DISCUSSION PAPER SERIES

DP11267

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FINANCIAL ECONOMICS, INDUSTRIAL ORGANIZATION and PUBLIC ECONOMICS

ISSN 0265-8003

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Discussion Paper 11267
Published 10 May 2016
Submitted 11 May 2016

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JEL Classification: C79, G21, G28

Keywords: Banking crises; Crisis Contracts; Excessive Risk Taking; Banker's Pay; Hedging; Capital Requirements.

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On the Economics of Crisis Contracts*

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This version: April 2016

Abstract

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*A first version of this paper has appeared as Working Paper No. 453 of the Center for Financial Studies (CFS), Goethe University Frankfurt. We would like to thank Antoine Bommier, Markus Brunnermeier, Martin Hellwig, Jan Krahnen, Jean–Charles Rochet, Hyun Song Shin, and Javier Suarez, as well as participants of the Law and Economics Conference 2014 at New York University and seminar participants at the Bank of England, University of Tübingen, and ETH Zurich for valuable comments.

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1 Introduction

In this paper, we provide a first analysis of so–called Crisis Contracts as a regulatory instrument in the banking sector. Under a Crisis Contract, bank managers contribute a certain share of their past earnings to public rescue funds when a banking crisis occurs.[1] Using a game-theoretic modeling approach, we will show that Crisis Contracts reduce excessive risk-taking and increase social welfare when combined with suitable capital requirements.

Motivation

In the context of the 2008 financial crisis, many governments felt compelled to provide extensive bailouts to financial institutions, implying a substantial transfer of risks from the banking sector to the government and, ultimately, the taxpayer. Moreover, there is ample evidence that excessive asset risk-taking has played a central role in this crisis (see Hellwig (2009), Chesney et al. (2012) and Efing et al. (2015)).[2] This development has led both to a major debate about the regulation of risk in the financial sector and to a controversy about the remuneration of bank managers and the associated "bonus culture." Crisis Contracts are linked to both of these issues.

Literature and Positioning

The classical regulatory response to excessive risk-taking in the banking sector is the modification of capital requirements. In the wake of the most recent crisis, for instance, Admati and Hellwig (2013) have proposed a drastic increase in capital requirements. There are various policy proposals which suggest complementing capital requirements with more direct government interventions in banking activities. Some examples are the forced separation of retail banking from investment banking[3], setting a limit on the size of banks, or imposing a downright ban on trading certain kinds of financial assets (for instance, forbidding short–sales). Such direct interventions in banking activities require the regulator to identify excessively risky assets or practices ex ante. That is, the regulator needs to specify which assets should be forbidden or penalized with high capital requirements. Therefore, such direct regulatory interventions require a lot of information and good judgment of the regulator, and they can be challenged by financial innovation.

Similar problems arise when the judicial system is used to punish excessive risk–taking

[1]Crisis Contracts were first suggested in Gersbach (2011).

[2]For empirical evidence on the evolution of the compensation of bank managers before and after the crisis, see Bell and Van Reenen (2014).

[3]The separation of retail and investment banking has a long history in banking regulation. One famous example is the 1933 Glass–Steagall Act.

ex post, for instance by tort action lawsuits. In reality, it may often be very difficult to assign individual responsibility to specific banks or managers. This is especially true in an environment where systemic risks are present at a macro level and depend, among other things, on the degree to which different banks are interconnected.[4] Armour and Gordon (2013) have recently pointed out that tort law is of limited use in internalizing social costs of banking crises. Moreover, even if each individual bank complies with regulations and has a sufficiently sound investment portfolio, the banking sector as a whole may still be exposed to excessive risk. This problem is discussed in Adrian and Brunnermeier (2011), who propose a modification of the common "Value-at-Risk" method which accounts for covariances.

A second class of policy proposals concerns the remuneration of bank managers. For instance, some possible regulations are an explicit limit on bank managers' fixed salaries, or a limit only on their bonuses, or an exceptional bracket of income taxation for bonus payments. Some governments have tried to limit managerial pay at least in those banks that were rescued by a bailout. The relation between government bailouts and managerial pay in the banking sector has been studied by Hakenes and Schnabel (2010). They develop a theoretical model in which bailout guarantees by the government encourage bank shareholders to offer their managers very variable compensation with a large bonus for high returns on investment. This remuneration policy, in turn, leads to excessive risk-taking by managers. Hakenes and Schnabel suggest a regulatory cap on bonus pay. Thanassoulis (2012a) proposes a limit to bonus pay that would vary with the bank's balance sheet. In a follow-up paper, Thanassoulis (2012b) examines the impact of such a regulation on banks' portfolio choices and finds that such regulation would encourage asset diversification and create incentives to focus more on retail banking. John et al. (2000) propose a deposit insurance scheme in which the insurance premium to be paid by a bank depends on that bank's payment practices. VanHoose (2011) gives an overview of different regulations for bankers' pay in the United States and provides a survey of theoretical and empirical findings on the effects of such regulations.

Overview of the Model

In this paper, we develop an alternative approach which avoids any explicit cap on bankers' pay as well as any judicial assignment of guilt to individual bankers. Instead we propose that in case of a banking crisis, all bankers pay a retroactive tax on their previous earnings

[4] The authors are grateful to Roberta Romano for her helpful comments on the limitations of individual liability and tort law in restricting excessive risk-taking.

from the banking sector. In particular, our proposal does not distinguish between "fixed pay" and "bonus pay," nor between bankers working for "prudent" banks and those working for "reckless" banks. In order to assess the effect of Crisis Contracts, we introduce a stylized two–period model of a financial sector and the strategic interaction of bank shareholders and bank managers. We assume that there are n banks, where each bank is owned by a shareholder and operated by a manager. In each of two time periods, the shareholder of each bank offers the manager a wage contract which conditions the pay on the return on investment. The manager may reject the offer and take an employment opportunity outside the banking sector. If the manager accepts to work for the bank, then the manager chooses between a risky and a safe investment. In the absence of a crisis, the rate of return on the risky investment is higher than on the safe investment. However, if more than a critical number of managers choose the risky investment, then a crisis occurs with positive probability. In that case, the risky investment leads to a loss which exceeds the limited liability of shareholders, and thus to an externality on the society at large.

The socially optimal outcome in this economy is that the number of banks choosing the risky investment is just low enough to avoid a crisis event. Shareholders, however, have a preference for excessive risk–taking, and will design managerial pay accordingly. We formalize Crisis Contracts as follows: If a crisis occurs in the second period, then the government collects a certain share of the first–period income of all managers. We give conditions under which Crisis Contracts shift the model economy towards the socially optimal outcome.

Main Results

More precisely, our main results are as follows: In the absence of Crisis Contracts, the unequivocal equilibrium prediction is that all banks choose the risky investment in both periods. This is the worst outcome from the social welfare point of view. If Crisis Contracts are introduced, multiple equilibrium outcomes are possible. We can give conditions on the model parameters such that the socially worst outcome is eliminated as an equilibrium. Moreover, we derive parameter scenarios in which the socially optimal outcome is attained at equilibrium. One interesting feature is that although a crisis tax is triggered only if a crisis is occurred in the second period, a crisis is already avoided in the first period. There are equilibria in which crisis never occurs.

We also establish conditions under which all equilibria with Crisis Contracts are strictly socially better than all equilibria without Crisis Contracts. In sum, the socially beneficial effect of Crisis Contracts hinges crucially on a number of restrictions on the model parameters which describe the asset payoff structure.

While the relevant model parameters have so far been taken as given, we now underpin them with an analysis of a bank balance sheet in the presence of capital requirements. This allows us to give an economic interpretation of the parameter conditions under which Crisis Contracts are socially beneficial. We illustrate how these model parameters can be derived from an analysis of the bank balance sheet in the presence of capital requirements. We demonstrate that a sufficient level of capital requirements ensures that the relevant parameter conditions are satisfied and Crisis Contracts are socially beneficial. Without sufficient capital requirements, Crisis Contracts would not be effective. Intuitively, the reason is that incentives for excessive risk–taking increase with leverage and thus can grow without bound in the limit as bank capital goes to zero. The disincentives provided by Crisis Contracts, on the other hand, are proportional to the tax rate, and therefore bounded. Given some sufficient level of capital requirements, there is some substitutability between both regulatory measures: Many pairs of a crisis tax rate and a capital requirement can sustain the same outcome. An increase in the tax rate can be offset with a lower capital requirement, or vice versa.

Thus, Crisis Contracts appear to be a useful tool for supplementing and strengthening the effects of capital requirements. Our results seem to confirm the idea that in the absence of suitable capital requirements, the financial system as a whole would be highly vulnerable to small shocks that cannot be effectively dealt with by other regulatory tools (Hellwig, 2009; Gersbach, 2013). Recent conceptual contributions identifying the working and design of such capital requirements are Repullo (2012), Repullo and Suarez (2013), and Admati and Hellwig (2013).

It is noteworthy that in the presence of Crisis Contracts we find equilibria in which excessive risk–taking is avoided in both the first and second time periods although the crisis tax is only contingent on the occurrence of a crisis in the second period. The intuitive reason is as follows: In a second period subgame, it is always consistent with equilibrium to take excessive risk. This "bad" equilibrium in the second period subgame can be used as a credible threat to establish tacit coordination on the socially optimal outcome in both periods.

Robustness

We provide a discussion on the robustness of our main results. In particular, we consider the possibility that managers may want to take positions on financial markets which hedge them against the risk of having to pay crisis tax. We argue that such hedging tactics cannot undermine the effectiveness of Crisis Contracts. A more detailed analysis of hedging, as well as some other robustness issues, is provided in Subsections 9.1ff.

Pay Caps

Intuitively, one important channel through which Crisis Contracts affect investment behavior in our model is that managers are only willing to take excessive risks if shareholders compensate them for the prospect of having to pay the crisis tax. As a result, shareholders might find it more expensive to provide managers with incentives for excessive risk-taking. In principle, one could try to obtain a similar effect by using explicit legal caps on bankers' pay. However, we argue that Crisis Contracts may avoid some difficulties of such explicit pay caps. In particular, we argue that the use of pay caps requires the regulator to gather information which is not needed in order to apply Crisis Contracts. A more detailed discussion of this issue is provided in Subsection 9.4.

Collective Liability

Given that Crisis Contracts rely on collective liability of bankers for banking crises, they do no not require authorities to discern individual responsibilities. Of course, collective punishment is unacceptable in penal law but Crisis Contracts impose collective liability through taxation only. It can be argued that in the absence of Crisis Contracts, a collective punishment applies to all taxpayers. Collective liability as inherent in Crisis Contracts might have the beneficial side–effect of contributing to a more risk–sensitive bank culture, as suggested in recent policy debates (see for instance the remarks by Dudley (2014)).

Organization

The paper is organized as follows: In Section 2, we provide the formal model description. Sections 3 and 4 deal with a number of preliminary results concerning the second period subgames and the equilibrium remuneration of managers. The analysis of the socially optimal and socially worst equilibria is given in Sections 5 and 6, respectively. In Section 7, we state the main welfare results of the paper and discuss equilibrium multiplicity. In Section 8, we provide a simple balance–sheet based underpinning to the assumptions and restrictions imposed on model parameters. Finally, a discussion on the robustness of the results as well as some remarks on potential extensions of the model and on the practical implementation of Crisis Contracts are given in Section 9.

2 The Model

2.1 A Two-period Economic Environment

We model a banking sector consisting of a finite set of identical banks $N = \{1, \ldots, n\}$ with $n \geq 2$, where the members of N are sometimes indexed by i or j. There are two time periods $t = 1, 2$. In each period, each bank either invests in a *risky asset*[5] or in a *safe asset* or is *out of business.* We capture the investment decision of bank i in period t with the indicator $A^{it} \in \{R, S, O\}$. We denote the *activity profile* $(A^{11}, \ldots, A^{n1}, A^{12}, \ldots, A^{n2})$ by $\mathcal{A}$ and write A^{-it} for the restriction of the activity profile to round t and banks $j \in N \setminus \{i\}$. Given the activity profile $\mathcal{A}$, we take $n_t(\mathcal{A})$ to denote the number of banks choosing the risky asset in round t. This variable reflects the overall level of risk-taking in the banking sector. We assume that there is a threshold $\bar{n} \in \{1, \ldots, n-1\}$ such that investment choices $\mathcal{A}$ trigger a banking crisis in period t with positive probability if and only if the number $n_t(\mathcal{A})$ of risk–taking banks attains (or exceeds) this threshold. We state this assumption more formally as follows:

Assumption 2.1. *Let the activity profile be given by $\mathcal{A}$. If $n_t(\mathcal{A}) \geq \bar{n}$, then a banking crisis occurs in period t with probability $p \in (0, 1)$. If $n_t(\mathcal{A}) < \bar{n}$, then no banking crisis occurs in period t.*

The key feature of our model is that the probability of a banking crisis depends on the investment decisions of all banks in the system. Assumption 2.1 formalizes this feature in a particularly simple and tractable way. It is consistent with the notion that crises occur when total risk–taking passes a critical "tipping point." Such tipping points arise naturally from models of systemic risk in banking. They have been the focus of some important recent contributions to the literature, such as Acemoglu, Ozdaglar, and Tahbaz–Salehi (2015), Amini, Cont, and Minca (2013), Battiston et.al. (2012), Battiston and Caldarelli (2013), and Hurd and Gleeson (2013).[6] We note that the restriction $\bar{n} \leq n-1$ implies that an individual bank alone cannot prevent a crisis by going out of business or by investing in the safe asset.

We use the pair of indicators (Z_1, Z_2) where $Z_t = 1$ if a crisis occurs at period $t = 1, 2$ and

[5]The risk involved in the "risky" asset should be thought of as non–diversifiable. One appropriate interpretation is that the risky asset is representative of a suitably diversified portfolio of component assets.

[6]We could also interpret the crisis in our model as a cascade that affects all banks who have invested in risky assets. An example could be fire sales by those banks.

$Z_t = 0$ otherwise.

We now turn to the asset structure of the economy. The safe asset yields a sure payoff of x_{rf}, whether or not a crisis occurs. The risky asset yields a payoff of x_g when there is no crisis and a payoff of x_b when there is a crisis. We assume that

$$x_g > x_{rf} > 0 > x_b. \tag{1}$$

These inequalities clearly reflect a risk-return trade-off. The risky asset outperforms the safe asset when there is no crisis, but the safe asset performs better than the risky asset when a crisis does occur. We assume that the bank could guarantee itself a sure payoff of zero in each period by staying out of business. Therefore, the payoff $x_b < 0$ from the risky investment in the case of a crisis is suitably interpreted as an (avoidable) loss. In other words, some risk-taking in the economy (by at most $\bar{n} - 1$ banks) guarantees high returns, but major losses are possible when risk-taking is excessive.

2.2 Limited Liability and Bailout

We assume in this paper that the public is to a large extent liable for the losses made by banks during a crisis. The rationale behind this assumption is that, on the one hand, a functioning banking sector is vital for the economy, while on the other hand, banks are owned by shareholders whose liability is limited.[7] We assume that bank equity is insufficient to buffer losses in the event of a crisis. In Section 8, we provide a simple balance–sheet based derivation of the above payoff structure where $|x_b|$ corresponds to the losses of a bank in crisis that invested in the risky asset after its equity has been wiped out. Government-backed deposit insurance schemes and downright bailouts as in the recent financial crisis are examples of mechanisms that eventually hold the public liable for losses in the banking sector. Such explicit or implicit liability of the public creates a distortion of the risk-taking incentives. In particular, banks may have an incentive to take risks that are harmful from the social welfare point of view. In a popular phrase, banks may have the possibility to *"privatize gains but socialize losses."* In order to restrict attention to those cases where such a conflict of interest does indeed arise, we assume henceforth that

$$px_b + (1-p)x_g < x_{rf} < (1-p)x_g. \tag{2}$$

[7] We do not consider the case of private or family-owned banks, where the owners are personally liable for losses.

The leftmost term is the expected payoff from the risky asset, given that a critical number of banks take risk. The rightmost term is that part of the aforementioned expected payoff which is internalized by a shareholder with limited liability: The possible negative realization x_b is ignored. Verbally, we are assuming that once a critical number of banks take risk, the interests of the public and the shareholders conflict: Shareholders prefer the risky asset to the safe asset, but the public would prefer the bank to invest in the safe asset rather than the risky one. We have now fully described the asset payoff structure in our model. This payoff structure is taken as a primitive of the formal model. In Section 8, however, we show how such a payoff structure can be derived from an analysis of a bank balance sheet in the presence of capital requirements. This analysis furthers the understanding of our assumptions and results.

2.3 The Banking Game

Having described the economic environment in which banks operate, we now turn to decision-making within banks. Each bank $i = 1, \ldots, n$ is owned by a single shareholder and run on his behalf by a manager. We will refer to the shareholder and the manager of bank i as shareholder i and manager i, respectively. The decision to invest in the risky or safe asset or to go out of business is the result of a strategic game (henceforth the *banking game*) played by the n shareholders and the n managers. More precisely, each period $t = 1, 2$ of the banking game proceeds as follows: First, all shareholders simultaneously offer a *wage scheme* to their respective manager. The wage scheme ω^{it} offered by shareholder i to manager i in period t is a triple $\omega^{it} = (\omega_g^{it}, \omega_{rf}^{it}, \omega_b^{it})$ specifying the manager's wage conditional on asset return. The shareholder can only use the asset return to finance the manager's wage. This budget constraint implies that the manager will earn zero if the asset return is negative. More formally, the set of feasible wage schemes is

$$\Omega := \{\omega^{it} \in \mathbb{R}_+^3 | \omega^{it} \leq (x_g, x_{rf}, 0)\}.$$

Note that the shareholder cannot condition the wage on anything other than the realized asset return in the current period. More particularly, the remuneration of one manager cannot be conditioned on the performance of other managers.

Once the shareholders have made their wage offers, each manager i observes the wage scheme ω^{it} but not the wage schemes ω^{jt} offered to the other managers $j \in N \setminus \{i\}$. Then each manager chooses simultaneously between three options: He may either refuse the offered wage scheme and work outside the banking sector ("opt out"), or accept the wage scheme and invest in the risky asset ("take risk"), or accept the wage scheme and invest in the safe asset ("invest safely"). If manager i does not opt out, then the instantaneous utilities of shareholder i and manager i in period t are

$$u_s^{it} = \max(x_k - \omega_k^{it}, 0), \tag{3}$$

and

$$u_m^{it} = \omega_k^{it} \tag{4}$$

for $k \in \{g, rf, b\}$, respectively. If manager i does opt out, then the resulting instantaneous utilities are

$$u_s^{it} = 0 \tag{5}$$

and

$$u_m^{it} = D > 0. \tag{6}$$

We interpret D as the wage that the manager could earn outside the banking industry in each period. We make the following assumptions on D in relation to the other model parameters:

$$x_{rf} \geq D > (1-p)x_g + px_b. \tag{7}$$

These inequalities are related to the social desirability of investments by banks. The safe asset is at least as socially desirable as the manager's outside option. However, the value of the manager's outside option is greater than the expected payoff from the risky investment if risk-taking in the banking system is excessive. Note that the second inequality is satisfied whenever x_b is negative and sufficiently large in absolute value, that is, when the adverse consequences of a crisis are sufficiently bad.

During each period, no actions by a shareholder or a manager of one bank are observable to any other bank's shareholder or manager. After the first period, the investment choices of the first period become publicly observable. Moreover, all shareholders and managers can observe the occurrence of a crisis. A shareholder cannot make a credible commitment in the first period to a wage scheme he will offer in the second period. Moreover, we assume that a shareholder never replaces the manager after the first period.[8]

We have now described how each period of the game is played. In order to complete the formal description of the incentives in this game, we have left to specify the inter–temporal utilities of shareholders and managers. For this purpose, it is now in order to formally introduce the *Crisis Contract*: It is a remuneration rule for bank managers which stipulates that the manager's wage from the first period is taxed retroactively at a flat rate of $c \in [0,1]$ in the event of a crisis in the second period. Hence a Crisis Contract leads to a kind of collective liability for bank managers.

Definition 2.2. *Suppose that manager i has earned wage ω_k^{i1} at $t = 1$, and suppose that a crisis occurs at $t = 2$. Then the manager will be charged a* crisis tax *of $c\ \omega_k^{i1}$, where $c \in [0,1]$ and $k \in \{g, rf, b\}$.*

For the implementation of Crisis Contracts, there are two implicit informational requirements: First, the government should have information about bankers' previous earnings from the banking sector. Within the same country, this information should be available from regular income taxation. In a more complex model, it could be conceivable, however, that managers might previously have worked for banks in other countries or jurisdictions in which case some degree of cross–border information exchange could be required. Second, in order to implement Crisis Contracts, the regulator needs to define an objective and verifiable criterion for the occurrence of a crisis. We call such a criterion a *contract trigger.* In Subsection 9.3, we offer a discussion on several potential contracts triggers. Of course, at more fundamental level, the implementation of Crisis Contracts requires that the government has sufficient coercive power to impose taxation, including retroactive taxes. For instance, one might object to the idea of Crisis Contracts that previous earnings might have been spent or transferred abroad before a crisis tax becomes effective. This problem could be counteracted by requiring the relevant share of the first period wage to be deposited in escrow or in a frozen account.

Note that the Crisis Contract is only relevant if the manager has worked for the bank and obtained a strictly positive wage in the first period. A manager who takes the outside option of D in the first period will never be liable for crisis tax. We have already seen that

[8]This could be justified for instance by the human capital argument of Hart and Moore (1994). Once a manager is employed, the shareholder faces a loss when he replaces him, as the manager has acquired human capital to run the bank. Our current set-up with wage offers by the shareholders assigns all bargaining power to shareholders. Our analysis could be extended to the case where managers can make counter–offers in a more elaborate wage bargaining process.

the interests of the shareholder and the public diverge. A shareholder can use "performance pay" (i.e., condition wage payment on the return on investment) to align the manager's interests with his own. The introduction of a Crisis Contract may allow the government to distort the alignment of shareholder and manager interests in order to better protect the interests of the public.[9]

We assume that managers' intertemporal utility is additively separable in the instantaneous utilities of the two periods and the potential crisis tax. More specifically, manager i's intertemporal utility is given by

$$U_m^i = u_m^{i1} + \delta u_m^{i2} - \delta Z_2 c u_m^{i1}, \tag{8}$$

where $\delta \in (0, 1]$ is the discount factor.

Intertemporal utilities of the shareholder are additively separable in instantaneous utilities, and all shareholders have the same time preferences as all managers. Accordingly,

$$U_s^i = u_s^{i1} + \delta u_s^{i2}. \tag{9}$$

Of course, the linear specification above implies that all shareholders and all managers are risk-neutral. We can think of the wage payments as a direct transfer of utility from the shareholders to the managers. In Figure 1, we illustrate the sequence of events in the banking game with a time line.

2.4 Banking Equilibrium

To complete the description of the game, we need to specify the appropriate notion of a strategy and the solution concepts. To begin with, we focus on second-period subgames of the banking game only. The *first-period history* of the banking game consists of the wage schemes offered in the first period, the investment decisions taken by the managers in the first period, and the realization of Z_1. We use h to denote such a first-period history of the banking game. The set of all first-period histories is denoted by $H \subset \Omega^n \times \{R, S, O\}^n \times \{0, 1\}$. We will only consider histories that are consistent with the rules of the game. For instance, a first-period history in which all managers have invested safely but a crisis has occurred is not consistent and hence does not belong to the set H.

[9] Like a Pigouvian tax, the crisis tax aims to correct a (negative) externality. However, the crisis tax is not itself a Pigouvian tax since it is levied on the managers of all banks, even those who did not cause the negative externality.

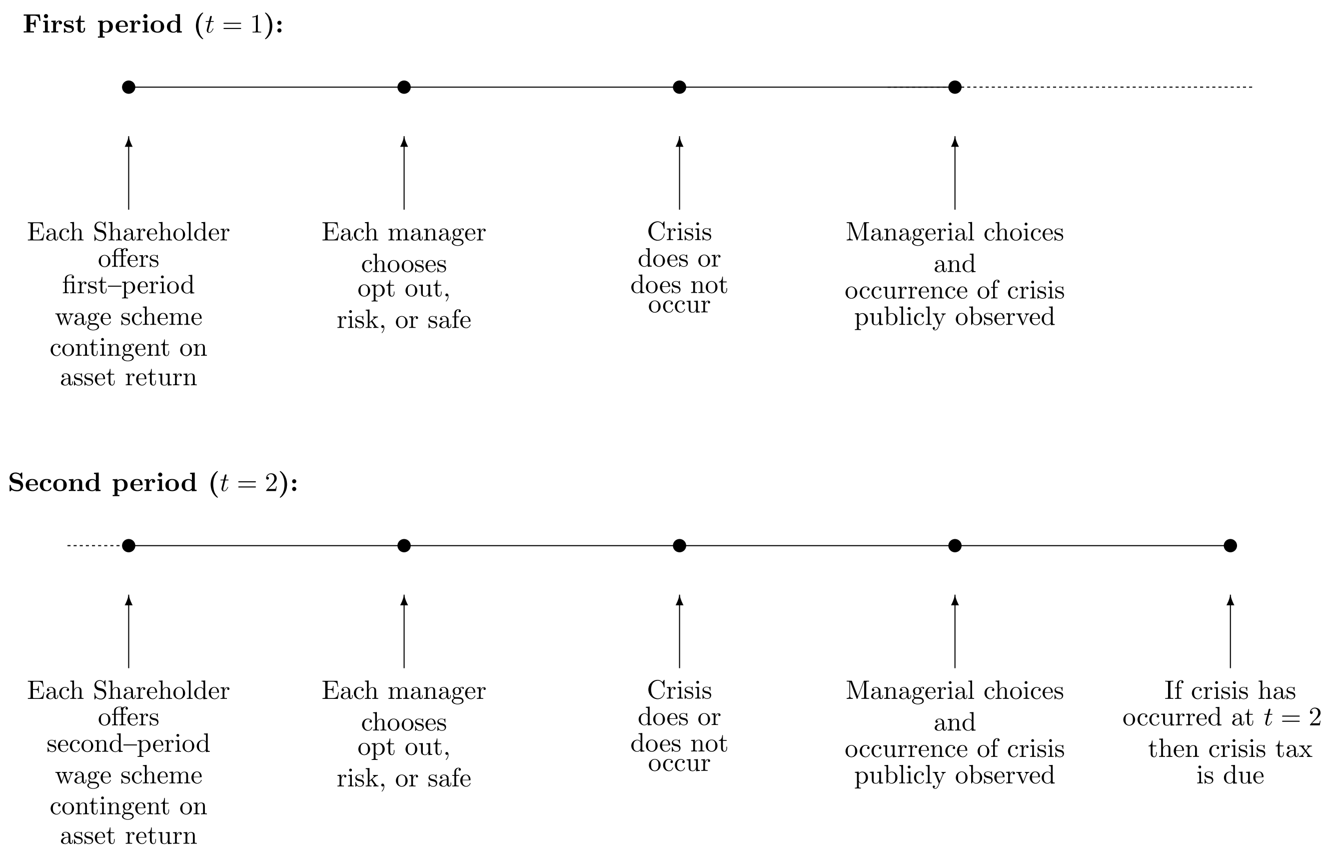

Figure 1: The banking game.

From the information contained in a history h one can infer the amount of crisis tax each manager i would have to pay in the second period if a crisis were to happen. We refer to this amount as the *looming crisis tax* and denote it by $\tau^i(h)$. We will refer to the subgame starting in the second period following first-period history h as the *h-subgame.* A strategy σ_s^{ih} for shareholder i in the h-subgame consists only of wage offer $\omega^{ih} \in \Omega$. A strategy σ_m^{ih} for manager i in the h-subgame is a partition of the set Ω into three subsets: the set of wage offers to which manager i responds by taking risk, those to which he responds by investing safely, and those to which he responds by opting out. Suppose that σ^h is a strategy profile for the h-subgame.[10] Such a strategy profile σ^h induces a second–period activity profile $A^2(\sigma^h)$ for all banks. We denote by $A^{-i2}(\sigma^h)$ the second-period investment decisions of all banks other than bank i as induced by σ^h. Assuming that managers $j \in N \setminus \{i\}$ do indeed choose according to $A^{-i2}(\sigma^h)$, and given the wage he has realized in the first period, manager i can calculate the expected amount of crisis tax he will have to pay if he takes

[10] That is, $\sigma^h \in \Omega^n \times (\Pi(\Omega))^n$, where $\Pi(\Omega)$ is the set of tripartitions of Ω.

risk, or invests safely, or opts out.

If, in addition, he is given any second-period wage scheme $\omega \in \Omega$, manager i can compute his expected payoffs from risk-taking, investing safely, and opting out. If the strategy σ_m^{ih} partitions the set Ω in such a way that manager i chooses an action with maximal expected payoff, then we will say that manager i's strategy σ_m^{ih} is *a best response to* $A^{-i2}(\sigma^h)$*.* Note that the optimality of σ_m^{ih} relates only to the activity profile, not to the whole profile σ^h. This kind of optimal behavior is crucial for the equilibrium concept we use to solve the h-subgame and to which we refer as the *h-banking equilibrium.*

Definition 2.3. *A strategy profile* $\sigma^h = (\sigma_m^{1h}, \ldots, \sigma_m^{nh}, \sigma_s^{1h}, \ldots, \sigma_s^{nh})$ *in the h-subgame is an* h-banking equilibrium *if*

1. *For each manager $i \in N$, the strategy σ_m^{ih} is a best response to $(A^{-i2}(\sigma^h), \tau^i(h))$.*
2. *For each shareholder $i \in N$, the strategy σ_s^{ih} is a best response to $A^{-i2}(\sigma^h)$ and σ_m^{ih}.*

The next step is to introduce the strategies and the solution concept for the entire banking game. A strategy σ_m^i for manager i in the banking game consists of a strategy σ_m^{ih} in the h-subgame for every $h \in H$ and a partition of Ω into three subsets, the set of wage offers to which manager i responds by risk-taking, those to which he responds by investing safely, and those to which he responds by opting out in the first period. A strategy σ_s^i of shareholder i consists of a strategy σ_s^{ih} in the h-subgame for every $h \in H$ and a wage offer ω^{i1}.

We assume that, for every $i \in N$, the strategies σ_s^i and σ_m^i must satisfy the following restriction: If two first-period histories $h', h'' \in H$ involve the same first-period investment choices by all banks and the same realization of Z_1, and if for bank i the first-period wage payment to manager i under h' is equal to the first-period wage payment to manager i under h'', then $\sigma_m^{ih'} = \sigma_m^{ih''}$ and $\sigma_s^{ih'} = \sigma_s^{ih''}$. Put the other way, a strategy cannot distinguish between two histories which only differ with respect to wage offers and realized wage payments of banks other than bank i and with respect to the wage offer of bank i except for the realized wage in the first period. [11] The motivation for this restriction is that the wage offers which have not been realized are irrelevant while the wage schemes of

[11]If this restriction was dropped from the definition of the strategy space, then additional equilibria could arise in which the investment choice of one bank depends on earlier wage offers made in other banks. But the wage is a mere redistribution of payoffs between the shareholder and manager of a particular bank and need not in any way concern the shareholders or managers of other banks. Accordingly, such equilibria seem implausible.

each bank should be thought of as "private information" of that bank's shareholder and manager. Rather than modeling a game of imperfect information, however, we formalize this idea indirectly as a restriction on the strategy space. This is convenient since it allows us to maintain a definition of the first-period history under which every such history is the root of a proper subgame. A banking equilibrium is then defined as follows:

Definition 2.4. *A strategy profile $\sigma = (\sigma_m^1, \ldots, \sigma_m^n, \sigma_s^1, \ldots, \sigma_s^n)$ is a* banking equilibrium *if the following holds for every $i \in \{1, ..., n\}$:*

1. *For every $h \in H$ consistent with σ, the restriction of σ to the h-subgame is an h-banking equilibrium.*
2. *Given $A^{i2}(\sigma^h)$ for every $h \in H$ consistent with σ and given $A^{-i1}(\sigma)$, the partition of Ω prescribed by σ_m^i for the first period is optimal.*
3. *Given $A^{i2}(\sigma^h)$ for every $h \in H$ consistent with σ, given $A^{-i1}(\sigma)$, and σ_m^i, the wage offer prescribed by σ_s^i for the first period is optimal.*

In the next section, we begin with a backward induction analysis of the banking game by studying subgames in the second time period.

3 Second-period Subgames

In this section we focus on the second period and deal first with the relationship between the shareholder and the manager of each bank. Later we deal with the strategic interaction between the different banks.

Fix a first-period history $h \in H$ and a strategy profile σ^h for the h-subgame. Let σ^h be such that manager i works for the bank (rather than taking the outside option) in the second period. In this case, we define manager i's *expected wage* in the second period as

$$\mu^{i2}(\sigma^h) = \begin{cases} \omega_g^{i2}(\sigma^h) & \text{if } n_2(\sigma^h) \leq \bar{n} - 1 \text{ and } A^{i2}(\sigma^h) = R, \\ (1-p)\omega_g^{i2}(\sigma^h) & \text{if } n_2(\sigma^h) \geq \bar{n} \text{ and } A^{i2}(\sigma^h) = R, \\ \omega_{rf}^{i2}(\sigma^h) & \text{if } A^{i2}(\sigma^h) = S. \end{cases}$$

This wage is "expected" in the sense that the realization depends on whether or not a crisis occurs if at least $\bar{n}$ banks invest in the risky asset. Observe that the expected wage has only been defined for the case where the manager works for the bank and thus forgoes his outside option. For each manager i, we define the *reservation wage* as

$$\kappa^{i2}(\sigma^h) = \begin{cases} D + p\tau^i(h) & \text{if } n_2(\sigma^h) = \bar{n} \text{ and } A^{i2}(\sigma^h) = R, \\ D & \text{otherwise.} \end{cases}$$

Manager i is called *pivotal under* σ^h if $n_2(\sigma^h) = \bar{n}$ and $A^{i2}(\sigma^h) = R$. In words, manager i is considered pivotal if his decision to take risk is responsible for attaining the threshold $\bar{n}$. Observe that the expected and reservation wages are defined in such a way that working for a bank rather than opting out can only be optimal for a manager if the expected wage is greater than, or equal to, the reservation wage. In the next lemma, our claim is that in equilibrium the expected wage is equal to the reservation wage. The intuition behind this claim is straightforward. If the expected wage were higher than the reservation wage, then it would be a profitable deviation for the shareholder to lower the remuneration by an infinitesimal amount. This is a simple adaptation of a standard argument from the literature on ultimatum and bargaining games, where equilibrium offers make the responding player exactly indifferent between accepting or declining the offer.

Lemma 3.1. *Fix a bank $i \in \{1, ..., n\}$. Suppose σ^h is a strategy profile in the h-subgame and $A^{i2}(\sigma^h) \neq O$. Also suppose the strategies σ_m^{ih} and σ_s^{ih} are best responses to σ^h. Then it holds that $\kappa^{i2}(\sigma^h) = \mu^{i2}(\sigma^h)$.*

Proof. The proof can be found in the appendix. □

It is now clear how the shareholder can align the manager's interests with his own: First, by setting the appropriate component of the wage scheme equal to zero, the shareholder can ensure that a manager who works for the bank will choose the asset preferred by the shareholder rather than the other asset. Second, by choosing the remaining component of the wage scheme so as to equalize expected and reservation wages, the shareholder can ensure that a manager will indeed work for the bank rather than opt out. A manager who works for the bank always expects to receive D unless he is pivotal, in which case he obtains an additional payment of $p\tau^i(h)$ to compensate him for the expected crisis tax payment.

Definition 3.2. *If all banks take risk in the h–subgame under the strategy profile σ^h, then we say that σ^h involves* full risk. *If exactly $\bar{n} - 1$ banks take risk in the h–subgame under strategy profile σ^h, then we say that σ^h involves* threshold risk.

We claim that only full risk and threshold risk are consistent with an h–banking equilibrium.

Lemma 3.3. *An h-banking equilibrium involves either full risk or threshold risk.*

Proof. The proof can be found in the appendix. $\square$

One implication of Lemma 3.3 is that no manager is pivotal in an h-banking equilibrium. But if a manager is not pivotal, his expected and reservation wages will both be equal to his outside option D.

Corollary 3.4. *In an h-banking equilibrium, the expected wage of each manager in the h-subgame is equal to D.*

Having excluded any other types of h-banking equilibria, we now turn to the conditions for the existence of h-banking equilibria involving either full risk or threshold risk. Recall that $\bar{n} \leq n-1$. In words, no individual bank can eliminate the risk of a crisis by choosing the safe asset. Moreover, given that at least $\bar{n}$ banks do take risk, our assumptions on the payoff structure imply that there is an incentive for other banks to take risk as well. Therefore, it seems intuitively clear that an h–banking equilibrium with full risk exists in every h–subgame. This is the claim of the theorem below.

Theorem 3.5. *For every h-subgame, there is an h-banking equilibrium involving full risk.*

Proof. The proof can be found in the appendix. $\square$

Now we turn to conditions for existence of an h–banking equilibrium with threshold risk. To this end, let us define the following critical value for the looming crisis tax:

$$\tau^* = \frac{(1-p)x_g - x_{rf}}{p}.$$

Our assumptions on the payoff structure imply that $\tau^* > 0$. The theorem below gives a necessary and sufficient condition for the existence of an h–banking equilibrium with threshold risk.

Theorem 3.6. *For every $h \in H$, the h–subgame admits an h-banking equilibrium involving threshold risk if and only if $\tau^i(h) \geq \tau^*$ for at least $n - \bar{n} + 1$ banks.*

Proof. The proof can be found in the appendix. □

When $c = 0$, then we have $\tau^i(h) = 0$ for all $i \in N$ and $h \in H$. Since $\tau^* > 0$, we know that an h-banking equilibrium with threshold risk does not exist in the absence of Crisis Contracts.

Corollary 3.7. *In the absence of Crisis Contracts all h-banking equilibria in all h-subgames involve full risk.*

We have now completed the analysis of the second period subgames of the banking game. In the next section we proceed by backward induction to the first period, and focus first on managerial pay.

4 Managerial Pay in the First Period

We now turn to the first period. The *expected wage* of manager i in the first period can be defined analogously to the earlier definition of μ^{i2} as follows:

$$\mu^{i1}(\sigma) = \begin{cases} \omega_g^{i1}(\sigma) & \text{if } n_1(\sigma) \leq \bar{n} - 1 \text{ and } A^{i1}(\sigma) = R, \\ (1-p)\omega_g^{i1}(\sigma) & \text{if } n_1(\sigma) > \bar{n} - 1 \text{ and } A^{i1}(\sigma) = R, \\ \omega_{rf}^{i1}(\sigma) & \text{if } A^{i1}(\sigma) = S. \end{cases}$$

However, the realized wage may be subject to the crisis tax in the second period. Given that some strategy profile σ is played throughout the banking game, we can define the *ex ante* probability $\rho(\sigma)$ with which a crisis will occur in the second period. In this context, ex ante means that $\rho(\sigma)$ has not been updated with the possible move of nature in the first period. For example, if σ is such that all managers invest safely in the second period, then $\rho(\sigma) = 0$. If, on the contrary, σ is such that all managers take risk in the second period, then $\rho(\sigma) = p$. It is possible, however, for $\rho(\sigma)$ to take other values than 0 or p. For example, suppose that under strategy profile σ managers $1, \ldots, \bar{n} - 1$ always take risk in the second period, whereas managers $\bar{n}, \ldots, n$ take risk in the second period if and only if a crisis has occurred in the first period. Suppose further that under σ all managers take risk in the first period. In that case, we have $\rho(\sigma) = p^2$. Based on the probability $\rho(\sigma)$ and the expected wage of manager i in the first period, we can define manager i's *expected net wage* from the first period under σ as follows:

$$\nu^{i1}(\sigma) = (1 - \delta c \rho(\sigma))\, \mu^{i1}(\sigma).$$

To understand this expected net wage intuitively, suppose that by the end of the first period a manager has earned a certain wage, say w. Since the manager has worked for a bank in the first period, he may now have to pay crisis tax. So, the realized wage of ω in the first period only increases his intertemporal utility in expected terms by the amount $(1 - \delta c \rho(\sigma))\, \omega$. The significance of $\nu^{i1}(\sigma)$ lies in the fact that this is the quantity which the manager compares to his outside option when deciding whether to work for the bank or to opt out, whence the following lemma.

Lemma 4.1. *If σ is a banking equilibrium and $A^{i1}(\sigma) \neq O$, then $\nu^{i1}(\sigma) = D$.*

Proof. The proof can be found in the appendix. $\square$

The above lemma shows that also in the first period, a shareholder extracts all surplus created by the investment. A manager receives a payment that makes him indifferent between working for the bank and opting out. If a banking equilibrium is such that a manager has to pay crisis tax with positive probability, then the shareholder has to compensate the manager for the expected crisis payment by a higher wage in the first period. The expected intertemporal utility for the manager is always equal to the payoff from taking the outside option in both periods.

Corollary 4.2. *In a banking equilibrium σ, each manager receives an expected intertemporal utility $U^i_m(\sigma) = (1 + \delta)D$.*

We have seen before that the manager's instantaneous payoff $u^{i2}_m(\sigma)$ in the second period is equal to D in every banking equilibrium. It follows that $u^{i1}_m(\sigma) \geq D$.

Corollary 4.3. *In a banking equilibrium, each manager's instantaneous payoff in the first period is at least D.*

Suppose that the first period has passed without a crisis and that bank i has not been out of business. We would like to be able to conclude from this that manager i has earned a realized wage of at least D. By Corollary 4.3, this is certainly true on the equilibrium path of play. Assumption 4.4 below imposes that, even out of equilibrium, a manager never accepts a wage scheme which would always lead to a realized wage less than D. We need to make this assumption because the manager and shareholder of bank $j \neq i$ cannot condition their second period actions on the first period wage scheme of bank i. The idea behind is that the wage schemes never become commonly known. However, the manager and shareholder of bank j can reasonably infer from the fact that manager i has worked for the bank that his wage scheme ω^{i1} has allowed for the possibility of earning at least D.[12]

Assumption 4.4. *A manager cannot accept a wage scheme* ω *such that* $D > \max\{\omega_g, \omega_{rf}\}$.

Here we conclude our discussion of managerial pay in the banking game. In the next two sections, we will discuss the equilibrium activity profiles. We will focus on two specific types of banking equilibria, called full risk equilibria and threshold equilibria. These types of equilibria are particularly interesting because, as we will show later, they achieve the highest and lowest possible level of social welfare in our model.

5 Full Risk Equilibria

We refer to a banking equilibrium as a *full risk equilibrium* if it involves full risk in both periods on the equilibrium path of play. In particular, a full risk equilibrium involves risk-taking by all managers in the second period, irrespective of the realization of Z_1. If σ is a full risk equilibrium, then we have $\rho(\sigma) = p$. In this section we give necessary and sufficient conditions for the existence of a full risk equilibrium.

To understand intuitively when a full risk equilibrium does or does not exist, let us consider an individual bank. If the bank is out of business in the first period, the manager's payoff is D and the shareholder's payoff is zero. Recall that the manager's outside payoff of D will never be subject to crisis tax, as a Crisis Contract applies only to wages earned in the banking sector in the first period. Now we turn to the case where the bank invests in the risky asset in both periods. For the sake of this intuitive argument, assume for a moment that the manager's realized wage is the entire realized asset return. Then the payoff from bank activities in the first period is equal to $(1-p)x_g - \delta p(1-p)cx_g$, which is shared by the manager and the shareholder of the bank under consideration. The first term is simply the expected return on the risky asset in the first period. The second term is the expected utility loss from the crisis tax. A crisis tax will only have to be paid if there is no crisis in the first period but a crisis does occur in the second period. Given that all banks

[12] This reasoning is similar in spirit to the concept of "forward induction" in game theory, that is, a player assumes that the past decisions of other players were rational in order to infer information about his own position in the game tree. As we have pointed out before, it is convenient for our purposes to impose some extra restrictions on the strategy space rather than model the banking game as a game of imperfect information.

take the risky investment in both periods, the probability of this event is $p(1-p)$. If this event occurs, then crisis tax cx_g has to be paid. It may now seem intuitive that a full risk equilibrium exists if $(1-p)x_g - \delta p(1-p)cx_g \geq D$ or, equivalently, if c does not exceed the threshold c' defined as

$$c' = \frac{(1-p)x_g - D}{\delta p(1-p)x_g}. \tag{10}$$

Theorem 5.1 below confirms this intuition. The formal proof of the result is more involved, however, since it has to take into account the strategic interaction between the shareholder and the manager of each bank.

Theorem 5.1. *A full risk equilibrium exists if and only if $c \leq c'$.*

Proof. The proof can be found in the appendix. □

We have shown previously that, without Crisis Contracts, the banking equilibrium unambiguously predicts full risk in the second period. This is the result of Corollary 3.7. The following theorem extends this insight to the entire banking game.

Theorem 5.2. *In the absence of Crisis Contracts, a full risk equilibrium exists. Moreover, all banking equilibria are full risk equilibria.*

Proof. The proof can be found in the appendix. □

Theorem 5.2 establishes an important benchmark for our further analysis of Crisis Contracts. It demonstrates that without Crisis Contracts, the banking equilibrium unambiguously predicts full risk in both periods. In the next section, we examine under which conditions the introduction of Crisis Contracts can give rise to equilibria with less risk–taking.

6 Threshold Equilibria

We define a *threshold equilibrium* as a banking equilibrium with threshold risk in both periods on the equilibrium path of play. Note that in a threshold equilibrium the probability of a crisis in either period is equal to zero. A strategy profile which is a threshold equilibrium may prescribe full risk in the second period after a crisis has occurred in the first period – such first-period histories are not on the equilibrium path. Let

$$c'' \;=\; \frac{(1-p)x_g - x_{rf}}{pD} = \tau^*/D. \tag{11}$$

We have shown in Theorem 3.6 that h–banking equilibria with threshold risk exist in h–subgames with $\tau^i(h) \geq \tau^*$. The following theorem establishes the analogous result for the entire banking game.

Theorem 6.1. *A threshold equilibrium exists only if $c \geq c''$.*

Proof. The proof can be found in the appendix. □

We have established a necessary condition for the existence of a threshold equilibrium. For the next theorem we shall now derive a set of sufficient conditions. Let us define $\hat{n} = (\bar{n}-1)/n$. This ratio corresponds to the share of the banks in the banking sector which can take the risky investment without running the risk of triggering a crisis. We can interpret $\hat{n}$ as a measure for the stability of the banking sector. We will also make use of the following condition:

$$x_{rf} \geq x_g \left(1 - p\left(\frac{1+\delta p}{1+\delta p - \delta}\right)\right). \tag{12}$$

Note that for any choice of parameters x_g, x_{rf}, and p, the above inequality is satisfied when δ is sufficiently close (or equal) to one.

Assuming that $\hat{n}$ is sufficiently large and that Ineq. (12) holds, we now construct a threshold equilibrium of the following kind: On the equilibrium path of play, exactly $\bar{n}-1$ banks take the risky asset in each period, while the remaining banks invest in the safe asset. All banks investing safely in the first period take the risky asset in the second period. (Clearly, this is only possible when $\hat{n} \geq \frac{1}{2}$.) If some bank deviates from the equilibrium path in the first period by investing in the risky rather than the safe asset, then the game enters into a "punishment mode." If a crisis occurs in the first period, then all banks take the risky asset in the second period. If the game is in the punishment mode, but no crisis has occurred in the first period, then the bank that has deviated from the equilibrium path in the first period is among those banks taking the safe asset in the second period. Since the punishment occurs in the second period, the shareholders and managers need to care sufficiently about the future payoff for the punishment to be effective. This makes it intuitively clear why Ineq. (12) is crucial for the result.

Theorem 6.2. *Suppose that $\hat{n} \geq \frac{1}{2}$, Ineq. (12) holds, and $c \geq c''$. Then a threshold equilibrium exists.*

Proof. The proof can be found in the appendix. □

We have now established sufficient conditions for the existence of a particular kind of threshold equilibrium. However, these conditions are not generally inconsistent with the conditions for existence of a full risk equilibrium. Put another way, the aforementioned threshold equilibrium may coexist with a full risk equilibrium. In Theorem 6.3 below, we provide sufficient conditions for the existence of a different type of threshold equilibrium which cannot coexist with a full risk equilibrium. Moreover, it does not require any additional restriction on $\hat{n}$. It does require, however, the following inequality to be satisfied:

$$x_g \leq \frac{x_{rf}(1+\delta) - D}{\delta(1-p)} \tag{13}$$

The idea behind the threshold equilibrium to be constructed now is that in both periods the banks $1, \ldots, \bar{n}-1$ make the risky investment, while the other banks make the safe investment. If one of the banks $\bar{n}, \ldots, n$ deviates from the equilibrium path of play in the first period by choosing the risky investment, then all banks will invest in the risky asset in the second period as a "punishment." Note that the threat of such a punishment is always credible since, in any second period subgame, risk-taking by all banks is consistent with the banking equilibrium described in Theorem 3.5. This type of threshold equilibrium can be constructed even in the extreme case of $\bar{n} = 1$. The idea behind this threshold equilibrium is as follows: The punishment mechanism ensures that full risk will be played in the second period if more than $\bar{n}-1$ managers take risk in the first period. Anticipating this punishment, a manager would only be willing to take risk in the first period if the shareholder offers him a compensation for the potential crisis tax payment. However, if the crisis tax rate is sufficiently high, then the shareholder cannot afford such a compensation.

Theorem 6.3. *Suppose that $c > c'$ and $c \geq c''$, and that Ineq. (13) holds. Then a threshold equilibrium exists.*

Proof. The proof can be found in the appendix. □

One interesting implication of Theorem 6.2 is that a Crisis Contract can prevent a crisis in the first period, although it mandates a retroactive tax to be paid only in the second period. Theorems 6.2 and 6.3 will be the basis of the analysis of welfare gains from Crisis Contracts in the next section.

7 Welfare Effects of Crisis Contracts

We now conduct a comparative statics analysis of the effects of Crisis Contracts. In particular, we will be interested in whether the introduction of Crisis Contracts enhances social welfare. Given some activity profile $\mathcal{A}$, the *instantaneous social welfare* in period t ($t \in \{1, 2\}$) is given by

$$y^t(\mathcal{A}) = \begin{cases} \sum_{i=1}^{n}(u_s^{it} + u_m^{it}) & \text{if } Z_t = 0, \\ \sum_{i=1}^{n}(u_s^{it} + u_m^{it}) + n_t(\mathcal{A})x_b & \text{if } Z_t = 1. \end{cases}$$

The instantaneous utilities u_s^{it} and u_m^{it} are as specified in equations (3) through (6). The term $n_t(\mathcal{A})x_b$ captures the social losses that occur in case of a crisis and that are neither internalized by the shareholders nor by the managers.

It is clear from the above utility functions that y^t depends solely on the activity profile at t, in what follows, we will omit the argument $\mathcal{A}$ where appropriate. For given investment choices, the wage payments are pure redistributions from shareholders to managers; they do not affect the social welfare accounting. We also consider tax revenue as part of social welfare, so the payment of crisis tax does not affect social welfare either. The above notion of social welfare implies that the managers' income is part of social welfare, whether or not they work in the banking sector. Hence, in the absence of any banking activity, the instantaneous social welfare level would be

$$y_0 = nD. \tag{14}$$

Under the above definition, instantaneous social welfare in period t is maximized when $\bar{n}-1$ managers take risk and $n-\bar{n}+1$ managers invest safely, i.e. social welfare is maximal under threshold risk. The maximal level of instantaneous social welfare is

$$\bar{y}^t = (\bar{n} - 1)x_g + (n - \bar{n} + 1)x_{rf}. \tag{15}$$

On the other hand, risk–taking by all managers leads to instantaneous expected social welfare given by

$$\underline{y}^t = n(1-p)x_g + npx_b. \tag{16}$$

Observe that $\bar{y}^t > y_0 > \underline{y}^t$ because of Ineq. (7). This reflects the fact that our model assumptions enable the banking sector both to enhance and to harm social welfare in expected terms as compared to a situation in which no bank activity takes place.

It remains to define aggregate social welfare over the two periods, denoted by Y. We assume that

$$Y = y^1 + \delta y^2. \tag{17}$$

We assume the same time preference for society at large as for the shareholders and managers, although this assumption is not essential for our results.

Under the above notion of social welfare, a full risk equilibrium achieves the lowest possible level of social welfare, while a threshold equilibrium achieves the optimal level of social welfare. So far in this paper, we have conducted a comparative statics analysis to see how the existence of these two types of equilibria depends on the model parameters, and in particular on the crisis tax rate c. In what follows, we discuss how an appropriate choice of c by the regulator can improve social welfare.

Let $\mathcal{E}(c)$ be the set of banking equilibria when the crisis tax rate is $c \in [0, 1]$. We use notations $\sigma' \succeq \sigma''$ to indicate that strategy profile σ' leads to at least as much expected social welfare as strategy profile σ'' and $\sigma' \succ \sigma''$ to indicate that social welfare under σ' is strictly greater than under σ''.

Definition 7.1. *A Crisis Contract with a tax rate of $c > 0$ is* weakly beneficial *if the following two conditions hold:*

1. *For all $(\sigma', \sigma'') \in \mathcal{E}(0) \times \mathcal{E}(c)$, it holds that $\sigma'' \succeq \sigma'$.*
2. *There exists a $\sigma' \in \mathcal{E}(c)$ such that $\sigma' \succ \sigma''$ for all $\sigma'' \in \mathcal{E}(0)$.*

The first part of the definition requires that the introduction of the Crisis Contract does not lead to an equilibrium which is worse that some equilibrium without Crisis Contracts. The second part of the definition requires that the introduction of the Crisis Contract leads to some equilibrium which is strictly better than any equilibrium without Crisis Contracts.

If an increase in social welfare can be obtained for any selection from the set of banking equilibria, then the Crisis Contract is considered to be *strictly beneficial,* as formalized in the next definition.

Definition 7.2. *A Crisis Contract with a tax rate of* $c > 0$ *is* strictly beneficial *if* $\mathcal{E}(c) \neq \emptyset$ *and* $\sigma'' \succ \sigma'$ *for all* $(\sigma', \sigma'') \in \mathcal{E}(0) \times \mathcal{E}(c)$.

Of course, a Crisis Contract that is strictly beneficial is also weakly beneficial.

We have seen that the existence of full risk and threshold equilibria depends on how the tax rate c relates to some threshold values c' and c''. In our model, the regulator is free to choose any tax rate c from the interval $[0, 1]$. Consequently, the power of the regulator to influence the existence of full risk and threshold equilibria hinges on whether c' and c'' fall into this interval. Using Eqns. (10) and (11), we can express conditions $c' < 1$ and $c'' < 1$ as restrictions on x_g relative to the other model parameters. Intuitively, the regulator's ability to improve social welfare through Crisis Contracts requires that x_g be not too big relative to payoffs x_{rf} and D and to probability p. More precisely, the relevant restrictions on x_g are captured in the following two inequalities:

$$x_g < \frac{D}{(1-\delta p)(1-p)}, \tag{18}$$

$$x_g < \frac{pD + x_{rf}}{1-p}. \tag{19}$$

In general, neither of these inequalities implies the other.

Theorem 7.3. *If Ineqs. (13), (18), and (19) are satisfied, then there exists a strictly beneficial Crisis Contract. Moreover, under this Crisis Contract the socially optimal outcome of the banking game is a banking equilibrium.*

Proof. The proof can be found in the appendix. □

One implication is that a strictly beneficial Crisis Contract always exists if p is sufficiently close to one. Example A.1 in the appendix provides some illustration of Theorem 7.3.

The following theorem establishes sufficient conditions for the existence of a weakly beneficial Crisis Contract.

Theorem 7.4. *Suppose that $\hat{n} \geq \frac{1}{2}$. If inequalities (12) and (19) hold, then there is a weakly beneficial Crisis Contract. Moreover, under this Crisis Contract the socially optimal outcome of the banking game is an equilibrium.*

Proof. The proof can be found in the appendix. □

We illustrate Theorem 7.4 with the numerical Example A.2 in the appendix.

8 Capital Regulation and Crisis Contracts

In the previous section, we derived the key welfare result of our paper. The welfare-enhancing potential of Crisis Contracts crucially hinges on a set of three conditions on the model parameters. Each of these conditions imposes upper bounds on x_g, the return of the risky asset when no crisis occurs. We will now argue that a moderate value of x_g is suitably interpreted as resulting from stringent capital requirements. This allows us to draw conclusions about the interaction between capital requirements and our idea of Crisis Contracts in the effective regulation of financial sector risk. In what follows, we give a very standard stylized model of bank balance sheets, and we show that this gives rise to an asset payoff structure like the one we have assumed in our analysis of Crisis Contracts. This balance sheet based underpinning of our original model allows us to gain some additional insights about the interplay of Crisis Contracts with capital requirements. We will see that a minimal level of capital requirements is needed for Crisis Contracts to be effective. Given that such a minimal capital requirement is in place, however, we find that both regulatory tools can be treated as substitutes.

Consider a bank financed through deposits and equity. Equity is given and we normalize the amount of equity to one. At the beginning of each period considered in our model, households deposit a total amount of d at the bank, and the bank promises them an interest rate of $r > 0$ over this period. Hence, at the end of a period, the bank owes $(1 + r)d$ to its depositors. We assume that the bank can invest its entire funds $1 + d$ in a risk-free asset, with interest rate r. Hence, the payoff that we have called x_{rf} in our model can be written as

$$x_{rf} = (1 + d)(1 + r) - d(1 + r) = 1 + r.$$

Alternatively, the bank may invest its entire funds in a risky asset which pays an interest rate of $r' > r$ if no crisis occurs, but which leads to a loss of fraction l ($l \in [0, 1]$) of the bank's total capital $1 + d$ in case of a crisis. When no crisis occurs the bank has an amount $(1+r')(1+d)$ at its disposal at the end of the period, while it owes $(1+r)d$ to the depositors. After paying out the depositors, the remaining amount is available to equity holders. Then, the payoff that we have called x_g in our model can be written as

$$x_g = (1 + d)(1 + r') - d(1 + r) = 1 + r' + d(r' - r).$$

The payoff that we have denoted by x_b in our model can be written as

$$x_b = (1 - l)(1 + d) - (1 + r)d.$$

Suppose that $d \leq \frac{1-l}{r+l}$ and thus $x_b \geq 0$. Then even in the worst case, bank equity would be sufficient to redeem all obligations towards the depositors. If, however, $d > \frac{1-l}{r+l}$, then $x_b < 0$, and thus a bank which invests in the risky asset cannot honor all obligations towards its depositors in a crisis. The shortfall will have to be covered by a public bailout fund. This is the scenario we have considered in our model.

We see that x_g tends to infinity as d grows without bound. If the regulator imposes a capital requirement ϕ, that is, an upper bound on the debt–equity ratio d, then this regulation leads to an upper bound on x_g in our model. In turn, a sufficiently low value of x_g is needed to make Crisis Contracts effective. We conclude that some minimal level of capital requirements is needed for Crisis Contracts to have an effect. However, given that such capital requirements are in place, capital requirements and Crisis Contracts act as substitutes: One can lower the crisis tax rate c in return for a tougher capital requirement, or one can compensate for a lower capital requirement by a higher choice of c. More formally, the relationship between Crisis Contracts and capital requirements can be wrapped up as follows:

Proposition 8.1. *There exist thresholds $\underline{\phi}, \overline{\phi} \in \mathbb{R}_+$ such that $\overline{\phi} > \underline{\phi}$ and*

1. *If the $\phi \leq \underline{\phi}$, no public bail–outs are ever necessary.*

2. *If the $\phi \geq d > \overline{\phi}$, then banks exhibit socially detrimental risk-taking irrespective whether Crisis Contracts are in place or not.*

3. *If $\phi \geq d > \underline{\phi}$ but $d \leq \overline{\phi}$, then Crisis Contracts are welfare-enhancing. The regulator can achieve the welfare-enhancing effect by using different combinations of the tax rate c and the capital requirement ϕ.*

9 Robustness, extensions, and concluding remarks

In this final section, we discuss some robustness issues, offer suggestions for extensions and further research, and add some remarks on the potential practical implementation of Crisis Contracts.

9.1 Robustness to Hedging

One potential objection to the idea of Crisis Contracts is that managers might try to take positions on financial markets which allow them to be "hedged" against the risk of a crisis tax payment. To be more precise, consider a threshold equilibrium of our banking game, and suppose that just before making the investment decision for the second period, a bank manager can purchase an insurance which pays off an amount cD if a crisis occurs. Differently put, this insurance fully compensates the manager for the possible crisis tax. (The looming crisis tax is cD because every manager earns D in the first period in a threshold equilibrium.) Applying similar arguments as in Section 3 above, we can conclude that a bank whose manager has bought the insurance is going to invest in the risky asset in the second period. This implies that the insurance company makes a loss on the insurance policy unless the premium is at least equal to cD. A shareholder i who wants to motivate manager i to risk in the second period must offer a wage scheme ω^{i2} such that $\omega_g^{i2} \geq \frac{D(1+pc)}{1-p}$. Verbally, the manager needs an expected payment of D to be willing to risk rather than opt out, and needs an additional expected payment of pcD in order to finance insurance premium. If the shareholder indeed makes the wage offer ω^{i2} which motivates the manager to risk, then the shareholder's expected payoff in the second period is $(1-p)x_g - D(1+pc)$. It is straight–forward that this is always strictly less than $x_{rf} - D$, which is the relevant payoff under the threshold equilibrium. Hence, even if we were to introduce the possibility of crisis insurance into the model, this would not eliminate threshold equilibria, and would therefore not change the welfare effects of crisis contracts. We observe that this conclusion would hold even if managers were risk–averse: A risk–averse manager would prefer to buy an insurance and risk over risking without buying an insurance, but nevertheless, the insurance premium would have to be at least pcD, and the above argument remains valid. The same argument also applies to other financial assets with a crisis–contingent payoff, for instance, one could replicate a crisis insurance by using a put option. Our argument is driven by the property that the counter–party does not make a loss.

9.2 Choice of the Tax base

In our stylized model, banks are of equal size, and every bank is owned by a single shareholder and run by a single manager. We have focused on the strategic interaction between the shareholder and manager of each bank and between the investment choices of the different bank managers. One might wonder whether our results would remain robust in a setting where larger banks are owned by several shareholders and the bank management consists of an entire hierarchy of bankers. In a large bank, it would be reasonable to expect that investment decisions are not made by a single manager but rather by the first one or two layers of the hierarchy or by certain specialists further down the hierarchy. In such a case, the effectiveness of Crisis Contracts could be preserved if all managers involved in investment decisions are subjected to the Crisis Contracts. Alternatively, one could also apply Crisis Contracts to all members of the management hierarchy who receive a significant amount of performance–related pay.

9.3 Contract Triggers

In order to implement Crisis Contracts in practice, the regulator needs to give an objective and verifiable definition of a banking crisis. In this way, it can be established that a banking crisis is indeed occurring and the concomitant crisis tax payments are due. One possibility is to trigger the Crisis Contract whenever a bailout has to be provided to a bank of at least some pre–defined size. Using government bailout as a trigger for the execution of Crisis Contracts would probably have further effects. For instance, troubled banks may be more willing to opt for the bail-in of private debtors to avoid execution of the crisis tax. In turn, the threat to bail out may help the regulator to induce better bank equity capitalization in the banking system. Moreover, when only one or a few banks are troubled and may need to be rescued by the government, other banks may be more willing to play an active role in rescue activities.

One alternative trigger could be the index of stock prices in the banking industry. Crisis Contracts would then be triggered if the index falls below a certain threshold. A third possibility for defining a trigger is the (weighted) average of the debt–equity ratios in the banking industry. If this average exceeds a threshold, crisis tax payments are due. The third trigger might be particularly appealing from a practical point of view, as it relies on accounting information that regulators collect anyway.

We note that triggers for Crisis Contracts are conditioned on aggregate events and thus are less susceptible to manipulation attempts in accounting by bank managers than when triggers are bank–specific. Moreover, since only previous earning of bank managers are at stake, self–fulfilling spirals that could occur when individual bank issues CoCos (Contingent Convertible Debt) cannot occur. However, manipulation may become more attractive. For instance, when the extent of bailouts of banks is used as a trigger the government may be tempted to increase the bailout to the level of the trigger in order to collect the crisis tax. For this reason, average debt–equity rations in the banking sector might be more appropriate than triggers that depend on discretionary actions by the government.

9.4 Pay Caps

We have pointed out before that Crisis Contracts make it more costly for shareholders to provide their managers with incentives for excessive risk–taking. Alternatively, one might design policies which achieve a similar effect by imposing explicit legal limits on bankers' pay. We argue that Crisis Contracts may avoid some difficulties of such explicit pay caps:

First, imposing explicit limits on bankers' pay might require the regulator to obtain detailed information about the payment practices in the banking sector, as well as about the opportunities available to bank managers outside the banking sector. In order to implement Crisis Contracts, the regulator needs to observe only the total remuneration received by the bankers, and to find an objective criterion for whether or not the banking sector is in a crisis.

Second, one more potential advantage of Crisis Contracts is that they apply indiscriminately to the entire remuneration given to bankers over a certain time horizon. In particular, there is no distinction between fixed pay and bonus pay. Given that shareholders have only limited liability, they find excessive risk–taking to be in their interest (Bolton et al. 2014). In the presence of regulatory limits on bonus pay, shareholders could find ways to circumvent such limits, in particular by disguising bonuses as part of a future fixed salary or as fringe benefits. It may require complicated and costly monitoring effort to counteract such behavior.

Third, if a crisis does occur, then Crisis Contracts lead to a collective "bail–in" of bank managers. As a result, at least some part of the financial burden of a bailout is shifted to bankers rather than to taxpayers. From an economic theory perspective, this could be described as an internalization of a small part at least of the externalities that reckless bankers can impose on the public. Thus, Crisis Contracts can be interpreted as promoting a fairer sharing of the burden caused by bankers' excessive risk–taking.

Fourth, an explicit cap on bankers' pay can be seen as too strong a curtailing of free enterprise and freedom to contract. In contrast, the Crisis Contracts we propose leave shareholders and managers totally free to negotiate any amount of pay and any combination of fixed and bonus pay. What we propose comes down to a retroactive tax which takes effect only if a banking crisis actually does occur. Hence, as long as the banking sector does not enter into a crisis and does not impose any negative externalities on society and taxpayers, the Crisis Contracts do not harm or restrict shareholders or managers.

One potential extension would be to analyze the complementary use of both Crisis Contracts and pay caps. For instance, one could combine standard clawbacks which become effective when an individual bank fails with Crisis Contracts which become effective in case of a systemic crisis. Such an analysis, however, is beyond the scope of our current model since we only consider systemic risk.

9.5 Further Extensions

In this subsection, we briefly discuss some potential extensions which are beyond the scope of our formal model and may be of interest for future research.

Exogenous risk

In our model, prudent investment behavior of bank managers perfectly forestalls banking crises. In reality, however, factors beyond bank managers' control may lead to a banking crisis. For instance, there might be a sudden stop of funding due to investors' solvency problems, or banks may face panic withdrawals of deposits. Integrating such exogenously caused crises into the model is possible, but requires adjustments to the way in which the crisis tax is specified.

Gradual buildup of crises

One aspect of financial crises which is not captured in our model is that vulnerabilities in the banking sector may build up gradually over time. Our model could be amended by assuming that the probability p of a crisis in the second period is endogenously determined by the level of risk–taking in the first period. We would expect the qualitative results of our model to carry over to such a setting.

Crisis–sensitive shareholders

One crucial assumption in our model is that a banking crisis does not harm shareholders in any way other than wiping out bank equity. One might expect, however, that at least some shareholders are averse to a banking crisis. For instance, they might fear macro–economic consequences of such a crisis or they might have a broad investment portfolio in which several assets might be affected by the crisis. We would expect that some degree of intrinsic shareholder sensitivity to crisis events would not change the qualitative predictions of the model. Quantitatively, it would reduce the extent of the negative externality which Crisis Contracts are designed to avoid.

Different social welfare functions

So far, we have argued that Crisis Contracts are beneficial in that they can prevent crises that would lead to social losses. When assessing "social" benefits and costs, we have considered a very simple additive social welfare function where payoffs to citizens, shareholders, and managers are treated equally. Crisis Contracts generate even more benefits if one applies a social welfare function which gives a higher weight to the interests of the public, and less weight to those of bank shareholder or managers. In recent public discussion, it has often been felt to be unfair that the welfare of ordinary citizens has apparently not had enough weight in the regulator's considerations. Crisis Contracts do not suffer from this problem and may therefore be seen as a "fair" regulatory tool.

Job mobility

We have assumed that the earnings from the first period are available for taxation in the second period. Typically, the state has the coercive power to tax retroactively as citizens have to declare to tax authorities their past earnings and become liable for the tax burden. More problematic may be the cases where bankers switch employees between periods. In the spirit of the crisis tax, when bankers remain in the banking system, the remain subject to crisis tax. With this additional rule, the incentives to avoid crises remain. Moreover, since bank managers are compensated by shareholders for potential crisis tax burden, they have no incentive to leave the banking system altogether.

9.6 Concluding Remarks

We have presented an initial analysis of Crisis Contracts and have gauged their potential and limitations. This first pass of the analysis suggests that Crisis Contracts could be a useful tool in the design of a financial architecture that is significantly more resilient than in the past. Crisis Contracts are effective only when combined with suitable capital requirements.

While we have used a stylized model to study the functions of Crisis Contracts, in practice they have to be based on assessments of the extent of risk-taking and the likelihood of crisis in the banking industry in a calibrated model (see e.g. Chesney et al. (2012)). Erring on the conservative side will not undermine the efficacy of Crisis Contracts, but being too optimistic about the stability of the banking system will. Moreover, Crisis Contracts will likely have further effects:

Crisis Contracts may help to break peer effects when it is common in the banking system to motivate managers with high bonuses to take risks that collectively exceed socially desirable levels.[13] Crisis Contracts may also induce banks to become more prudent regarding their counter–parties in the interbank market, which may promote stability.

[13] It is well-known that peer effects play a considerable role in banking. For instance, herding with regard to risk-taking is significant among the largest banks, see Bonfim and Kim (2012).

Appendix

Proof of Lemma 3.1

Suppose σ^h is an h-banking equilibrium in the h-subgame and $A^{i2}(\sigma^h) \neq O$. Suppose $\mu^{i2}(\sigma^h) > \kappa^{i2}(\sigma^h)$. Let $\bar{\omega}^{i2}$ be the wage offer made under σ^h. For $\varepsilon > 0$, define the triple $\hat{\omega}^{i2}$ as follows:

$$\hat{\omega}^{i2} = \begin{cases} (\bar{\omega}_g^{i2} - \varepsilon, 0, 0) & \text{if } n_2(\sigma^h) \leq \bar{n} - 1 \text{ and } A^{i2}(\sigma^h) = R \\ (\bar{\omega}_g^{i2} - \frac{\varepsilon}{(1-p)}, 0, 0) & \text{if } n_2(\sigma^h) \geq \bar{n} \text{ and } A^{i2}(\sigma^h) = R \\ (0, \bar{\omega}_{rf}^{i2} - \varepsilon, 0) & \text{if } A^{i2}(\sigma^h) = S \end{cases}$$

Note that for sufficiently small $\varepsilon > 0$, the triple $\hat{\omega}^{i2}$ belongs to the set Ω and is therefore a wage scheme to which the strategy σ_m^{ih} must assign a response from $\{R, S, O\}$. We argue that it is the same response as the one assigned to wage scheme $\bar{\omega}^{i2}$. In order to see this, first observe that if manager i responds to the offer $\hat{\omega}^{i2}$ in the same way as to the offer $\bar{\omega}^{i2}$, then by the construction of $\hat{\omega}^{i2}$ he will obtain a payoff of $\mu^{i2}(\sigma^h) - \varepsilon > D$ for $\varepsilon > 0$ small enough. It is clear that manager i will not respond to $\hat{\omega}^{i2}$ by opting out. Now suppose, by way of contradiction, that strategy σ_m^{ih} responds to $\hat{\omega}^{i2}$ by working for the bank but taking a different asset than in response to $\bar{\omega}^{i2}$. Again, by the construction of $\hat{\omega}^{i2}$ this would lead to a zero payoff for manager i. However, $\mu^{i2}(\sigma^h) - \varepsilon > D > 0$, so it is clear that manager i will not respond to $\hat{\omega}^{i2}$ by working for the bank and choosing a different asset than in response to $\bar{\omega}^{i2}$. We have now established that strategy σ_m^{ih} prescribes the same response from manager i to both wage schemes $\bar{\omega}^{i2}$ and $\hat{\omega}^{i2}$. To complete the proof of the lemma, observe that for shareholder i it is a profitable deviation from strategy profile σ^h to offer $\hat{\omega}^{i2}$ instead of $\bar{\omega}^{i2}$. This deviation increases shareholder i's payoff by $\varepsilon > 0$. $\square$

Proof of Lemma 3.3

The proof of Lemma 3.3 rests on two contradictions. Suppose first that σ^h is an h-banking equilibrium but $n_2(\sigma^h) < \bar{n} - 1$. Then there is $i \in N$ such that $A^{i2}(\sigma^h) \neq R$. Clearly, manager i is not pivotal under σ^h, so his payoff is D. From the supposition that σ^h is an h-banking equilibrium we conclude that strategy σ_m^{ih} prescribes taking risk as a response to offer $(D + \varepsilon, 0, 0)$ for $\varepsilon > 0$ sufficiently small (and in particular $\varepsilon < (1-p)x_g - x_{rf}$). If shareholder i deviates from σ^h by making the offer $(D + \varepsilon, 0, 0)$, then he obtains a payoff of $x_g - D - \varepsilon$. Under σ^h, however, his payoff would be either $x_{rf} - D$ or zero. Since $x_g > x_{rf}$ and $x_g > D$, we see that shareholder i has a profitable deviation from σ^h. Hence we obtain a contradiction and conclude that $n_2(\sigma^h) \geq \bar{n} - 1$.

Now suppose secondly that σ^h is an h-banking equilibrium but $n > n_2(\sigma^h) \geq \bar{n}$. Then there is $i \in N$ such that $A^{i2}(\sigma^h) \neq R$. Clearly, manager i is not pivotal under σ^h, so his payoff is D. From the supposition that σ^h is an h-banking equilibrium we conclude that strategy σ_m^{ih} prescribes taking risk as a response to the offer $(\frac{D+\varepsilon}{1-p}, 0, 0)$ for $\varepsilon > 0$ sufficiently small. If shareholder i deviates from σ^h by making the offer $(\frac{D+\varepsilon}{1-p}, 0, 0)$, he obtains a payoff of $(1-p)x_g - D - \varepsilon$. Under σ^h, however, his payoff would be either $x_{rf} - D$ or zero. Since by assumption $(1-p)x_g > x_{rf} + \varepsilon$, shareholder i has a profitable deviation from σ^h. Therefore we again obtain a contradiction, so $n_2(\sigma^h) = \bar{n} - 1$ or $n_2(\sigma^h) = n$. $\square$

Proof of Theorem 3.5

The proof is constructive. Let $\bar{\sigma}^h$ be the strategy profile for the h-subgame, where all shareholders $i \in N$ make offer $\bar{\omega}^{i2} = (\frac{D}{1-p}, 0, 0)$ to their managers. All managers will take risk in response to any wage offer $\omega \in \Omega$ that satisfies $(1-p)\omega_g \geq D$ and $(1-p)\omega_g \geq \omega_{rf}$. If the wage offer $\omega \in \Omega$ fails to satisfy one or both of these inequalities, then the manager will invest safely if and only if $\omega_{rf} > D$. Otherwise he will opts out. We show that $\bar{\sigma}^h$ is an h-banking equilibrium.

Fix a bank $i \in N$. Given $A^{-i2}(\bar{\sigma}^h)$, a crisis will occur in the second period with probability p. For every $\omega \in \Omega$, strategy $\bar{\sigma}_m^{ih}$ chooses an option from $\{R, S, O\}$ that leads to a weakly higher payoff for manager i than any other choice. It is straightforward to see that manager i does not have any profitable deviation from $\bar{\sigma}^h$.

If manager i opts out, then shareholder i will obtain a payoff of zero. By construction of $\bar{\sigma}_m^{ih}$, manager i only works for the bank if his expected wage is at least D. Accordingly, in the case where manager i invests safely, the expected payoff to shareholder i is bounded from above by $x_{rf} - D$. And in the case where manager i takes risk, the expected payoff to shareholder i is bounded from above by $(1-p)x_g - D$. Since $(1-p)x_g > x_{rf} > 0$, it follows that given $A^{-i2}(\bar{\sigma}^h)$ the expected payoff to shareholder i is bounded from above by $(1-p)x_g$. But this is the expected payoff of shareholder i under $\bar{\sigma}^h$. We see that shareholder i has no profitable deviation from $\bar{\sigma}^h$. $\square$

Proof of Theorem 3.6

Only if: Suppose that σ^h is an h-banking equilibrium and $n_2(\sigma^h) = \bar{n} - 1$. Then there are $n - \bar{n} + 1$ banks $i \in N$ such that $A^{i2}(\sigma^h) \neq R$. Take one such bank, say i. Observe that i is not pivotal under σ^h. Hence, from the supposition that σ^h is an h-banking equilibrium, we obtain that $\mu^{i2}(\sigma^h) = D$. We argue that strategy σ_m^{ih} prescribes taking risk as the response to offer $\hat{\omega}^{i2} = (\frac{D+\varepsilon+p\tau^i(h)}{1-p}, 0, 0)$. To see this, note that the expected payoff to manager i from taking risk in response to $\hat{\omega}^{i2}$ is equal to $D+\varepsilon+p\tau^i(h) - p\tau^i(h) = D+\varepsilon$, whereas the expected payoff to manager i from investing safely or opting out in response to $\hat{\omega}^{i2}$ is zero and D, respectively. Now suppose that shareholder i deviates from σ^h by making offer $\hat{\omega}^{i2}$. Then he will obtain an expected payoff of $(1-p)x_g - D - \varepsilon - p\tau^i(h)$, whereas his payoff under σ^h is $x_{rf} - D$. We conclude that shareholder i has a profitable deviation from σ^h if $(1-p)x_g - p\tau^i(h) > x_{rf}$, or, equivalently, if $\tau^i(h) < \tau^*$. Repeating the argument for every $i \in N$ with $A^{i2}(\sigma^h) \neq R$, we obtain the claim of the lemma. $\square$

If: The proof is constructive. Let $\bar{\sigma}^h$ be the strategy profile for the h-subgame where shareholders $i = 1, \ldots, \bar{n}-1$ all make wage offer $\bar{\omega}^{i2} = (D, 0, 0)$ and shareholders $j = \bar{n}, \ldots, n$ make wage offer $\bar{\omega}^{j2} = (0, D, 0)$. Managers $i = 1, \ldots, \bar{n}-1$ will take risk in response to wage offer $\omega \in \Omega$ if and only if $\omega_g \geq \omega_{rf}$ and $\omega_g \geq D$. Otherwise those managers will invest safely if $\omega_{rf} \geq D$ and opt out if $\omega_{rf} < D$. Managers $j = \bar{n}, \ldots, n$ will respond to wage offer $\omega \in \Omega$ by taking risk if and only if $(1-p)\omega_g - p\tau^j(h) > \omega_{rf}$ and $(1-p)\omega_g - p\tau^j(h) > D$. Otherwise those managers will invest safely if $\omega_{rf} \geq D$ and opt out if $\omega_{rf} < D$.

Consider a manager $i = 1, \ldots, \bar{n}-1$. Given $A^{-i2}(\bar{\sigma}^h)$, no crisis occurs. So manager i chooses from the payoffs D (opting out), $\bar{\omega}_{rf}^{ih} = 0$ (investing safely), and $\bar{\omega}_g^{ih} = D$ (investing in the risky asset). Clearly, taking risk is optimal.

Consider a manager $j = \bar{n}, \ldots, n$. Given $A^{-j2}(\bar{\sigma}^h)$, there will be a crisis with probability p if j takes risk and with probability zero otherwise. Manager j chooses from the payoffs D (opting out), $\bar{\omega}_{rf}^{jh} = D$ (investing safely), and $(1-p)\bar{\omega}_g^{jh} - p\tau^j(h) \leq 0$ (taking risk). Investing safely is optimal.

Take a shareholder $i = 1, \ldots, \bar{n}-1$. Under $\bar{\sigma}^h$, his payoff is $x_g - D > 0$. Shareholder i will only receive a positive payoff if manager i works. However, no manager works in the second period for an expected wage of less than D. Since x_g is the highest possible asset return, $x_g - D$ is an upper bound on the payoff for any shareholder in any h-subgame. In particular, shareholder i has no profitable deviation from $\bar{\sigma}^h$.

Finally, consider shareholder $j = \bar{n}, \ldots, n$. His payoff under $\bar{\sigma}^h$ is $x_{rf} - D \geq 0$. If shareholder j has a profitable deviation from $\bar{\sigma}^h$, it must involve manager j working for the bank. However, manager j will only invest safely for an expected wage of at least D and will only take risk for an expected wage of at least $(1-p)\omega_g^{jh} - p\tau^j(h)$. So the payoff for shareholder j from offering a wage scheme to which manager j responds by investing safely is bounded from above by $x_{rf} - D$. No such deviation can be profitable.

The payoff for shareholder j from offering a wage scheme to which manager j responds by taking risk is bounded from above by $(1-p)x_g - D - p\tau^j(h)$. It follows that no profitable deviation from $\bar{\sigma}^h$ is possible for shareholder j if $(1-p)x_g - p\tau^j(h) \leq x_{rf}$. $\square$

Proof of Lemma 4.1

First suppose, by way of contradiction, that $\bar{\sigma}$ is a banking equilibrium and $\nu^{i1}(\bar{\sigma}) < D$. By Corollary 3.4, manager i's expected wage at $t = 2$ equals D. Hence, his expected intertemporal wage under $\bar{\sigma}$ is $\nu^{i1}(\bar{\sigma}) + \delta D < (1+\delta)D$. However, by opting out in both periods, manager i could have obtained the intertemporal payoff of $(1+\delta)D$, which is a contradiction.

Second, suppose now that $\bar{\sigma}$ is a banking equilibrium and $\nu^{i1}(\bar{\sigma}) > D$. Again, we show that this leads to a contradiction. Let $\bar{\omega}^{i1}$ and $\bar{\omega}^{i2}$ be the wage schemes offered by shareholder i associated with the supposed banking equilibrium $\bar{\sigma}$. Moreover, consider the following alternative wage schemes:

$$\hat{\omega}^{i1} = \begin{cases} (\bar{\omega}^{i1}_g - \frac{2\varepsilon}{1-\delta c\rho(\sigma)}, 0, 0) & \text{if } n_1(\sigma) \leq \bar{n} - 1 \text{ and } A^{i1}(\sigma) = R, \\ (\bar{\omega}^{i1}_g - \frac{2\varepsilon}{(1-p)(1-\delta c\rho(\sigma))}, 0, 0) & \text{if } n_1(\sigma) \geq \bar{n} \text{ and } A^{i1}(\sigma) = R, \\ (0, \bar{\omega}^{i1}_{rf} - \frac{2\varepsilon}{1-\delta c\rho(\sigma)}, 0) & \text{if } A^{i1}(\sigma) = S, \end{cases}$$

for the first period, and

$$\hat{\omega}^{i2} = \begin{cases} (\tilde{\omega}^{i2}_g + \varepsilon, 0, 0) & \text{if } A^{i2}(\bar{\sigma}) = R, \\ (0, \tilde{\omega}^{i2}_{rf} + \varepsilon, 0) & \text{if } A^{i2}(\bar{\sigma}) = S, \end{cases}$$

for the second period.

The proof strategy is to show that a unilateral deviation by shareholder i from $\bar{\sigma}$ to the alternative wage schemes $(\hat{\omega}^{i1}, \hat{\omega}^{i2})$ is profitable. In the first step below, we demonstrate that under banking equilibrium profile $\bar{\sigma}$, manager i will respond to both $\hat{\omega}^{i1}$ and $\bar{\omega}^{i1}$ with the same choice from $\{R, S, O\}$.

Step 1. Suppose that this is not the case. That is, suppose that strategy $\bar{\sigma}^i_m$ assigns different responses to wage offers $\hat{\omega}^{i1}$ and $\bar{\omega}^{i1}$. If manager i opts out in response to $\hat{\omega}^{i1}$, then his payoff from the first period is D. If manager i does not opt out in response to $\hat{\omega}^{i1}$, then, by construction of $\hat{\omega}^{i1}$, his payoff from the first period is zero. Since $\bar{\sigma}$ is a banking equilibrium, manager i's expected payoff in the second period is D. If he does not opt out in response to $\hat{\omega}^{i1}$, his intertemporal payoff is δD, but if he does opt out, it is $(1+\delta)D$. We see that manager i reacts to $\hat{\omega}^{i1}$ by opting out. He obtains the intertemporal payoff of $(1+\delta)D$ in the banking game under $\bar{\sigma}$. However, if manager i did respond to $\hat{\omega}^{i1}$ and $\bar{\omega}^{i1}$ with the same action, then, by construction of $\hat{\omega}^{i1}$, his intertemporal payoff would be $\nu^{i1}(\bar{\sigma}) - 2\varepsilon + \delta D > (1+\delta)D$, where the inequality follows directly from the supposition that $\nu^{i1}(\bar{\sigma}) > D$ when $\varepsilon > 0$ is small enough. We see that manager i has a profitable deviation from $\bar{\sigma}$, which yields the desired contradiction.

We conclude that if $\bar{\sigma}$ is a banking equilibrium, then manager i responds by the same action to two wage offers $\hat{\omega}^{i1}$ and $\bar{\omega}^{i1}$.

Step 2. Now suppose that shareholder i deviates from $\bar{\sigma}$ by offering $\hat{\omega}^{i1}$ in the first period and $\hat{\omega}^{i2}$ in the second period. Clearly, shareholder i's payoff from the first period increases by $2\varepsilon > 0$. As we have shown, the deviation to $\hat{\omega}^{i1}$ does not have any effect on the investment choices of the banks in the first period. Hence the actions of shareholders and managers $j \in N \setminus \{i\}$ in the second period are unaffected by the deviation to $\hat{\omega}^{i1}$; consequently, banks $j \in N \setminus \{i\}$ will act according to activity profile $A^{-i2}(\bar{\sigma})$ in the second period.

Step 3. We now want to show that manager i responds to wage offer $\hat{\omega}^{i2}$ by the same investment choice with which he responds to $\bar{\omega}^{i2}$. Notice that under $\bar{\sigma}$, manager i's payoff from the second period is D. If he responds to $\hat{\omega}^{i2}$ with the same action as to $\bar{\omega}^{i2}$, then the resulting payoff will be $D+\varepsilon$. If manager i opts out in response to $\hat{\omega}^{i2}$, then his expected payoff from the second round is D. If he works for the bank, but makes a different investment choice than under $\bar{\sigma}$, then, by construction of $\hat{\omega}^{i2}$, his payoff is zero. We see that following the unilateral deviation by shareholder i to wage offers $(\hat{\omega}^{i1}, \hat{\omega}^{i2})$, activity profiles $A^{i1}(\bar{\sigma})$ and $A^{i2}(\bar{\sigma})$ remain unchanged.

Step 4. We have considered a unilateral deviation by shareholder i from the supposed banking equilibrium $\bar{\sigma}$ to wage offers $(\hat{\omega}^{i1}, \hat{\omega}^{i2})$. We have shown that this deviation leaves activity profiles $A^{i1}(\bar{\sigma})$ and $A^{i2}(\bar{\sigma})$ unchanged in both rounds. But then, by the construction of $(\hat{\omega}^{i1}, \hat{\omega}^{i2})$, the deviation increases shareholder i's net expected payoff from the first round by 2ε and decreases shareholder i's expected payoff from the second round by ε. Indeed, the deviation increases shareholder i's utility by the amount $2\varepsilon - \delta\varepsilon \geq \varepsilon > 0$; it is thus profitable. We have obtained the desired contradiction, and the proof of the lemma is complete. □

Proof of Theorem 5.1

($\Leftarrow$) Suppose $c \leq c'$. The proof is constructive. Consider a strategy profile $\bar{\sigma}$, under which every shareholder $i \in N$ makes wage offers

$$\begin{aligned}
\bar{\omega}^{i1} &= \left(\frac{D}{(1-p)(1-\delta pc)}, 0, 0\right) \text{ and} \\
\bar{\omega}^{i2} &= \left(\frac{D}{1-p}, 0, 0\right).
\end{aligned}$$

The managers' choices under $\bar{\sigma}$ are as follows:

- At $t=1$, each manager $i \in N$ opts out in response to the wage scheme $\omega^{i1} \in \Omega$ if and only if $D > \max\{(1-p)(1-\delta pc)\omega_g^{i1}, (1-\delta pc)\omega_{rf}^{i1}\}$. Conditional on not opting out, manager i will take risk if and only if $(1-p)(1-\delta pc)\omega_g^{i1} > (1-\delta pc)\omega_{rf}^{i1}$.
- At $t=2$, each manager $i \in N$ opts out in response to the wage scheme $\omega^{i2} \in \Omega$ if and only if $D > \max\{(1-p)\omega_g^{i2}, \omega_{rf}^{i2}\}$. Conditional on not opting out, manager i will take risk if and only if $(1-p)\omega_g^{i2} > \omega_{rf}^{i2}$.

Moreover, under $\bar{\sigma}$ each manager i will choose to work at his bank in the second period if $(1-p)\max(\bar{\omega}_g^{i2}, \bar{\omega}_{rf}^{i2}) \geq D$. If he works at his bank in the second period, he will take risk if and only if $\bar{\omega}_g^{i2} \geq \bar{\omega}_{rf}^{i2}$. In the first period, each manager i chooses to work at his bank if $(1-p)(1-\delta cp)\max(\bar{\omega}_g^{i1}, \bar{\omega}_{rf}^{i1}) \geq D$. If he works at his bank, he will take risk if and only if $\bar{\omega}_g^{i1} \geq \bar{\omega}_{rf}^{i1}$ and invest safely otherwise.

For any history $h \in H$, the relevant restriction $\bar{\sigma}^h$ of strategy profile $\bar{\sigma}$ is an h-banking equilibrium in the h-subgame. This has been demonstrated in the proof of Theorem 3.5. Hence we need only consider unilateral deviations in the first period. It is straightforward to see that the managers' decisions in the first period are optimal. We show that no shareholder has a profitable unilateral deviation from $\bar{\sigma}$ in the first period. Under $\bar{\sigma}$, shareholder i's payoff in the first period equals $(1-p)x_g - \frac{D}{1-\delta pc}$. Suppose that shareholder i deviates from $\bar{\sigma}$ by offering some $\tilde{\omega}^{i1}$ to which manager i responds by investing safely. Since manager i does not opt out, it must be true that $(1-\delta pc)\tilde{\omega}_{rf}^{i1} \geq D$. Then, however the shareholder' s payoff in the first period is bounded from above by $x_{rf} - \frac{D}{1-\delta pc}$. Since $(1-p)x_g > x_{rf}$, this deviation is not profitable. Now suppose that shareholder i deviates from $\bar{\sigma}$ by offering some $\tilde{\omega}^{i1}$ to which manager i responds by opting out. In that case, the payoff to shareholder i in the first period is zero. By rewriting the supposition that $c \leq c'$, it holds that $(1-p)x_g - \frac{D}{1-\delta pc} \geq 0$, so this deviation is again not profitable. Indeed, $\bar{\sigma}$ is a banking equilibrium.

($\Rightarrow$) Suppose that a full risk equilibrium σ exists. Then $\nu^{i1}(\sigma) = D$ implies $\mu^{i1}(\sigma) = \frac{D}{1-\delta pc}$. Hence the payoff of shareholder i from the first period is $(1-p)x_g - \frac{D}{1-\delta pc}$. Since shareholder i could guarantee a payoff of zero by proposing $(0,0,0)$ to manager i, it must be true that $(1-p)x_g - \frac{D}{1-\delta pc} \geq 0$. Indeed, rearranging this inequality yields $c \leq c'$. □

Proof of Theorem 5.2

The existence of the full risk equilibrium follows from Theorem 5.1. We show that all banking equilibria are full risk equilibria when $c = 0$.

Indeed, suppose that $c = 0$. Let $\bar{\sigma}$ be a banking equilibrium. By Corollary 3.7 it holds that $A^{i2}(\sigma^h) = R$ for all $h \in H$ and $i \in N$. Consequently, a deviation from $\bar{\sigma}$ in the first period has no effect on risk choices or wages in the second period.

Suppose, by way of contradiction, that there is $i \in N$ so that $A^{i1}(\bar{\sigma}) \neq R$. Either $A^{i1}(\bar{\sigma}) = O$ and then the shareholder will earn zero, or $A^{i1}(\bar{\sigma}) = S$ and then the shareholder will earn $x_{rf} - D > 0$. If $c = 0$ and if $\bar{\sigma}$ is a banking equilibrium but not a full risk equilibrium, then at least one shareholder will earn $x_{rf} - D$ in the first period.

Consider wage offer $\tilde{\omega}^{i1} = (\frac{D+\varepsilon}{1-p}, 0, 0)$. Manager i would respond to this proposal by taking risk. However, if shareholder i were to deviate from $\bar{\sigma}$ by proposing $\tilde{\omega}^{i1}$, then the resulting expected payoff for shareholder i would be either $x_g - \frac{D+\varepsilon}{1-p}$ or $(1-p)x_g - D - \varepsilon$. Clearly, the latter term is smaller than the former, so the deviation yields shareholder i a gain of at least $(1-p)x_g - D - \varepsilon - x_{rf} + D = (1-p)x_g - x_{rf} - \varepsilon$. This gain is positive when $\varepsilon > 0$ is chosen sufficiently small. Shareholder i then has a profitable unilateral deviation from $\bar{\sigma}$. This is a contradiction. □

Proof of Theorem 6.1

Suppose that $\bar{\sigma}$ is a threshold equilibrium. Let $\bar{h}$ be the first-period history induced by playing according to $\bar{\sigma}$ in the first period. Then, by the definition of a threshold equilibrium, we know that $\bar{\sigma}^{\bar{h}}$ is an h-banking equilibrium that involves threshold risk in the $\bar{h}$-subgame. By Theorem 3.6, this implies that $\tau^i(\bar{h}) \geq \tau^*$ for at least $n - \bar{n} + 1$ banks. Since under $\bar{\sigma}$ the crisis probability in either period is zero, we have $\mu^{i1}(\bar{\sigma}) = \nu^{i1}(\bar{\sigma}) = D$ for all $i \in N$, and the realized wage in the first period is D for all $i \in N$. Hence $\tau^i(\bar{h}) = cD$ for all $i \in N$. It follows that $cD \geq \tau^*$. Substituting from the definition of τ^* and rearranging this inequality, we find that $c \geq c''$, as desired. □

Proof of Theorem 6.2

Define a strategy profile $\bar{\sigma}$ as follows: In the first period, shareholders make the following wage offers:

$$\begin{aligned} \bar{\omega}^{i1} &= (D, 0, 0), \ i = 1, \ldots, \bar{n} - 1, \\ \bar{\omega}^{j1} &= (0, D, 0), \ j = \bar{n}, \ldots, n. \end{aligned}$$

Furthermore, under $\bar{\sigma}$ managers $i = 1, \ldots, \bar{n} - 1$ respond to the wage offer ω^{i1} by opting out if and only if $D > \max\{\omega_g^{i1}, \omega_{rf}^{i1}\}$. If a manager does not opt out, he will respond by taking risk if and only if $\omega_g^{i1} \geq \omega_{rf}^{i1}$ and invest safely otherwise. Furthermore, under $\bar{\sigma}$ manager $j = \bar{n}, \ldots, n$ will react to the wage offer ω^{j1}

in the following way: He opts out if and only if $D > \max\{(1-p)\omega_g^{j1}, \omega_{rf}^{j1}\}$. Conditional on not opting out, manager j will take risk if and only if $(1-p)\omega_g^{j1} > \omega_{rf}^{j1}$ and invest safely otherwise.

We now define the restriction $\bar{\sigma}^h$ of $\bar{\sigma}$ to the h-subgame for each $h \in H$. If all shareholders and all managers play according to $\bar{\sigma}$ in the first period, then there will be no crisis. That is, play according to $\bar{\sigma}$ induces a unique history, which we will denote henceforth by $\bar{h} \in H$. To define $\bar{\sigma}^h$, we distinguish three cases.

1. Suppose that h is a first-period history involving the same investment choices by all banks as in $\bar{h}$. By Assumption 4.4, it holds that $\tau^k(h) \geq cD$ for all $k \in N$. By the supposition that $c \geq c''$, it follows that $\tau^k(h) \geq \tau^*$ for all $k \in N$. There exists an h-banking equilibrium involving threshold risk, in which all banks $j = \bar{n}, \ldots, n$ take risk. Let $\bar{\sigma}^h$ be that h-banking equilibrium.
2. Suppose that history h is such that no bank has been out of business in the first period and $Z_1 = 0$. Moreover, suppose that the investment choices under h differ from those under $\bar{h}$ with regard to exactly one bank, say $k' \in N$. Again, by Assumption 4.4 it holds that $\tau^k(h) \geq cD$ for all $k \in N$. By the supposition that $c \geq c''$, it follows that $\tau^k(h) \geq \tau^*$ for all $k \in N$. There exists an h-banking equilibrium involving threshold risk in which bank k' makes the safe investment. Let $\bar{\sigma}^h$ be such an h-banking equilibrium.
3. For any other histories $h \in H$, let $\bar{\sigma}^h$ be an h-banking equilibrium involving full risk.

Now we need to show that $\bar{\sigma}$ is in fact a banking equilibrium. By construction, it holds for all $h \in H$ that $\bar{\sigma}^h$ is an h-banking equilibrium of the h-subgame. Hence, one only has to verify that there is no profitable unilateral deviation in the first period. Moreover, it holds by construction of $\bar{\sigma}$ that a unilateral deviation by shareholder k' or manager k' will lead to an h-banking equilibrium in which no crisis tax is to be paid by manager k'. This implies that manager k' expects a payoff of D in the second period, regardless of whether bank k' makes the first-period investment choice prescribed by $\bar{h}$ or whether bank k' is the only bank to make a different investment choice. Consequently, a deviation by a manager in the first-period can only be profitable if it increases that manager's instantaneous payoff in the first period. It is now straightforward to see that there is no profitable unilateral deviation from $\bar{\sigma}$ in the first period for any manager.

What is left to show is that no shareholder can gain from unilateral deviation from $\bar{\sigma}$ in the first period.

First, consider a shareholder $i = 1, \ldots, \bar{n}-1$. Clearly, wage offer $\bar{\omega}^{i1}$ is optimal among all those wage offers to which manager i responds by taking risk under $\bar{\sigma}$. Suppose that shareholder i deviates from $\bar{\sigma}$ by offering a wage scheme ω^{i1} to which manager i responds by investing safely. Then shareholder i's payoff is bounded from above by $(1+\delta)(x_{rf} - D)$. However, under $\bar{\sigma}$, shareholder i's payoff is $x_g - D + \delta(x_{rf} - D)$. Since $x_g > x_{rf}$, this deviation is not profitable. Now suppose that shareholder i deviates from $\bar{\sigma}$ by offering a wage scheme ω^{i1} to which manager i responds by opting out. Then shareholder i's payoff is $0 + \delta(x_{rf} - D)$. Since $x_g - D > 0$, this deviation is not profitable.

Now consider a shareholder $j = \bar{n}, \ldots, n$. Clearly, wage offer $\bar{\omega}^{j1}$ is optimal among all those wage offers to which manager j responds by choosing the safe investment under $\bar{\sigma}$. Suppose that shareholder j deviates from $\bar{\sigma}$ by offering a wage scheme to which manager j responds by opting out. The resulting payoff for shareholder j is $0+\delta(x_{rf}-D)$. However, under $\bar{\sigma}$, shareholder j's payoff would be $x_{rf}-D+\delta(x_g-D)$. Since $x_g > D$, this deviation is not profitable. Finally, suppose that shareholder j deviates from $\bar{\sigma}$ by offering a wage scheme to which manager j responds by taking risk. Then shareholder j's payoff is bounded from above by

$$(1-p)x_g + \delta p(1-p)x_g + \delta(1-p)x_{rf} - (1+\delta)D.$$

To see this, recall that after a change in the investment choice of a single bank in the first period, no crisis tax will have to be paid by that bank in the second period. This explains the last term in the expression above. If bank j makes the risky investment in the first period, then a crisis will happen with probability p. So the expected asset return in the first period is $(1-p)x_g$, explaining the first term in the expression above. If a crisis does occur in the first period, then we have a situation where an h-banking equilibrium with full risk is played in the second period, hence the second term. If, by contrast, no crisis occurs in the first period, then we have a situation where the h-banking equilibrium with threshold risk is played in the second period and bank j makes the safe investment, hence the third term. In order to complete the proof, we need to show that

$$(1-p)x_g + \delta p(1-p)x_g + \delta(1-p)x_{rf} - (1+\delta)D \leq (x_{rf} - D) + \delta(x_g - D).$$

Rearranging this inequality yields (12), which holds by the supposition of the theorem. $\square$

Proof of Theorem 6.3

The proof is constructive. Define the strategy profile $\bar{\sigma}$ as follows: In the first period, shareholders make the wage offers

$$\begin{aligned}\bar{\omega}^{i1} &= (D, 0, 0),\ i = 1, \ldots, \bar{n} - 1,\\ \bar{\omega}^{j1} &= (0, D, 0),\ j = \bar{n}, \ldots, n.\end{aligned}$$

A manager $i = 1, \ldots, \bar{n} - 1$ will opt out in response to wage offer ω^{i1} if and only if $D > \max\{\omega_g^{i1}, (1 - \delta pc)\omega_{rf}^{i1}\}$. Conditional on not opting out, he will select the risky investment if and only if $\omega_g^{i1} \geq (1-\delta pc)\omega_{rf}^{i1}$.

A manager $j = \bar{n}, \ldots, n$ will opt out in response to wage offer ω^{j1} if and only if $D > \max\{(1-p)(1-\delta pc)\omega_g^{j1}, \omega_{rf}^{j1}\}$. Conditional on not opting out, he will take risk if and only if $(1-\delta pc)(1-p)\omega_g^{i1} \geq \omega_{rf}^{i1}$.

Now we define $\bar{\sigma}^h$ for every $h \in H$. Note that $\bar{\sigma}$ induces a unique first-period history, say $\bar{h}$. We distinguish two cases.

1. If h is a history involving the same investment choices by all banks in the first period as $\bar{h}$, then there has been no crisis. By Assumption 4.4, it holds that $\tau^k(\bar{h}) \geq cD$ for all $k \in N$. From the supposition that $c \geq c''$ it follows that $\tau^k(\bar{h}) \geq \tau^*$ for all $k \in N$. There exists an h-banking equilibrium involving threshold risk in which each shareholder makes the same wage offer at $t = 2$ as at $t = 1$. Let $\bar{\sigma}^h$ be that h-banking equilibrium.
2. If h is a history that does not involve the same investment choices by all banks in the first period as $\bar{h}$, then let σ^h be an h-banking equilibrium involving full risk.

Now we need to show that $\bar{\sigma}$ is a banking equilibrium. By construction, $\bar{\sigma}^h$ is an h-banking equilibrium for every $h \in H$. We need to verify the absence of any profitable unilateral deviation in the first period. Note that by construction of $\bar{\sigma}$, a crisis tax will only have to be paid if some bank $j = \bar{n}, \ldots, n$ has made the risky investment in the first period but there has been no crisis in that period. This reveals that there is no profitable unilateral deviation from $\bar{\sigma}$ for any manager. It remains to be shown that no shareholder has a profitable deviation from $\bar{\sigma}$ in the first period.

First, consider a unilateral deviation by shareholder $i = 1, \ldots, \bar{n} - 1$ in the first period. Clearly, $\bar{\omega}^{i1}$ is optimal among all those wage schemes to which manager i responds by taking risk. Suppose shareholder i deviates from $\bar{\sigma}$ by offering some wage scheme ω^{i1} to which manager i responds by investing safely. Shareholder i's payoff from this deviation is bounded from above by $x_{rf} - \frac{D}{1-\delta pc} + \delta(x_{rf} - D)$. However, his payoff under $\bar{\sigma}$ is $x_g - D + \delta(x_g - D)$. We see that the deviation is not profitable. Now suppose that shareholder i deviates from $\bar{\sigma}$ by offering some wage scheme ω^{i1} to which manager i responds by opting out. The resulting payoff to shareholder i is $0 + \delta(1-p)x_g - \delta D$. Again, we find that this is strictly less than the (expected) payoff $x_g - D + \delta(x_g - D)$ for shareholder i under $\bar{\sigma}$. Therefore the deviation is not profitable.

Now consider a unilateral deviation by shareholder $j = \bar{n}, \ldots, n$. Clearly, $\bar{\omega}^{j1}$ is optimal among all those wage offers to which manager j responds by investing safely. Suppose shareholder j deviates from $\bar{\sigma}$ with a wage offer ω^{j1} to which manager j responds by opting out. Then shareholder j's payoff is $0+\delta(1-p)x_g-\delta D$. But his payoff from $\bar{\sigma}$ is $(x_{rf}-D)(1+\delta)$. Rearranging inequality (13) yields $\delta(1-p)x_g-\delta D \leq (x_{rf}-D)(1+$

δ). We see that the deviation is not profitable. Finally, suppose that shareholder j deviates from $\bar{\sigma}$ by offering a wage scheme ω^{j1} to which manager j responds by taking risk. But manager j will only respond to ω^{j1} by taking risk if $\omega_g^{j1} \geq \frac{D}{(1-p)(1-\delta pc)}$. By the shareholder's budget constraint we have $x_g \geq \omega_g^{j1}$, so $x_g \geq \frac{D}{(1-p)(1-\delta pc)}$. Appropriately rearranging this inequality, we find $c \leq c'$ - a contradiction to the supposition of the theorem. We conclude that there is no profitable unilateral deviation from $\bar{\sigma}$ for any shareholder in the first period. Hence $\bar{\sigma}$ is a banking equilibrium. □

Proof of Theorem 7.3

Note that, due to Theorem 5.2, all elements of $\mathcal{E}(0)$ are full risk equilibria and thus induce the strictly lowest social welfare among all equilibria. On the other hand, due to Theorem 5.1 and inequality (18), there exists $c \in (0, 1)$ such that $\mathcal{E}(c)$ does not contain a full risk equilibrium. Due to inequalities (13), (18), and (19), by Theorem 6.3 we may choose the value of c such that $\mathcal{E}(c)$ contains a threshold equilibrium, which leads to the socially optimal outcome of the banking game. Hence $\mathcal{E}(c) \neq \emptyset$. □

Proof of Theorem 7.4

Note that, due to Theorem 5.2, all elements of $\mathcal{E}(0)$ are full risk equilibria. Due to inequalities (12) and (19), by Theorem 6.2, we may choose the value of c such that $\mathcal{E}(c)$ contains a threshold equilibrium, which leads to the socially optimal outcome of the banking game. Hence c fulfills the first condition in Definition 7.1. Since any full risk equilibrium induces the strictly lowest social welfare among all equilibria, c fulfills the second condition in Definition 7.1. Hence a Crisis Contract with tax rate c is weakly beneficial.

□

Example A.1

Consider an example where the discount factor is $\delta = 1$ and the crisis probability $p = 0.5$. Let the payoffs be $D = 1$ and $x = (3,\ 1.4,\ -1.5)$.

In the benchmark scenario with no Crisis Contracts, all banking equilibria are full risk equilibria. The social welfare is predicted to be $2n(1 - 0.5)3 + (2n)(0.5)(-1.5) = 3n - 1.5n = 1.5n$. However, if there was no bank activity, the social welfare level of $2n$ could be reached. In the example at hand, the banking equilibrium unambiguously predicts a welfare loss from bank activity in the absence of Crisis Contracts.

Note that inequality (13) holds in this example. Now suppose we introduce a Crisis Contract into the example. We calculate $c' = \frac{2}{3} \approx 0.66$ and $c'' = 0.2$. Take a crisis tax rate of $c = 0.67$. The introduction of such a Crisis Contract will lead to the existence of a threshold equilibrium. The social welfare in this equilibrium is given by
$2((\bar{n} - 1)3 + (n - \bar{n} + 1)1.4) > 2n$. Note that this holds independently of the value of $\bar{n}$.
Finally note that the Crisis Contract rules out the full risk equilibria. Hence it is strictly beneficial.

Example A.2

Consider an example where the discount factor is $\delta = 1$ and the crisis probability $p = 0.5$. Let the payoffs be $D = 1$ and $x = (3,\ 1.2,\ -1.5)$.

Note that inequality (13) does not hold in this example. Hence Theorem 7.3, which guarantees the existence of a strictly beneficial Crisis Contract, does not apply here. However, note that due to $\delta = 1$ inequality (12) holds. Assume in addition that the banking system is stable to some extent, namely such that $\tilde{n} \geq 0.5$ holds. It holds that $c'' = 0.6$. Then the Crisis Contract with tax rate $c = 0.61$ is weakly beneficial.

References

Acemoglu, D., A. Ozdaglar and A. Tahbaz–Salehi (2015), Systemic Risk and Stability in Financial Networks, *American Economic Review, 105(2),* 564–608.

Admati, A.R. and M. Hellwig (2013), *The Bankers' New Clothes: What's Wrong with Banking and What to Do about It,* Princeton University Press, Princeton, New Jersey.

Adrian, T. and M.K. Brunnermeier (2011), CoVaR, National Bureau of Economic Research Working Paper No. 17454.

Amini, H., R.Cont and A.Minca (2013), Resilience to Contagion in Financial Networks, *Mathematical Finance,* doi: 10.1111/mafi.12051.

Armour, J. and J.N. Gordon (2013), Systemic Harms and Shareholder Value, Columbia Law and Economics Working Paper No. 452.

Battiston, S. and G. Caldarelli (2013), Systemic Risk in Financial Networks, *Journal of Financial Managements Markets and Institutions 1,* 129–154.

Battiston, S., D. Delli Gatti, M. Gallegati, B.Greenwald, J.E.Stiglitz (2012), Liaisons dangereuses: Increasing connectivity, risk sharing, and systemic risk, *Journal of Economic Dynamics and Control, 36,* 1121–1141.

Bonfim, D. and M. Kim (2012), Liquidity Risk in Banking: Is there Herding?, European Banking Center Discussion Paper No. 2012-024.

Bell, B. and J. Van Reenen (2014), Bankers and their Bonuses, *Economic Journal 124* (574), F1–F21.

Chesney, M., J. Stromberg and A.F. Wagner (2012), Managerial Incentives to Take Asset Risk, Swiss Finance Institute Research Paper No. 10-18.

Dudley, W.C. (2014), Enhancing Financial Stability by Improving Culture in the Financial Services Industry, Remarks at the Workshop on Reforming Culture and Behavior in the Financial Services Industry, Federal Reserve Bank of New York, New York City. October 20, 2014. Retrieved from *http://www.newyorkfed.org/newsevents/speeches/2014/dud141020a.html* on September 10, 2015.

Efing, M., H. Hau, P. Kampkötter, and J. Steinbrecher (2015), Incentive Pay and Bank Risk–Taking: Evidence from Austrian, German, and Swiss Banks, *Journal of International Economics,* forthcoming.

Gersbach, H. (2011), Crisis Contracts, 2 April 2011, *VoxEU.org.*

Gersbach, H. (2013), Preventing Banking Crises — With Private Insurance?, *CESifo Economic Studies 59* (4), 609–627.

Hakenes, H. and I. Schnabel (2010), Bank Bonuses and Bail-out Guarantees, Beitraege zur Jahrestagung des Vereins fuer Socialpolitik 2010: Oekonomie der Familie — Session: Causes and Consequences of Bank Bail-outs D7-V2.

Hart, O. and J. Moore (1994), A Theory of Debt Based on the Inalienability of Human Capital, *Quarterly Journal of Economics 109* (4), 841–879.

Hellwig, M. F. (2009), Systemic Risk in the Financial Sector: An Analysis of the Subprime-Mortgage Financial Crisis, *De Economist 157* (2), 129–207.

Hurd, T.R. and J.P.Gleeson (2013), On Watt's cascade model with random link weights, *Journal of Complex Networks, 1,* 25–43.

John, K., A. Saunders and L.W. Senbet (2000), A Theory of Bank Regulation and Management Compensation, *Review of Financial Studies 13* (1), 95–125.

Repullo, R. (2012), Cyclical Adjustment of Capital Requirements: A Simple Framework, SSRN Scholarly Paper No. 2153440.

Repullo, R. and J. Suarez (2013), The Procyclical Effects of Bank Capital Regulation, *Review of Financial Studies 26*(2), 452–490.

Thanassoulis, J. (2012a), The Case for Intervening in Bankers' Pay, *Journal of Finance 67*(3), 859–895.

Thanassoulis, J. (2012b), Bank Pay Caps, Bank Risk, and Macroprudential Regulation, University of Oxford Department of Economics Discussion Paper Series No. 636.

VanHoose, D. (2011), Regulation of Bank Management Compensation, In J.A. Tatom (ed.) *Financial Market Regulation*, 163–183, Springer, New York.