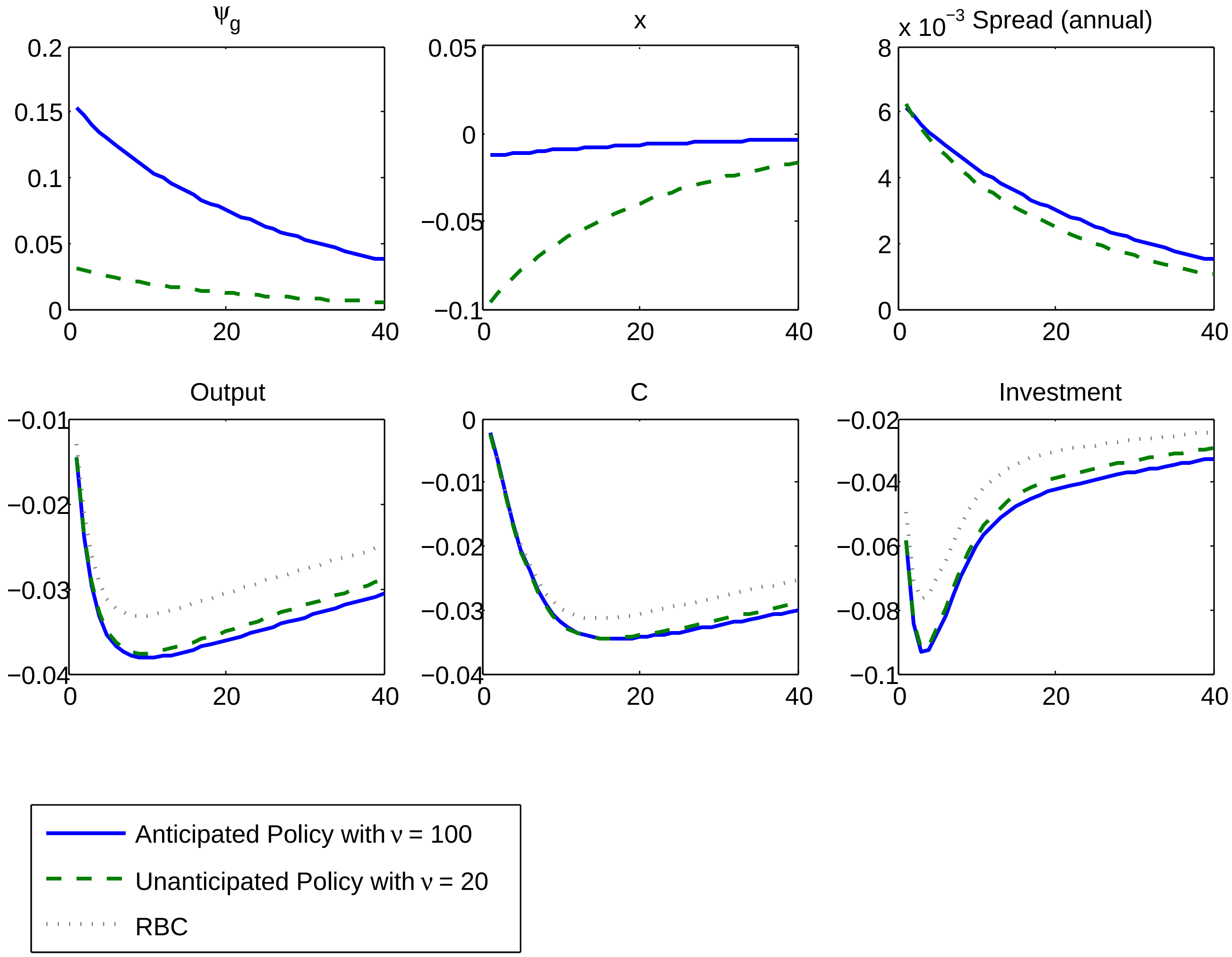

Figure 5: Macroprudential along with Credit Policy in the High Risk Economy

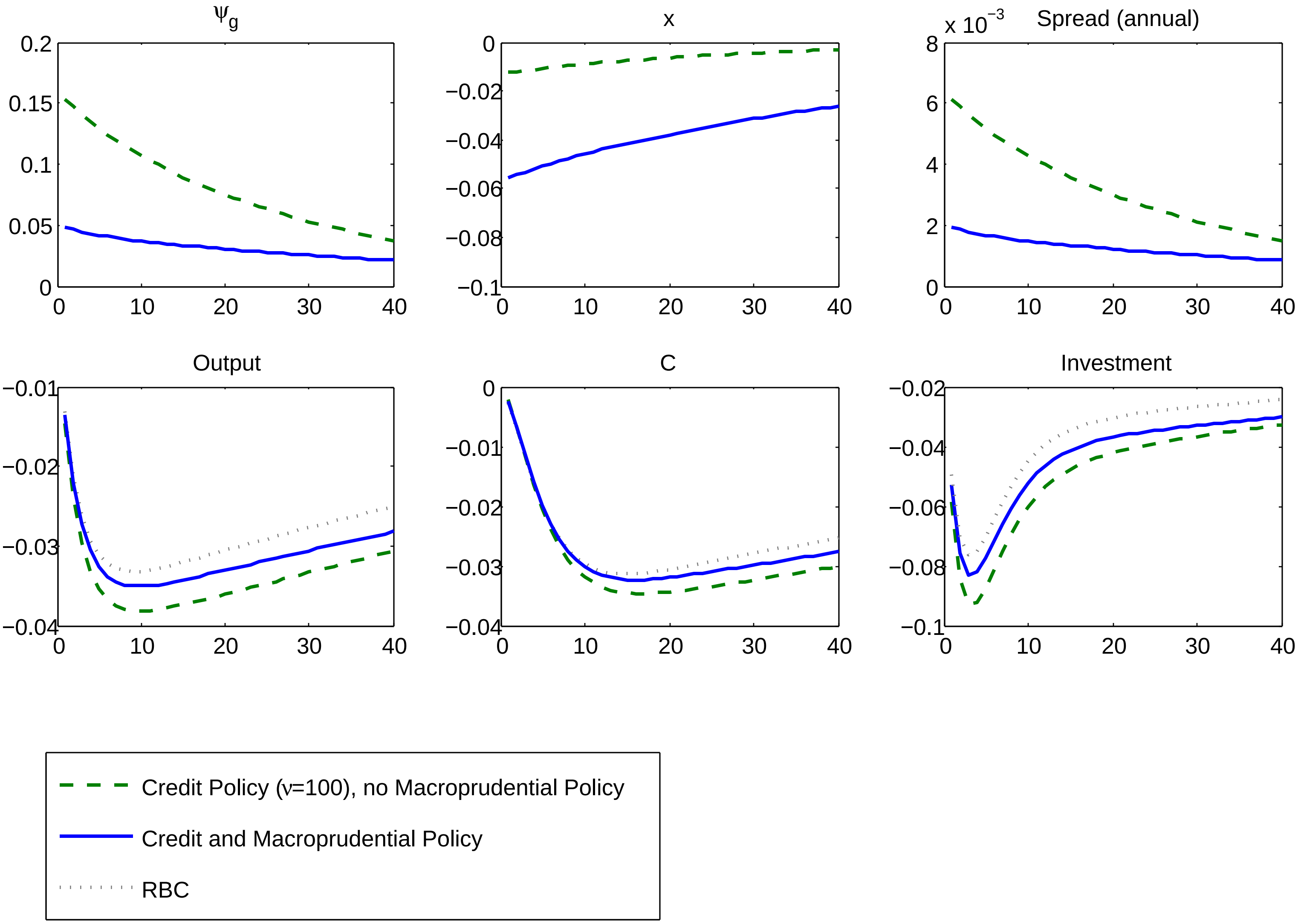

Figure 6: Macroprudential Policy without Credit Policy in the Low Risk Economy