

# Financial crisis resolution

Josef Schroth<sup>1</sup>  
EUI, UCLA

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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 inefficient when the economy experiences a financial crisis. A pecuniary externality entails that bank back-loading may weaken bank incentives. 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.

## 1 Introduction

Financial crises can have considerable economic consequences for entire or even groups of countries. Various authors show how to limit their occurrence and cost.<sup>2</sup> However, policy makers 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 how 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 which will then forego profitable investment opportunities.<sup>3</sup> Such a credit crunch is the result of optimal decision making by banks and bank creditors that are wary of restricted liquidity of bank

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<sup>2</sup>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.

<sup>3</sup>See Ivashina and Scharfstein (2010) and Campello, Graham, and Harvey (2010) for some evidence that this narrative may have characterized the 2007-2009 US financial crisis.

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 focussing 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. 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.

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 makes bank loans illiquid 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. 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. 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 leverage, and thus profits, 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 for banks leads to a welfare loss that is of a second order compared to the first-order welfare gain from increased bank lending in all preceding periods. The planner back-loads distortionary rents in the same way as banks back-load dividend payments.<sup>4</sup> 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, for example, the case of a sudden increase in bank competition in the US around 1980. Keeley (1990) finds that banks with lower future profits (as implied by a markup of market to book asset values) seem to have been more likely to try to exploit the deposit insurance scheme.<sup>5</sup> In my model any insurance scheme would

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<sup>4</sup>Suppose it would not be possible to shut down the bank such that the financial friction manifests itself as a collateral constraint rather than an individual rationality constraint. Then a planner would see no benefit from guaranteeing future rents to banks.

<sup>5</sup>Marcus (1984) also formalizes the relationship between charter value and bank moral hazard.

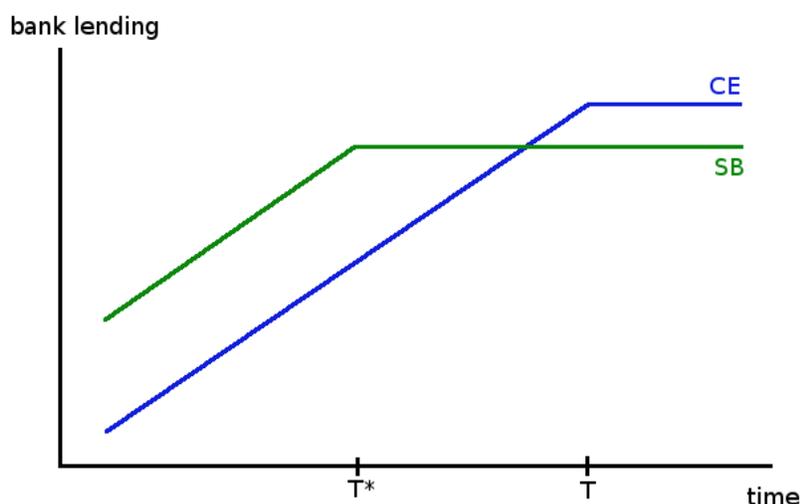


Figure 1: The blue line shows bank lending over time in competitive equilibrium. Banks accumulate equity until some unconstrained steady state is reached. In contrast, the green line shows bank lending as prescribed by a social planner. Banks are required to pay out equity before rents drop to zero. 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.

be fairly priced such that a reduction in future profits leads to a reduction in bank lending rather than increased bank moral hazard. Future profits are thus positively correlated with bank leverage in the model, while Keeley (1990) finds a negative correlation. Specifically, I ignore the possibility of bank moral hazard at the point in time where banks are impacted by the exogenous unexpected shock. The important point is that bank future profits are positively related to bank incentives not to engage in moral hazard. As another example, take the account of a sudden decrease in bank equity presented in Peek and Rosengren (2000a). 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. Due to the segmentation of real estate markets 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), much theoretical research on financial regulation employed 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 in private contracts freely. 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 builds on the insight developed in Kehoe and Levine (1993) that private contracts may lead to equilibrium prices which cannot support all potential gains from trade. Closely related

is work by Kehoe and Perri (2004) and Abraham and Carceles-Poveda (2006) who study corrective taxation or quantity restrictions in economies where the usual second welfare theorem fails. In these 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. In that sense, the planner chooses to back-load distorting the capital stock. To do so, the planner must effectively restrict the agent's desire for back-loading. Specifically, banks will not be allowed to accumulate equity beyond a certain threshold in order to limit future bank lending.

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. In section 5, I discuss policy implications when bank risk management is of concern. Section 6 concludes.

## 2 Model

Time is discrete and infinite with periods  $t = 0, 1, 2, \dots$ . 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  $c = \{c_t\}_{t=0,1,2,\dots}$  represented by

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

where  $\beta \in (0, 1)$  is the subjective discount factor of both workers and banks. Workers each receive an endowment  $w_0 > 0$  of the consumption in period  $t = 0$  and an endowment of one unit of labor in periods  $t = 1, 2, \dots$ . Banks are risk neutral and have preferences over non-negative dividend plans  $d = \{d_t\}_{t=0,1,2,\dots}$  represented by

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

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  $t = 1, 2, \dots$ .

Each worker owns a firm. At each  $t = 0, 1, 2, \dots$ , 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

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

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

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

**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. In an unconstrained First Best, where assumption 1 is dropped, aggregate physical capital employed by firms would be given by

$$K_{FB} = \left( \frac{\alpha\beta}{1 - \beta(1 - \delta)} \right)^{\frac{1}{1-\alpha}}. \quad (5)$$

## 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 offer financial contracts to workers. These contracts specify a sequence of promised payments from banks to workers, or bank debt levels,  $\{b_t\}_{t=0,1,2,\dots}$ , with  $b_0 = 0$ .<sup>6</sup> A bank can keep its promise in period  $t$  by making a partial repayment  $x_t$  to the worker or by issuing a new 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 initial endowment  $w_0$  is large enough to guarantee that worker consumption  $c$  is strictly positive.<sup>7</sup> Then the following two conditions need to be satisfied if workers are willing to roll over debt.

$$x_t + \beta b_{t+1} \geq b_t, \quad t = 0, 1, 2, \dots \quad (6)$$

$$\sum_{t=0}^{\infty} \beta^t x_t \geq 0 \quad (7)$$

Banks will only offer contracts such that (6) and (7) hold with equality. Then (7) can be written as

$$\lim_{t \rightarrow \infty} \beta^t b_t = 0. \quad (8)$$

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

<sup>6</sup> $b_0 < 0$  would violate worker participation while  $b_0 > 0$  is clearly not optimal for the bank.

<sup>7</sup>A sufficient condition is  $w_0 \geq K_{FB} - a_0$  and  $1 - \alpha > (1 - \delta)\beta \left[ \alpha\beta^{1-\frac{1}{\alpha}} + 1 - 2\alpha \right]$ .

lending to firms,

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

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

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

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

$$d_t + k_{t+1} \leq a_t + \beta b_{t+1}. \quad (9)$$

The financial contract characterized by  $\{b_{t+1}, d_t\}_{t=0,1,2,\dots}$  is subject to limited commitment of banks and workers. It is assumed that workers' endowments cannot be seized such that the worker no-default condition is simply

$$b_t \geq 0, \quad t = 1, 2, \dots \quad (10)$$

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. Suppose 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  $\Theta_t$  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

$$V_t(d) \equiv \sum_{s=0}^{\infty} \beta^s d_{t+s} \geq \Theta_t k_t. \quad (11)$$

Condition (11) 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.<sup>8</sup> Without loss of generality I can restrict attention to financial contracts that are renegotiation-proof, which is the case whenever no-default conditions (10) and (11) hold.

## 2.2 Individual decision problems and definition of competitive equilibrium

The bank offers a contract  $\{b_{t+1}, d_t\}_{t=0,1,2,\dots}$  to a worker and chooses a firm lending policy  $\{k_{t+1}\}_{t=0,1,2,\dots}$  to maximize bank value (2) subject to worker participation (8), bank budget balance (9), worker no-default condition (10), bank no-default condition (11), and dividend non-negativity. The worker

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<sup>8</sup>To be more precise, the bank loses its ability to monitor firms in  $t + 1, t + 2, \dots$  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 (11) 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).

decides whether to accept the contract and consumes lifetime income,  $U(c) = w_0 + \sum_{t=1}^{\infty} \beta^t (w_t + \pi_t)$ . Firms choose a profit-maximizing input plan. Prices  $\{w_t, R_t\}_{t=1,2,\dots}$  are taken as given by all agents.

**Definition 1.** A competitive equilibrium is given by a financial contract  $\{b_{t+1}, d_t\}_{t=0,1,2,\dots}$ , a bank lending policy  $\{k_{t+1}\}_{t=0,1,2,\dots}$ , a worker consumption plan  $\{c_t\}_{t=0,1,2,\dots}$ , and a firm input plan  $\{k_{f,t+1}, l_{f,t+1}\}_{t=0,1,2,\dots}$  such that, given prices  $\{w_t, R_t\}_{t=1,2,\dots}$  and endowments  $\{a_0, w_0\}$  (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) and no-default constraint (10) hold. Firms will take a passive role as long as prices are as given in lemma 1. The lemma also shows that the bank default value depends on aggregate bank lending. Intuitively, the bank can decide how much to lend to a firm but a firm's demand for bank loans is determined in equilibrium.

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

(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  $t = 1, 2, \dots$

(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.

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

subject to

$$k_{t+1} + d_t = \beta b_{t+1} + a_t,$$

$$a_{t+1} = R_{t+1} k_{t+1} - b_{t+1},$$

$$V_{t+1} = \sum_{\tau=t+1}^{\infty} \beta^{\tau-t-1} d_{\tau} \geq \Theta_{t+1} k_{t+1},$$

$$d_t \geq 0, \quad \lim_{\tau \rightarrow \infty} \beta^{\tau} b_{t+\tau} = 0,$$

for  $t = 0, 1, 2, \dots$ , 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 worker no-default condition  $b_t \geq 0$  has been suppressed as it will not bind (after substituting  $b_0 = 0$ ). The problem takes a familiar form and has a straightforward solution that is stated in proposition 1.<sup>9</sup>

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

- (i) *if  $a_t \geq \bar{a}_0$ , then bank lending is equal to  $K_{FB}$  and remains at that level thereafter,*
- (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.<sup>10</sup> 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.<sup>11</sup> Bank future profits at date  $t$  are given by

$$\Pi_t = \sum_{s=1}^{\infty} \beta^s \left[ R_{t+s} - \frac{1}{\beta} \right] k_{t+s}. \quad (12)$$

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

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

From proposition 1 and lemma 1 we see that  $\Pi_t$  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  $t = 1, 2, \dots$  can be expressed as  $V_t = a_t + \Pi_t$  by summing over (9) and using (8). Then the bank no-default condition can be written as

$$a_t + \Pi_t \geq \Theta_t k_t. \quad (13)$$

<sup>9</sup>This is very similar to, for example, the dynamics described in Albuquerque and Hopenhayn (2004).

<sup>10</sup>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 does not come from the bank's access to firms per se, but rather from the scarcity of bank equity. See Holmstrom and Tirole (1997) for a further discussion.

<sup>11</sup>For example, in Albuquerque and Hopenhayn (2004) size and profits move in the same direction.

A bank back-loads dividend payments in order to accumulate equity and relax (13).<sup>12</sup> In equilibrium, however, the fact that all banks engage in such back-loading implies that each bank's no-default condition (13) actually may become tighter due to a decrease in bank lending returns. 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.

## 4 Constrained-efficient allocation

Consider a social planner that can choose a financial contract  $\{b_{t+1}, d_t\}_{t=0,1,2,\dots}$ . 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 and the worker's respective no-default conditions.<sup>13</sup> 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 2.** A constrained-efficient allocation is given by a financial contract  $\{b_{t+1}, d_t\}_{t=0,1,2,\dots}$ , with associated bank lending,  $\{k_{t+1}\}_{t=0,1,2,\dots}$  that maximizes joint welfare given by

$$W_0 \equiv \sum_{t=0}^{\infty} \beta^t d_t + \sum_{t=0}^{\infty} \beta^t c_t = d_0 + w_0 + \sum_{t=1}^{\infty} \beta^t [d_t + (1 - \alpha)k_t^\alpha]$$

subject to

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

with  $a_0$  and  $w_0$  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 constrained. We expect the planner to choose a financial contract that features back-loading similar to the contract that

<sup>12</sup>To be precise, the bank internalizes that higher bank equity increases  $\Pi_t$  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  $l_\infty^*$  for all  $t = 0, 1, 2, \dots$  such that  $\Pi_t$  is bounded. However, this direct positive effect is dominated by the negative indirect effect via the decrease of return on bank loans for  $K_t \geq K_M$ .

<sup>13</sup>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  $b_0 \geq 0$  as workers can sell their labor endowment even after defaulting.

arises in competitive equilibrium. Bank lending will 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  $1, 2, \dots, t - 1$ . This relaxes banks' no-default constraints and enables the planner to increase bank lending at  $1, 2, \dots, t - 1$ . 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 it 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  $t = 1, 2, \dots$ , 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 steady state but 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 a 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. 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  $\theta$ ) 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  $\theta$  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.<sup>14</sup> Another way to curb bank back-loading and to guarantee bank future profits would be to tax bank lending at the constant rate  $\tau_0$  and rebate tax revenues back to banks as a lump sum instantaneously. This differs from a Ramsey taxation approach in that there is no government with an intertemporal budget constraint. If the latter would be 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).

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<sup>14</sup>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.

## 4.2 Numerical example

Consider a particular numerical example with parameter values given by  $\alpha = \theta = 0.4$ ,  $\beta = 0.95$ ,  $\delta = 0.08$ , and with initial bank equity  $a_0 = 0.01$ . From figure 2 it can be seen that the constrained-efficient allocation reaches its steady state immediately. Relative to the competitive equilibrium the planner is able to roughly double date zero bank lending. Welfare  $W_0$  increases by about 2 percent. Note that if we assume the economy is in an unconstrained steady state prior to period zero, then bank equity dropped from 0.83 to 0.01. But the difference in steady state welfare between competitive equilibrium and constrained efficient equilibrium is not much higher. In fact, the planner can reduce the social cost of the financial crisis by about 90 percent once we net out the exogenous drop in bank equity.

In the constrained-efficient allocation bank value at date zero is about 30 percent higher compared to the competitive equilibrium. Worker value, which is the by far largest part of total welfare, is by about 1 percent higher. From panel 2(e) we can see that the planner constrains back-loading of equity distribution early on and starts paying dividends in  $t = 2$  rather than  $t = 7$ . The planner supports a high level of bank debt by guaranteeing a bank profit margin of 80 basis points. Bank future profits are thus at a constant high level while they reach zero fast in competitive equilibrium.

## 5 Aggregate uncertainty and bank risk management

This section examines the implications of banks' risk management for regulation in an environment with aggregate uncertainty. Here, bank risk management refers to the bank trading contingent claims to avoid low levels of bank equity when the return on bank equity is high.<sup>15</sup> Of particular interest is the effect of bank risk management on the spot prices of assets held by bank borrowers. For example, a sudden reduction in the supply of bank lending, due to insufficient bank risk management, may force borrowers to sell assets to remain solvent. To the extent that this leads to a decrease in the spot prices of these assets a loss for borrowers may result in a loss for banks and hence a further decrease in bank lending. As banks do not internalize their role in fueling such a "fire sale" they may engage in inefficient risk management.

Consider a version of the above economy with only three periods,  $t = 0, 1, 2$ . At  $t = 1$  aggregate productivity is either  $z_L \in (0, \beta)$  or  $z_H = 2 - z_L$  with equal probability while in  $t = 2$  aggregate productivity is unity irrespective of history. Note that all equity will be paid out as a dividend at  $t = 2$  - everything else is as in section 2. Let  $k_1$  denote bank lending in period  $t = 0$  and let  $k_2(s_j)$  denote bank lending in period  $t = 1$  when productivity was  $z_j$  in  $t = 1$ ,  $j = L, H$ . As before, upper case versions of these variable will denote aggregate quantities.

Suppose firms cannot convert physical capital back into the consumption good in  $t = 1$ . When banks do not hedge financing risk sufficiently they are forced to reduce bank lending to firms in

<sup>15</sup>For a more general treatment of risk management in partial equilibrium see Rampini and Viswanathan (2010).

certain states of the world. It may then be the case that firms do not receive enough bank loans to employ all undepreciated capital such that  $(1 - \delta)K_1 - K_2(s_j) > 0$  for some  $j = L, H$ . Similar to Lorenzoni (2008), assume there is some alternative sector ("scrap yard") which can absorb any left-over physical capital but which is strictly less productive than the technology  $F$ . Without modeling the alternative technology explicitly suppose the price for physical capital in  $t = 1$  is given by  $p_1(s_j) = (1 + \max(0, (1 - \delta)K_1 - K_2(s_j)))^{-\gamma}$  for  $j = L, H$  and  $\gamma > 0$ . (For simplicity, the scrap yard is abroad and its producer surplus not part of the welfare criterion.) Note that when firms can obtain sufficient loans from banks to employ all undepreciated capital the price of physical capital is one. On the other hand, if banks do not hedge financing risk sufficiently this may result in "fire sales" of assets (physical capital) at the firm level. In that latter case, banks will receive a reduced repayment on outstanding loans to firms and an increased return on new loans to firms. The net effect is a reduction in bank equity in states of the world where bank equity is already low.

The bank's problem is given by

$$\begin{aligned} & \max \beta^2 \frac{1}{2} (a_2(s_L) + a_2(s_H)) \\ \text{subject to } & k_1 = a_0 + \beta \frac{1}{2} (b_1(s_L) + b_1(s_H)) \\ & p_1(s_j) k_2(s_j) = a_1(s_j) + \beta b_2(s_j) \\ & a_1(s_j) = R_1(s_j) k_1 - b_1(s_j) \\ & a_2(s_j) = R_2(s_j) k_2(s_j) - b_2(s_j) \\ & \beta a_2(s_j) \geq \Theta_1(s_j) k_1 \\ & a_2(s_j) \geq \Theta_2(s_j) k_2(s_j) \end{aligned}$$

with  $a_0 > 0$  given. A social planner also internalizes  $p_1(s_j) = (1 + \max(0, (1 - \delta)K_1 - K_2(s_j)))^{-\gamma}$  as well as the following equilibrium objects

$$\begin{aligned} R_1(s_j) &= z_j \alpha K_1^{\alpha-1} + (1 - \delta) p_1(s_j), & R_2(s_j) &= [\alpha K_2^{\alpha-1} + (1 - \delta)], \\ \Theta_1(s_j) &= \theta z(s_j) K_1^{\alpha-1}, & \Theta_2(s_j) &= \theta K_2(s_j)^{\alpha-1}. \end{aligned}$$

Table 1 shows a numerical example with parameter values given by  $\alpha = \theta = 0.4$ ,  $\beta = 0.93$ ,  $\delta = 0.08$ ,  $z_L = 0.8$ ,  $\gamma = 0.2$ , and with initial bank equity  $a_0 = 0.05$ . The tax on bank lending that targets the constrained efficient level of bank lending in  $(t = 2, s = s_H)$  cannot implement the constrained efficient allocation fully. The planner uses future rents to improve risk management significantly and avoid a severe drop in the price of capital in the low state, while the bank uses future rents to secure finance for excessive lending to firms. The last column of table 1 shows the price of physical capital when productivity has been low,  $p_1(s_L)$ . When productivity has been high then  $p_1(s_H) = 1$  in all three economies. A separate regulatory intervention is needed to

	$K_1$	$K_2(s_L)$	$K_2(s_H)$	$W_0$	$p_1(s_L)$
CE	1.5083	1.0352	2.8527	1.7539	0.9413
SB	1.5152	1.3607	2.3923	1.7794	0.9934
$CE_\tau$	1.5328	1.3275	2.3923	1.7789	0.9842

Table 1: The table shows aggregate investment in the laissez-faire competitive equilibrium (CE), the constrained Second Best (SB), and the competitive equilibrium with a constant tax on bank lending ( $CE_\tau$ ). The constant tax of  $\tau = 0.0706$  has been chosen to equate  $K_2(s_H)$  in SB and  $CE_\tau$ . We see from the table that this tax is not sufficient to implement the SB as a competitive equilibrium: initial bank lending in  $CE_\tau$  is excessive.

target the pecuniary externality via  $p_1(s_j)$ . For example, the constrained efficient allocation could be implemented by a tax on bank lending that exceeds  $\tau = 0.0706$  in  $t = 0$  and then falls to  $\tau = 0.0706$  in  $t = 1$ .

## 6 Conclusion

This paper examines the role of regulation in reducing the social cost of banking 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 to grow 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. A numerical example illustrates that the planner may be able to reduce the magnitude of the welfare cost of the banking crisis.

## 7 Appendix

### 7.1 Discussion of related empirical literature

#### 7.1.1 Entry of multinational banks

Entry of foreign banks can help to sustain the flow of credit to domestic firms even as domestic banks face binding capital requirements. Peek and Rosengren (2000b) discuss this for Argentina, Brazil, and Mexico, and argue that foreign banks also bring expertise to the domestic banking system. The problem is that severe banking crises may lead to not just insufficient, but actually negative bank net assets. If the country's government lets foreign banks enter then competition for loans drives down the value of struggling domestic banks to zero. Governments most likely will not allow all

struggling domestic banks to file bankruptcy at the same time. In fact, during the Brazilian banking crisis, Brazil made it a condition for entering multinational banks to absorb struggling domestic banks. But then the entering bank likely requires the government to restrict further entry: there need to be sufficient rents from loans to be earned during the transition to earn back the cost of absorbing negative equity of troubled domestic banks. Further, if domestic bank shareholders have a stronger lobby than domestic workers, then a government is unlikely to allow foreign bank capital as it will dilute domestically held equity.

### 7.1.2 Recapitalization

In the economy studied in this paper a recapitalization of banks at  $t = 0$  is not feasible since workers would default immediately. In practice, special regulatory circumstances may play a role in making a timely recapitalization difficult. Swire (1992) documents how, for the US, regulatory powers have been expanded significantly in the wake of banking crises. He argues that this might lead to a time inconsistency problem. 'Superpowers' granted to the FDIC include determining when a bank is insolvent, and subordinating claims of insiders and outsiders to the deposit insurance fund's claims. In particular, informal agreements will not be honored by the FDIC, which acts as a receiver. Swire (1992) argues that the specialness of bank, compared to nonfinancial corporate, insolvency law leads to a different kind of bank run. Bank creditors as well as debtors will cease business relations with the bank once it has low equity, as the point of insolvency is unclear due to FDIC discretion in that matter. Hence, FDIC's ex-post toughness on third parties may lead to excessive bank insolvencies ex ante. In particular, recapitalization of banks may become more difficult: potential investors would prefer to wait until after the bank went through an FDIC-orchestrated insolvency as this can eliminate hidden liabilities.<sup>16</sup> Hoshi and Kashyap (2010) describe how uncertainty over regulators' intentions slowed down recovery from the Japanese banking crisis of the 1990s.

### 7.1.3 Collusion or concentration

The constrained-efficient banking crisis resolution proposed above involves collusion (implemented by a tax on bank lending) rather than concentration on the market for bank loans. However, both are ways to recapitalize banks. Cetorelli and Gambera (2001) find that bank concentration is positively correlated with growth in fast growing, underdeveloped sectors, while negatively correlated with growth in general. In particular, it may be beneficial if the banks serving an industry that experiences a scarcity of investment have some market power. However, bank concentration differs from collusion in that it may also affect otherwise perfectly competitive product markets on which borrowers are active. Cartelization of firms as a result of bank concentration around 1900 has been

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<sup>16</sup>Coates and Scharfstein (2009) argue that attempts to recapitalize banks should involve forgiving debt partially. The idea is to reduce the amount of new private equity needed to avoid a de facto nationalization of banks, given that current regulation (in the US) prohibits individual non-financial investors to hold large stakes in banks.

discussed by Simon (1998). For a recent example of how debt dependence may increase margins on the product market see Chevalier (1995). Rajan and Zingales (2003) argue that incumbent banks influence regulators to hinder financial reform, and thus keep bank industry concentrated, unless pressures from trade and capital flow liberalization are strong.<sup>17</sup>

While bank concentration, as opposed to bank collusion, may be interpreted as a possible 'third best' response to a bank crisis, it cannot be cleanly separated from political economy issues. For example, the 1923 Tokyo earthquake cost 38% of Japanese GDP at that time and arguably also represented a large shock to bank net assets. In fact, the number of banks dropped from 2000 before the disaster to about 65 after, while the fraction of total deposits held by the five largest banks increased from 20.5% to 45.7%. In addition, banks became to head bond committees which may have allowed them to exert power over borrowers that had access to direct finance. However, these measures cannot be interpreted solely in the light of optimal regulation, as the Japanese government at that time was also in need of a strong and willing banking sector to finance two wars (1937 war against China, and the second world war).

#### **7.1.4 Causes of financial crises**

With respect to the 2007-2009 financial crisis, Acharya, Cooley, Richardson, and Walter (2010) argue that large complex financial institution (LCFI) deliberately exposed themselves to severe tail risk, thereby using their recently<sup>18</sup> obtained status as 'too big to fail' to realize and maximize the option value on their holdings of securitized assets. Wilmarth (2008) argues that LCFI exposed themselves to tail risk as an unintended by-product of their quest to maximize fee income from various financial services derived from an originate to distribute policy. For example, LCFI ended up warehousing a substantial part of the asset-backed securities (ABS) they created, and also provided guarantees to ease passing on these ABS to other investors. Both papers acknowledge special macroeconomic conditions (especially, high international savings and loose monetary policy) leading to exceptionally high demand for ABS by relatively ingenuous investors, as well as a regulatory failure to prescribe adequate minimum equity requirements as essential amplifiers. However, while Wilmarth (2008) believes that LCFI shared the misperception, for example, about the likelihood of a decline in house prices with investors and regulators, Acharya et al. (2010) believe that LCFI intentionally manufactured tail risk.

In the analysis provided in this paper it is assumed that the regulator thinks a future financial crisis is impossible. Hence, the optimal regulation is derived without worrying about its effect on the likelihood or severity of future crises. I think this is a good assumption since it is generally

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<sup>17</sup>In that sense regulators may be forced to renege on an earlier promise to grant rents, if international financial integration arrives suddenly and unexpectedly. In that case banks will suddenly be severely under-funded as the loss of future rents would lead to increased capital requirements.

<sup>18</sup>The repeal of the Glass-Steagall triggered remarkable concentration in the market for financial services which ultimately led to only a handful of dominant 'universal banks'.

observed that regulators did not make use of the tools they had to avert a disastrous economic outcome: if most market participants do not see the crisis coming, regulators probably will not either.<sup>19</sup> Conversely, if LCFI are in fact guilty of deliberately bringing about a financial crisis, then regulators are very likely guilty of gross negligence. Hence I do not think that regulators should worry about being too lenient in providing assistance to LCFI during banking crises.<sup>20</sup>

## 7.2 Proofs

*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  $\theta K_t^\alpha$ . (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  $K_t^{\alpha-1} k_t = \Theta_t k_t$ . Note that the firm's equilibrium demand for loans  $K_t$  is taken as given by the bank.  $\square$

*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 net investment. 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 labor income must increase if  $W_0$  increases. Hence workers are better off as well.  $\square$

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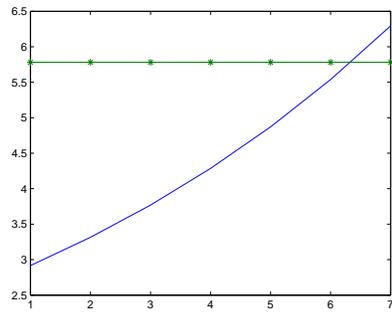
<sup>19</sup>Former member of the Securities and Exchange Commission Paul S. Atkins has been quoted saying "Remember this crisis began in regulated entities ... This happened right under our noses". See also Rajan (1996): "... in the course of performing their traditional activities, banks have acquired competencies that enable them to perform a variety of other financial and non-financial activities that deregulation has opened up to them. While some of these activities hold out considerable promise, bank executives are wisely approaching these new activities with caution and restraint." On the other hand, potential moral hazard problems with an originate-to-distribute policy are well understood, see for example Gorton and Pennacchi (1995).

<sup>20</sup>The proposal developed in Admati and Pfleiderer (2009) may be a way around that problem.

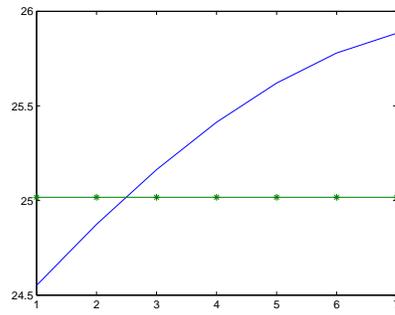
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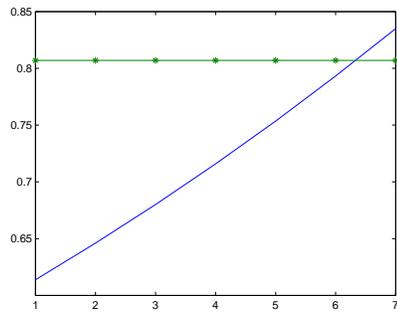
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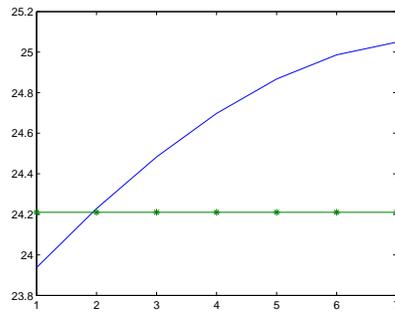
(a) Bank lending  $K_t$



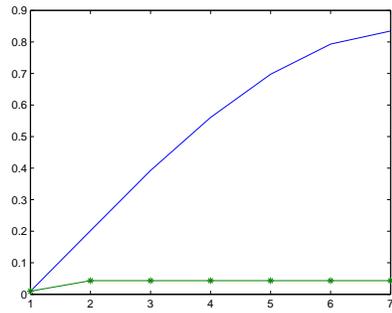
(b) Welfare  $V_t + U_t$



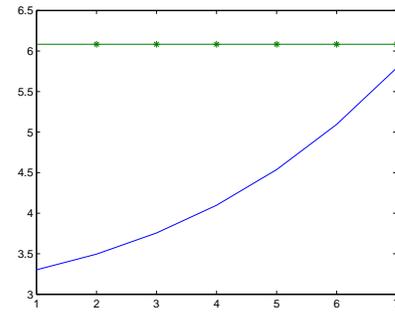
(c) Bank value  $V_t$



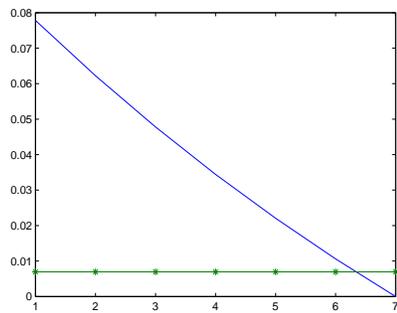
(d) Worker value  $U_t$



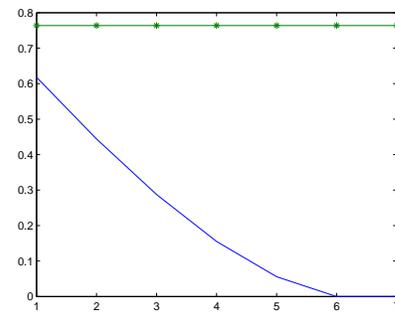
(e) Bank equity  $a_t$



(f) Bank debt  $b_t$



(g) Bank profitability  $R_t - \frac{1}{\beta}$



(h) Bank future profits  $\Pi_t$ .

Figure 2: The blue line shows the competitive equilibrium allocation and the green line shows the constrained-efficient allocation.