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Financial Crisis Resolution

by Josef Schroth

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Abstract

This paper studies a dynamic version of the Holmstrom-Tirole model of intermediated finance. I show that competitive equilibria are not constrained efficient when the economy experiences a financial crisis. A pecuniary externality entails that banks' desire to accumulate capital over time aggravates the scarcity of informed capital during the financial crisis. I show that a constrained social planner finds it beneficial to introduce a permanent wedge between the deposit rate and the economy's marginal rate of transformation. The wedge improves borrowers' access to finance during a financial crisis by strengthening banks' incentives to provide intermediation services. I propose a simple implementation of the constrained-efficient allocation that limits bank size.

JEL classification: G01, G10, D53, G18, E60
Bank classification: Financial system regulation and policies; Financial markets

Résumé

Dans cette étude, l'auteur utilise une version dynamique du modèle d'intermédiation financière de Holmstrom et Tirole. Il montre que les équilibres concurrentiels ne sont pas soumis à une contrainte d'efficience quand l'économie subit une crise financière. Sous l'effet d'une externalité pécuniaire, le désir des banques d'accumuler des fonds propres au fil du temps aggrave, lors de la crise financière, la rareté des capitaux en provenance d'investisseurs disposant d'un avantage informationnel. L'auteur fait ressortir que, pour un planificateur central soumis à une contrainte, il est avantageux d'introduire un écart permanent entre le taux de rémunération des dépôts et le taux marginal de transformation de l'économie. Cette différence améliore l'accès des emprunteurs au crédit en période de crise financière, car elle rend l'offre de services d'intermédiation plus attrayante pour les banques. L'auteur propose une simple application d'une allocation sous contrainte d'efficience qui limite la taille des banques.

Classification JEL : G01, G10, D53, G18, E60
Classification de la Banque : Réglementation et politiques relatives au système financier; Marchés financiers

1 Introduction

Financial crises can lead to considerable welfare costs. Various authors show how to limit the occurrence and cost of financial crises.[3] However, policymakers understand that severe financial crises can still occur and may wish to explore their role in crisis resolution. There is relatively little theoretical research characterizing what an optimal regulatory response (if any) to a financial crisis might look like. When bank capital is reduced during a crisis, banks experience a decrease in their access to outside finance and respond by reducing lending to borrowers, who may then forgo profitable investment opportunities.[4] Such a credit crunch is the result of optimal decision making by banks and bank creditors that are wary of limited liquidity of bank loans. To assess the need for a regulatory intervention we need to understand how privately optimal decisions can lead to socially inefficient outcomes.

In this paper, I address this question by focusing on a pecuniary externality which arises from the combination of financial constraints and a competitive market for bank lending. I analyze constrained efficiency by considering a planner who faces the same constraints faced by banks and bank creditors, and asking whether a change in bank lending policy can lead to a Pareto improvement. A financial crisis is taken as a given initial condition, caused by an exogenously low level of initial bank capital. My main result is that banks grow too large in equilibrium eventually, which negatively affects their ability to supply funds to borrowers during a credit crunch. Specifically, the paper shows that a planner

[3]See Kashyap, Rajan, and Stein (2008) for a proposal of how banks should insure against large shocks, which opens the recent discussion about "bail-ins" and contingent debt. See Lorenzoni (2008), Jeanne and Korinek (2010), and Gersbach and Rochet (2011) for a discussion of ex-ante "macro-prudential" regulation to limit the severity of crises.

[4]See Ivashina and Scharfstein (2010), Campello, Graham, and Harvey (2010) and Adrian, Colla, and Shin (2011) for some evidence that this narrative may have characterized the 2007-2009 US financial crisis. There is also some evidence that a scarcity of bank capital may have played a role in propagating the US recessions of 1990–1991 (see Bernanke and Lown (1991) and the papers discussed in Peek and Rosengren (1995)) and 1929–1930 (see Bernanke (1983)). Admittedly, financing available to non-financial firms not only depends on bank capital but also on the value of the firms' collateral. However, in this paper I abstract from this latter channel by allowing for costless transformation of capital goods into consumption goods and vice versa. Lorenzoni (2008) studies optimal regulation when this latter channel is active.

(regulator) should use banks' future profitability as a tool to achieve optimal financial crisis resolution. To my knowledge this has not been established elsewhere.[5]

The paper develops a model of an infinite horizon production economy. Firms produce and have the ability to misappropriate cash flows. Banks can prevent firm theft but cannot commit to do so. This limits the liquidity of bank loans and is the reason for the financial friction in the economy. Bank creditors thus demand that deposits be secured by bank loans as well as bank equity (capital). Banks can be shut down such that in equilibrium bank creditors will accept a higher bank loan-to-equity ratio when bank future profits are higher. A financial crisis is modeled as initial bank equity being low enough to cause a credit crunch. During a credit crunch, banks are profitable as they are collecting a rent on scarce bank equity. Each bank will maximize its net present value by retaining profits and accumulating equity over time. Banks will only start paying dividends when the economy reaches an unconstrained steady state at which bank rents are zero. Banks understand that deferring the distribution of equity has the direct effect of increasing profits, and thus leverage during the credit crunch. However, banks (and bank creditors) do not internalize that excessive back-loading of dividend payments drives bank rents to zero eventually, which in turn reduces bank leverage during a credit crunch. The pecuniary externality arises from excessive bank lending in steady state which reduces bank incentives to monitor firms during a credit crunch. A social planner will require banks to start paying out equity as dividends before bank rents drop to zero. The planner thus guarantees strictly positive bank rents by limiting the size of banks. By reducing future aggregate bank lending a planner can strengthen bank incentives and thus increase bank leverage during a credit crunch. Intuitively, a small distortionary future rent to banks in steady state leads to a welfare loss that is of a second order compared to the first-order welfare gain from increased bank lending in preceding periods. The planner back-loads distortionary rents in the same

[5] There is a large literature studying the relationship between financial stability and intermediary competition. See Allen and Gale (2003) for an overview and Beck, Demirguc-Kunt, and Levine (2006) for empirical results. In my model, markets are complete such that stability is of no concern to a regulator, see also Allen and Gale (2004).

way as banks back-load dividend payments.[6] Figure 1 illustrates how the constrained-efficient allocation differs from the laissez-faire competitive equilibrium.

Much research focuses on how banks react to external shocks. Take the case of a sudden increase in bank competition in the US around 1980. Keeley (1990) finds that banks with lower future profits seem to have been more likely to try to exploit the deposit insurance scheme.[7] In my model any insurance scheme would be priced fairly such that a reduction in future profits leads to a reduction in bank lending rather than increased bank moral hazard. The important point is that it is plausible that bank future profits are positively related to bank incentives not to engage in moral hazard. Take also the account of a sudden decrease in bank equity presented in Peek and Rosengren (2000). They show how a decrease in the equity of Japanese banks due to a drop in Japanese assets held by these banks caused those banks to reduce lending to the US real estate sector. They are able to show that the negative shock to bank loan supply had significant economic consequences. In the paper, I model the effect of bank future profits and bank equity on bank lending and economic activity.

Following Kiyotaki and Moore (1997), a growing body of theoretical research on financial regulation has been employing rich models suitable for quantitative analysis. This paper focuses on a particular financial friction and derives an optimal regulatory response in a framework where agents, rather than facing a set of ad-hoc constraints on financial transactions, enter freely into private contracts. More recent research explores rich models with a stronger emphasis on motivating financial frictions. For example, my results are applicable in the setup developed in Gertler and Kiyotaki (2010) where debt constraints depend on future prices.

This paper is closely related to work by Kehoe and Perri (2004) and Abraham and Carceles-Poveda (2006) who study corrective taxation in economies where the aggregate

[6]Suppose it would not be possible to shut down the bank such that the financial friction manifests itself as a collateral constraint. Then a planner would see no benefit from guaranteeing future rents to banks.

[7]Marcus (1984) also formalizes the relationship between charter value and bank moral hazard, as do many subsequent papers in the banking literature. See Bhattacharya, Boot, and Thakor (1998) for an overview. In this paper, I derive the need for a regulatory intervention from an inefficiency of decentralized contracting between banks and their creditors, given an initial scarcity of bank capital.

capital stock affects agents' incentives. In those papers, the aggregate capital stock positively affects the value of a default such that an aggregate welfare measure can be increased by limiting capital accumulation. This paper studies the case where the aggregate capital stock negatively affects the value of staying in the contract, and where optimal regulation yields a Pareto improvement by limiting capital accumulation. Moreover, if the planner distorts the capital stock in a given period it will increase the value of staying in the contract in all preceding periods. As a result the planner chooses to back-load distorting the capital stock.[8] To do so, the planner must effectively restrict the agent's desire for back-loading – banks will not be allowed to accumulate equity beyond a certain threshold.

The paper is organized as follows. In section 2, I introduce the model. In section 3, I characterize the competitive equilibrium. In section 4, I characterize the constrained-efficient allocation and discuss policy implications. Section 5 concludes.

2 Model

Time is discrete and infinite with periods $t = 0, 1, 2, \ldots$ There is a measure one of identical workers and a measure one of identical banks. There are three goods: a perishable consumption good, physical capital, and labor. The consumption good can be turned into physical capital instantaneously and costlessly, and vice versa.

Workers are risk neutral and have preferences over non-negative consumption plans $c = \{c_t\}_{t=0,1,2,\ldots}$ represented by

$$U(c) = \sum_{t=0}^{\infty} \beta^t c_t, \tag{1}$$

where $\beta \in (0, 1)$ is the subjective discount factor of both workers and banks. Workers each receive an endowment $\omega > 0$ of the consumption in periods $t = 0, 1, 2, \ldots$ and an endowment of one unit of labor in periods $t = 1, 2, \ldots$ Banks are risk neutral and have

[8]In Abraham and Carceles-Poveda (2006) future prices enter incentive constraints as well but it is not clear whether a constrained social planner would want to distort them.

preferences over non-negative dividend plans $d = \{d_t\}_{t=0,1,2,\ldots}$ represented by

$$V(d) = \sum_{t=0}^{\infty} \beta^t d_t. \tag{2}$$

Banks each have an endowment $a_0 > 0$ of the consumption good at $t = 0$, and have access to a monitoring technology in each period $t = 1, 2, \ldots$.

Each worker owns a firm, such that there is a measure one of identical firms as well. At each $t = 0, 1, 2, \ldots$, the firm borrows $k_{f,t+1}$ units of the consumption good and turns it into physical capital. In period $t + 1$, the firm hires $l_{f,t+1}$ units of labor, produces

$$F(k_{f,t+1}, l_{f,t+1}) = k_{f,t+1}^{\alpha} l_{f,t+1}^{1-\alpha} \tag{3}$$

units of the consumption good and also retains $(1 - \delta)k_{f,t+1}$ units of undepreciated capital, with $\alpha \in (0, 1)$ and $\delta \in (0, 1]$. Without loss of generality we can assume that firms borrow from banks at interest rate R_{t+1}, and hire labor on a competitive labor market at wage rate w_{t+1}. It is assumed that each firm borrows from any one bank in a given period. At the end of period $t + 1$, the worker receives firm profits of

$$\pi_{t+1} = k_{f,t+1}^{\alpha} l_{f,t+1}^{1-\alpha} + (1 - \delta)k_{f,t+1} - R_{t+1}k_{f,t+1} - w_{t+1}l_{f,t+1}. \tag{4}$$

Assumption 1. *A firm loses fraction $\theta \in (0, \alpha]$ of production unless it is monitored by a bank.*

The crucial assumption is that a worker cannot run its own firm and relies on a bank to monitor it. Assumption 1 also ensures that, in equilibrium, a firm has sufficient cash flows to pay workers even when it is not monitored.

Definition 1. *In an unconstrained First Best, where productive efficiency is not affected by assump-*

tion 1, aggregate physical capital employed by firms is given by

$$k_{f,t+1} = K_{FB} \equiv \left(\frac{\alpha\beta}{1-\beta(1-\delta)} \right)^{\frac{1}{1-\alpha}} \textit{ for all } t = 0, 1, 2, \ldots. \tag{5}$$

2.1 Financial contracts and limited commitment

Banks use internal funds (equity) and external funds (debt) to finance loans to firms. At date zero, banks can obtain external funds by offering financial contracts to workers. These contracts specify a sequence of promised payments from banks to workers, or bank debt levels, $\{b_t\}_{t=0,1,2,\ldots}$, with $b_0 = 0$.[9] Specifically, a bank can keep its promise in period t by making a partial repayment x_t to the worker and a promise b_{t+1}. The repayment x_t may be negative, in which case a bank becomes more indebted to the worker.

It is assumed that a worker's consumption good endowment is large enough ($\omega > K_{FB} - a_0$) to guarantee that worker consumption c is strictly positive. Then the following two conditions need to be satisfied if workers are willing to roll over debt.

$$x_t + \beta b_{t+1} \geq b_t, \quad t = 0, 1, 2, \ldots \tag{6}$$

$$\sum_{t=0}^{\infty} \beta^t x_t \geq 0 \tag{7}$$

Condition (6) can be interpreted as a promise keeping constraint while condition (7) is the worker's participation constraint. Banks will only offer contracts such that (6) and (7) hold with equality. Then (7) can be written as a transversality condition for the bank,

$$\lim_{t\to\infty} \beta^{t+1} b_{t+1} = 0. \tag{8}$$

In period zero, the bank uses initial equity a_0 and payment $x_0 < 0$ to finance dividends

[9] b_t denotes debt at the beginning of period t. Then $b_0 < 0$ would violate worker participation while $b_0 > 0$ is clearly not optimal for the bank.

and lending to firms,

$$d_0 + k_1 + x_0 \leq a_0.$$

In periods $t = 1, 2, \ldots$, the bank faces budget constraints of the form

$$d_t + k_{t+1} + x_t \leq R_t k_t.$$

For $t = 0, 1, 2, \ldots$, let $a_{t+1} = R_{t+1} k_{t+1} - b_{t+1}$ denote beginning of period $t + 1$ bank equity then, with (6) binding, bank budget constraints can be written as

$$d_t + k_{t+1} \leq a_t + \beta b_{t+1}. \tag{9}$$

The financial contract characterized by $\{b_{t+1}, d_t\}_{t=0,1,2,\ldots}$ is subject to limited commitment of banks. If the bank defaults on the contract in t its assets (outstanding loans to the firm) will be seized by the worker and it will be excluded from future lending to firms. However, the worker will only be able to collect partially on outstanding loans. It is assumed the bank can make a take-it-or-leave-it offer at that point. The bank can thus obtain a payment from the worker in exchange for monitoring the firm and making full loan collection possible for the worker. Let Θ_t be the payment, per unit of the loan, that the bank can obtain from the worker during a bank default. Then the condition that prevents bank default is given by

$$V_t(d) \equiv \sum_{s=0}^{\infty} \beta^s d_{t+s} \geq \Theta_t k_t. \tag{10}$$

Condition (10) differs from a collateral constraint in that the bank is allowed to make a take-it-or-leave-it-offer only after it has been excluded from future lending activity.[10] Without loss of generality I can restrict attention to financial contracts that are renegotiation-proof,

[10]To be more precise, the bank loses its ability to monitor firms in $t + 1, t + 2, \ldots$ if it defaults in period t. This does not depend on how long a bank lends to the same firm. Another way to arrive at (10) would be to assume bank moral hazard in the form of diverting firm cash flow or enjoying a private benefit from not monitoring as in Holmstrom and Tirole (1997).

which is the case whenever the no-default condition (10) holds.

2.2 Individual decision problems and definition of competitive equilibrium

The bank offers a contract $\{b_{t+1}, d_t\}_{t=0,1,2,\ldots}$ to a worker and chooses a firm lending policy $\{k_{t+1}\}_{t=0,1,2,\ldots}$ to maximize bank value (2) subject to worker participation (8), bank budget balance (9), bank no-default condition (10), and dividend non-negativity. The worker decides whether to accept the contract and consumes income, yielding value of $U(c) = \omega/(1-\beta) + \sum_{t=1}^{\infty} \beta^t (w_t + \pi_t)$. Firms choose a profit-maximizing input plan. Prices $\{w_t, R_t\}_{t=1,2,\ldots}$ are taken as given by all agents.

Definition 2. *A competitive equilibrium is given by a financial contract $\{b_{t+1}, d_t\}_{t=0,1,2,\ldots}$, a bank lending policy $\{k_{t+1}\}_{t=0,1,2,\ldots}$, a worker consumption plan $\{c_t\}_{t=0,1,2,\ldots}$, and a firm input plan $\{k_{f,t+1}, l_{f,t+1}\}_{t=0,1,2,\ldots}$ such that, given prices $\{w_t, R_t\}_{t=1,2,\ldots}$ and endowments $\{a_0, \omega\}$ (i) the respective decision problems are solved, (ii) markets for bank loans and labor clear.*

3 Competitive equilibrium

This section characterizes the competitive equilibrium. Workers will take a passive role as long as their participation constraint (8) holds. Firms will take a passive role as long as prices are as given in lemma 1.[11]

Lemma 1. *Let K_t denote aggregate bank lending to firms in period $t = 1, 2, \ldots,$*

[11] The lemma also shows that the bank default value depends on aggregate bank lending. Alternatively, we could assume firms could lose fraction θ of their borrowed capital rather than production, such that $\Theta_t = \theta$ for all $t = 1, 2, \ldots$.

(i) A firm will demand bank loans $k_{f,t} = K_t$ and labor $l_{f,t} = 1$ whenever

$$R_t = \alpha K_t^{\alpha-1} + 1 - \delta,$$
$$w_t = (1-\alpha)K_t^{\alpha}.$$

Further, firm profits are zero, $\pi_t = 0$ for all $t = 1, 2, \ldots$

(ii) The bank default value is given by $\Theta_t = \theta K_t^{\alpha-1}$ per unit of the loan.

To complete the characterization of the competitive equilibrium it is necessary to find the optimal financial contract. It can be found as the solution to the following bank problem.

$$\max_{\{k_{t+1}, b_{t+1}, d_t\}_{t=0,1,2,\ldots}} \sum_{t=0}^{\infty} \beta^t d_t$$

subject to

$$k_{t+1} + d_t = \beta b_{t+1} + a_t,$$
$$a_{t+1} = R_{t+1}k_{t+1} - b_{t+1},$$
$$V_{t+1} = \sum_{\tau=t+1}^{\infty} \beta^{\tau-t-1} d_\tau \geq \Theta_{t+1}k_{t+1},$$
$$d_t \geq 0, \quad \lim_{t\to\infty} \beta^{t+1} b_{t+1} = 0,$$

for $t = 0, 1, 2, \ldots$, where initial equity $a_0 \in \mathbb{R}_{++}$ is given. Note that $\frac{1}{\beta}$ can be interpreted as the bank's deposit rate and that it also equals the bank's discount rate. The problem takes a familiar form and has a straightforward solution that is stated in proposition 1.[12]

Proposition 1. *A competitive equilibrium is characterized by a cutoff $\bar{a}_0 = \beta\theta K_{FB}^{\alpha}$ such that for $t = 0, 1, 2, \ldots$*

(i) if $a_t \geq \bar{a}_0$, then bank lending is equal to K_{FB} and remains at that level thereafter,

[12]This is very similar to, for example, the dynamics described in Albuquerque and Hopenhayn (2004).

(ii) if $a_t < \bar{a}_0$, then there is a $T \geq 1$ such that bank lending grows at rate $g = \beta^{-\frac{1}{\alpha}}$ for $T-1$ periods and is equal to K_{FB} thereafter.

As long as aggregate bank lending is below K_{FB}, the bank prefers to increase its debt. The reason is that it wishes to exploit the arbitrage opportunity $R_{t+1} - \frac{1}{\beta} > 0$. Since any financial contract satisfies the bank no-default condition bank leverage is constrained. The bank then finds it optimal to retain earnings to maximize equity available for lending to the firm. When equity is high enough, $a_t \geq \bar{a}_0$, such that bank leverage is no longer constrained by the bank no-default condition then $K_{t+1} = K_{FB}$ and bank profits are zero.[13] The blue line in figure 1 illustrates the transition that results from an initial scarcity of bank equity, $a_0 < \bar{a}_0$.

A less familiar feature of the competitive equilibrium is that bank future profits generally decrease as bank equity increases.[14] Bank future profits at date t are given by

$$\Pi_t = \sum_{s=1}^{\infty} \beta^s \left[R_{t+s} - \frac{1}{\beta} \right] k_{t+s}. \tag{11}$$

The level of bank lending that a monopolistic bank would choose is given by

$$K_M = \left(\frac{\alpha^2 \beta}{1 - \beta(1-\delta)} \right)^{\frac{1}{1-\alpha}} < K_{FB}.$$

From proposition 1 and lemma 1 we see that Π_t decreases monotonically for $K_t \geq K_M$ and reaches zero after finitely many periods. To see how this affects the bank's incentive to default, note that the bank's value in $t = 1, 2, \ldots$ can be expressed as $V_t = a_t + \Pi_t$ by

[13]Recall that we could assume the worker provides finance to the firm and pays the bank for its monitoring service. Then the financial contract would not prescribe bank debt but rather payments to the bank in exchange for its monitoring service. Low bank equity then implies that banks cannot commit to monitor firm investment of size K_{FB}. The bank's monitoring service can then command a premium, i.e. the payments are strictly positive (bank's monitoring cost is zero). The bank's profit $R_t - \frac{1}{\beta} > 0$ per unit of firm investment monitored comes from the scarcity of bank equity. See Holmstrom and Tirole (1997) for a further discussion.

[14]For example, in Albuquerque and Hopenhayn (2004) size and profits move in the same direction.

summing over (9) and using (8). Then the bank no-default condition can be written as

$$a_t + \Pi_t \geq \Theta_t k_t. \tag{12}$$

A bank back-loads dividend payments in order to accumulate equity and relax (12) by increasing the first term on the left-hand side.[15] In equilibrium, however, the fact that all banks engage in such back-loading implies that each bank's no-default condition (12) actually may become tighter due to a decrease in bank lending returns, i.e. a decrease of the second term on the left-hand side. In other words, the bank's private return on equity exceeds the social return on equity. This is the pecuniary externality that I focus on in the paper.

3.1 Financial crises

In this paper a financial crisis is defined as a competitive equilibrium with an initial value for bank equity that is low in the sense that $a_0 < \bar{a}_0$. Specifically, it is assumed that a financial crisis is an exogenous event and that further financial crises are not possible. This latter assumption is not necessary for the analysis to go through: for example, we could assume that with probability $\epsilon > 0$ all banks experience a drop in bank equity to some $a_0 < \bar{a}_0$ (equal to the initial equity and the same for all banks and all financial crises). If we further assume that at that point all bank promises to repay workers are wiped out (workers have once again net assets of ω, which does not depend on the capital stock installed before the crisis event) then all we would have to change in the model is to replace β with $\beta(1-\epsilon)$. In the paper I normalize $\epsilon \to 0$.

[15]To be precise, the bank internalizes that higher bank equity also increases Π_t directly by allowing for higher lending to firms. Future profits can be written as the inner product $\Pi_t = Q_{t+1} \cdot k$, where $k = \{k_1, k_2, k_3, \dots\}$ is the bank lending plan and where $Q_{t+1} = \{0, \dots, 0, \beta(R_{t+1} - 1/\beta), \beta^2(R_{t+2} - 1/\beta), \dots\}$ with the first t entries zero is taken as given by the bank. Note that $k \in l_\infty$ and Q_{t+1} is an element of the dual space l_∞^* for all $t = 0, 1, 2, \dots$ such that Π_t is bounded. However, this direct positive effect is dominated by the negative indirect effect via the decrease of return on bank loans for $K_t \geq K_M$.

3.2 Testable implications of the model

Before moving on to analyze constrained efficiency in this economy I briefly confront the model with some stylized facts. Recently, Adrian et al. (2011) collected stylized facts they deem crucial characteristics of financial crises. They find that during a financial crisis the quantity of bank financing decreases while the margin that bank borrowers pay for bank loans in excess of the risk free rate increases. This is consistent with the model. Note that they also report that borrowers use direct finance as an imperfect substitute for bank loans in times of banking crises. In my model this channel is open but inactive: as only banks have the monitoring ability workers weakly prefer intermediation by banks at all times. However, the model could easily be extended by a non-trivial, downward sloping demand curve of workers for directly issued firm debt.

Adrian et al. (2011) also find procyclical bank leverage. In the model bank leverage is given by equation (13) as the ratio of bank assets to bank value.

$$L_t = \frac{R_t k_t}{V_t} = \frac{\alpha k_t^\alpha + (1-\delta)k_t}{\theta k_t^\alpha} = \frac{\alpha + (1-\delta)k_t^{1-\alpha}}{\theta} \quad \text{for } t = 1, 2, \ldots, T. \tag{13}$$

In deriving (13) I made use of the simple structure of the bank balance sheet in the model (only one asset, only one-period maturities). Total assets equal the revenue the bank earns on its lending activity. The value of the bank can be set equal to the bank default value since condition (10) binds during the credit crunch. Note that the denominator is interpreted as market capitalization, rather than book value.[16] We see from (13) that bank leverage increases over time as bank lending increases (proposition 1). The model thus produces procyclical bank leverage.

[16] Definition (13) follows the argument in Arvind Krishnamurthy's discussion of Adrian et al. (2011). Using net assets a_t in the denominator of expression (13) instead does not yield a simple closed form expression for bank leverage. Numerical results suggest a non-monotonic (U-shaped) path for leverage for this case.

4 Constrained-efficient allocation

Consider a social planner that can choose a financial contract $\{b_{t+1}, d_t\}_{t=0,1,2,...}$. The planner is constrained in the sense that it faces the same constraints as the bank, in particular, it must offer a contract that satisfies the bank's no-default condition and the worker's participation condition.[17] A constrained-efficient financial contract maximizes joint welfare of banks and workers, taking into consideration the effect of the bank lending policy on the return on bank lending, worker labor income and bank default values.

Definition 3. *A constrained-efficient allocation is given by a financial contract $\{b_{t+1}, d_t\}_{t=0,1,2,...}$, with associated bank lending, $\{k_{t+1}\}_{t=0,1,2,...}$ that maximizes joint welfare given by*

$$W_0 \equiv \sum_{t=0}^{\infty} \beta^t d_t + \sum_{t=0}^{\infty} \beta^t c_t = d_0 + \frac{\omega}{1-\beta} + \sum_{t=1}^{\infty} \beta^t \left[d_t + (1-\alpha) k_t^{\alpha}\right]$$

subject to

$$\begin{aligned} k_{t+1} + d_t &= \beta b_{t+1} + a_t, \\ a_{t+1} &= \left[\alpha k_{t+1}^{\alpha-1} + 1 - \delta\right] k_{t+1} - b_{t+1}, \\ V_{t+1} &= \sum_{\tau=t+1}^{\infty} \beta^{\tau-t-1} d_\tau \geq \theta k_{t+1}^{\alpha}, \\ d_t &\geq 0, \quad \lim_{\tau\to\infty} \beta^\tau b_{t+\tau} = 0, \end{aligned}$$

with a_0 and ω given.

When initial bank equity is low, $a_0 < \bar{a}_0$, then bank lending is below its unconstrained First Best level K_{FB} such that output, and in particular workers' wages, are depressed. We expect the planner to choose a financial contract that features back-loading of dividend payments similar to the contract that arises in competitive equilibrium. Bank lending will

[17] With scarce bank equity an initial transfer from worker to the bank (setting $b_0 < 0$) would increase joint welfare. However, the planner is constrained by the worker participation requirement.

increase as long as banks accumulate equity. However, the planner internalizes the pecuniary externality and will require banks to pay out equity as dividends before aggregate bank lending reaches K_{FB}. To see this, suppose we have $k_t = K_{FB}$ in some period t. Then a marginal reduction in bank lending k_t results in a redistribution from workers to banks. Since bank lending is at the unconstrained First Best and since the social value of banks' internal funds (weakly) exceeds that of workers it follows that joint welfare at t does not decrease. But since the redistribution to banks increases bank value at t it also increases bank value at $1, 2, \ldots, t-1$. This relaxes banks' no-default constraints and enables the planner to increase bank lending at $1, 2, \ldots, t-1$. Since bank lending was scarce in $t = 1$ joint welfare strictly increases at date zero. When the planner distorts the steady state this will result in a distortionary cost that is of second order compared to the first-order gain of increased bank lending initially. The planner back-loads distortionary bank rents — but that implies she must limit banks' back-loading of equity distributions. This is summarized in proposition 2. Lemma 2 verifies that banks and workers are better off under the constrained-efficient allocation.

Proposition 2. *If $a_0 < \bar{a}_0$ then the constrained-efficient allocation is characterized by numbers $K^* \in (K_M, K_{FB})$ and $T^* \geq 1$ such that*

(i) $k_t \leq K^* < K_{FB}$ at all times $t = 1, 2, \ldots$, where k_1 higher than first-period bank lending in competitive equilibrium,

(ii) bank lending grows at rate $g = \beta^{-\frac{1}{\alpha}}$ for $T^* - 1$ periods and is equal to K^* thereafter.

Lemma 2. *A constrained-efficient allocation is a Pareto improvement relative to the competitive equilibrium.*

Proposition 2 clearly shows how a planner can improve on the competitive equilibrium. By reducing steady state bank lending the planner is able to fast-forward the recovery from the initial scarcity of bank equity. This is illustrated by the green line in figure 1

4.1 Implementing the constrained-efficient allocation

The above analysis shows that banks in competitive equilibrium accumulate bank equity beyond the point where it is socially beneficial. Excessive back-loading by banks enables them to supply an inefficiently high amount of loans to firms in a steady state and reduces the amount of loans that can be supplied early on (during the credit crunch). We know from proposition 2 that a planner rather prefers to smooth out bank lending over time. Proposition 3 shows how to decentralize the constrained-efficient allocation as a competitive equilibrium with an upper bound on bank size as measured by equity.

Proposition 3. *The constrained-efficient allocation can be decentralized as a competitive equilibrium where the size of banks, as measured by bank equity, is constrained. The upper bound on bank equity is given by*

$$A^* = \theta K^{*\alpha} - \Pi^*,$$

where

$$K^* = \left(\frac{\alpha}{\frac{1}{\beta(1-\tau_0)} - 1 + \delta}\right)^{\frac{1}{1-\alpha}}, \quad \Pi^* = \frac{1}{1-\beta}\frac{\tau_0}{1-\tau_0}K^*,$$
$$\tau_0 = \kappa_0 \frac{1-\beta(1-\delta)}{1-\kappa_0\beta(1-\delta)}, \quad \kappa_0 = (1-\alpha)\left(1-\frac{1}{\lambda_0}\right),$$

and where $\lambda_0 = \frac{dW_0}{da_0} \geq 1$ *is date zero social return on bank equity. When* $a_0 < \beta\theta K_{FB}^{\alpha}$*, then* $\lambda_0 > 1$ *and* $\tau_0 > 0$*.*

It is important to see that the theory developed here concerns a pecuniary externality affecting incentives over time. Suppose a version of the model where banks cannot be excluded from earning future profits when engaging in moral hazard. A planner will then see no benefit from distorting steady state bank lending, and has in fact no tools to improve upon the competitive equilibrium. From this we can derive an interesting implication for institutional design. Suppose a planner has political capital to spend on alleviating the bank moral hazard problem directly (lowering θ) or indirectly (more effectively exclude banks upon moral hazard). While the first measure reduces the cost of financial crises, the second measure also increases the potency of optimal financial crisis resolution. Unless θ can be driven to zero the second measure should be given sufficient consideration.

The upper bound on bank equity could in practice be enforced by imposing additional wasteful regulation on banks that exceed a certain size.[18] Another way to curb bank back-loading and to guarantee bank future profits would be to tax bank lending at the constant rate τ_0 and rebate tax revenues back to banks as a lump sum. This differs from a Ramsey taxation approach in that there is no government with an intertemporal budget constraint. If the latter were available, bank lending should be taxed in steady state and the proceeds could be given to banks at date zero. Then it would be useful to distort steady state bank lending even if the bank no-default condition takes the form of a collateral constraint (when the bank cannot be excluded from lending to firms).

It is worthwhile to examine the role of workers in recapitalizing banks in more detail. Recall that in the absence of a worker participation constraint the planner would simply tax workers lump sum initially and give the proceeds to banks until First Best investment is reached. The worker participation constraint at date zero can be written as

$$\sum_{t=0}^{\infty} \beta^t c_t \geq \sum_{t=0}^{\infty} \beta^t w_t, \tag{14}$$

where $w_0 \equiv \omega/(1-\beta)$. The constraint says that workers will not accept higher wages in return for a date zero transfer to bankers (cannot prevent workers from earning those higher wages). Rather, workers need to be promised seizable financial assets (debt issued by banks) in return for any initial payments to banks. In order to keep banks from defaulting on their financial promise to workers the planner offers future rents to banks.

[18] For example, in many countries companies face stricter labor laws when their work force exceeds a certain threshold. This sometimes affects the steady state size-distribution of companies.

5 Conclusion

This paper examines the role of regulation in reducing the social cost of financial crises. In the model, banks have a special monitoring ability and will thus perform an economically valuable intermediation service. Bank creditors are wary of bank moral hazard such that bank intermediation is constrained when bank equity is low (credit crunch). Banks back-load the distribution of equity as dividends in an effort to alleviate the moral hazard problem. In equilibrium, however, all banks accumulate equity and expand lending to bank borrowers which reduces bank profitability. I show that bank back-loading is excessive and harms bank incentives during a credit crunch in a way that reduces welfare. A planner would prevent bank equity growing beyond a certain threshold, effectively limiting the size of banks. What makes the regulatory invention worthwhile is that banks lose access to future profits when engaging in moral hazard. The planner can benefit from back-loading distortionary rents.

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6 Appendix

Proof of lemma 1. Part (i) is standard. To see part (ii) consider the following. If the bank defaults in period t the worker can collect on the bank loan of size k_t. If the bank does not monitor the firm then the firm's loan repayments decrease by θK_t^α. (I assume that wages are senior to the loan repayment.) The firm's creditors bear this loss proportionally, such that the loss to the worker is $\theta K_t^\alpha \frac{k_t}{K_t} = \theta K_t^{\alpha-1} k_t$. The bank can offer the worker to monitor the firm in exchange for $\theta K_t^{\alpha-1} k_t = \Theta_t k_t$. Note that the firm's equilibrium demand for loans K_t is taken as given by the bank. □

Proof of proposition 1. The bank problem is linear and the objective function is bounded above by the present value of monopolist profits. As long as $R_{t+1} > \frac{1}{\beta}$ the bank retains dividends and accumulates equity. When bank lending reaches a steady state at $K_t = K_{FB}$ bank future profits are zero $\Pi_t = 0$ and the bank no-default constraint reduces to $a_t \geq \theta K_t^{\alpha}$. Hence we have $K_{t+1} < K_{FB}$ whenever $a_t < \beta\theta K_{FB}^{\alpha} = \bar{a}_0$. Suppose the steady state is reached in period T then bank value $V_T = \theta K_{FB}^{\alpha}$. Prior to period T bank value grows at rate $\frac{1}{\beta}$ such that bank lending grows at rate $g = \beta^{-\frac{1}{\alpha}}$ (possibly at a lower, but strictly positive, rate in period $T-1$). But then T is finite. □

Proof of proposition 2. The social planner faces a concave maximization problem with objective function bounded from above by $\frac{1}{1-\beta}\left(K_{FB}^{\alpha} - \delta K_{FB}\right)$. To verify concavity of the bank individual rationality constraint note that it can be written as

$$a_t + \Pi_t - \theta k_t^{\alpha} \geq 0 \Leftrightarrow (\alpha - \theta)k_t^{\alpha} - (1-\delta)k_t - b_t + \Pi_t \geq 0.$$

The left-hand side of this equation is concave in k_t since $\alpha - \theta \geq 0$ by assumption 1. Note that Π_t is concave in k_{t+s} for all $s = 1, 2, \ldots$. Note that the planner solves essentially a finite-dimensional problem since a steady state is reached in a similar fashion as described in the proof of proposition 1. The Karush-Kuhn-Tucker theorem then yields the following Euler equation for the planner

$$\beta\left(\alpha k_{t+1}^{\alpha-1} + 1 - \delta - \frac{1}{\beta}\right) = \frac{\lambda_0 - 1}{\lambda_0}\alpha(1-\alpha)\beta k_{t+1}^{\alpha-1} + \beta\frac{\psi_{t+1}}{\lambda_0}\theta\alpha k_{t+1}^{\alpha-1},$$

where $\lambda_0 > 1$ is the Lagrange multiplier on the bank budget constraint at date zero and ψ_{t+1} is the Lagrange multiplier on the bank individual rationality constraint. In a steady state of the constrained-efficient allocation, the right-hand side is strictly positive even though $\psi_{t+1} = 0$ and hence $k_{t+1} \equiv K^* < K_{FB}$. For $k_t < K^*$ bank lending grows at rate g such that the planner steady state is reached after some finitely many periods T^*. Since the planner improves upon the competitive equilibrium we have $k_1|_{SB} > k_1|_{CE}$ and hence $T^* < T$. □

Proof of lemma 2. The constrained-efficient allocation features higher date zero value for each bank, hence banks are better off. Further, we can use $V(d) = a_0 + \Pi_0$ to write W_0 as the present value (using the subjective discount factor) of the economy's output net of investment up to a constant. Since the planner faces the same constraints as agents in competitive equilibrium, W_0 is at least as high as in competitive equilibrium. Due to the distortionary nature of the increase in bank value worker lifetime labor income at date zero must increase if W_0 increases. Hence workers are better off as well. □

Proof of proposition 3. Evaluate the Euler equation in the proof of proposition in steady state such that $\psi_{t+1} = 0$. □

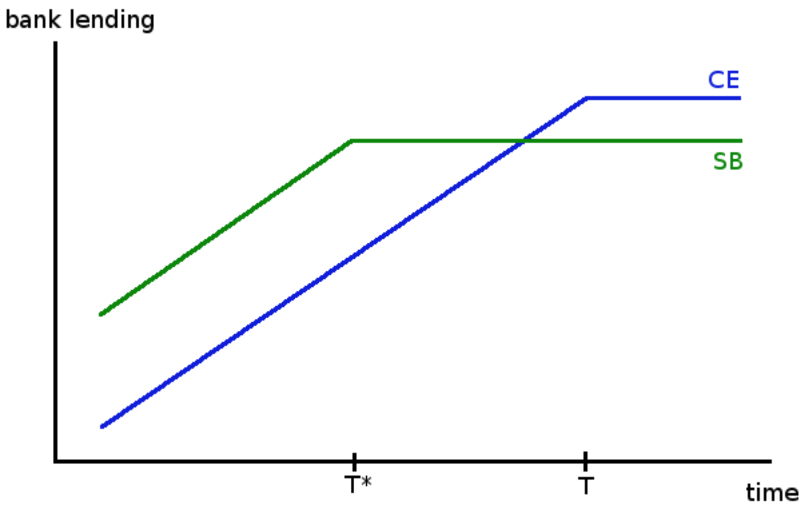

Figure 1: The blue line shows bank lending over time in competitive equilibrium. Banks accumulate equity until some unconstrained steady state is reached. In contrast, the green line shows bank lending as prescribed by a social planner. Banks are required to pay out equity before rents drop to zero. This guarantees bank future profits by keeping bank equity scarce and strengthens bank incentives initially. Bank leverage and lending increases initially — a social planner smoothes out the scarcity of bank lending over time.