Long-run productivity growth, credit booms, and financial crises*

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Abstract

Empirically, financial crises tend to follow credit booms in which high economic growth prospects do not materialise. I develop a model in which crises become possible following booms because of increased fragility of the banking sector. Banks raise financing from households to invest in long-term projects, but their ability to do so is limited by moral hazard. Demandable deposits create discipline by exposing misbehaving banks to runs, and thus help banks increase external financing. Normally, banks finance themselves with a mix of equity and deposits that maximizes discipline, but ensures that they always remain solvent. When growth prospects become sufficiently strong, however, worsening moral hazard induces banks to rely exclusively on deposits, leading to higher credit, asset prices, and investment. If the anticipated growth fails to come about, though, the excessive deposit financing leads to a systemic banking crisis. I also study policy implications of the model.

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I. Introduction

It is well-documented that major financial crises are typically preceded by booms in credit and asset prices[1] and are followed by protracted periods of slow growth.[2] Existing literature often studies booms as the result of financial liberalisation, excessive risk taking, or over-optimistic expectations,[3] while slow recoveries are attributed to ensuing credit crunches and deleveraging during crises.[4] These mechanisms are undoubtedly important, but there are several empirical observations linking financial cycles to the real economy which they cannot account for. Firstly, starts of credit booms are often associated with accelerated trend growth rate of real productivity, and, importantly, most credit booms do not end up in crises. When they do, however, financial crises tend to follow, rather than lead, persistent slowdowns in productivity growth (Gorton and Ordoñez, 2019; Dell'Ariccia et al., 2012; Paul, 2020).[5] This suggests that slow economic growth cannot be attributed solely to crises, and, in fact, it is deteriorating economic prospects that could be among the factors that trigger crises in the first place. Strikingly, Cao and L'Huillier (2018) document that the three largest economic disasters in the developed world, – The Great Depression, The Japanese Slump, and The Great Recession, – were all preceded by periods of major technological innovations and rapid productivity growth which ran out of steam before the crises. The evidence thus suggests that the ingredients for a typical financial crisis include deteriorating macroeconomic fundamentals, but also a preceding period of economic prosperity. This leads to an important question which I study theoretically in this paper: why do booms make the economy susceptible to potential crises?

To address it, I develop a model in which the key mechanism is a build-up of financial fragility in the banking sector during periods of booming productivity growth, when expected returns on banks' long-term investments are high. Building on the seminal work of Diamond and Rajan (2001b, 2000), part of banks' external financing comes in the form of short-term demandable deposits, which, through exposing banks to potential runs, discipline them against trying to squeeze external claimholders. Crucially, bankers' moral hazard becomes worse during booms, prompting them to

[1] See Reinhart and Reinhart (2010); Mendoza and Terrones (2008, 2014); Schularick and Taylor (2012); Reinhart and Reinhart (2010); Krishnamurthy and Muir (2017).

[2] See Cerra and Saxena (2008); Reinhart and Reinhart (2010); Reinhart and Rogoff (2009, 2014); Krishnamurthy and Muir (2017); Queralto (2019).

[3] For example, different strands of literature emphasized either moral hazard due to implicit government guarantees (Farhi and Tirole, 2012; Chari and Kehoe, 2016), overoptimism (Bordalo et al., 2018), or pecuniary externalities operating through borrowing constraints (see e.g. Lorenzoni (2008)).

[4] See, for example, Queralto (2019); Anzoategui et al. (2019); Bianchi et al. (2019); Guerron-quintana and Jinnai (2014); Garcia-Macia (2017); Ennis and Keister (2003).

[5] For the Great Recession, Fernald (2014); Cette et al. (2016); Cao and L'Huillier (2018) provide evidence that productivity has slowed *well before* the onset of the Financial Crisis. An updated version of Kahn and Rich (2007) gives a similar conclusion – see the appendix for details.

rely heavily on deposit financing. If future aggregate growth prospects deteriorate prematurely, the value of banks' assets falls sharply, rendering them insolvent, and instigating systemic bank runs. A long period of slow subsequent growth is then not just the result of the crisis, but also its cause.

More specifically, banks in the model have access to productive long-term projects that require capital investments. The long-run payoff of banks' projects is uncertain, and can be either high or low, depending on the aggregate productivity state. Capital is supplied by households, who cannot use it as productively as banks. Banks purchase capital on a competitive market, using their own net worth and financing they raise from households. While banks would prefer to finance their uncertain long-term investments with outside equity or similar flexible state-contingent instruments, their ability to issue equity is constrained by moral hazard and limited commitment. Specifically, banks can take actions that irreversibly reduce the ability of external investors to collect repayments from them in the future.[6] But since equity investors cannot commit to act against their best collective interest, they cannot credibly threaten to punish and liquidate opportunistic banks that try to squeeze them down to the liquidation value of assets.

Banks can, however, increase their financing by issuing deposits that are demandable at any time and feature a sequential service (aka first-come first-served) property, as in Diamond and Rajan (2001b). This creates a built-in collective action problem among depositors: when faced with a prospect of lower repayments than promised, each individual depositor finds it optimal to run and demand full repayment, hoping to be among the first in line. Deposits thus act as a disciplining device, since depositors will run and liquidate bank's assets whenever the bank is unable to repay them in full, even if it is not in their best collective interest. Foreseeing this, the bank will have strong incentives to maintain high pledgeability of future returns.

In normal times, when low productivity growth is a fairly likely outcome, banks are careful: they limit the level of deposits to what they can repay in both high and low productivity states, and issue an incentive-compatible amount of risky outside equity against the high state. As the probability of the high state increases, however, the amount of financing that safe banks can raise relative to the value of their projects falls, because banks have a greater incentive to squeeze the equity investors' share of the high state returns. Therefore, when the high productivity state becomes sufficiently likely, banks find it optimal to follow a risky strategy and finance themselves exclusively with deposits which they will be unable to repay if the low aggregate state materialises. This allows banks to increase the total amount of financing in a boom, and leads to higher equilibrium asset prices and investment. On the dark side, however, this introduces

[6]What I have in mind is that banks can create obscure and opaque corporate structure, reduce transparency about nature of their investments, maintain weak accounting standards etc.

financial fragility, and there is a systemic banking crisis in the low productivity state.

I then turn to the implications of the model for welfare and optimal government policy. In contrast to much of the post-Great Recession focus on macroprudential regulation, the model presented here cautions against relying solely on ex-ante preventive policies like leverage restrictions. While a strict macroprudential limit on banks' depositary liabilities can eliminate crises, it also limits investment at times of high productivity growth, precisely when it is the most desirable, and thus reduces welfare.

Focusing on ex-post policies, government bailouts can save the banking sector from a collapse and improve welfare *in a crisis*. However, unrestrained bailouts, if anticipated, completely destroy market discipline of deposits, and may lead to an inefficient level of investment, hurting welfare. Ex-post interventions are thus only desirable and welfare-improving if the government can commit to help banks in case of a systemic banking crisis driven by worsening fundamentals, but not to interfere when the market carries out justice against opportunistic banks that attempt to extract rents from their investors.

Of course, even well-targeted ex-post bailouts deal with symptoms rather than the underlying problem, namely inability of banks to credibly pledge future returns to investors. The model thus suggests that improving banks' transparency and accountability to their investors can not only increase their intermediation capacity, but also reduce reliance of banks on demandable deposit-like instruments, and thus have a benefit of making the financial system more stable. This motivates the question: should the banks always be monitored during booms to mitigate agency problems and enforce repayments to outside investors? Under simple assumptions about costs and benefits of supervision, I find that the regulator will indeed sometimes supervise banks, increasing their financing and eliminating crises, thus improving welfare. However, the regulator may optimally choose to withdraw and let banks rely on discipline provided by deposits when the confidence in high productivity growth is particularly strong. This potentially sheds light on why, for example, regulation and supervision of the financial sector in the US appear particularly lax in the years preceding the 2008 Financial Crisis.

II. Literature Review

This paper builds on Diamond and Rajan (2001b) who, in a similar vein to the seminal paper of Calomiris and Kahn (1991), strive to explain banks' reliance on short-term demandable deposits that expose them to runs. In these papers, demandable deposits with the first-come first-served feature align incentives and preclude banks from acting against depositors interests. Similarly to the present work, Diamond and Rajan (2000) also analyse optimal bank capital structure under uncertainty. The contribution of my paper is incorporation of this mechanism in the context of a simple macroeconomic model with aggregate uncertainty. I then demonstrate how systemic fragility of the banking sector increases in order to facilitate financing of investments during periods of strong economic growth, thus explaining why financial crises tend to follow credit booms.

The underlying idea that productivity underpins credit booms and financial crises can be traced back to at least Fisher (1933). Closely related recent studies include Gorton and Ordoñez (2019), L'Huillier et al. (2020), Boissay et al. (2016). While in these models crises are certain and perfectly predictable during booms, in my model crises are low probability events, consistent with evidence on agents' expectations.[7]

My paper also contributes to the literature on bank runs. Following Thakor (2018), the literature can be loosely divided into "illiquidity" and "insolvency" camps, although the line between the two issues is thin in practice. According to the first camp, rooted in the seminal work of Diamond and Dybvig (1983), runs are panic-based phenomena, and are essentially coordination failures in a world with multiple equilibria. The present paper belongs to the second camp, which seeks to explain bank runs as driven by the insolvency risk of banks due to weak economic fundamentals, consistent with a number of empirical findings.[8] One prominent example of this literature is Allen and Gale (1998), who build a model in which partial bank runs are an efficient way to improve aggregate risk sharing between early and late consumers. In a series of recent notable papers by Gertler and Kiyotaki (2015); Gertler et al. (2019a); Martin et al. (2014), while bank runs are still mostly panic-based, run equilibria are only possible when the fundamentals are sufficiently weak. In contrast to the present paper, however, the above papers do not account for why banking crises tend to follow credit booms, or why banks finance themselves with deposits or repos.

Gertler et al. (2019b) develop a model in which banking panics are preceded by credit booms, but not all credit booms are "bad", i.e. result in crises. While this is similar to my mechanism, I differ from them in that runnable deposits constitute part of banks' optimal capital structure in my model, and their use endogenously rises in booms. The advantage of this is that banks cannot eliminate the problem by making suspension of convertibility (temporary ban on withdrawals) in case of a run part of the deposit contract.

Starting with Aguiar and Gopinath (2007), there has been a growing literature on

[7]See also Cao and L'Huillier (2018), who similarly relate major economic booms and slumps to low frequency variations in the trend productivity growth. They abstract from financial crises altogether, however, and instead focus on consumption behaviour over the medium run in a permanent income framework with learning about permanent productivity shocks.

[8]For example, Calomiris and Gorton (1991) document that banking crises are not random events, but are accounted for by bad macroeconomic news and high insolvency risk of banks; Calomiris and Mason (2003) show that most bank failures during the Great Depression can be well explained by fundamentals, leaving only limited role to panics; Thakor (2018) surveys empirical evidence and concludes that the 2008 Financial Crisis was an insolvency risk crisis, and not an illiquidity crisis.

small open emerging economies that associates Sudden Stops with changes in trend productivity growth in these countries due to frequent policy regime changes, e.g. Flemming et al. (2019), Seoane and Yurdagul (2019), and Akıncı and Chahrour (2018). These models feature pecuniary externalities due to occasionally binding collateral constraints, and show that trend, rather than transitory shocks, produce realistic Sudden Stops dynamics, and can account for both preceding credit booms and slow recoveries. In this paper I leave out the pecuniary externalities and financial accelerator effect that are central to these papers, and specifically focus on bank runs and insolvency crises.[9]

III. The Model

III.A. The framework

There are three periods: $t \in \{0,1,2\}$. I shall also refer to period 2 as the 'long run'. There are two types of agents in the economy: households and bankers. There are two types of goods: consumption good, which is the numeraire, and physical capital. Capital is produced by households, and is used to produce consumption good, as described below, but cannot be consumed itself. Lastly, all agents are risk-neutral, and, for simplicity, I assume that there is no discounting, and everyone consumes in the last period.

In period 0, banks can invest in productive projects that mature and pay off in the long run, i.e. period 2. For simplicity, I assume that banks manage their projects directly, while households do not have the expertise necessary to invest in or run them.[10] Each project requires investment of one unit of physical capital, which bankers need to purchase from households in period 0 on a competitive market. Capital is produced by households using only their labour as input. Each household solves:

$$\max_{k_i} Qk_i - \gamma\frac{k_i^2}{2}, \tag{1}$$

where Q is the price of capital in period 0, k_i is the amount of capital produced, and the quadratic term represents the disutility from producing k_i units of capital. First-order

[9]There has been a large post-crisis literature on the role of BGG/KM-like financial accelerator effect during the financial crisis. Gertler and Karadi (2011) build a macro model where the banking sector is subject to balance sheet constraints and thus the classic financial accelerator. Brunnermeier and Sannikov (2014); Mendoza (2010); He and Krishnamurthy (2019) emphasize asymmetries and nonlinearities of models with financial frictions away from steady state. Lorenzoni (2008); Stein (2012) theoretically study the ex ante overborrowing and inefficiency associated with pecuniary externalities interacting with borrowing constraints.

[10]The model could be enriched by introducing entrepreneurs who run the projects. The above assumptions would correspond to a setup in which: (a) entrepreneurs are penniless and need to raise external financing; (b) households are unable to finance the entrepreneurs directly due to agency problems, whereas banks have the expertise to resolve them; (c) entrepreneurs compete for bank funding, so that project returns go to banks.

condition aggregated over all households yields the aggregate supply of capital:[11]

$$K^S(Q) = \frac{Q}{\gamma}. \tag{2}$$

Banks are scalable and perfectly diversify away any idiosyncratic uncertainties pertaining to individual projects. However, there is also aggregate uncertainty about the long-run productivity that pertains to all banks' projects. Specifically, there are two possible aggregate states $s \in \{H, L\}$, with respective ex-ante probabilities π and $1-\pi$. In the high productivity state H, the average return per project is R^H in period 2, whereas it is R^L in the low productivity state L, with $R^L < R^H$. The state is realised in period 1 and is observed by all agents. However, it is not verifiable in court until period 2, and thus contracts cannot be state-contingent in period 1. In addition, there is limited commitment on behalf of households, precluding banks from being able to purchase insurance against the aggregate state.

Projects are bank-specific, and other banks or households cannot run them profitably after the investment is made in period 0. This assumption reflects the fact that banks are relationship lenders who possess superior information about their borrowers.[12] Nevertheless, projects can be liquidated in period 1 before they mature. If liquidated, a project's capital is extracted in full and sold back to the households, who employ it in a traditional sector. The traditional technology is significantly less productive, however, and yields only a fraction $\lambda \in (0,1)$ of the return that capital could earn if remained with the bank. Assuming secondary capital market is competitive and liquid, the liquidation value of a project in state s is thus:[13]

$$\Lambda^s = \lambda R^s. \tag{3}$$

Each bank starts with a positive endowment of consumption good, which we will call net worth.[14] Banks finance their capital purchases with their net worth and financing they obtain from households. In what follows, aggregate net worth of the banking sector, N, is sufficiently scarce such that banks need to raise additional financing from households.[15]

[11]The results are similar if we assume that the stock of capital is fixed instead. Assumption of variable capital investment, however, introduces realistic deadweight losses from restricting banks' leverage and investment.

[12]It is important: if projects could be transferred between banks, some banks could find it optimal to bet on buying projects cheaply in a crisis for high returns, thus precluding their inefficient liquidation. This would not be profitable if the liquidation value is high enough, and preliminary work suggests that this assumption can be relaxed.

[13]The assumption that the liquidation value is state-contingent and is proportional to returns is not critical for the results, but simplifies the exposition.

[14]The results would be similar if, instead, we assumed that banks start with a stock of physical capital and liabilities to households.

[15]I assume that households are never constrained in their ability to provide financing to banks in

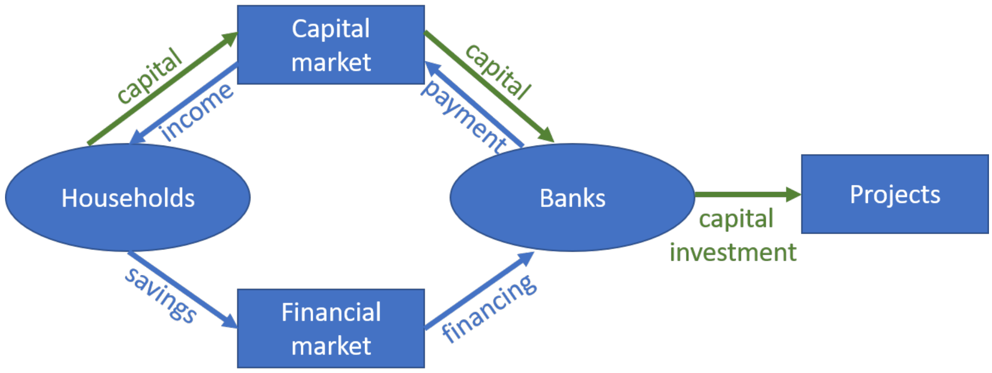


FIGURE 1: Flow of resources in period 0

Financial market is competitive, and households earn zero interest in expectation. Figure 1 illustrates the flow of resources in period 0.

III.B. Financial frictions

Banks suffer from limited pledgeability of future returns: at most fraction $\theta \in (0,1)$ of banks' returns is collectable by external claimholders in period 2. What is worse, after the investments in period 0, banks can also take actions that further irreversibly reduce the ability of investors to collect from them in the future. What I have in mind is that banks can create obscure and opaque corporate structure, reduce transparency about nature of their investments, maintain weak accounting standards, and collude with auditors. Formally, a bank can choose any pledgeability $\tilde{\theta} \in [0,\theta]$, meaning that outside investors will be able to collect no more than fraction $\tilde{\theta}$ of bank's returns in period 2. Bank's choice of $\tilde{\theta}$ is observable in period 1, but not verifiable and cannot be included in a contract. Bankers cannot commit to maintain high $\tilde{\theta}$ if it is not in their best interest.

Financial contracts can give investors control rights to liquidate banks' assets in period 1, although it is not possible to denominate contracts in capital goods.[16] I assume it is always feasible to force banks to liquidate projects and pay proceeds to the investors, irrespective of $\tilde{\theta}$. Without the liquidation rights, investors would not be able to get any repayments, since banks would always set $\tilde{\theta} = 0$, and thus banks would not be able to obtain any financing from the households in the first place. To keep the

period 0, or purchase banking sector's capital in case of liquidation in period 1. This, of course, will be always true if households have sufficiently large endowments of consumption good. This would also be the case, however, even if households start with zero endowments if we assume that all transactions happen instantaneously. In that case, household sector effectively ends up producing and lending capital to banks partly in exchange of promises of future payments (or, conversely, accepting physical capital in lieu of repayments with consumption good when banks liquidate projects).

[16]Because in the model liquidation value of capital is state-contingent in period 1 and perfectly correlated with the state in the interest of simplicity, ability to denominate contracts in terms of capital could prevent bank runs.

model interesting, we need to assume $\theta > \lambda$, so it is theoretically feasible for banks to repay more than the liquidation value of their assets in period 1.

III.C. The first best

It is instructive to describe the first-best outcome in this model. Absent limited pledgeability and agency problems described above, it is never desirable to liquidate banks' projects in period 1. Any financing banks raise from households, therefore, takes the form of long-term, state-contingent liabilities that are repaid in period 2 when projects mature.

Consider a bank with net worth n. If the bank raises additional b, it can start $\frac{n+b}{Q}$ projects. As the expected value of future repayments is just b, the bank's expected return is:

$$\frac{n+b}{Q}\left[\pi R^H + (1-\pi)R^L\right] - b.$$

Clearly, as long as $Q \neq \pi R^H + (1-\pi)R^L$, banks are either willing to expand borrowing to infinity, or are not willing to invest into projects at all, neither of which can be the equilibrium. The first-best equilibrium thus requires:

$$Q^* = \pi R^H + (1-\pi)R^L. \tag{4}$$

Capital investment is $K^* = {Q^*}/{\gamma}$, and marginal disutility of labour is equated with expected return on capital in banking sector; there is no capital produced for the traditional sector. Intermediation is costless and efficient, as banks earn zero expected profits.

IV. Financial contracts: equity vs. deposits

In this section we explore the instruments that banks can use to raise financing from households in light of the agency problems outlines above. When investors are well-coordinated and act as one, banks will never be inefficiently liquidated. However, inability of investors to commit to punish a banker that tries to squeeze them leads to severely constrained ability of banks to finance their capital investments. As in Diamond and Rajan (2001b), banks can overcome this by issuing demand deposits, which effectively commit depositors to run and liquidate banks that are not able to repay them in full, even if it is not in their best collective interest. While deposits bring about the much-needed discipline, they can also lead to socially undesirable bank failures.

IV.A. Equity financing: the case of well-coordinated investors

I first assume that bank investors are well-coordinated and always act as one to maximize their collective payoff: whenever there is a conflict of interest between individual investors, they are always able to efficiently negotiate among themselves. Therefore, the distribution of claims among investors is irrelevant for banks' ability to raise financing. What matters is that contracts specify total state-contingent payouts in period 2, as well as give investors the control rights to liquidate banks' assets in period 1. If a bank is unable to repay its investors in full in period 2, they are entitled to everything that can be recovered from it.[17]

For concreteness, I will henceforth refer to all financing obtained from well-coordinated investors as (outside) *equity*. Of course, there are many arrangements other than equity that facilitate coordination between investors, e.g. long-term debt. The choice to use term 'equity' is motivated in by its prevalence in the discussions of banks' capital structure. Moreover, as we shall see, the optimal contract with well-coordinated investors in this simple setting can be represented as a share of net collectable bank's returns accruing to them in period 2, thus vindicating the use of language.

Equity investors cannot commit ex ante to act against their best interest ex post. They will thus never liquidate assets of a bank if they stand to gain more from letting it continue running until period 2, even if the bank is not able to repay the promised amount in full. This lenience is a double-edged sword. While it assures that equity-financed banks will never get liquidated while they generate value for their investors, it also allows banks to squeeze their investors by reducing their ability to collect from them in the future. As a consequence:

Lemma 1. *The amount of financing that a bank can raise by issuing equity is limited to the expected liquidation value of its assets, namely* $\mathbb{E}\Lambda = \pi\lambda R^H + (1-\pi)\lambda R^L$ *per project.*

This result follows because the bank can always set $\tilde{\theta} = \lambda$ after selling equity, such that investors will be unable to collect more than $\Lambda^s = \lambda R^s$ per project in period 2. Since investors cannot gain more by liquidation, they will not liquidate. Foreseeing this, investors will refuse to lend to the bank more than the expected liquidation value of its assets in the first place.

IV.B. Deposits: creating collective action problem among investors

The central problem with equity is that coordinated investors cannot make credible threats to punish and liquidate banks that try to squeeze them, since this is not in

[17] We could explicitly allow for renegotiation between the bank and investors in the model in period 1. Contracts here are renegotiation-proof if we assume that parties can specify bargaining powers in advance as in Harris and Raviv (1995).

their best interest ex post. In the seminal paper, Diamond and Rajan (2001b) suggest that the use of 'harder' claims like demandable deposit contracts disciplines the banks against trying to be opportunistic. Their idea is that deposit contracts that promise repayments on demand (forcing banks to liquidate assets in period 1, if necessary), and are subject to the sequential service (aka first-come first-served) constraint, can break the coordination between investors and make it impossible for the banks to reduce their liabilities on deposits. This is because there is a built-in collective action problem among depositors: whenever a bank is unable to repay all of them in full, each individual depositor has an incentive to run on the bank hoping to be among the first in line and be made whole, rather than accept lower repayment. An attempt to squeeze depositors will thus trigger a run in which all depositors try to withdraw, even when it is in their best collective interest to agree to a lower payment.[18] To put differently, deposits commit creditors to punish and liquidate opportunistic banks ex ante, even if they would not choose to do so ex post. Foreseeing this, banks that are funded by deposits to a sufficiently high extent will have stronger incentives to maintain high pledgeability of their future returns, allowing them to borrow beyond their liquidation value.

I assume that deposit contracts with sequential service constraint are available to agents in the economy, and it is the only mechanism capable of creating a collective action problem among investors. Because the state cannot be verified until period 2, however, face value of deposits in period 1 cannot be made state-contingent. In fact, I assume without loss of generality that banks issue only simple deposits that have fixed face value across both periods and states; banks can then issue equity against the states in which they are able to repay more than the face value of deposits.[19] Lastly, by virtue of their instant demandability, deposits are always senior to equity: assuming depositors can run and liquidate assets quicker than equity investors in period 1, equity always gets only the residual value, if any, after all depositors are served.[20]

Crucially, deposit funding also has a dark side: a bank may be inefficiently run and liquidated even when it does not try to extract rents from its creditors, if the pledgeable value of its assets falls below the value of its depositary liabilities due to unfavourable

[18]For the detailed formal development of this argument, see section III.D, and also the proof of Lemma 2 in the Appendix of Diamond and Rajan (2001b).

[19]Firstly, it would be suboptimal for a bank to issue deposits that promise lower payments in period 2 than in period 1 in some states, since depositors would then always run in period 1 in those states. Secondly, while it is in principle possible to issue state-contingent deposits that pay more in period 2 than period 1 in some states, it does not make a difference to total financing that bank is able to raise. Since a prospect of reduction in future repayments would not trigger a run as long as depositors get at least as much as the current face value of their deposits, they cannot commit not to negotiate period 2 repayments that are in excess of the face value of deposits in period 1. But then they are not different from equity investors with respect to those excess repayments.

[20]This is because in period 1 equity investors will always agree to a necessary reduction in their period 2 claims to forestall a run by depositors.

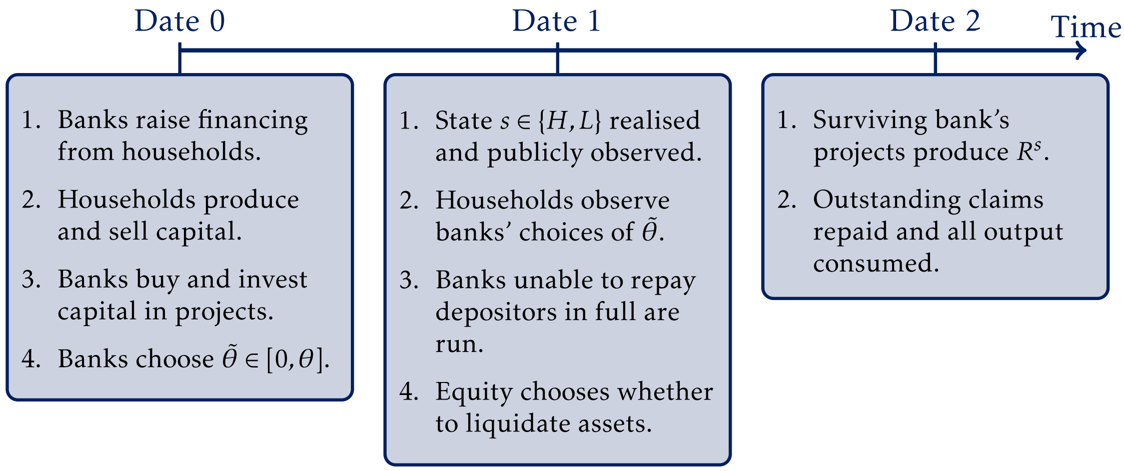


FIGURE 2: Timeline

economic conditions. In that case it would be desirable for depositors to agree to lower repayment, but, alas, deposit contracts are explicitly designed to prevent that from happening. At the same time, I assume that banks cannot fall prey to classic panic bank runs as in Diamond and Dybvig (1983), and fundamentally solvent banks are always able to obtain financing in period 1.

Figure 2 summarizes the timing of events. Now it is time to turn to how banks combine equity and deposit financing in equilibrium.

V. Banks' choice of financing, equilibrium, and financial crises

In this section we first consider an individual profit maximizing bank that takes market price of capital as given. I show that when the probability of the high productivity state is relatively modest, the bank can raise the maximum feasible amount of external financing and maximize its payoff by relying on a healthy mix of outside equity and deposits that it can repay in all states – the bank is safe. However, when the high productivity state becomes more likely, the ability of a safe bank to raise external financing declines due to moral hazard. At some point the bank finds it optimal to leverage itself up with deposits beyond what it can safely repay in the low state, i.e. become risky. This improves discipline and allows the bank to pledge more high-state returns to external financiers, but comes at the cost of making its demise inevitable in the low state. Secondly, I show that the model has a unique equilibrium. Similarly to the case of individual bank, if probability of the high state is sufficiently high, and the aggregate net worth of the banking sector is scarce, all banks choose risky strategy in equilibrium. This increases aggregate asset prices and investment during booms, but results in a financial crisis if the low state materializes.

V.A. *Banker's problem*

Let b be the total amount of financing that a bank with net worth n raises; and d and e^s be the face values of deposits and equity in state s, respectively. Without loss of generality we can assume that e^s is always incentive-compatible amount that actually gets repaid. Throughout most of this subsection, we also assume that $Q < \pi R^H + (1-\pi)R^L$, such that banks earn positive profits in expectation. This is indeed the case in equilibrium when the aggregate net worth of the banking sector is relatively scarce such that even with external financing banks cannot bid up capital price to the full value of the projects, $\pi R^H + (1-\pi)R^L$;[21] we shall briefly discuss the latter case at the end of the subsection. Let $m \equiv \frac{n+b}{Q}$ then be the number of projects the bank starts. We can make several immediate observations and assumptions wlog:

- $d \geq m\Lambda$, i.e. the face value of deposits is at least equal to the liquidation value of bank's assets. This is because deposits have no effect whatsoever when $d \leq m\Lambda$.[22]

- Bank is never liquidated in the high state. Liquidation in the high state happens if the banks is not able to repay depositors in full, or can repay less than the liquidation value of its assets, i.e. $m\tilde{\theta}R^H < \max\{d, m\lambda R^H\}$. This, however, implies that $m\tilde{\theta}R^L < d$ and bank is also liquidated in the low state. But, of course, being liquidated in both states cannot be an optimal solution to the bank's profit maximization problem.

- $e^L = 0$. If this wasn't the case, bank could always squeeze equity investors to zero in the low state by setting $\tilde{\theta} = \frac{d}{mR^L}$, while avoiding a run and liquidation in the H state because $m\tilde{\theta}R^H > \max\{d, m\lambda R^H\}$.

  Remark (More traditional representation of equity contract). *Since equity does not receive anything in the low state, the bank can simply promise them fraction $\alpha = \frac{R^L e^H}{d(R^H - R^L)}$ of collectable returns available after all depositors are paid – this results in equity investors receiving exactly e^H in the high state.*

The banker's payoff then is:

$$v = \pi\left[mR^H - d - e^H\right] + (1-\pi)\mathbb{I}_s\left[mR^L - d\right], \tag{5}$$

where $\mathbb{I}_s$ indicates whether the bank is *safe* and remains solvent even in the low state. Whether a bank is safe or risky boils down to how much it relies on deposits. A safe

[21] Of course, the price of capital can never exceed $\pi R^H + (1-\pi)R^L$ in equilibrium, since in that case there would be no demand for capital from banks.

[22] If $d \leq m\lambda R^L$, equity investors always optimally liquidate the bank that is not able to repay at least $m\lambda R^L$ in the L state; if $d > 0$, this first triggers a run, followed by equity investors receiving the liquidation value of the remaining assets.

bank will have $d \leq m\theta R^L$, whereas a bank will always fail if $d > m\theta R^L$. Bank will choose to be safe or risky depending on which one yields higher expected payoff. We can then look at these two strategies separately, and compare the resulting payoffs.

V.A.1 Safe strategy

Taking as given that it is optimal for the bank to be safe, i.e. $\mathbb{I}_s = 1$, the bank's maximization problem can be written as:

$$\max \quad v = m\Big[\pi R^H + (1-\pi)R^L\Big] - d - \pi e^H \tag{6}$$

$$\text{s.t.} \quad m = \frac{n+b}{Q} \tag{7}$$

$$b = d + \pi e^H \tag{8}$$

$$d \leq m\theta R^L \tag{9}$$

$$d + e^H \leq d\frac{R^H}{R^L} \tag{10}$$

$$v \geq \pi\Big(mR^H - \max\{d, m\lambda R^H\}\Big) \tag{11}$$

Constraint (8) is the break-even condition for bank's financiers; (9) restricts deposit liabilities of a safe bank to what it can feasibly pay out in the low state; (10) places the limit on the maximum repayment in the high state that the bank cannot reduce simply by lowering $\tilde{\theta}$ to $\frac{d}{mR^L}$, and still avoiding liquidation in both states; lastly (11) is the incentive compatibility constraint that ensures that the safe bank does not benefit in expectation from squeezing equity investors completely in the high state by setting $\tilde{\theta} = \max\Big\{\frac{d}{mR^H}, \lambda\Big\}$, and failing in the low state.[23]

Since $Q < \pi R^H + (1-\pi)R^L$, the bank will strive to raise as much external financing as possible, i.e. V is maximized when b is maximized. Ignoring constraint (11), this is achieved when both (9) and (10) bind, i.e. bank operates with the highest possible safe level of deposits. This is intuitive, because deposits provide discipline. If (11) is satisfied at that point, we have the solution. If not, it means that the safe bank cannot sustain such a high level of external financing and remain safe, and needs to reduce either equity or deposits, or both. (11) wont be a problem when the probability of high state π is low, but becomes a binding constraint when the high state becomes more likely. Formally, we get:

LEMMA 2. *The solution to a safe bank's maximization problem depends on the probability of*

[23]In fact, the bank does not fail if $d = m\lambda R^L$, but then constraint (11) is slack anyway; in addition, we shall see that it is always optimal to set $d > m\lambda R^L$.

the high state. Let

$$\dot{\pi} \equiv \frac{(1-\theta)R^L}{\theta R^H - \max\{\theta R^L, \lambda R^H\} + (1-\theta)R^L} \in (0,1). \tag{12}$$

- *When $\pi \leq \dot{\pi}$, constraints* (9) *and* (10) *bind, constraint* (11) *is slack, and the bank is able to pledge the maximum fraction θ of expected future returns to external financiers. As a result, the bank raises $b_s/m_s = \theta\left(\pi R^H + (1-\pi)R^L\right)$ per project, supervises*

$$m_s = \frac{n}{Q - \theta\left(\pi R^H + (1-\pi)R^L\right)} \tag{13}$$

  projects, and its expected payoff is

$$v_s = m_s(1-\theta)\left(\pi R^H + (1-\pi)R^L\right). \tag{14}$$

- *When $\pi > \dot{\pi}$, constraint* (11) *binds, and the bank can only raise $b_s/m_s = \pi \max\{\theta R^L, \lambda R^H\} + (1-\pi)R^L$ per project externally. The bank runs*

$$m_s = \frac{n}{Q - \pi \max\{\theta R^L, \lambda R^H\} - (1-\pi)R^L} \tag{15}$$

  projects, and earns the expected payoff

$$v_s = m_s \pi \left(R^H - \max\{\theta R^L, \lambda R^H\}\right). \tag{16}$$

Corollary 1. *Ability of a safe bank to finance its projects externally falls as the high state becomes more likely. Specifically, the fraction of expected returns which the bank can pledge to external financiers, $\frac{b_s}{m_s(\pi R^H + (1-\pi)R^L)}$, decreases in π (strictly decreases when $\pi > \dot{\pi}$).*[24]

The intuition for the result in the corollary is simple. As the high state becomes more likely, the banker's moral hazard becomes worse: he has stronger incentive to squeeze equity investors and get higher share of the pie in the high state. The ability of a safe bank to use deposits to reduce this moral hazard is limited by the fact that it must be able to repay depositors in full in all states. The solid line in Figure 3 illustrates the fraction of expected returns pledgeable by a safe bank as a function of π.

V.A.2 Risky strategy

This brings us to the second, risky, strategy that the bank may pursue when the high state is sufficiently likely: accept that it will fail in the low state in exchange of being

[24] The result is even stronger if $\lambda R^H < R^L$: in this case not just the relative fraction, but also the absolute amount of external financing per project strictly decreases in π when $\pi > \dot{\pi}$ due to moral hazard.

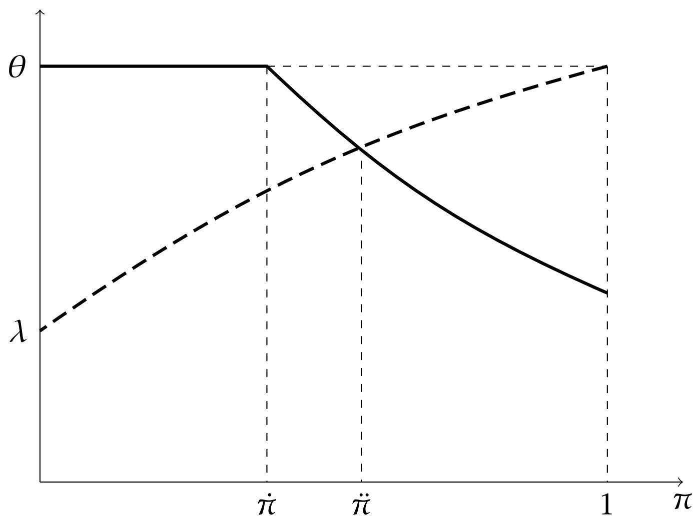


Figure 3: Fraction of expected projects' value that safe (solid line) and risky (dashed line) banks can pledge to external financiers

able to raise more financing against the high state using deposits and run more projects. Taking as given that the bank fails in the low state, its problem becomes:

$$\max \quad v = \pi\left(mR^H - d - e^H\right) \tag{17}$$

$$\text{s.t.} \quad m = \frac{n+b}{Q}$$

$$b = \pi\left(d + e^H\right) + (1-\pi)m\lambda R^L \tag{18}$$

$$d \leq m\theta R^H \tag{19}$$

$$d + e^H \leq \max\{d, m\lambda R^H\} \tag{20}$$

Constraint (18) is the break-even condition of bank's financiers, who liquidate the bank and keep the proceeds in the low state; (19) limits deposit liabilities of a risky bank to what it can feasibly repay in the high state; lastly, (20) places the limit on the maximum repayment in the high state that the bank cannot reduce with impunity simply by lowering $\tilde{\theta}$ to $\max\left\{\frac{d}{mR^H}, \lambda\right\}$ and squeezing equity investors.

Combining (17) and (18), it is easy to see that for the risky strategy to earn positive profit, and thus for the bank to even consider it over the safe one, we must have $Q < \pi R^H + (1-\pi)\lambda R^L$. Assuming that's the case, the bank's payoff is again maximized when external financing, b, is maximized. This is achieved when constraints (19)-(20) bind and the risky bank finances itself exclusively with deposits ($d = m\theta R^H$, $e^H = 0$), since that way the bank commits to repay the maximum pledgeable fraction θ of returns in the high state, and thus maximizes the external financing. Formally:

Lemma 3. *The solution to the risky bank's problem is achieved when constraint* (19) *binds and the bank promises maximum pledgeable fraction of returns in the high state to depositors.*

This allows the bank to raise externally $b_r/m_r = \pi\theta R^H + (1-\pi)\lambda R^L$ per project, supervise

$$m_r = \frac{n}{Q - \pi\theta R^H - (1-\pi)\lambda R^L} \tag{21}$$

projects, and earn the expected payoff

$$v_r = m_r \pi (1-\theta) R^H. \tag{22}$$

With such a high level of deposit liabilities the bank indeed fails in the low state. On the other hand, the risky strategy allows the bank to raise more external financing against the high state, so as the high state becomes more likely, the ability of a risky bank to finance itself externally improves. The dashed line on Figure 3 shows the amount of external financing that a risky bank can raise as a fraction of the full expected value of its projects.[25] As π approaches 1, this fraction approaches maximum feasible value θ.

V.A.3 Safe or risky?

So when will the bank turn risky?

Lemma 4. *The necessary conditions for a bank to even consider risky strategy are $Q < \pi R^H + (1-\pi)\lambda R^L$ and $\pi > \ddot{\pi}$, where*

$$\ddot{\pi} \equiv \frac{(1-\lambda)R^L}{\theta R^H - \max\{\theta R^L, \lambda R^H\} + (1-\lambda)R^L} \in (\dot{\pi}, 1). \tag{23}$$

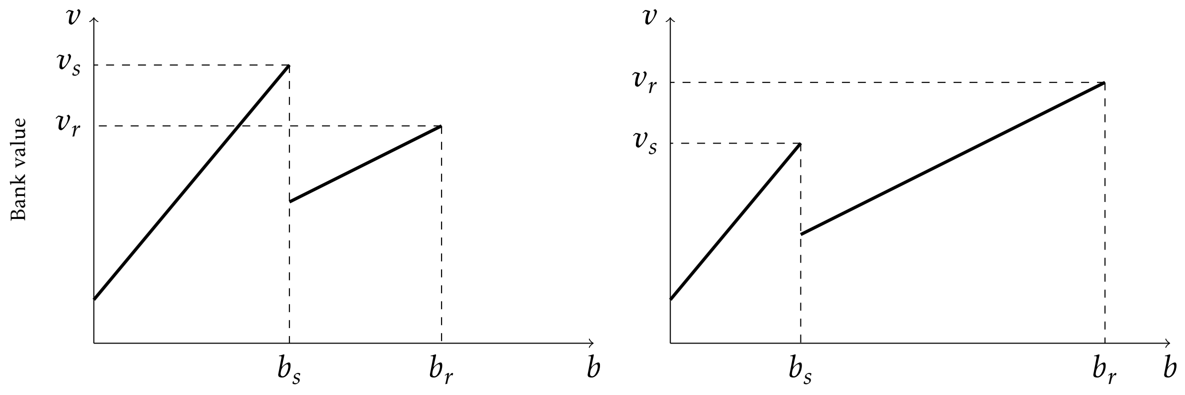
Then, the bank strictly prefers risky strategy to safe strategy whenever:

$$Q < \pi R^H + (1-\pi)\lambda R^L - \frac{(1-\pi)(1-\theta)(1-\lambda)R^H R^L}{\theta R^H - \max\{\lambda R^H, \theta R^L\}}, \tag{24}$$

i.e., ceteris paribus, (a) π is sufficiently high; (b) Q is sufficiently low.

When $\pi < \ddot{\pi}$, the bank can obtain more external financing following the safe strategy, hence there is no benefit at all of increasing leverage and becoming risky. When $\pi > \ddot{\pi}$, the bank trades off the ability to rise more financing and intermediate more projects offered by the risky strategy vs. losses due bank run and liquidation in the low state. Figure 4 depicts the bank's expected value as a function of its reliance on external financing, holding the market price of capital fixed. It increases linearly up until b_s, at which point it drops discontinuously: to raise more external financing than b_s, the bank must lever itself up with deposits beyond what it can repay in the low state, causing a bank run and liquidation in the L state. The value then continues to increase linearly in

[25] I.e. ignoring losses in the low state and valuing projects at full potential $\pi R^H + (1-\pi)R^L$ – this is to enable comparison with the safe case.



(a) Bank chooses safe strategy (b) Bank chooses risky strategy

FIGURE 4: Bank's value as a function of external financing

b up until b_r, although now with a lower slope. A bank's problem then reduces to simply choosing between the two peaks: v_s (playing it conservatively) and v_r (betting on the high growth, but defaulting if it slows down), whichever yields a higher value. Using (22) and (16), the second claim in the lemma follows.[26] More likely high productivity state and cheaper capital make the risky strategy more appealing (the latter because additional financing bank is able to obtain translates into more additional projects when Q is lower).

Lets conclude this section by looking at the case we have so far brushed off, namely $Q = \pi R^H + (1-\pi)R^L$. As already mentioned, the bank will never choose to be risky in this case. The safe strategy earns zero expected profit, no matter in how many projects the bank invests in, leaving it indifferent about how much external financing to raise. Such situation can only arise in equilibrium when the banking sector is sufficiently well endowed so that it can bid up the price of capital to the full value of the projects before constraints on external financing begin to bind, resulting in the first-best outcome. Since this is not a particularly interesting case, we shall not look into it in detail; for the purposes of characterising the equilibrium below, it suffices to assume that in such situation a safe bank can always raise any arbitrary amount of external financing within the limits imposed by financial constraints.[27]

[26]Here I make use of the fact that in equilibrium we will necessarily have $Q > \pi\theta R^H + (1-\pi)\lambda R^L$ and $Q > \pi \max\{\theta R^L, \lambda R^H\} + (1-\pi)R^L$, otherwise banks could make infinite profits and would demand infinite amount of capital.

[27]This remark is necessary because so far we have taken it as given that external investors can liquidate all bank's assets in period 1. While it makes sense when the bank tries to maximise external financing, it is undesirable if the bank needs to borrow less than the expected liquidation value of its assets. For this to be possible, there must be a way to restrict liquidation rights of external investors to a subset of bank's assets.

V.B. *Equilibrium and Financial Crises*

Equilibrium in this model requires that financial and capital markets clear in period 0. The key equilibrating variable is the price of capital Q: demand for capital from banks that take Q as given must equal supply of capital by households; at the same time, banks' demand for capital depends on the amount of external financing they obtain, which, as we have seen, also depends on Q.

I define equilibrium with financial crisis as an equilibrium in which all banks choose risky strategy in period 0, and are run and liquidated in the L state. The following proposition establishes that such equilibrium exists and is unique if aggregate banks' net worth is relatively scarce, and the probability of a high productivity state is sufficiently high.

Proposition 1. *There is a unique equilibrium, which is parameter-dependent. Suppose the aggregate net worth of the banking sector is sufficiently scarce, namely* $N < \frac{1-\theta}{\gamma} {R^H}^2$. *Then there exist thresholds* $\underline{\pi}, \overline{\pi}$, *with* $\ddot{\pi} < \underline{\pi} < \overline{\pi} < 1$, *such that:*

- *If* $\pi \leq \underline{\pi}$, *all banks choose safe strategy, and never fail in equilibrium.*
- *If* $\pi \in (\underline{\pi}, \overline{\pi})$, *there is a mixed strategy equilibrium in which some banks are safe, and some are risky.*
- *If* $\pi \geq \overline{\pi}$, *all banks choose risky strategy and there is a financial crisis if the low state materialises.*

The condition $N < \frac{1-\theta}{\gamma} {R^H}^2$ is a plausible one – assuming otherwise would imply that the banking sector has enough own resources to be able to bid up capital prices to the full value of the investment projects even when the high state is certain, and thus can never earn positive profits. But it is unlikely that bankers would have accumulated that much net worth, especially if during normal times the probability of high state is not spectacularly high.[28]

In general, solving for the thresholds $\underline{\pi}, \overline{\pi}$, equilibrium capital prices and quantities is rather involved: see the appendix for details and the proof of the proposition. However, it is straightforward to characterize the equilibrium in the limiting case where $N \to 0$, i.e. the banking sector is close to penniless in the aggregate, and raises most of its financing externally. In that case, price of unit of capital approaches the amount of external financing that banks can raise per project, and we have the following:

[28]Competition forces would have driven banks' returns on own net worth to 0 at $N \ll \frac{1-\theta}{\gamma} {R^H}^2$ during times when $\pi \ll 1$.

Proposition 2. *As $N \to 0$, both thresholds $\underline{\pi}, \overline{\pi} \to \ddot{\pi}$, and the equilibrium capital price*

$$Q^* \to \begin{cases} \theta\left(\pi R^H + (1-\pi)R^L\right) & \text{if } \pi \leq \dot{\pi} \\ \pi \max\{\theta R^L, \lambda R^H\} + (1-\pi)R^L & \text{if } \pi \in (\dot{\pi}, \underline{\pi}] \\ \pi\theta R^H + (1-\pi)\lambda R^L & \text{if } \pi \geq \overline{\pi}, \end{cases} \tag{25}$$

where the last case corresponds to the equilibrium with a possible financial crisis. The equilibrium capital investment is $K^* = Q^*/\gamma$.

When banks have very low net worth, the ability to raise external financing becomes a crucial concern in equilibrium, and banks are willing to become risky the moment it allows them to better finance themselves, as reflected in $\overline{\pi}$ falling to $\ddot{\pi}$. Because risky banks are able to raise more financing, increasing the demand for capital, we also have:

Corollary 2. *In equilibrium with financial crisis, the capital prices and aggregate investment are higher compared to a case in which all banks restrict their leverage to avoid a financial crisis in the L state.*

VI. Welfare and policy implications

In this section I discuss policy implications of the theory presented above. We'll find that ex-ante leverage restrictions and ex-post bailouts hurt welfare by stifling investment and destroying discipline, respectively. However, regulatory supervision of banks that enhances their transparency and governance can sometimes eliminate crises and improve welfare.

VI.A. Ex-ante leverage restrictions

While financial crises in the model are destructive and undesirable ex post, equilibria with crises are ex-ante constrained efficient: unlike many models with financial accelerator effects, here are no pecuniary externalities that agents do not take into account. Even though growing reliance of banks on deposit-like short-term financing introduces the risk of financial disaster, it also allows to increase financing of capital investment when it is most valuable: during booms with strong prospects of high future returns.

It is easy to see that sufficiently hard restrictions on ability of banks to leverage with deposits can always preclude financial crises in the present setting. However, this will not be Pareto improving: restricted leverage also means lower capital prices, and necessarily lower welfare of households, who are employed in the capital producing sector. Interestingly, in some cases leverage restrictions may lead to higher profits of the banking sector, since they effectively limit the competition between banks on the capital market, and allow them to enjoy higher returns per project. Nevertheless, there is a net loss to the society in the form of missed investment opportunities.

This point is quite general, and would remain an important consideration in more realistic settings that incorporate additional social costs of bank failures which may not be fully internalised by financial market participants, e.g. unemployment. Even if these additional costs tilt the balance in favour of using leverage restrictions to preclude possible financial crises, policy makers must understand that such policies are not free to use.

VI.B. Cleaning-up ex post: government bailouts

Unlike the models in which financial crises stem from panics and illiquidity, notably Diamond and Dybvig (1983), in the present model banking crisis is not a result of agents' failure to coordinate on a 'good' equilibrium. Once growth opportunities deteriorate during a boom, banks are run by depositors because they become fundamentally insolvent, in the sense that their liabilities on deposits exceed what they can possibly repay.

Despite this, saving banks in a crisis is, in principle, desirable *ex post*, since liquidation of banking assets destroys wealth for both households and banks. In practice, government rescue could take many forms: costly government guarantees of problematic banks' debt; lending to troubled banks at below-market interest rates; or simply injecting equity into banks. Arguably, most of these tools were used in the US during the 2008 Financial Crisis.[29]

However, recommending unrestrained government support to failing banking sector would be ill advised. The theory suggests that fragile capital structure is a market solution to bank discipline problem, and expectations of government rescue could completely destroy ex-ante incentives. If creditors expect that the government will use taxpayers' money to bail out troubled banks, they will have no reasons to care about bankers' conduct and incentives, leading to an overheated credit market, inflated asset prices, and high rent extraction by bankers. Incentives of banks to maintain high pledgeability of returns would be lost, and aggregate investment could be severely distorted.

Government bailouts would thus only be desirable ex ante if they are carried out in a way that preserves market discipline. This requires that the government must be able to commit to bail out banks only in a genuine crisis driven by a significant decline

[29] Despite the fact that Lehman Brothers was allowed to fail because the Fed deemed it fundamentally insolvent at the time, one can argue that other insolvent banks were effectively bailed out. Notwithstanding popular claims that the US government has made money on assisting troubled banks, this is not true if one takes into account the fair economic value of government's assistance: Lucas (2019) estimates the direct cost of bailouts to the US government to be in excess of £500bn, or 3.5% of GDP.

in expected economic growth, but let fail any bank that tries to extract rents from its financiers or taxpayers.[30] How to generate such a commitment remains an important question actively discussed in academic literature and policy circles. In essence, this is an institutional design problem of giving proper incentives to the regulator responsible for bailouts. I conjecture that the optimal design would at least require that the regulator (i) is well informed about the aggregate state of the economy, and (ii) is more reluctant to assist banks than a benevolent social planner would be. The latter would ensure that the regulator does not intervene unless there are significant benefits to households from doing so, and could be achieved by making bailouts legally difficult and politically costly to the regulator.

VI.C. Addressing financial frictions directly

The fundamental problem described in the paper is inability of banks to credibly pledge future returns to external financiers. Financing with rigid, demandable deposit-like instruments during booms, and the resulting financial crises are thus just the symptoms of the underlying cause.

One implication of the theory is the empirically valid prediction that banking crises are more likely to erupt in developing countries that are characterised by weak financial institutions and governance problems, while, at the same time, having less stable political regimes and more volatile economic trends. The second implication is that the best remedy against financial crises is a developed and transparent financial sector with sufficient intermediation capacity to allow it to refrain from fragile short-term financing – a point also forcefully stressed in Diamond and Rajan (2001a).

Acknowledging that developing financial institutions takes a long time, we can ask a more immediate question: should the government monitor banks during booms to mitigate agency problems and enforce repayments to outside investors? The answer, of course, depends on the feasibility and costs of monitoring. Formally, suppose that, by tightly supervising banks, the regulator can ensure that at least a fraction φ of banks' returns gets repaid: the banks cannot set $\tilde{\theta}$ below φ, and, if $\varphi \geq \theta$, the moral hazard is eliminated completely. However, active regulator's interference in banks' business also reduces future returns by a fraction $1-\chi$, such that banks' projects only generate χR^s in state s. Of course, we need to assume $\varphi\chi > \lambda$, otherwise the supervision is way too costly and inefficient to ever be used.

Even with this simple formulation of regulator supervision technology, analysing its desirability in the general case quickly becomes cumbersome. For simplicity, here I focus on the limiting case presented in the proposition 2, namely in which banks are penniless in the aggregate and the demand for capital is generated chiefly by external

[30] Of course, if such commitment is in place, no bank attempts to do so in equilibrium.

financing that banks rise in equilibrium. I also assume that the regulator is household-friendly, i.e. its sole objective is to maximize the welfare of household, and places zero weight on bankers' profits. Since households are employed in the capital-producing sector, and always break-even in expectation on the financial market, household welfare maximization is tantamount to maximizing capital price, and thus the amount of financing that banks can intermediate. Then one can show that:

Proposition 3. *Suppose N is negligibly small, and equilibrium capital price is equal to the amount of external financing that banks raise per project. The decision of a household-friendly regulator to supervise banks depends on the costs and effectiveness of supervision in the following way:*

1. *If $\varphi\chi \geq \theta$, the regulator always supervises banks and financial crises are completely eliminated.*

2. *If $\varphi\chi < \theta$ but $\varphi \geq \theta$, the necessary condition for the regulator to supervise banks is*

$$\varphi\chi > \frac{\ddot{\pi}\theta R^H + (1-\ddot{\pi})\lambda R^L}{\ddot{\pi}R^H + (1-\ddot{\pi})R^L}. \tag{26}$$

   Then, there exist π_1, π_2, with $\dot{\pi} < \pi_1 < \ddot{\pi} < \pi_2 < 1$, such that the regulator supervises banks iff $\pi \in [\pi_1, \pi_2]$. However, there is no supervision otherwise, and the equilibrium features potential financial crisis if $\pi > \pi_2$.

3. *If $\varphi\chi < \theta$ and $\varphi < \theta$, the necessary condition for the regulator to supervise banks is*

$$\varphi\chi > \max\left\{\theta\frac{R^L}{R^H}, \lambda\right\}. \tag{27}$$

   Then, provided the cost of supervision $1-\varphi$ is sufficiently low,[31] *there exist π_1, π_2, with $\dot{\pi} < \pi_1 < \pi_2 < 1$, such that the regulator supervises banks iff $\pi \in [\pi_1, \pi_2]$. However, there is no supervision otherwise, and the equilibrium features potential financial crisis if $\pi > \max\{\pi_2, \ddot{\pi}\}$.*

The first case is straightforward, since not only does the supervision eliminate the main agency problem on behalf of banks, – limited commitment to maintain high collectability of future returns, – but it also improves upon the best outcome market discipline can possibly achieve. The more interesting cases 2 and 3 with $\varphi\chi < \theta$ are broadly similar. The main message is that the regulator will indeed actively supervise banks, sometimes eliminating the possibility of a financial crisis, when the probability of the high state is moderately high. The regulator, however, will choose to leave

[31] The exact condition is too complicated to be included here; please see the proof in the appendix for details.

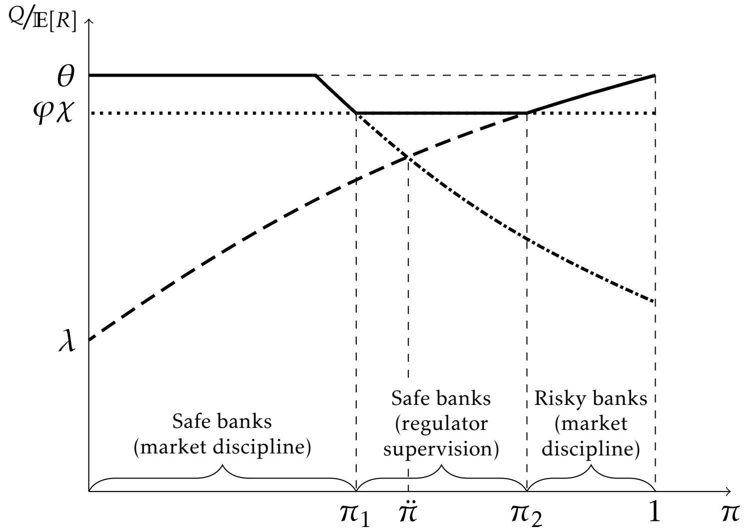


FIGURE 5: Capital price as a fraction of its first best level: market discipline vs regulatory supervision

the market to its own devices once the high productivity state becomes very likely. Intuitively, when the probability of the low state becomes small, expected benefit of preventing a crisis falls; on the other hand, regulatory supervision also becomes less effective than deposits in forcing repayments from banks in the high state. This sheds some light on why, for example, regulation and supervision of financial sector in the US appears particularly lax in the years preceding the 2008 Financial Crisis: on the back of strong confidence in the high productivity growth, the regulators might had been afraid to do more harm than good by interfering.

Figure 5 illustrates case 2, which is more straightforward to analyse.[32] It plots the price of capital Q as a fraction of its first-best level, $\mathbb{E}R = \pi R^H + (1-\pi)R^L$, assuming that either (i) regulator actively supervises banks (dotted line), (ii) all banks rely on market discipline and choose the safe strategy (dash-dotted line), or (iii) all banks rely on market discipline and choose the risky strategy (dashed line); the latter two lines are effectively the same as in Figure 3. In equilibrium, and with optimal supervision, the price of capital is the highest of the three, highlighted by the solid line on the plot. Supervision can achieve greater repayment from banks than market discipline when $\pi \in [\pi_1, \pi_2]$, and it eliminates financial crises when $\pi \in (\ddot{\pi}, \pi_2]$. However, the regulator prefers to let banks finance themselves with risky level of deposits when $\pi > \pi_2$.

VII. Concluding remarks

This paper presents a model in which financial crises result from build-ups of bank leverage and financial fragility during periods of rational optimism, when banks expect

[32]Since $\varphi \geq \theta$, supervision completely eliminates moral hazard in this case, while in case 3 regulatory supervision and market discipline interact with each other.

high returns on their long-term investments that ultimately do not materialise. The key mechanism is an increasing reliance of banks on deposit financing, which helps them overcome agency problems and increase funding, but also exposes them to runs. The model is consistent with empirical evidence that credit booms and financial crises appear to be preceded by swings in the long-run productivity trends.

Ex-ante leverage restrictions can eliminate crises, but may hurt welfare, because they stifle investment at the time when it is most valuable. Unrestrained ex-post bailouts destroy ex-ante incentives and lead to inefficient levels of investment. They are therefore desirable only if the government can commit to interfere only when banks require help because of deteriorating fundamentals, but otherwise allow them to fail. How to engender such a commitment is a fascinating direction for future research.

Regulatory supervision of banks that enhances their accountability to investors can sometimes eliminate crises and improve welfare. However, it may still be optimal for the regulator to back away and let banks rely solely on market discipline during times when the confidence in high productivity growth is very strong. More generally, the theory presented here emphasizes that a transparent financial sector with strong corporate governance may not only enable superior allocation of resources, but also improves financial stability.

Appendix

Productivity, Booms, and the 2008 Crisis

There is ample empirical evidence of low-frequency variation in the long-run growth rate of productivity. For example, Kahn and Rich (2007) show that a Markov switching model in which labour productivity growth can be either high or low, with a small probability of transition between the states, fits the postwar US data surprisingly well.[33] Moreover, accelerations in average productivity growth appear to be associated with starts of credit booms; and, while financial crises often follow credit booms, many credit booms do not, in fact, end up in crises (Gorton and Ordoñez, 2019; Dell'Ariccia et al., 2012). Crises, however, typically follow after several years of slow productivity growth (Gorton and Ordoñez, 2019; Paul, 2020). Cao and L'Huillier (2018) document that the three deepest recessions in developed economies, – The Great Depression, The Japanese Slump, and The Great Recession, – were all preceded by periods of major technological innovations and rapid productivity growth, which ran out of steam *before* the crises. Evidence thus appears to suggest that, paraphrasing Schularick and Taylor (2012), crises are productivity booms gone wrong: they follow booms in which accelerated productivity growth ultimately disappoints.

[33]See also Edge et al. (2007); Benati (2007), and references therein.

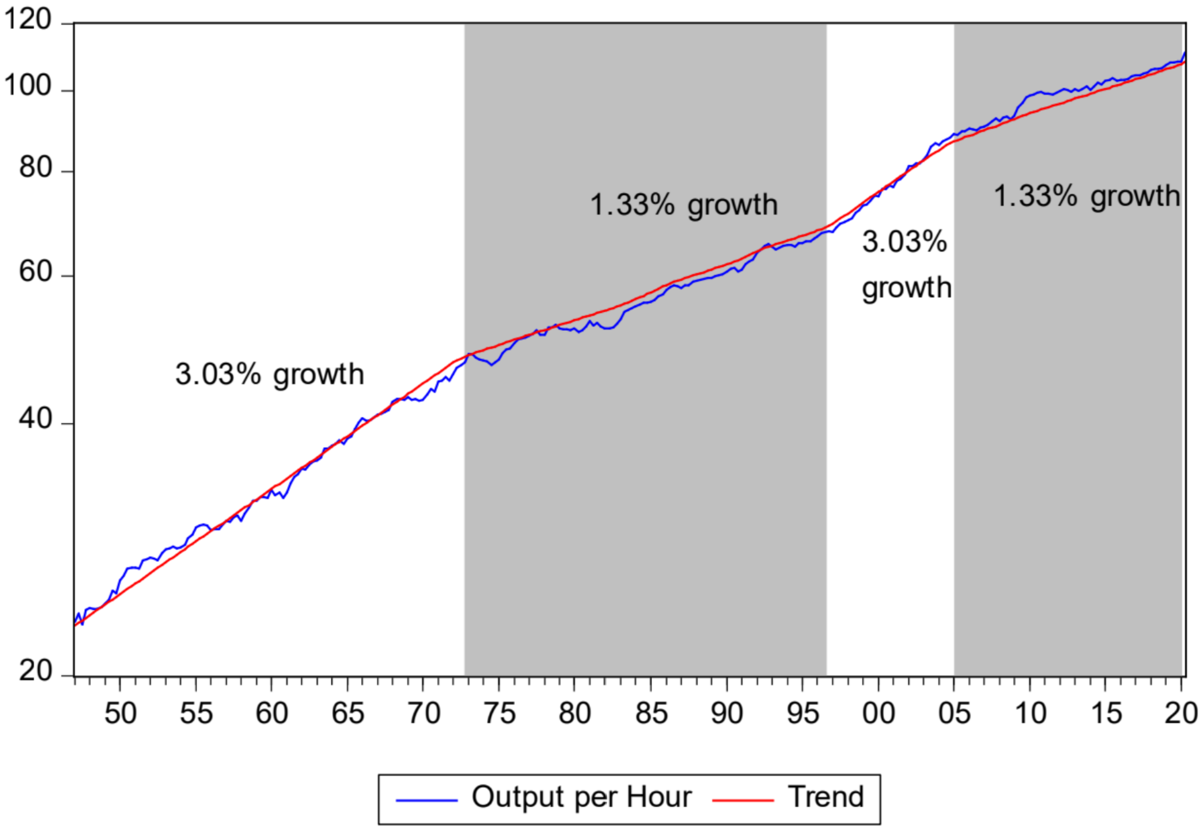


Figure A.1: US labour productivity growth trends (log scale) from Kahn and Rich model

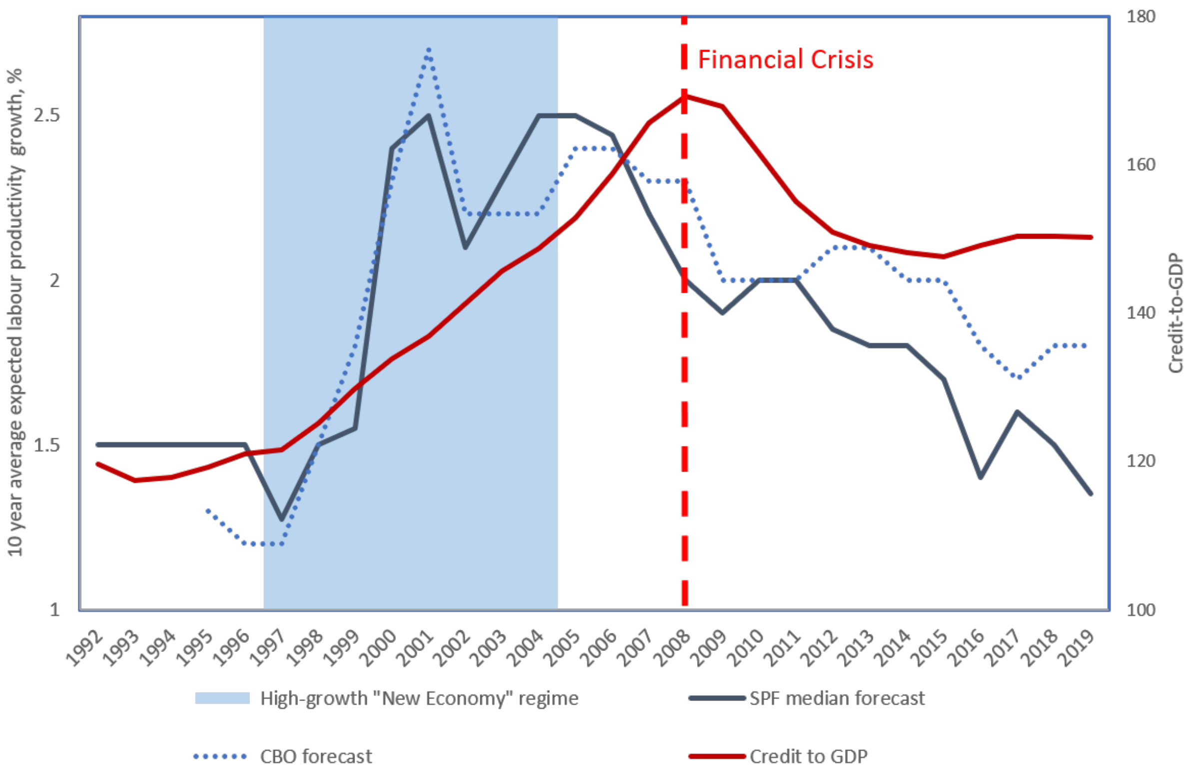


Figure A.2: The New Economy, long-run productivity growth expectations, and credit

The Great Recession is a case in point. It is well documented that there has been a marked acceleration in the US productivity growth in the mid 1990s after more than 25 years of sluggish growth, widely attributed to information and communication technologies.[34] Figure A.1, taken from the up-to-date version of Kahn and Rich (2007), demonstrates a shift to the high-growth regime around 1997. The gradual recognition of the New Economy prompted many people, including professional economists, to express confidence in high rate of growth for the decades to come.[35]. Figure A.2 shows that medium professional forecasts of 10-year average productivity growth nearly doubled in the 3 years 1997-2000, and were hardly affected by the dot-com bust. At the time, they were not necessarily unreasonable: since shifts in trend are infrequent and difficult to predict, the best forecast following an acceleration of productivity may well be to expect that the economy will experience a prolonged period of high growth. The figure also shows that this period was marked by a large credit boom in the US. As is evident from the figures, however, the trend productivity growth has slowed down again around the beginning of 2005.[36] Long-term forecasts began to decline, and the Financial Crisis broke out three years later.

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[34]See Benati (2007); Kahn and Rich (2007); Fernald (2014). In addition, Fernald (2014) demonstrates that although capital deepening played a role, high growth of labour productivity in the late 1990s- early 2000s was driven primarily by TFP.

[35]Among many others were: De Long (2003); Cummins and Violante (2002); Jorgenson et al. (2004); Stiroh and Botsch (2007); Gordon (2003).

[36]The evidence that productivity has slowed *well before* rather than as a result of the Great Depression is also presented in Fernald (2014); Cette et al. (2016); Cao and L'Huillier (2018).

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