Essays on Banking with Asymmetric Information

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Abstract

This thesis studies the information frictions in the banking system. It comprises three separate essays in Chapters II-IV, respectively.

The first essay develops a model in which a bank seeks funding for two projects at two different points in time but cannot commit to borrowing from the same investor in both periods. Despite this restriction, on-balance sheet funding with cross-subsidisation across projects dominates off-balance sheet funding with voluntary support in mitigating information frictions considered for all parameters, resulting in an efficient outcome (second-best). We uncover two novel channels through which on-balance sheet funding can create value, providing a rationale for the recent rise of Private Debt funds.

The second essay demonstrates that off-balance sheet financing functions in resolving the adverse selection problem constrained by the implicit condition of strong creditor rights, while debt contract financing can be feasible with fewer conditions. Moreover, with regulatory intervention, debt contract financing dominates, as the limited liability created by the off-balance sheet financing weakens banks' incentive to compensate investors after failure, which may exacerbate the moral hazard problem. This essay also advocates for strong creditor rights, which are beneficial for social surplus.

The third essay focuses on capital requirements and provides a novel rationale for imposing them. Existing literature explores it based on the assumption that the regulator has superior information about bank type, suggesting that risk-sensitive capital requirements should be imposed to mitigate information frictions. However, we demonstrate that information frictions may be mitigated without regulatory intervention, thus relaxing the assumption, and that capital requirements can be imposed, in combination with other regulations, to rectify the divergence between individual banks acting in self-interest and the aspirations of the regulator.

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Declaration

I declare that this thesis is a presentation of original work and any material contained in this thesis has not been presented for a degree or other qualification at this, or any other, University. All sources are acknowledged as References.

Chapter II is co-authored with Prof. Kostas Koufopoulos and Dr. Sonny Biswas. Inspired by Prof. Kostas Koufopoulos, I realized that direct investment serves as a costless signalling way for good banks to reveal their type. I then constructed the initial version of the model, wrote the first draft, made some revisions and presented an earlier version at the University of York's Thursday Workshop Seminar.

Chapter III is a single-author paper.

Chapter IV is co-authored with Prof. Kostas Koufopoulos. Inspired by his insights, I identified a gap in Ahnert et al. (2021)'s paper, specifically that the regulator's intervention may not be necessary to mitigate informational frictions, which opens the possibility of relaxing the assumption of the regulator's superior information. I subsequently constructed the model, wrote the draft of the paper and made revisions. I contributed to the development of the research idea of this paper.

Chapter I

Introduction

Asymmetric information denotes a situation where one side has more information than the other. Prominent models include adverse selection and moral hazard problems, which are the circumstances explored in this thesis. This thesis consists of three essays, organised as Chapters II,III, and IV. The first essay explores effective approaches to mitigating aforementioned information frictions and concludes that on-balance sheet financing with cross-subsidisation dominates the off-balance sheet solution for all parameter values. The second essay continues on this issue and indicates that off-balance sheet financing functions in resolving the adverse selection problem under the implicit condition of strong creditor rights, further emphasising the effectiveness of on-balance sheet funding with cross-subsidisation in mitigating information frictions. The third one provides a novel rationale for imposing capital requirements, relaxing the assumption of the regulator's superior information in existing literature.

Extensive research has been conducted on the issue of asymmetric information. Akerlof's *Market for Lemons* demonstrates that adverse selection of low-quality goods exists in markets where sellers have more information than buyers about product quality, which may cause the market to shrink or even disappear. Applying this idea to credit markets plagued by adverse selection suggests that issuers may raise funds at a higher cost, or potential issuers may refrain from entering the market (Tirole, 2010). The informed party has an incentive to resolve this problem by introducing a distortion as a signal to convey private information to the uninformed party. The signal could be costly for good borrowers but should be even more so for bad borrowers (Spence, 1973). Following this, Segura and Zeng (2020) rationalise the voluntary support after an off-balance sheet financed project fails as a signal. Although voluntarily supporting non-contractual debt repayment can be seen as ”money-burning”, it is more costly for bad banks with negative net present values of future projects. Segura and Zeng (2020) then emphasise the contribution of off-balance sheet activities in mitigating the adverse selection problem. Barbara Casu and Thomas (2011) and Duran and Lozano-Vivas (2013) also support the adverse selection hypothesis theoretically and empirically, respectively. However, various signals can be used by good borrowers to reassure investors and secure favourable financing conditions, such as costly collateral pledging or underpricing (Tirole, 2010). This thesis therefore suggests that an increase in a bank's own capital input can serve as a signal indicating the project's high quality. This is empirically supported by Ivashina (2009), who find that the premium interest required by investors due to asymmetric information can be reduced by the lead bank retaining a fraction of the loan issued by the syndicate participants and acts as the intermediary.

The moral hazard problem is pervasive in situations where the principal has little information about the fulfilment of a contract agreed upon by the agent, which is defined as hidden action in Arrow (1984). Agents, maximising their private benefit, may not act in the principal's best interest, leading to market inefficiency. For example, when a project is fully funded by investors, the manager incurs minimal losses from the failure and may have less incentive to exert effort, resulting in the project becoming less profitable. To resolve this, the manager's earnings may need to be partially aligned with the investors' interests. Hence, the manager experiences large volatility in the benefits between success and failure, and may have a strong incentive to exert effort.

Banks are at the centre of economic activity, as intermediaries transforming deposits into loans and facilitating the match between supply and demand for funds. Any regulations external to banks can significantly influence these intermediaries, and thus the economy. Banks are also subject to information frictions in the process of granting loans to firms with funds raised from investors. A better understanding of these financial intermediaries' behaviour in the face of information frictions contributes to the regulator maintaining a stable and efficient financial market. Therefore, this thesis concentrates on banks plagued by adverse selection and moral hazard problems.

Segura and Zeng (2020) construct a model to demonstrate the efficiency of off-balance sheet funding with voluntary support signalling in resolving adverse selection, and thus assert that regulatory restrictions on the provision of voluntary support should be prudent. However, non-contractual compensation may be too costly. We reconsider their model in the first essay (Chapter II) and attempt to identify another costless approach. Then, we derive that on-balance sheet funding with cross-subsidisation dominates the off-balance sheet solution for all parameter values. Furthermore, our analysis uncovers that banks can create value through the cross-subsidisation across projects, where the effort moral hazard constraint can be relaxed, boosting effort provision. By highlighting the advantages of the on-balance sheet funding mode, we provide a new explanation for the emergence and rise of the Private Debt funds in recent years.

The model in the first essay involves a bank that has two investment opportunities. The first investment suffers from an effort moral hazard problem, while the second suffers from an adverse selection problem. To mitigate the moral hazard problem, the expected net present value of the adverse selection project can be pre-sold, and the resulting funds can be used to reduce the face value of debt, which is a claim on the cash flow generated from the first project. The lower promised repayment relaxes the bank's effort moral hazard constraint and boosts effort provision. Regarding the project associated with adverse selection, we show that a unique fully separating equilibrium, in which only good banks invest, arises at zero cost under on-balance sheet funding. Separation arises through the violation of the bad bank's participation constraint rather than through the standard incentive compatibility constraint. We demonstrate that the equilibrium allocation is second-best, as it is consistent with the planner's solution.

Segura and Zeng (2020) examine identical information frictions, proposing that off-balance sheet funding alleviates the adverse selection problem by allowing good banks to (partially) separate through the provision of voluntary support, although it may lead to a lower effort level in the first project. Voluntary support relaxes the adverse selection constraint in the second project, but it makes the moral hazard constraint in the first project more binding. Thus, the off-balance sheet funding mode alleviates the adverse selection problem, while having a perverse impact on the moral hazard constraint. Our solution, however, resolves the adverse selection problem costlessly and frees up resources that can be used to relax the moral hazard constraint. The separating equilibrium can be achieved by violating the participation constraint of bad banks, and the funds raised from the pre-sale of the expected NPV of the adverse selection project can be directly invested in the moral hazard project to relax the moral hazard constraint. Our solution is generally available, even if we restrict our attention to situations where the bank cannot commit to dealing with the same investor in both periods, where the realisation of the second-best is more difficult, since the contracts used must be zero-profit on a contract-by-contract basis.

Our result implies that using a part of the funds raised for one project in another can relax information constraints and create value for the bank, which substantially supports the existence of cross-subsidisation across different activities in financial institutions. Through this, we also provide a new potential explanation for the emergence and rise of the Private Debt/Credit (PD) funds in recent years. Our analysis implies that the on-balance sheet funding mode of PD funds is more effective at resolving informational frictions than the off-balance sheet funding mode of traditional banks. Thus, informationally sensitive credit is moving away from traditional banks towards PD funds.

Existing literature presents divergent views on the role of off-balance sheet activities. Some accuse banks of approaching regulatory capital arbitrage through these activities, while others affirm their contribution to reinforcing economic flexibility and liquidity. For example, Duran and Lozano-Vivas (2013) support the latter, arguing that banks deal off-balance sheet to resolve the adverse selection problem rather than to eliminate undesirable risks from their books. However, in their empirical results, a sub-sample unexpectedly contradicts their adverse selection hypothesis. In order to provide an explanatory direction for this disagreement, we examine the effectiveness of the off-balance sheet solution in mitigating the adverse selection problem in the second essay (Chapter III), emphasising that it can be functional when implicitly conditioned on strong creditor rights. Our results further underscore the merit of on-balance sheet funding with cross-subsidisation, whose feasibility in relaxing the adverse selection constraint requires fewer conditions. Nevertheless, we still argue for strong creditor rights with which greater social surplus could be achieved.

In the second essay, we develop a model in which a bank has two investment opportunities. The first opportunity suffers from an effort moral hazard problem, while the second may suffer from an adverse selection problem if the first investment fails due to a systematic shock. Through this model, we demonstrate that if banks finance the first investment off-balance sheet, they are capable of resolving the potential adverse selection problem in the second investment. The limited liability created by off-balance sheet financing protects the bank's existing assets, which provides the bank with flexibility to send a signal and reveal its type after the asymmetric information arises. Good banks can use these protected funds to voluntarily support the debt repayment in the first investment, which is more costly for bad banks and can be seen as a signal.

However, after introducing creditor rights associated with the maximised repayment that investors receive into the model, we additionally show that off-balance sheet financing can only function in resolving the adverse selection problem if creditor rights are strong enough. The voluntary support compensates for the first project and has no impact on the amount raised externally for the second one. Thus, investors' participation constraints in the second investment are rigid and can only be satisfied when banks commit to sharing a substantial share of the project's return with them. Otherwise, if creditor rights, and hence investors' bargaining power, are weak, banks may not be willing to offer investors such high repayments, and there is no scope for the adverse selection hypothesis. Banks may be mainly prompted by other objectives to finance off-balance sheet, resulting in the association of off-balance sheet deals with "junk" assets. This may provide a direction for interpreting divergent empirical results in Duran and Lozano-Vivas (2013), which show that except for the sub-sample with an extremely low credit risk ratio, others, including the overall sample, support their adverse selection hypothesis.

We then propose that financing the first investment through a debt contract is an alternative approach to addressing the potential adverse selection problem in the second investment. Banks can design a contract in which the repayment in the failure state is limited. Through this, banks can retain some funds and thus gain the flexibility to signal. When asymmetric information arises, good banks can invest this part into the second project to reveal their type, which is costly for bad banks. Direct investment relaxes the adverse selection constraint with fewer restrictions on creditor rights, since the signalling amount invested in the second project reduces the funds raised externally, thereby relaxing investors' participation constraints and the restrictions on creditor rights as well.

Furthermore, we assess the performance of these two approaches in mitigating information frictions and find that debt contract financing with direct investment is more efficient, since the limited liability created by off-balance sheet financing diminishes banks' incentives to compensate, thereby exacerbating the moral hazard problem. Moreover, although there are no implicit conditions required for debt contract financing to resolve the adverse selection problem, we still argue for strong creditor rights, which could lead to a greater social surplus.

The third essay (Chapter IV) focuses on capital requirements, which have been emphasised since Basel II, and have attracted further attention in the aftermath of the global financial crisis. Some studies favour risk-sensitive capital requirements, arguing that they can be imposed to mitigate the adverse selection problem based on the assumption that the regulator has superior skills in distinguishing bank types compared with the public, and relate the risk sensitivity to the accuracy of the superior information (Morrison and White, 2005). Ahnert et al. (2021) state the separation can be realised through risk-sensitive capital requirements, when the superior information is sufficiently accurate. However, we argue that this result derives because they ignore good banks' own incentive and ability to separate. We reconsider their model in this essay, emphasising good banks' motivation, and show that regulatory intervention is not essential in mitigating information frictions. We provide a novel rationale for imposing capital requirements, which can be used to rectify the divergence between the regulator, who considers the social surplus, and individual banks acting in their self-interest. Regulators can improve upon the unregulated equilibrium even if they lack superior information regarding bank types.

In the third essay, we construct a model where a bank funds a project with uninsured deposits and costly capital, suffering from two information frictions: a moral hazard problem arising from the bank's choice of the probability of default, and an adverse selection problem stemming from the bank's type, which refers to the project's loss given default. The moral hazard problem may be severe when banks fund the project mainly through borrowed funds, as banks undertake little risk in the failure state by placing minimal capital in the project, and therefore they may not have sufficient incentive to control risk, resulting in a higher probability of default. Some existing literature thus rationalises risk-insensitive capital requirements, requiring banks to have enough skin in the game. In this way, banks' profits can be sufficiently tied to the success of the project. Banks may then have a greater incentive to exert effort, thus mitigating the moral hazard problem. As for the adverse selection problem, since investors have no superior information to distinguish good banks, the literature states there is scope for risk-sensitive capital requirements to implement a separating equilibrium when the regulator receives sufficiently accurate signals about banks' types.

However, we argue that good banks are able to separate themselves from bad banks since they dominate in the failure state and can send a signal by proposing higher repayment in that state. They are also motivated to do so to avoid higher financing costs. Through the model, we derive that separation can arise without regulatory intervention. A unique separating unregulated equilibrium emerges when the asymmetric information problem is severe, while the situation may be complicated when the asymmetric information problem becomes mild. The cost of enforcing separation remains constant, while the mispricing cost associated with accommodating bad banks decreases as the proportion of good banks increases. By trading off these two costs, good banks may decide to shift from excluding bad banks to pooling with them, reducing the compensation in the failure state to dilute their dominance when the proportion of good banks is large enough. However, investors observing this deviation cannot attach zero probability to the offer coming from bad banks, as both types can benefit from this deviation, and may reject the offer. Therefore, when the asymmetric information problem is less severe, the unregulated equilibrium may be separating or pooling, depending on the beliefs of depositors. As for the moral hazard problem, investors, with an incentive to preserve their interests, may require a minimum level of banks capital input, forcing banks to exert effort. It follows that regulatory intervention may not be essential for mitigating information frictions.

We additionally introduce a novel rationale for imposing capital requirements. The regulator values an equilibrium that maximises social welfare, which is distinct from the unregulated equilibrium shaped by individual banks acting in their own self-interest, even if information frictions have been mitigated. Capital requirements can rectify such a divergence, in conjunction with other regulations.

From the regulator's perspective, separation impedes the banking sector's expansion, raising a social cost associated with costly capital, while there is also a social cost generated from accommodating value-destroying bad banks in the market, which decreases as the proportion of good banks increases. Thus, when the asymmetric information problem is severe and the proportion of good banks is small, the regulator may prefer to separate, as individual banks do. However, the unregulated separating equilibrium is not preferred by the regulator, who desires a higher borrowing rate to maximise the size of the banking sector, which undermines good banks' profits. To correct this divergence, minimum collateral requirements should be imposed to transfer project profits to investors, in combination with minimum capital requirements to rule out bad banks. When the proportion of good banks increases to a sufficiently high level and asymmetric information is mild, both the regulator and good banks prefer to accommodate bad banks in the market. However, some inefficient unregulated equilibria with lower leverage cannot be ruled out due to investors' off-equilibrium beliefs. Thus, minimum leverage requirements should be imposed, forcing banks to achieve the pooling equilibrium with the maximum leverage.

The situation becomes complex when the asymmetric information problem is moderate. If the cost of capital is low, there may exist a situation in which the regulator prefers to pool, whereas the unregulated equilibrium is separating. Thus, the regulator can achieve pooling by setting minimum collateral to dilute the good banks' dominance in the failure state, forcing them to embrace bad banks. If the cost of capital is high, a situation arises in which the regulator prefers separation to maximise net social surplus, while the good bank may desire to pool. This divergence emerges because good banks anticipate a higher capital input in the unregulated separating equilibrium and thus overestimate the benefit of accommodating bad banks, especially with the multiple effect of the high cost of capital. In this case, minimum capital and collateral requirements should be imposed jointly to achieve the separation desired by the regulator.

Chapter II

Efficient on-balance sheet funding with cross-subsidisation across projects

II.1 Introduction

A bank has the choice to finance lending either on- or off- balance sheet. Segura and Zeng (2020) present a model to provide an economic rationale driven by information frictions for the emergence of off-balance sheet funding. Although they obtain an inefficient partial pooling equilibrium, they claim that off-balance sheet funding with voluntary support is a more effective signalling device than on-balance sheet funding. While we reconsider their model, relax that restriction, and show that a fully separating equilibrium arises at zero cost under on-balance sheet funding, and this solution strictly dominates the off-balance sheet funding solution for all parameter values. Furthermore, our analysis uncovers that banks can create value by composing a portfolio using projects suffered different information frictions and cross-subsidizing across projects to mitigate those frictions and realize a more efficient outcome. By highlighting the advantages of the on-balance sheet funding mode, we provide a new direction to explain the increasing size of the Private Debt funds in recent years.

In the model, there are two investment opportunities for a bank – the first suffers from an effort moral hazard problem, while the second suffers from an adverse selection problem. An additional offer is built into the contract financing the first project, providing investors a contingent claim on the cash flow generated by the adverse selection project. Through this, the bank pre-sells the expected net present value (NPV) of the adverse selection project and uses these funds to reduce the face value of debt which is a claim on the cash flow generated by the moral hazard project. The lower promised repayment relaxes the bank's effort moral hazard constraint and boosts effort provision in the first project. Regarding the project associated with adverse selection, we show there always exists a unique fully separating equilibrium in which only good banks invest. Separation arises through the violation of the bad bank's participation constraint rather than through the standard incentive compatibility constraint. We show that this equilibrium allocation coincides with the planner's solution (i.e., the equilibrium allocation is second-best).

Considering identical information frictions, Segura and Zeng (2020) suggest that off-balance sheet funding allows a good bank to voluntary support to (partially) separate, but resulting in a lower effort level in the first project. Thus, while the provision of voluntary support relaxes the adverse selection constraint in the second project, it makes the moral hazard constraint in the first project more binding. In contrast, in our solution, the good bank could invest in the adverse selection project to relax the constraint. Thus, our separating equilibrium can be implemented is costlessly (e.g., there is no money-burning) achieved through the violation of the participation constraint of the bad banks. The funds raised from the pre-sale of the expected NPV of the adverse selection project are directly invested in the moral hazard project which relaxes the moral hazard constraint. While, in the off-balance sheet funding mode, the mitigation of the adverse selection problem has a perverse impact on the moral hazard constraint. In our case, the costless solution of the adverse selection problem frees up resources which are used to relax the moral hazard constraint.

In summary, the off-balance sheet solution of Segura and Zeng (2020) is inefficient for three reasons: First, in their solution, good banks signal by burning money, leading an inefficient partial pooling equilibrium in which some value-destroying bad banks invest. Second, since some bad banks (those who do not mimic the good banks) do not use the cash flows generated by the asset-in-place to repay the debt on the moral hazard project, the face value of debt for this project is higher which makes the effort moral hazard problem more binding and leads to lower effort provision. In contrast, signalling in our solution is not socially costly, and we show that there exists a unique equilibrium which is always fully separating where only good banks invest. Third, our solution increases effort provision even further by transferring the expected NPV of the second project to reduce the promised repayment for the first project. Hence, given the information frictions in this model, the off-balance sheet funding mode is inefficient and does not maximize bank profit. Therefore, a rational profit-maximizing bank will never choose it.

In order to highlight the generality of our solution, we restrict attention to the case that the bank cannot commit to dealing with the same investor in both periods. This restriction implies that the contracts used must be zero profit on a contract-by-contract basis which makes the implementation of the second best potentially more difficult. Of course, the second-best outcome could also be implemented when the funds for both projects are offered by the same investor [1].

We show that, through a contingent claim, one project's profit can be used to alleviate

[1] The solution for this case is available upon request.

information constraints in another project and create value for the bank. There is substantial evidence on the existence of cross-subsidisation across different activities in financial institutions in various contexts (see e.g., Drucker and Puri, 2005; Griffin et al., 2007; Santikian, 2014; Jenkinson et al., 2018). Our analysis draws attention to a different kind of cross-subsidisation which has not been directly tested yet.

One potential application of our theory is to provide a new explanation for the emergence and rise of the PD funds in recent years. Our analysis implies that the on-balance sheet funding mode is more effective at resolving information frictions than the off-balance sheet funding mode. In the last couple of decades, potentially due to binding regulatory constraints, traditional banks sell large portions of their loans in the secondary loan market or move them off their balance sheets through securitization. The evolution of the banking business away from on-balance sheet funding has coincided with the emergence of the PD funds. Thus, we provide a novel direction to interpret the emergence of the PD funds, which is contributed by the preference of informationally sensitive credit to the on-balance sheet financing and the evolution of traditional banks. The PD funds is already a $1.7 trillion market in 2023 and rapidly growing. These PD funds make direct loans which are informationally sensitive and typically retain the entire loan on their balance sheets (see Block et al., 2024; Haque et al., 2024). We explain the rise of the PD funds as the informationally sensitive credit is moving away from the traditional banks towards the Private Debt/Credit (PD) funds.

Our theory generates two novel empirical predictions: First, the spread on debt is lower and monitoring intensity is higher for lenders with better growth prospects. Second, the spread on debt falls in the lender's growth opportunities if these are positively correlated with its core activities, while the direction of the effect is not clear if there is a negative correlation.

Literature Review.

In most existing theories, financial intermediaries have special skills in acquiring or processing information[2]. For example, Diamond (1984) and Holmstrom and Tirole (1997) emphasize the role of banks as monitors – in Diamond (1984) banks mitigate an ex post moral hazard problem through monitoring, while in Holmstrom and Tirole (1997) they mitigate an ex ante moral

[2]There is a separate strand of the literature which focuses on the liquidity creation/provision role of banks (see e.g., Diamond and Dybvig, 1983; Gorton and Pennacchi, 1990; Diamond and Rajan, 2001; Donaldson et al., 2020).

hazard problem. Ramakrishnan and Thakor (1984) and Allen (1990) focus on the screening role of banks in which banks can distinguish between good and bad borrowers. In these models, banks have a monitoring or screening cost advantage over non-intermediated outcomes (depending on the model, this advantage is either assumed, or it arises as an equilibrium outcome). In contrast, banks in our model do not have superior skills in resolving any information frictions, yet they generate value through two novel channels:

First, in our model an efficient separating equilibrium arises through socially costless signaling where as in existing banking theories separation is achieved through costly information production. Second, in our model there is cross-subsidisation across projects which is absent in existing models: the solution of the adverse selection problem requires that investors make strictly positive expected profits which are transferred to relax the moral hazard constraint. Coval and Thakor (2005) also do not assume that banks have special information processing skills; rational banks form a beliefs-bridge between optimistic entrepreneurs and pessimistic investors. In our theory, all agents are rational, so we explore a different role of banks than the one considered by Coval and Thakor (2005).

Improved effort incentives due to cross-subsidisation across projects is not a new idea. In Tirole (2010), cross-pledging across imperfectly correlated projects subject to effort moral hazard leads to greater effort provision by the manager (see also Diamond, 1984; Cerasi and Daltung, 2000; Laux, 2001; Axelson et al., 2009; Maurin et al., 2023) – the optimal contract entails that the bank is only compensated when all projects succeed; this relaxes the limited liability constraint of the agent and induces the efficient level of effort provision. The cross-pledging mechanism relies on exploiting the diversification effect resulting from imperfectly correlated projects and it is ineffective if projects are perfectly correlated. Our mechanism works differently: There exists a unique separating equilibrium in which only good banks invest and they effectively pre-sell the expected NPV of the second project. They invest the proceeds from this sale in the first project which reduces the amount of external funding required for this project. This allows the bank to retain a higher fraction of the cash flow generated by this project, and therefore, it exerts more effort. Thus, in contrast to existing models, the correlation structure across projects does not play a role which implies that the cross-subsidisation channel in our model is distinct from the well-known diversification effect.

II.2 Model

II.2.1 Set-up

There are four dates $t \in \{0, 1, 2, 3\}$. There is a bank which has no funds of its own at $t = 0$ and obtains a pay-off from assets-in-place at $t = 1$. The bank has two investment opportunities, the first at $t = 0$ and the second at $t = 2$; each project requires 1 and generates a payoff in the period following the investment. The funds are raised from competitive external investors. All agents are risk-neutral and the discount rate is set to 0.

The first project is always good (g), while the second project may be either good or bad (b). In either case, a project produces R per unit of investment if it succeeds and zero if it fails. A project succeeds with probability p_i. We assume that only good projects are profitable:

Assumption II.1. *$p_g R > 1 > p_b R$;*

The first project to be undertaken at $t = 0$ is subject to effort moral hazard. The project succeeds with probability p_g and fails with probability $1 - p_g$. The bank can exert unobservable effort $e \in [0, 1]$ at a cost $c(e)$ to reduce the probability of failure. Taking into account the bank's effort provision, the first project's success probability is $p_g + me$ and its failure probability is $1 - p_g - me$, with $m \leq 1 - p_g$ to ensure non-negative probability of failure. m is a constant which is interpreted as the marginal value of effort. The cost of effort $c(e)$ satisfies:

Assumption II.2. *(i) $c(0) = 0$; (ii) $c'(0) = 0$ and $c'(1) > mR$; (iii) $c''(e) > (\frac{m}{p_g})^2$.*

The bank obtains pay-off Y at $t = 1$ from its assets-in-place. We assume that Y is not so large such that the $t = 0$ debt becomes riskless, as otherwise the first-best effort level could be implementable:

Assumption II.3. $Y < 1 - \alpha(p_g R - 1)$

At $t = 1$, the bank privately learns whether the second project is good or bad. The second project to be undertaken at $t = 2$ is of type g with probability $\alpha \in (0, 1)$. The bank privately observes the project's type. We assume that α is small such that the average NPV of the pool is negative:

Assumption II.4. $\alpha < \frac{1 - p_b R}{p_g R - p_b R}$

II.2.2 The Game

We consider a two-stage sequential game, the second stage of which itself is a standard two-stage signalling game.

- Stage 1: At $t = 0$ (when the bank is unaware of its own type), the bank propose the following contract: $(D_1, K, D_{0,3}, Z)$ to competitive investors[3]. The contract provides an additional offer to investors to obtain a debt with face value $D_{0,3}$ at a price Z, which is a claim on the cash flow generated by the adverse selection project, if the second project is undertaken by the bank. This debt is senior to any security which may be subsequently issued. When the bank chooses to undertake the second project, it raises funds Z from investors taken this offer and other funds $1 - Z$ from others. Furthermore, investor gets D_1 if the first project succeeds and Y if it fails. In either state at $t = 1$, the investor gives an amount, K, to the bank. The bank may use these funds to directly invest in the adverse selection project or consume it. In the next stage, the bank will try to raise funding from a potentially different investor playing a two-stage signalling game which follows.

- Stage 2a (which occurs at $t = 2$): the bank, now privately aware of its type, seeks to raise funds for the second project from competitive investors (who may be different from the one who provided the funds at $t = 0$). The bank offers a contract which specifies whether K will be invested directly in the second project or not, and offers to investors debt with face value, $D_{2,3}$, which is junior to the debt in the additional offer in the contract issued at $t = 0$, in exchange for the remaining amount of funds necessary for undertaking the project.

- Stage 2b: given the contract offered by the bank in Stage 2a, investors will form beliefs about the second project's type. Given these beliefs, investors will decide whether they will accept the contract and provide the funds necessary to undertake the project or not.

We look for the pure strategy Perfect Bayesian equilibria of this game that satisfy the Intuitive

[3] We obtain identical results if there are two separate contracts at this stage of the game offered by two different investors, one relating to the first project and another relating to the second project.

Criterion of Cho and Kreps (1987)[4]. Note that we do not impose exogenously whether the bank pre-sells a fraction of the cash flows from the second project at $t = 0$ or not, i.e., K, Z, and $D_{0,3}$ are chosen optimally in equilibrium.

II.2.3 First-best benchmark

In the first-best, the effort level exerted by the bank is observable and verifiable, and the type of the second project is publicly known. In this case, the bank always undertakes the first project and, given Assumption II.2, the level of effort is:

$$c'(e^{FB}) = mR \tag{II.1}$$

The bank invests in the second project only if it is good.

II.2.4 Equilibrium

The two key dates of strategic interaction between the bank and investors are $t = 0$ and $t = 2$, when the bank raises funds for projects. We solve for the equilibrium using backward induction.

II.2.4.1 Financing at t=2

Because the pair $(K, D_{0,3})$ is determined at Stage 1 of the game, when the two-stage signalling game starts at $t = 2$, $(K, D_{0,3})$ are exogenously given. Hence, the only endogenous variable to be chosen in Stage $2a$ is $D_{2,3}$. Given that, below we list all the candidate equilibria of the subgame which starts at $t = 2$.

1. A candidate separating equilibrium in which only bad banks obtain financing.

2. A candidate pooling equilibrium in which both bank types obtain financing.

3. A candidate pooling equilibrium in which neither bank type obtains financing (market breakdown).

[4]The appropriate solution concept is Perfect Bayesian since in the second stage of the game banks may signal about their type through the use of K, which implies that inferences are made.

4. A candidate separating equilibrium in which both bank types obtain financing, but at different terms.

5. A candidate separating equilibrium in which only good banks obtain financing.

Below we consider each candidate equilibrium.

The contract at Stage 1 specifies the pair, $(K, D_{0,3})$. At Stage $2a$, good banks choose to invest K, rather than consume, to signal its type, since investing own capital in the project is costlier to bad banks known their project's negative NPV. Therefore, investors believe banks choosing to consume are bad types and will not provide funds to them. Thus, banks, who wish to raise funds, need to invest K in the second project. If the second project is undertaken, bank i's expected profit is denoted Π_i and its participation constraint is given by:

$$\Pi_i = p_i(R - D_{0,3} - D_{2,3}) - K \geq 0 \tag{II.2}$$

We derive the slope of $\Pi_i = 0$ in the $(K, D_{2,3})$ space by totally differentiating Eq. II.2 with respect to $D_{2,3}$ and K:

$$\left.\frac{dD_{2,3}}{dK}\right|_{\Pi_i=0} = -\frac{1}{p_i} < 0 \tag{II.3}$$

Investors at $t = 2$ facing a type i bank make an expected profit which is denoted γ_i, and they provide the necessary funds for investment if $\gamma_i \geq 0$:

$$\gamma_i = p_i \cdot \min\{D_{2,3}, R - D_{0,3}\} - (1 - K - Z) \geq 0 \tag{II.4}$$

In the main text, we consider the case that $D_{2,3} \leq R - D_{0,3}$ holds as this is the relevant case for the results[5]. We derive the slope of $\gamma_i = 0$ in the $(K, D_{2,3})$ space by totally differentiating Eq. II.4 with respect to $D_{2,3}$ and K:

$$\left.\frac{dD_{2,3}}{dK}\right|_{\gamma_i=0} = -\frac{1}{p_i} < 0 \tag{II.5}$$

Lemma II.1. *There cannot exist a separating equilibrium in which only bad banks obtain financing or both good and bad banks obtain financing but at different terms.*

[5] In Appendix A, we consider the case of $D_{2,3} > R - D_{0,3}$.

Proof. Suppose bad banks can obtain financing without mimicking good banks, participation constraints of bad banks Eq. II.2 ($i = b$) and investors facing bad banks Eq. II.4 ($i = b$) are satisfied simultaneously, derived $p_b(R - D_{0,3}) \geq 1$ which is in conflict with Assumption II.1. Therefore, there cannot exist a separating equilibrium in which bad banks obtain financing. □

Lemma II.2. *There cannot exist a pooling equilibrium in which both good and bad banks obtain financing.*

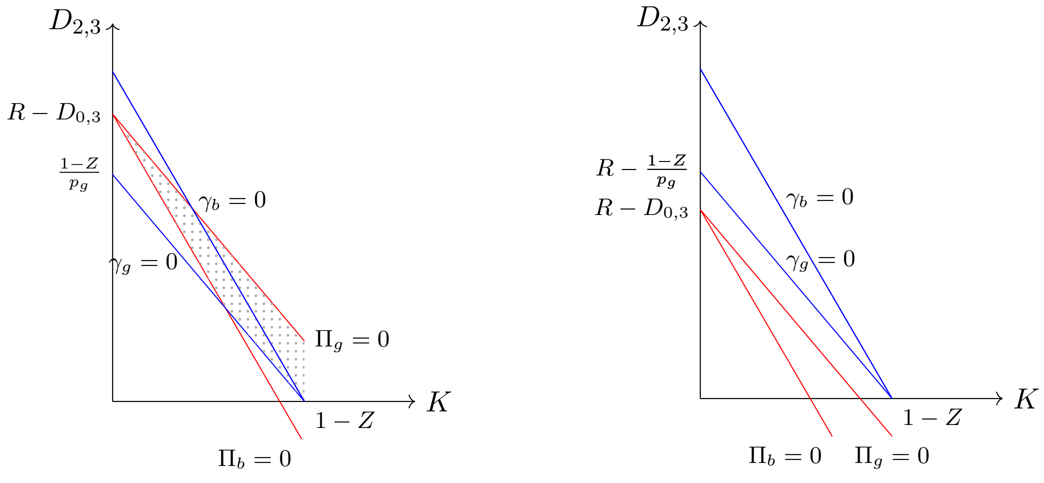
Proof. Suppose that the equilibrium is pooling. Bad banks' participation constraint Eq. II.2 ($i = b$) is satisfied, and investors are willing to provide funds to bank whose type is not clear, $[\alpha p_g + (1-\alpha)p_b]D_{2,3} - (1 - K - Z) \geq 0$. Combined with good banks' participation constraint Eq. II.2 ($i = g$), we can derive that $[\alpha p_g + (1-\alpha)p_b](R - D_{2,3}) \geq 1$, which violates the rationality assumption Assumption II.1. Thus, the conjectured equilibrium may not exist. □

In Fig. II.1, we plot the binding participation constraints of banks (red lines) and investors (blue lines) in the $(K, D_{2,3})$ space. Both $\Pi_i = 0$ and $\gamma_i = 0$ have a negative slope and are linear in the $(K, D_{2,3})$ space. Since the slopes are the same, $\Pi_i = 0$ and $\gamma_i = 0$ do not cross for any i. $\Pi_i = 0$ implies that $D_{2,3} = R - D_{0,3} - \frac{K+Z}{p_i}$ for $K = 0$ and $D_{2,3} = R - D_{0,3} - \frac{1}{p_i}$ for $K = 1 - Z$. $\gamma_i = 0$ implies that $D_{2,3} = \frac{1-Z}{p_i}$ for $K = 0$ and $D_{2,3} = 0$ for $K = 1 - Z$. A bank of type i is willing to undertake the project in the region below its participation constraint, while an investor facing a bank of type i is willing to provide funds in the region above the corresponding participation constraint.

Lemma II.3. *Depending on the terms of the contract offered in Stage* 1 *of the game, there either exists a pooling equilibrium in which neither bank obtains funding (market breakdown) or a separating equilibrium in which only good banks obtain funding.*

Proof. We present a graphical proof and refer to Fig. II.1.

There exists a funding equilibrium in the shaded region in Fig. II.1a: here, investors' participation constraints are slack and they make positive profits when they face good banks (i.e., $\gamma_g > 0$), a good bank's participation constraint is satisfied (i.e.,$\Pi_g \geq 0$), while a bad bank's participation constraint is (weakly) violated (i.e., $\Pi_b \leq 0$). Funding is infeasible above the shaded region since the good bank's participation constraint is violated. Below the shaded



(a) $D_{0,3} \leq R - \frac{1}{p_g}$

(b) $D_{0,3} > R - \frac{1}{p_g}$

Figure II.1: Feasible equilibria

region, the market breaks down since either the bad bank's participation constraint is satisfied and/or investors' participation constraint is violated.

Both the breakdown equilibrium and the separating equilibrium with only good banks participating are feasible along the bad bank's participation constraint bordering the shaded region up to $(K = 0, D_{2,3} = \frac{1}{p_g})$. For these parameters, a bad bank is indifferent between participating or not, which implies that the breakdown equilibrium cannot be ruled out for these parameters in this subgame.

Note, when the repayment occurs to the threshold $D_{0,3} = R - \frac{1}{p_g}$, the intersections of $\Pi_g = 0$ and $\gamma_g = 0$ with the vertical axis coincide. Since they have the same slope, these two lines coincide and the shaded area shrinks to the $\Pi_g = \gamma_g = 0$ line. The coexistence of the breakdown equilibrium and the separation equilibrium is possible at the vertical intercept $(K = 0, D_{2,3} = \frac{1-Z}{p_g})$.

Funding is infeasible when $D_{0,3} > R - \frac{1-K-Z}{p_g}$, shown as no shaded area in Fig. II.1b. Intuitively, the good bank will forgo undertaking the second project if it commits too much, resulting in insufficient funds to meet investor's minimum requirements at $t = 2$. □

The proposition below summarizes the results from the Lemmas II.1-II.3, and characterizes the equilibria that may arise in the two-stage signalling game played at $t = 2$:

Proposition II.1. *In the two-stage signalling game played at $t = 2$, there can exist two potential* *equilibria:*

1. *a separating equilibrium in which only good banks invest and*
2. *a pooling equilibrium in which no banks invest (market breakdown).*

II.2.4.2 Financing at t=0

At $t = 0$, the bank finances the first project through a contract (D_1, K), with an additional offer. If investors take the offer, they'll have the chance to purchase a fraction of the cash flow from the second project $D_{0,3}$, at a price Z. If the first project succeeds, investors obtain repayment D_1. In the case of failure, investors obtain $Y - K$. Thus, the bank can always retain K whether or not the first project succeeds. At $t = 2$, the bank privately knows the second project's type to be good or bad. Then, good banks can directly invest K in the second project to separate, combined with an appropriate $D_{2,3}$ to violate bad banks' participation constraint, shown as the pair $(K, D_{2,3})$ belonging to the shaded area in Fig. II.1. With that contract, bad banks will be screened out, not undertake the second project and consume the K. Given the contract offered, investors' zero profit condition at $t = 0$ is as follows:

$$\underbrace{(p_g + me)D_1 + (1 - p_g - me)Y - 1 - K}_{\text{Investors' expected profit from 1st project}} + \underbrace{\alpha(p_g D_{0,3} - Z)}_{\text{2nd project}} = 0 \tag{II.6}$$

From the zero profit condition, we can derive the minimum repayment D_1 required by investors. The bank's expected profits is:

$$\Pi_1 = \underbrace{(p_g + me)(R - D_1 + Y) - c(e)}_{\text{Bank's expected profit from 1st project}} + \underbrace{\alpha p_g(R - D_{0,3} - D_{2,3}) + (1 - \alpha)K}_{\text{2nd project}} \tag{II.7}$$

The first part is the expected profit from the first project, net of the cost of effort. The second part is the expected profit from the second project depending on the bank's use of K.

Lemma II.4. *From the $t = 0$ perspective, there cannot exist an equilibrium in which a good project at $t = 2$ does not obtain financing.*

Proof. Suppose there exists a market breakdown equilibrium at $t = 2$. Anticipate little possibility obtaining profit, investors may not take the additional offer. Thus, the bank needs to propose a higher face value of debt to finance the moral hazard project, comparing to the case when there will be expected a funding for the good-type second project. From Lemma II.3, the separation can be achieved through appropriate pair ($K > 0$, $D_{0,3} < R - \frac{1}{p_g}$) in the shaded region of Fig. II.1a, such that investors can offer funding to the good-type second project. In this case, good banks at $t = 2$ will invest since their participation constraint is satisfied, while bad banks will not invest due to their violated participation constraint in this region. By the Intuitive Criterion, investors assign a probability 1 to the event that only good banks will invest. Thus, there exists a profitable deviation from the $K = 0$ market breakdown equilibrium to the situation in which investors offer $K > 0$ to ensure that good projects have the ability to separate at $t = 2$. Anticipating that good banks will invest, the investors are willing to take the additional offer, which reduces the bank's funding requirement for the first project and, in turn, reduces the promised repayment for the first project, D_1. This lower D_1 will induce higher effort provision and lead to higher profits which the bank will (at least partly) capture. Therefore, this deviation is strictly profitable both for the bank and the investors, and hence, the market breakdown equilibrium cannot exist. □

Starting from a non-financing equilibrium, an investor can profitably deviate by offering a new pair $(K, D_{0,3})$, which would allow good banks to implement a separation, shown as the shaded region in Fig. II.1 where which satisfies the good bank's and investors' participation constraints and violates the bad bank's participation constraint at $t = 2$.

To determine the terms of contract, we should consider banks' problem. The equilibrium effort level bank exerted to maximise its profit satisfies Eq. II.8, which is derived by taking the first order condition of Eq. II.7 with respect to the effort level.

$$\begin{aligned} c'(e) &= m(R - D_1 + Y) \\ &= m\left[R - \frac{1-Y}{p_g + me} - \frac{K - \alpha(p_g D_{0,3} - Z)}{p_g + me}\right] \end{aligned} \tag{II.8}$$

Because $c(e)$ is strictly convex in e, $c'(e)$ is strictly increasing in e. The right hand side of Eq. II.8 is falling in K and increasing in the expected early promised profit from the additional offer, related to a higher $D_{0,3}$ and lower Z. The intuition is as follows: The lower signalling cost K bank remains, the higher compensation investors received after the first project fails, and thus a lower face value of debt they can accept. Then, more effort can be exerted since the bank expects to retain more in the case of success. The higher profit investors anticipated from the additional offer, the lower face value of debt for the first project D_1 they can accept. This, in turn, implies that the bank retains more in the case that the first project succeeds, which relaxes the effort moral hazard constraint, and therefore, the bank exerts more effort.

Considering bank's profit Eq. II.7, in addition to the indirect effect through effort level, Z has little direct effect to bank's profit. Thus, a lower Z may be preferred to increase the effort level and the bank value. However, changes in K and $D_{0,3}$ have a direct impact on the bank's profit. To explore bank's choice on these two, we differentiate its profit with respect to them respectively:

$$\begin{aligned}\frac{d\Pi_1}{dD_{0,3}} &= m(R - D_1 + Y)\frac{de}{dD_{0,3}} - (p_g + me)\frac{dD_1}{dD_{0,3}} - c'(e)\frac{de}{dD_{0,3}} - \alpha p_g \\ &= \underbrace{\left[m(R - D_1 + Y) - c'(e)\right]}_{>0} \underbrace{\frac{de}{dD_{0,3}}}_{>0} > 0\end{aligned} \tag{II.9}$$

Since the first-best effort level is not implementable, the net margin gain from effort is positive. It follows that banks' profit increases with $D_{0,3}$. Thus, the bank may prefer the early promised repayment maximize to its extent $D^*_{0,3} = R - \frac{1}{p_g}$ to obtain the highest profit, combined with a minimum $Z^* = 0$.

$$\begin{aligned}\left.\frac{d\Pi_1}{dK}\right| &= m(R - D_1 + Y)\frac{de}{dK} - (p_g + me)\frac{dD_1}{dK} - c'(e)\frac{de}{dK} - \alpha p_g \frac{dD_{2,3}}{dK} + (1 - \alpha) \\ &= \underbrace{\left[m(R - D_1 + Y) - c'(e)\right]}_{>0} \underbrace{\frac{de}{dK}}_{<0} < 0\end{aligned} \tag{II.10}$$

In the case of $(D^*_{0,3},\ Z^*)$, the pair of $(D_{2,3},\ K)$ available for separating collapses to $\Pi_g = 0$. That is $\frac{dD_{2,3}}{dK} = \frac{dD_{2,3}}{dK}\big|_{\Pi_g=0} = -\frac{1}{p_g}$. Hence, banks' profit is falling in K, as does the effort level.

Lemma II.5. *There cannot exist an equilibrium in which the contract specifies $K > 0$. In any equilibrium, the contract must specify $K = Z = 0$ and $D_{0,3} = R - \frac{1}{p_g}$.*

Proof. Suppose that $K > 0$, $Z > 0$ and $D_{0,3} < R - \frac{1}{p_g}$. It is clear from Eq. II.10, Eq. II.8 and Eq. II.9 that bank profits are maximized when K and Z takes its smallest value and $D_{0,3}$ takes its largest possible value. Hence, for any $K > 0$, $Z > 0$ and $D_{0,3} < R - \frac{1}{p_g}$ situation, a new investor will enter the market to offer a smaller K and Z and a higher $D_{0,3}$, attracting the bank profitably. The bank anticipating a higher profit will accept the deviant offer. Thus, competition among investors sets $K^* = Z^* = 0$ and $D^*_{0,3} = R - \frac{1}{p_g}$. □

From above, bank profit can be maximized with the smallest possible K, and the largest possible profit from the additional offer, which can be achieved by the smallest possible price Z for the largest face value $D_{0,3}$ of the debt with. Competition among investors drives K and Z to 0, and $D_{0,3}$ to its upper bound $p_g R - 1$. For any $K > 0$, there exists a deviation in which the $t = 0$ investors offer a smaller K, a higher $D_{0,3}$ and a smaller Z which, in turn, relaxes the bank's effort moral hazard constraint by reducing D_1, and increases bank value. Effectively, a positive K implies that some resources are left unused at $t = 0$, which leads to an inefficiency. Note from Lemma II.3, $K = 0$ can potentially lead to two equilibria in the second stage subgame: one is the separating one considered above and the other is the market breakdown equilibrium. But from the perspective of $t = 0$, the market breakdown equilibrium cannot exist due to the possibility of profitable deviations. Thus, the separating equilibrium with ($K = Z = 0$, $D_{0,3} = R - \frac{1}{p_g}$) is the unique equilibrium of the full game. While K equals 0 on the equilibrium path, it is the off-path threat of positive K that sustains the equilibrium.

Substituting the equilibrium values, ($K^* = Z^* = 0$, $D^*_{0,3} = R - \frac{1}{p_g}$) in Eq. II.6 we derive the promised repayment in the first project, D^*_1:

$$D^*_1 = \frac{1 - (1 - p_g - me)Y}{p_g + me} - \frac{\alpha(p_g R - 1)}{p_g + me} \tag{II.11}$$

Lemmas II.4 and II.5 rule out all candidate equilibria, but one: ($D_1 = D^*_1$, $K^* = Z^* = 0$, $D^*_{0,3} = R - \frac{1}{p_g}$). Now we need to show that there is no profitable deviation from this equilibrium. To see why this is the case, note that any deviation would have to increase bank profits by relaxing the moral hazard constraint further. To do so, $D_{0,3}$ must be higher than $D^*_{0,3}$, a higher profit promised to investors to minimize the face value of debt in the first project to a lower level $D_1 < D^*_1$, leading a higher profit. However, $D^*_{0,3}$ has already hit its maximum extent, otherwise the separation in the second project cannot be implemented, shown as Fig. II.1b. Thus, $D_1 < D^*_1$ is not feasible and this candidate equilibrium exists. Using $D_1 = D^*_1$, $K^* = Z^* = 0$ and

$D^*_{0,3} = R - \frac{1}{p_g}$ in Eq. II.8, the equilibrium effort level is given by:

$$c'(e^*) = m\left(R - \frac{1-Y}{p_g + me} + \frac{\alpha(p_g R - 1)}{p_g + me}\right) \tag{II.12}$$

Given Assumption II.3, $D^*_1 > Y$, implying that the debt is risky. In turn, this prevents equilibrium level of effort from reaching the first-best level, i.e., $e^* < e^{FB}$. This is the reason why optimality requires that we set $K^* = Z^* = 0$ (its lowest possible value) and $D^*_{0,3} = R - \frac{1}{p_g}$ (its highest value) in order to achieve the maximum possible effort level (second best, see Section II.2.5). We characterize the equilibrium in Proposition II.2.

Proposition II.2. *There exists a unique equilibrium in which the contract specifies ($D_1 = D^*_1, K^* = Z^* = 0, D^*_{0,3} = R - \frac{1}{p_g}$) at $t = 0$. There is full separation in the second project and only good banks participate. Effort provision in the first project is given by $c'(e^*)$.*

The contract in Proposition II.2 does not include provision for funding the second project and competitive investors make zero profits in expectation, as in Segura and Zeng (2020). Still, our solution differs since the bank pre-sells the NPV of the second project at $t = 0$ to reduce the amount it needs to borrow for the first project. We do not impose how much of the cash flow from the second project the bank pre-sells, and allow for all possibilities, including no pre-selling (which corresponds to the solution in Segura and Zeng (2020)). We show that not pre-selling is off the equilibrium path. That is, a rational profit-maximizing bank will never choose to not pre-sell.

II.2.5 The planner's solution

The objective of the planner is to maximize the net social surplus (the bank value). The net social surplus consists of two parts: the value created by the project associated with adverse selection and the value created by the project associated with effort moral hazard. With regards to the project which is subject to adverse selection, maximization of the net social surplus requires that only good projects are undertaken. The planner can achieve this separation by giving K to the bank and allow banks to play a two-stage signalling game similar to the one we consider above (stages 2a and 2b) where the role of the investors is played by the planner. Furthermore, in order to maximize the aggregate net social surplus, the planner will extract the full NPV of the second project and transfer it to the first project to relax the effort moral hazard constraint as much as possible. Hence, at the optimum, he will set $K = 0$. Formally, the planner's problem reduces to:

$$\begin{aligned}
&\underset{\tau_1,\tau_3,K}{\text{Max}} \quad (p_g + me)(R - \tau_1 + Y) - c(e) \\
&\text{subject to} \\
&\qquad \text{IC} \qquad c'(e^*) = m(R - \tau_1 - Y) \\
&\qquad \text{PC} \qquad p_g(R - \tau_3) - K \geq 0 \geq p_b(R - \tau_3) - K \\
&\qquad \text{FC} \qquad (p_g + me)\tau_1 + (1 - p_g - me)Y - K + \alpha(p_g\tau_3 - (1 - K)) \geq 1 \\
&\qquad \text{LL} \qquad \tau_3 \leq R
\end{aligned} \tag{II.13}$$

The planner provides the required funds and sets transfers from the bank to himself as τ_1 which is the repayment at $t = 1$ and τ_3 which is the repayment at $t = 3$. The planner maximizes the objective function with respect to the effort exerted by the bank subject to four constraints. The first constraint is the effort moral hazard constraint (IC). The second constraint is related to truth-telling about the second project. The third constraint is the planner's feasibility constraint (FC) (analogous to Eq. II.6 in the equilibrium analysis). The final constraint is the limited liability constraint.

The planner's objective is to maximize the net social surplus. Given that full separation can be achieved on the second project and the planner can extract the full surplus (NPV) on this project, the planner's problem reduces to maximizing the bank's effort in the first project. From the IC, this can be done by reducing τ_1 to the maximum extent possible (given Assumption II.3, the first-best cannot be reached). To minimize τ_1, the FC must bind. The choice variables are τ_3 and K. From the FC the aggregate effect of K is $-(1 - \alpha)K$, implying that a strictly positive K diverts resources which could be used to reduce τ_1 and increase effort. Thus, at the optimum, the planner will set $K = 0$. Also, from the second line of the FC, higher the τ_3, lower is the τ_1 consistent with the planner's FC being satisfied. Thus, the planner will set the transfer to the maximum possible amount consistent with the limited liability constraint, i.e., $\tau_3 = R$. $\tau_3 = R$ and $K = 0$ satisfies the truth-telling constraint, and hence, is consistent with a separating equilibrium which allows the planner to extract the full surplus[6]. Substituting $K = 0$ and $\tau_3 = R$ in the FC, we obtain $\tau_1 = D_1^*$ (see Eq. II.12). From the planner's perspective, the optimal equilibrium is characterised as ($\tau_1 = D_1^*$, $K = 0$), which is coincide with that in the competitive equilibrium allocation (Proposition II.3), and hence, the competitive equilibrium allocation is optimal (second-best).

Proposition II.3. *The equilibrium allocation of our game coincides with the planner's solution, and hence, it is efficient (second-best).*

Effectively, the planner lends to the bank at $t = 0$, and commits to lend again at $t = 2$, if the bank turns out to be of the good type. We show that the allocation in the planner's equilibrium can be replicated in the decentralized equilibrium even when we do not allow for the bank to form long-term relationships with fund providers.

II.3 Benchmarks

In this section, we contrast our solution with two benchmarks (market funding and off-balance sheet funding).

II.3.1 Market financing

Instead of a bank seeking joint financing for the two projects, suppose that there are two separate firms, each managing one of the projects, which obtain financing directly from the market. We assume that the firm managing the first (resp. second) project has assets-in-place which produce $Y_1 > 0$ (resp. $Y_2 > 0$), with $Y_1 + Y_2 = Y$.

With regards to the second project, the good bank offers a pair (K, D_3) along the lower contour of the shaded region in Fig. II.1a(where D_3 corresponds to $D_{2,3}$, and $D_{0,3} = 0$). The offer is on the bad bank's participation constraint for $K \in [0, \overline{K}]$ and on investors' participation constraint (when facing good borrowers) for $K \in (\overline{K}, 1]$, where $\overline{K}$ is the intersection point of Π_b and γ_g. It is assumed that bad banks stay out in case of indifference between investing or not. Despite perfect competition, investors obtain positive profits in expectation and the expected

[6] By an argument similar to the one developed in Lemma II.4 we can show that this is indeed the unique equilibrium in the game played by the planner and the investors

profits are smaller as direct investment by the bank increases (for $K > \overline{K}$, investors' expected profits become 0). In this case, the bank invests all available cash flows, $K = Y_2$, into the project to minimize sharing profits with investors. Regardless of the split of the surplus, the outcome is efficient since the equilibrium is separating and only good projects obtain financing for any $Y_2 > 0$.

With regards to the first project, the face value of debt is D_1 and the zero profit condition of investors is given as follows:

$$(p_g + me)D_1 + (1 - p_g - me)Y_1 - 1 = 0 \tag{II.14}$$

From the zero profit condition, we derive the repayment, D_1^D. The bank maximizes its expected profit from the first project by choosing the level of effort:

$$\Pi_1^D = (p_g + me)(R - D_1^D + Y_1) - c(e) \tag{II.15}$$

Taking the first order condition, and substituting the investor's zero profit condition (Eq. II.14), we obtain the equilibrium effort exerted:

$$D_1^D = \frac{1 - (1 - p_g - me)Y_1}{p_g + me} \tag{II.16}$$

$$c'(e^D) = m(R - D_1^D + Y_1) \tag{II.17}$$

Proposition II.4. *On-balance sheet bank funding strictly dominates market funding for all parameter values.*

Proof. With regards to the adverse selection project, there is full separation between good and bad banks in both single bank and market funding cases. Thus, to show that single bank funding dominates market funding in terms of efficiency, we need to show that $e^* > e^D$ for all parameter values. First, we show that $D_1^* < D_1^D$. Using Eq. II.11 and Eq. II.16:

$$D_1^* = \frac{1 - (1 - p_g - me)Y}{p_g + me} - \underbrace{\frac{\alpha(p_g R - 1)}{p_g + me}}_{>0} < \frac{1 - (1 - p_g - me)Y_1}{p_g + me} = D_1^D \tag{II.18}$$

Using $D_1^* < D_1^D$ and Eq. II.11 and Eq. II.17:

$$c'(e^*) = m(R - D_1^* + Y) > m(R - D_1^D + Y) = c'(e^D) \tag{II.19}$$

Since $c'(e)$ is increasing in e, it holds that $e^* > e^D$. □

$e^D < e^*$ for all parameter values. The reason is that with market financing, the two projects are separately financed and the borrower cannot bring forward the expected profits to investors in the second project to reduce the repayment for the first project, i.e., $D_1^D < D_1^*$ for any $Y_1 \leq Y$. Since the provider of effort retains more of the surplus from effort provision in the case of on-balance sheet bank funding, effort is higher in this case compared to the market financing case.

On-balance sheet bank funding and market funding are welfare-equivalent in the case of the second project, while bank funding delivers a strictly more efficient outcome in the case of the first project. The result is driven by cross-subsidisation across projects in the case when the a single bank owns both projects.

II.3.2 On- versus Off-balance sheet

Segura and Zeng (2020) consider a very similar setting and consider the case that the first project may be funded on- or off-balance sheet. First, we recap their analysis in brief, and then we provide a comparison.

Under the on-balance sheet financing mode, investors in the first project have unlimited recourse to cash flows from the assets-in-place. In the absence of cross-subsidisation across projects, the promised repayment to investors in the first project, D_1^{on}, and effort provision, e^{on}, are given by:

$$D_1^{on} = \frac{1 - (1 - p_g - me)Y}{p_g + me} \tag{II.20}$$

$$c'(e^{on}) = m(R - D_1^{on} + Y) \tag{II.21}$$

Under this funding mode, there is a partial pooling equilibrium in which all good banks and a fraction of bad banks invest in the second project.

Under the off-balance sheet financing mode, in the event of failure of the first project, there is no obligation for the bank to make repayments using cash flows arising from the bank's assets-in-place. However, the good bank can signal its second project's type by voluntarily using cash flows from the assets-in-place to repay the investors in the first project. The promised repayment to the investors in the first project, D_1^{off} , and effort provision, e^{off}, are given by:

$$D_1^{off} = \frac{1-\alpha Y}{p_g + me} \tag{II.22}$$

$$c'(e^{off}) = m(R - D_1^{off}) \tag{II.23}$$

The ratio of marginal cost of providing voluntary support to the marginal benefit is smaller for good banks compared to bad banks, implying that voluntary support can be an effective signalling device. There is a partial pooling equilibrium in which all good banks and a fraction of bad banks invest; due to the voluntary support, the fraction of bad banks investing in the off-balance sheet case is always smaller than in the on-balance sheet case[7].

The trade-off between on-balance sheet financing (without cross-subsidisation across projects) and off-balance sheet financing is the following: under on-balance sheet financing, the effort provision in the first project is higher, while under off-balance sheet financing signalling in the second project is stronger. The optimal financing mode is determined from this trade-off. Our solution differs since we allow (but do not impose) the pre-sale of cash flows from the second project at $t = 0$. To facilitate comparisons, we present the following Lemma:

Lemma II.6. *The face value of debt and the corresponding effort levels under different financing modes are as follows:* $D_1^* < D_1^{on} < D_1^{off}$ *and* $e^* > e^{on} > e^{off}$.

Proof. First we show that $D_1^* < D_1^{on} < D_1^{off}$. Noting that $1 - p_g - \alpha > me$ since it is assumed that $1 - p_g \geq me$ and using Eq. II.11, Eq. II.20 and Eq. II.22:

$$\begin{aligned} D_1^* &= \frac{1-(1-p_g-me)Y}{p_g+me} - \underbrace{\frac{\alpha(p_gR-1)}{p_g+me}}_{>0} \\ &< D_1^{on} = \frac{1-(1-p_g-me)Y}{p_g+me} = \underbrace{\frac{1-(1-p_g-me-\alpha)Y-\alpha Y}{p_g+me}}_{\text{add and subtract}\alpha Y} \\ &< D_1^{off} = \frac{1-\alpha Y}{p_g+me} \end{aligned} \tag{II.24}$$

[7] If cash flows from assets-in-place are large enough to make the second project riskless, there is full separation.

Using $D_1^* < D_1^{on} < D_1^{off}$ and Eq. II.12, Eq. II.21 and Eq. II.23:

$$\begin{aligned} c'(e^*) &= m(R - D_1^* + Y) \\ > c'(e^{on}) &= m(R - D_1^{on} + Y) \\ > c'(e^{off}) &= m(R - D_1^{off} + Y) \end{aligned} \tag{II.25}$$

Since $c'(e)$is increasing in e, it holds that $e^* > e^{on} > e^{off}$. □

Our solution, (D_1^*, e^*), strictly dominates both the on-balance sheet solution without cross-subsidisation, (D_1^{on}, e^{on}), and the off-balance sheet solution, (D_1^{off}, e^{off}).

1. $e^* > e^{on} > e^{off}$ (Lemma II.6). Effort provision in our solution dominates the effort provision in either case above for all parameter values since $D_1^* < D_1^{on} < D_1^{off}$. Intuitively, the first-period debt is priced by rationally anticipating that investors will make positive expected profits in the second project; this reduces the promised repayment D_1 and, since the bank retains more of the surplus from exerting effort, effort provision is higher.

2. In relation to the second project, Segura and Zeng (2020) obtain a partial pooling equilibrium in which all good banks and a fraction of bad banks invest if cash flows from the assets-in-place are sufficiently high (inefficiency); otherwise, there is a market breakdown equilibrium with no financing at all (inefficiency). In contrast, our equilibrium is always separating in which only good banks invest (efficiency) even if the cash flows generated by the assets-in-place is 0.

Proposition II.5. *For all parameter values, on-balance sheet financing with cross-subsidisation across projects strictly dominates on-balance sheet financing without cross-subsidisation and off-balance sheet financing.*

In the choice of the financing mode, Segura and Zeng (2020) trade-off the efficiency gains from mitigating the adverse selection constraint with the efficiency losses from tightening the moral hazard constraint; mitigating one makes the other constraint more binding. In our case, the existence of a fully separating equilibrium in the adverse selection project allows the transfer of the expected NPV of this project to the moral hazard project and this relaxes the moral hazard constraint; indeed, as we show in Section II.2.5, our solution implements the second-best outcome. Hence, given the information frictions in this model, the off-balance sheet funding mode is inefficient and does not maximize bank profit. Therefore, a rational profit-maximizing bank will never choose it.

II.4 Empirical implications

Our analysis implies that informationally sensitive loans should be financed on the balance sheet. Consistent with this prediction, in recent years, vast amounts of informationally sensitive lending has migrated away from banks, who increasingly use the off-balance sheet funding mode and sell their loans upon origination, towards Private Debt funds, who typically retain the entire loan that they issue on their balance sheets (see Block et al., 2024; Haque et al., 2024). Viewed through the lenses of our model, the funding mode of PD funds which is the retention of loans on their balance sheets, confers upon them an advantage in making informationally sensitive loans to borrowers. We also derive two new testable empirical predictions, which we state below:

1. *The spread on debt is lower and monitoring intensity is higher for lenders with higher expected growth opportunities.*

   Lenders which have stronger growth prospects, i.e., a higher α, can use the future profits to reduce the spread on debt. A key feature of this prediction is that the lower spread is, in part, driven by higher effort provision. This is potentially testable. One can proxy lender monitoring and effort provision with borrower site visits, hiring third party appraisers, or the frequency with which lenders demand loan-specific information (see Gustafson et al. (2021)).

   The intuition is as follows: At $t = 0$, a higher α implies higher expected NPV on the second project. This has two effects: a direct one and an indirect one. The increase in the expected NPV (which is sold to the $t = 0$ investor) directly reduces the face value of debt, D_1, in the first project due to a bigger reduction in this project's funding requirement. This fall in D_1 relaxes the effort moral hazard constraint in the first project and leads to higher effort provision which, in turn, reduces the bank's default probability, and hence, the spread on debt falls further.

2. *The spread on debt falls in the bank's growth opportunities if these are positively correlated with its core activities. If they are negatively correlated, the effect may reverse.*

   If there is a positive correlation between the lender's growth opportunities, α, and the return on its assets-in-place, Y, then an increase in one is accompanied by an increase in the other. The effect of both changes are in the same direction, which is that the spread on debt falls. If on the other hand, Y and α are negatively correlated, then an increase in one is accompanied by a fall in the other. As a result, these two changes have opposite effects on the spread and which effect dominates depends on the parameters.

The implications also support the explanation for the increasing size of PD funds. For PD funds concentrating on investment, their core activities are more relevant to growth opportunities. An increase in the proportion of good projects decreases the spread on debt and increases the lenders' monitoring intensity, deriving a higher effort level and bank value. That is, higher benefit can be earned through the PD funds during booms, which explains their rising size.

II.5 Conclusion

We present a model in which there are two investment opportunities for a bank; the first suffers from an effort moral hazard problem, while the second suffers from an adverse selection problem. We show that on-balance sheet funding with cross-subsidisation across projects strictly dominates market funding, on-balance sheet funding without cross-subsidisation and off-balance sheet financing with voluntary support for all parameter values, and delivers the second-best outcome. In our solution, expected profits from projects which suffer from adverse selection are used to induce higher effort provision in projects subject to effort moral hazard. Our analysis implies that, given the information frictions in the present setting, the optimal solution requires on-balance sheet funding rather than off-balance sheet funding. Hence, in order to provide a rationale for voluntary support in off-balance sheet funding, we need to identify a different combination of frictions.

Chapter III

Off-Balance Sheet Financing, Adverse Selection, and Creditor Rights

III.1 Introduction

A debate persists on the role of off-balance sheet activities. Some argue that banks conduct regulatory capital arbitrage through these activities (Jones, 2000; Uzun and Webb, 2007; Dionne, 2008; Battaglia and Gallo, 2013), while others affirm their contributions to enhancing economic flexibility and liquidity (Hill, 1997; Kolari et al., 1998). Duran and Lozano-Vivas (2013) support the latter view and empirically demonstrate that banks engage in off-balance sheet activities to resolve the adverse selection problem rather than to eliminate risky assets from their books. However, in their empirical results, a sub-sample with an extremely low credit risk ratio unexpectedly contradicts their adverse selection hypothesis. This paper constructs a model where the bank faces a potential adverse selection problem to examine the effectiveness of off-balance sheet financing in resolving that problem. We also introduce creditor rights in the model to offer a direction for interpreting this discrepancy, suggesting that the adverse selection hypothesis can only be realised under the implicit condition of strong creditor rights.

This model is closely related to Segura and Zeng (2020), in which there are two investment opportunities for a bank. The first investment suffers from an effort moral hazard problem, while the second one may face an adverse selection problem if the the first fails due to a systematic shock. In contrast to Segura and Zeng emphasis on the benefit of limited liability for off-balance sheet financing to signal, we show that the voluntary support signalling method they suggest is costly and only effective when creditor rights is sufficiently strong, which can be supported by González (2023) who find the increase in creditor rights increases bank market competition more in countries with less stringent restrictions non-traditional bank activities.

In this paper, we relate strong creditor rights to a high repayment in the second project. Since voluntary support compensates for the first project, investors' participation constraints in the second project are rigid and can only be satisfied when the bank proposes high enough repayments that meet investors' requirements. Otherwise, when creditor rights, and hence investors' bargaining power, are weak, the bank may not be willing to share much of the project return. There may be no scope for voluntary support signalling, and the off-balance sheet activities may be driven by a desire to escape "junk" assets. This may offer a direction to rationalise the divergent empirical results for adverse selection hypothesis proposed by Duran and Lozano-Vivas (2013). The result is also consist with Jayaraman and Thakor (2013); Houston et al. (2010) who state the increases in creditor rights increase bank risk-taking.

One innovation in this paper is that we introduce creditor rights in the model. As Bernhardt et al. (2024) finds, the real effects of creditor rights critically depend on the degree of lender competition. In the first project, the bank's type is well-known as good. Investors are competitive and has little bargaining power to provide funds. Thus, we assume the creditor rights also has little effect in the first project. After the first project fails due to systematic reasons and asymmetric information arises, investors are less competitive due to the uncertain bank type. In this case, banks are more contestable. Investors holding higher bargain power would like to ask a higher repayment, while banks may or may not accept it. Therefore, we assume that the second project repayment has a cap accepted by the bank, relating to the creditor rights.

This paper also proposes another financing mode which is more beneficial to both banks and social net surplus. Financing through a cross-subsidisation debt contract, the bank can reach a higher level of effort, while addressing the potential adverse selection problem. We propose the good bank invest its own capital in the second project as a effective signalling way as it is more costly for bad banks, and it functions with fewer restrictions on creditor rights. The signalling amount invested into the second project reduces the funds raised externally, thereby relaxing investors' participation constraints in the second project. Through the contract, the bank pre-sells the expected net present value of the adverse selection project as a contingent claim to reduce the face value of debt when financing the moral hazard project. Thus, the bank's effort moral hazard constraint can be relaxed and a larger effort level can be exerted in the first project.

Comparing the effectiveness of these two approaches in mitigating information frictions, we find that the on-balance sheet financing with cross-subsidization dominates the off-balance sheet financing at the level of social surplus, as the limited liability arising from off-balance sheet financing weakens banks' incentives to compensate, thus exacerbating the moral hazard problem. While, the bank can also seize more profit through that on-balance sheet financing, which means it will not be resisted when that financing mode is advocated. Furthermore, although debt contract financing does not rely on strong creditor rights to mitigate the adverse selection problem, we still emphasise the critical role of strong creditor rights, as it may lead to better outcomes in alleviating the moral hazard problem.

Literature Review.

The existing literature contains two different perspectives on off-balance sheet financing. Some previous studies blame off-balance sheet financing for exacerbating systemic risk. Jones (2000) argues that securitisation provides opportunities for regulatory capital arbitrage, through which banks reduce their regulatory capital requirements with little reduction in overall economic risks. This lowers effective capital requirements in ways that are difficult to quantify given available supervisory tools. Uzun and Webb (2007) support this by analysing data on US banks and concluding that regulatory capital arbitrage exists in credit card securitisation. Dionne (2008) also derives a similar result using data from the Canadian financial sector. Others argue that it is not a means used by banks to get rid of the risk of low-quality assets. Barbara Casu and Thomas (2011) state that banks have typically viewed securitisation as a financing rather than a risk management mechanism. Greenbaum and Thakor (1987) find that banks prefer to securitise better-quality assets in a setting with asymmetric information and without government intervention. This aligns with Duran and Lozano-Vivas (2013), who proposes an adverse selection hypothesis for off-balance sheet activities and empirically affirms that banks' behaviour is consistent with the motivation to address the adverse selection problem, although a sub-sample unexpectedly contradicts their adverse selection hypothesis.

To offer a new perspective on this disagreement, we integrate creditor rights with the adverse selection hypothesis, concluding that weak creditor rights may shift the focus of banks' off-balance sheet activities from addressing adverse selection issues to regulatory arbitrage. To introduce creditor rights, we refer to González (2023), who analyse data and find that an increase in creditor rights increases bank market competition on average. Therefore, we associate strong creditor rights with a higher fraction of the project's return that the bank agrees to share with investors, indicating investors' greater bargaining power. The result in Section III.3.2.2 supports the findings of Jayaraman and Thakor (2013), which suggest that banks tilt their capital structures away from equity and towards deposits when creditor rights become stronger.

The model in this paper is similar to that in Segura and Zeng (2020) who demonstrate that off-balance sheet financing is efficient in resolving the adverse selection problem by enabling voluntary support signalling. However, they impose a rigid assumption that investors make zero expected profit in the project subject to the adverse selection problem, which confines the result to a partial pooling equilibrium in which some bad banks participate. We relax that assumption and show that a separating equilibrium, where only good banks participate, can be achieved. Dionne (2008) also attempts to rationalise this disagreement, showing that it is high regulatory capital that induces banks to shift towards securitising more risky assets.

III.2 Model

III.2.1 Set-up

There are four dates $t \in \{0, 1, 2, 3\}$. A bank has two investment opportunities, respectively at $t = 0$ and $t = 2$, each involving a one-period project with a scale of 1. The bank can receive a payoff Y at $t = 1$ from its existing assets, but it has no funds at $t = 0$. Therefore, it needs to raise funds from external competitive investors. All agents are risk-neutral and the discount rate is 0.

The bank's investment opportunities can be either good (g) or bad (b). A type $i \in \{g, b\}$ project succeeds with probability p_i, yielding a return R, or fails with probability $1-p_i$, yielding nothing. We assume that only good projects are profitable:

Assumption III.1. $p_g R > 1 > p_b R$

The first project is always good (g), so the bank always undertakes it. We assume the bank faces a moral hazard problem in the first investment, where it can exert an unobservable effort $e \in [0, 1]$ to increase the probability of success and reduce that of idiosyncratic failure by me at a cost $c(e)$, where m captures the marginal value of effort. We assume the project may fail due to systematic reasons with probability q, then the project may fail due to idiosyncratic reasons with probability $1 - p_g - q - me$ or succeed with probability $p_g + me$. Taking into account the bank's effort provision, we assume the constant m satisfies $m \leq 1 - p_g - q$, ensuring that the failure probability is non-negative, and the cost of effort $c(e)$ satisfies:

Assumption III.2. *(i)* $c(0) = 0$*; (ii)* $c'(0) = 0$ *and* $c'(1) > c'(e^{FB}) = mR$*; (iii)* $c''(e) > (\frac{m}{p_g})^2$

, ensuring there is one unique effort level solution to the effort choice of the bank.

The second investment is of type g with certainty if the first project succeeds or fails due to idiosyncratic reasons. While, if the first project fails due to a negative systematic shock, asymmetric information arises. Only the bank can privately observe the project's type at $t = 1$, investors believe the bank is of type g with probability $\alpha \in (0, 1)$. Thus, there may exist an adverse selection problem in the second investment. We assume

Assumption III.3. $\alpha < \bar{\alpha} \equiv \frac{1-p_b R}{p_g R - p_b R}$

, α is small such that the average NPV of the pool is negative.

Additionally, we restrict the highest repayment in the second project referred to creditor rights. The stronger creditor rights, the larger fraction of the second project's return μR that the bank would accept to share to investors, where $\mu \in (0, 1)$.

III.2.2 The Game

Banks can finance the first project either on- or off-balance sheet. In order to resolve the adverse selection problem, the bank needs to ensure that it is able to signal after the first investment fails due to systematic reasons. We consider a two-stage sequential game in each financing mode, involving a standard signalling game. If the non-systematic state is realized at $t = 1$, the type of the second project is well known as g, and there is no significant difference shown in the second investment under different financing modes. Thus, for the second investment, this paper focuses on the situation asymmetric information arisen and ignores the cases in the non-systematic state.

If the bank chooses the off-balance sheet financing, it needs to set up a separate legal entity and sell the first project to this entity. The entity then finances the project by issuing debt backed only by the project return. In this case, the bank has no contractual obligation to repay investors after the project fails, its payoff Y can be protected, offering the bank flexibility to signal.

- Stage 1a: At $t = 0$, the vehicle issues a debt with face value D_1^{off} to raise 1 from investors. At $t = 1$, if the project succeeds, investors receive D_1^{off}. If the project fails due to idiosyncratic reasons, there is no asymmetric information arisen and banks do not need to signal. So, banks keep the payoff Y and investors receive nothing. If the project fails due to systematic reasons, asymmetric information arises. Banks, privately known of its type, decide the amount of its own funds to voluntarily repay investors. Good banks want to voluntarily support and send a signal $K^{off} \in (0, Y]$ to reveal its type. We refer to voluntary support as a signalling way since it is costlier to bad banks.

- Stage 2: Given the situation in Stage 1b, each bank type decides whether to undertake the second project and issue a debt with face value D_3^{off} to raise 1 from investors. Investors form beliefs about the second project's type and decide whether or not accept the contract and provide 1 to undertake the project.

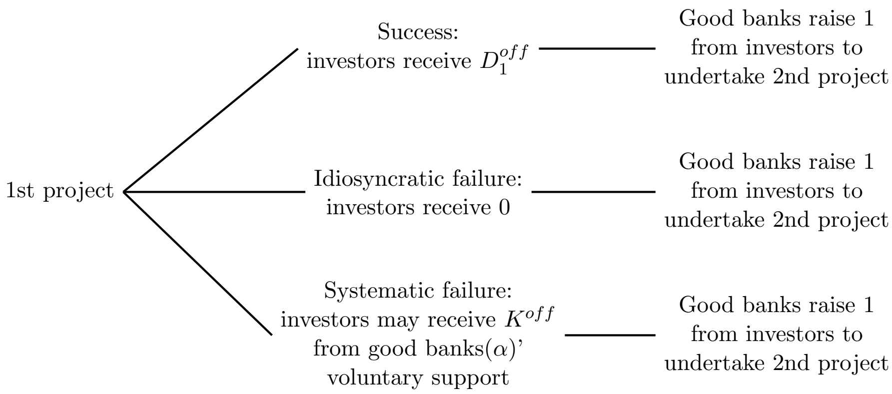


Figure III.1: Sequence of decisions and events in off-balance sheet financing

If it chooses the on-balance sheet financing, the bank can also retain the flexibility to signal by proposing a contract that limit the repayment in the systematic failure state.

- Stage 1: At $t = 0$, the bank, ignorant of its future type, proposes a contract (D_1^{on}, $K^{on}, D_{0,3}^{on}, Z^{on}$) to raise 1 from investors. With this contract, investor obtains a contingent claim $D_{0,3}$ at price Z^{on} on cash flow generated by the second project, if it is undertaken by the bank after the first investment fails due to systematic reasons, and this debt is senior to any security which may be subsequently issued. Furthermore, the contract states that investors get D_1^{on} if the first project succeeds, Y if it fails due to idiosyncratic reasons, and $Y - K^{on}$ in the systematic failure state. Thus, the bank can retain a signalling amount in hand $K^{on} \in (0, Y]$ when the asymmetric information arises. Banks can either directly invest in the second project to signal or consumes it. We refer to direct investment as a signalling way since it is costlier to bad banks.

- Stage 2: At $t = 2$, banks raise funds for the second project. After a systematic shock, the bank now privately knows its type and proposes a contract which specifies whether K^{on} will be invested directly in the second project, and a debt with face value $D^{on}_{2,3}$, which is junior to the debt proposed at $t = 0$. Given the contract, investors form beliefs about the bank's type and decide whether they will accept and provide funds. In other cases that there is no need to signal, banks propose contract to raise 1.

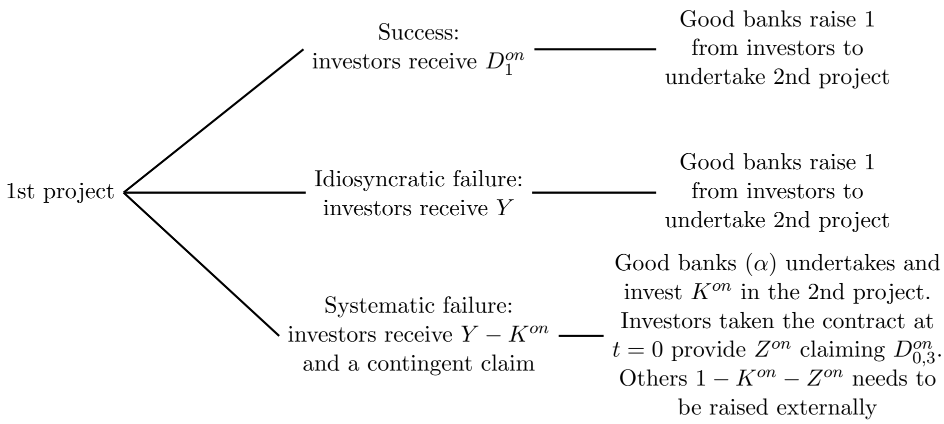


Figure III.2: Sequence of decisions and events in on-balance sheet financing

We look for the pure strategy Perfect Bayesian equilibria of this game that satisfy the Intuitive Criterion of Cho and Kreps (1987).

III.2.3 First-best benchmark

In the first-best situation, the effort level exerted by the bank can be observable and verifiable, and the type of the second project is publicly known. In this case, the bank always undertakes the first project and, given Assumption III.2, the level of effort is:

$$c'(e^{FB}) = mR \tag{III.1}$$

The bank invests in the second project only if it is good.

III.3 Equilibrium

We solve for the equilibrium under these two funding modes using backward induction.

III.3.1 Second project with adverse selection problem

If the non-systematic state is realized at $t = 1$, the type of the second investment is well known as g and there is no adverse selection problem. We focuses on banks facing the potential adverse selection problem, and does not consider the cases in the non-systematic state. The following are the candidate equilibria for the second investment after the first project fails due to systematic reasons.

1. A candidate separating equilibrium in which only bad banks obtain financing.
2. A candidate separating equilibrium in which only good banks obtain financing.
3. A candidate separating equilibrium in which both bank types obtain financing, but at different terms.
4. A candidate pooling equilibrium in which both bank types obtain financing.
5. A candidate pooling equilibrium in which neither type of bank obtains financing (market breakdown).

Below we consider each candidate equilibrium.

Lemma III.1. *There cannot exist a separating equilibrium in which only bad banks obtain financing or both good and bad banks obtain financing but at different terms.*

Proof. In a separating equilibrium in which the bad bank do not pool with good banks, the participation constraints of the bad bank and investors cannot be satisfied simultaneously, due to the limited liability constraint ($D_3 \leqslant R$) and Assumption III.1 ($p_b R < 1$). Therefore, there cannot exist a separating equilibrium in which bad banks obtain financing. □

Lemma III.2. *There cannot exist a pooling equilibrium in which both bank types obtain financing.*

Proof. In a pooling equilibrium in which both good and bad banks obtain financing, the participation constraints of banks and investors cannot be satisfied simultaneously, due to the limited liability constraint ($D_3 \leqslant R$) and Assumption III.3 ($[\alpha p_g + (1-\alpha)p_b]R < 1$). Therefore, there cannot be an equilibrium in which both good and bad banks obtain financing. □

According to Assumptions III.1 and III.3, investors, who believe the bank is of g with probability α, may not be willing to provide funds. In order to finance the second investment, good banks therefore need to signal investors and rule bad banks out. Otherwise, it can raise nothing.

III.3.1.1 Voluntary support signalling

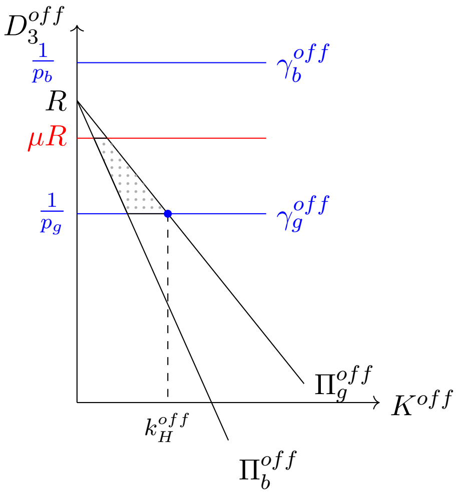
The bank can voluntarily support the debt repayment K^{off} after the first investment fails due to a systematic shock to signal, if it chooses the off-balance sheet financing. If it decides to undertakes the second project, the bank of type i has expected profit Π_i^{off}, and its participation constraint in the second investment is given by:

$$\Pi_{3,i}^{off} = p_i(R - D_3^{off}) - K^{off} \geq 0 \tag{III.2}$$

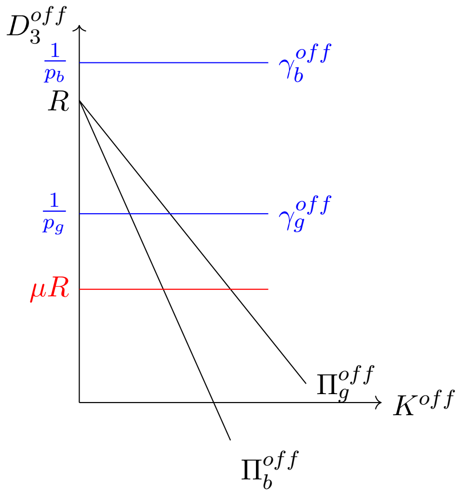
Since the signalling amount is used to voluntarily support the first investment, it has no impact on the amount externally raised for the second investment. The bank still needs to raise 1 from investors at $t = 2$. Denoted investors' expected profit as γ_i^{off} facing bank i, they are willing to provide funds when $\gamma_i^{off} \geq 0$.

$$\gamma_i^{off} = p_g D_3^{off} - 1 \tag{III.3}$$

In Fig. III.3, we illustrate participation constraints of banks (red lines) and investors (blue lines) in (K^{off}, D_3^{off}) space. γ_i^{off} are flat since the signalling amount is repaid to the first investment. $\Pi_i^{off} = 0$ have negative slopes and cross with $\gamma_g^{off} = 0$ cross due to Assumption III.1. A bank of type i is willing to undertake the project in the region below its participation constraint, while an investor facing a bank of type i is willing to provide funds in the region above the corresponding participation constraint. Besides, we plot a repayment ceiling $D_3^{off} \leq \mu R$, which also limits the area in which the bank undertakes the projects.



(a) $\mu \geq \mu^*$



(b) $\mu < \mu^*$

Figure III.3: voluntary support

Lemma III.3. *When creditor rights are strong, there may exist a pooling equilibrium in which neither bank obtains financing (market breakdown) or a separating equilibrium in which only good banks obtain financing.*

Proof. We present a graphical proof and refer to Fig. III.3a.

Suppose creditor rights are strong, $\mu \geq \mu^* \equiv \frac{1}{p_g}$. A financing equilibrium is possible, shown as the shaded area in the figure where participation constraints of good banks and investor facing good banks are satisfied, while the bad bank's participation constraint is violated.

Funding is infeasible outside the shaded region, either good banks are unwilling to undertake the project or investors refuse to provide funds since their requirements cannot be satisfied. □

Lemma III.4. *When creditor rights are strong, there cannot exist a "reasonable" equilibrium where the market breaks down.*

Proof. Suppose creditor rights are strong, $\mu \geq \mu^* \equiv \frac{1}{p_g}$ and the market breaks down in the equilibrium. Since the good bank dominates the bad bank, shown in Fig. III.3 that $\Pi_g^{off} = 0$ is above $\Pi_b^{off} = 0$, it can profitably deviate from the market breakdown equilibrium by voluntary supporting more or offering a higher repayment, to violate the bad bank's participation constraint. During that, the good bank can be better off, while the bad bank is worse off. According to the Intuitive Criterion, investors will believe this deviation is offered by the good bank, and will accept the new contract and provide funds since they can also be better off. Therefore, the market breakdown equilibrium cannot survive the Intuitive Criterion. □

Lemma III.5. *When creditor rights are weak, there exists a pooling equilibrium in which neither bank obtains financing (market breakdown).*

Proof. We present a graphical proof and refer to Fig. III.3b.

Suppose creditor rights are weak, $\mu < \mu^* \equiv \frac{1}{p_g R}$. Banks are not willing to share a high fraction of return to investors, while investors require a higher interest rate which cannot be satisfied. Thus, investors' participation constraint may be violated $\gamma_g^{off} = p_g D_3^{off} - 1 < 0$, due to the lower repayment ceiling $D_3^{off} \leq \mu R < \mu^* R$. As shown in the figure, the upper bound of the repayment is below, and does not cross with the investors' participation constraint lines.

Therefore, financing is infeasible since even the maximised repayment proposed by the bank cannot meet the investors' minimum requirement. There is no scope where both investors' and banks' participation constraints can be satisfied. □

This follows that the off-balance sheet financing mode functions in resolving the adverse selection problem under an implicit condition of strong creditor rights and banks may hold other purpose financing off-balance sheet when creditor rights are weak.

III.3.1.2 Direct investment signalling

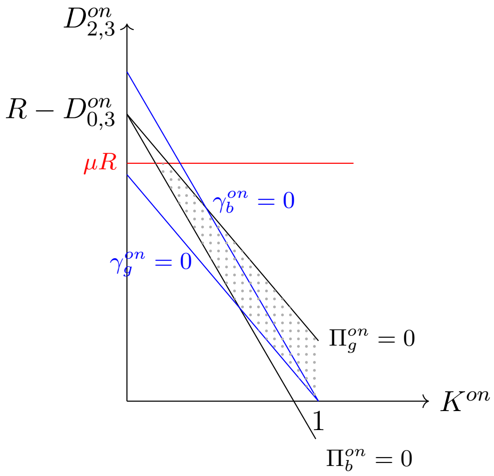
The bank can also directly invest K^{on} in the second project to reveal its type in the on-balance sheet financing mode. Π_i^{on} denotes the profit of banks of type i, and banks undertakes the second project when $\Pi_i^{on} \geq 0$.

$$\Pi_{3,i}^{on} = p_i(R - D_{0,3}^{on} - D_{2,3}^{on}) - K^{on} \geq 0 \tag{III.4}$$

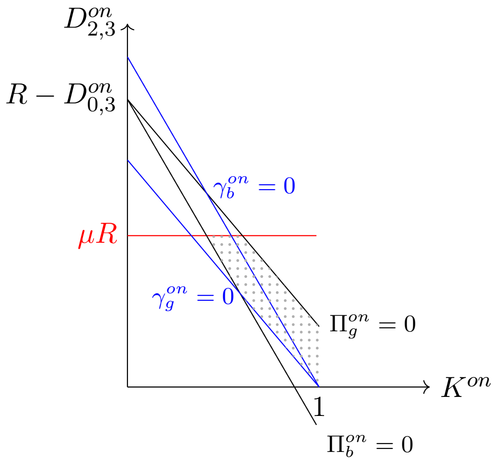
If the bank participates the second investment, it needs to raise the other $1 - K^{on} - Z^{on}$ at $t = 2$. Thus, investors' participation constraint is given by:

$$\gamma_i^{on} = p_i D_{2,3}^{on} - (1 - K^{on} - Z^{on}) \geq 0. \tag{III.5}$$

We plot participation constraints of banks and investors in Fig. III.4, and also the repayment ceiling. Both $\Pi_i^{on} = 0$ and $\gamma_i^{on} = 0$ have a negative slope. Since the slopes are the same, $\Pi_i^{on} = 0$ and $\gamma_i^{on} = 0$ do not cross for any i. A bank of type i is willing to undertake the project in the region below its participation constraint, while an investor facing a bank of type i is willing to provide funds in the region above the corresponding participation constraint.



(a) $\mu \geq \mu^*$



(b) $\mu < \mu^*$

Figure III.4: direct investment

Lemma III.6. *There exists either a pooling equilibrium in which neither bank obtains financing (market breakdown) or a separating equilibrium in which only good banks obtain financing, regardless the creditor rights level.*

Proof. We present a graphical proof and refer to Fig. III.4.

A financing equilibrium exists in the shaded area in Fig. III.4, where both investors' and good banks' participation constraints are satisfied, while the bad banks' participation constraint is violated.

The financing equilibrium is feasible whether creditor rights are strong or weak, depicted by the shaded area in Fig. III.4a and Fig. III.4b. Since $\gamma_g^{on} = 0$ is always below $\Pi_g^{on} = 0$ with no cross, there is always a region where both good banks' and investors' participation constraints are satisfied, regardless of the level of the repayment cap. When the creditor rights are weak $\mu < \mu^*$ that banks are not willing to share a high fraction of return to investors, it can invest more and reduce the amount raised from investors to avoid violating the investors' participation constraint.

Financing is infeasible outside the shaded area, in which either good banks or investors may not want to participate. □

Compared with voluntary support, direct investment works as a signal with fewer restrictions on creditor rights, since the signalling amount invested in the second project reduces the funds raised externally, thereby relaxing investors' participation constraints.

Lemma III.7. *There cannot exist a "reasonable" equilibrium where the market breaks down.*

Proof. Suppose the market breaks down in the equilibrium. Since the good bank dominates the bad bank shown as $\Pi_g^{on} = 0$ is above $\Pi_b^{on} = 0$ in Fig. III.4, it can profitably deviate from the market breakdown equilibrium by investing more or offering a higher repayment, to violate the bad bank's participation constraint. With this new offer, the good bank is better off, while the bad bank is worse off. According to the Intuitive Criterion, investors will believe this is provided by the good bank, and will accept it, from which they can also be better off. Therefore, the market breakdown equilibrium cannot survive the Intuitive Criterion. □

III.3.2 First project with moral hazard problem

At $t = 0$, the bank decides the funding mode and finances the first project. This section we explore the equilibrium contract under either of two financing modes.

III.3.2.1 Off-balance sheet financing

Suppose the bank finances the first project off-balance sheet. Since the bank has no contractual obligation to repay investors after the project fails and only good banks may voluntarily support K^{off} to reveal their type in the systematic state, investors' zero profit condition at $t = 0$ is:

$$(p_g + me)D_1^{off} + q\alpha K^{off} = 1 \tag{III.6}$$

From the zero profit condition Eq. III.6, we derive that investors require a minimum repayment of D_1^{off} to provide funds. Banks' expected profit for the first investment is:

$$\begin{aligned}\Pi_1^{off} =&(p_g + me)(R - D_1^{off} + Y) + (1 - p_g - me)Y - c(e) \\ &+ q\alpha[p_g(R - D_3^{off}) - K^{off}]\end{aligned} \tag{III.7}$$

The top line is the expected profit from the first project, net of the cost of effort. The second line is the expected profit from the second project in the systematic state. Taking the first order condition with respect to the effort level, we obtain the condition of the equilibrium effort level chosen by banks to maximise its profit.

$$\begin{aligned} c'(e^{off}) &= m(R - D_1^{off}) \\ &= m\left(R - \frac{1 - q\alpha K^{off}}{p_g + me}\right) \end{aligned} \tag{III.8}$$

Because $c(e)$ is strictly convex in e, $c'(e)$ is strictly increasing in e. The right-hand side of Eq. III.8 increases with K^{off}, which implies that a higher effort level can be achieved with a larger signalling amount. Intuitively, investors can accept a lower repayment after success if they anticipate a higher compensation after failure, and therefore a higher retention after success stimulates banks to exert more effort.

The bank's objective is to maximize its profit Eq. III.7. In addition to its indirect effect through effort level, K^{off} also direct affects the bank's profit. To consider these effects comprehensively and determine the equilibrium contract, we differentiate its profit with respect to K^{off}.

$$\begin{aligned} \frac{d\Pi_1^{off}}{dK^{off}} =& m(R - D_1^{off} + Y)\frac{de}{dK^{off}} - (p_g + me)\frac{dD_1^{off}}{dK^{off}} - mY\frac{de}{dK^{off}} - c'(e)\frac{de}{dK^{off}} + q\alpha\frac{d\Pi_{3,g}^{off}}{dK^{off}} \\ =& \underbrace{\left[m(R - D_1^{off}) - c'(e)\right]}_{>0}\underbrace{\frac{de}{dK}}_{>0} - q\alpha p_g \underbrace{\frac{dD_3^{off}}{dK^{off}}}_{\leq 0} > 0 \end{aligned} \tag{III.9}$$

Since $c(e)$ is strictly convex in e, the first-best effort level cannot be reached and $c(e^{FB}) = mR$, the net margin gain from effort is positive. From Fig. III.3, banks may propose minimum repayments $D_3^{off} = \max\{R - \frac{K^{off}}{p_b}, \frac{1}{p_g}\}$ to implement the separating equilibrium. Thus, D_3^{off} is decreasing or indifferent with K^{off}.

From Eq. III.9, banks' profit increases with K^{off}, as does the effort level. Thus, banks may prefer to voluntarily support more in the systematic state $K^{off} = \min\{k_H^{off}, Y\}$, where $k_H^{off} \equiv p_g R - 1$.

Lemma III.8. *If the bank finances the first project off-balance sheet. The bank's optimal effort* *choice is* e^{off*}*, where* $c'(e^{off*}) = m(R - \frac{1-q\alpha \cdot min\{k_H^{off}, Y\}}{p_g+me})$.

III.3.2.2 On-balance sheet financing

Suppose the bank finances the first project through the debt contract. Investors obtain repayment D_1^{on} in the success state, Y in the idiosyncratic failure state, and $Y - K^{on}$ in the systematic failure state at $t = 1$. After the asymmetric information arises, investors observe the bank's use of K^{on}, form a belief on its type and decide whether to claim the senior debt. With this contract, investors' zero profit condition at $t = 0$ is:

$$(p_g + me)D_1^{on} + (1 - p_g - me - q)Y + q[Y - K^{on} + \alpha(p_g D_{0,3}^{on} - Z)] = 1. \tag{III.10}$$

Solving zero profit condition, we derive the minimum repayment required by investors to provide funds D_1^{on}. Banks' expected profit for the first investment is:

$$\begin{aligned}\Pi_1^{on} =& (p_g + me)(R - D_1^{on} + Y) + qK^{on} - c(e) \\ &+ q\alpha[p_g(R - D_{0,3}^{on} - D_{2,3}^{on}) - K^{on}]\end{aligned} \tag{III.11}$$

The top line is the net expected profit from the first project, and the second line is the expected profit from the second project in either non-systematic state or systematic state. Taking the first order condition with respect to the effort level, we obtain the condition of the equilibrium effort level chosen by banks to maximise its profit.

$$\begin{aligned}c'(e^{on}) &= m(R - D_1^{on} + Y) \\ &= m\left[R - \frac{1 - Y + qK^{on} - q\alpha(p_g D_{0,3}^{on} - Z^{on})}{p_g + me}\right]\end{aligned} \tag{III.12}$$

The right-hand side of Eq. III.12 is decreasing in K^{on} and Z^{on}, and increasing in $D_{0,3}^{on}$. A larger effort level can be realized with a smaller signalling amount, since the less the bank retains for signalling, the more compensation investors anticipate and therefore accept a lower repayment in the success state, and the bank can be motivated to exert more effort to increase the success probability. Similarly, a higher profit investors anticipated from the second project can also stimulate a higher effort level, which relates to a higher $D_{0,3}^{on}$ and lower Z^{on}.

While the bank's profit is indirectly affected by effort, it is also directly affected by $D^{on}_{0,3}$ and K^{on}. To determine the equilibrium contract, we need to consider these two effects together and differentiate its profit with respect to them respectively:

$$\begin{aligned}\frac{d\Pi^{on}_1}{dD^{on}_{0,3}} =& m(R - D^{on}_1 + Y)\frac{de}{dD^{on}_{0,3}} - (p_g + me)\frac{dD^{on}_1}{dD^{on}_{0,3}} - c'(e)\frac{de}{dD^{on}_{0,3}} - q\alpha p_g \\ =& \underbrace{\left[m(R - D^{on}_1 + Y) - c'(e)\right]}_{>0} \underbrace{\frac{de}{dD^{on}_{0,3}}}_{>0} > 0\end{aligned} \tag{III.13}$$

Since the first-best effort level cannot be realized, the net margin gain from effort is positive. It follows that the bank may prefer to propose a higher second project profit to investors to increase its own profit in this portfolio. The whole project profit can be transferred to investors with $D^{on}_{0,3} = R - \frac{1}{p_g}$ and $Z^{on} = 0$.

$$\begin{aligned}\frac{d\Pi^{on}_1}{dK^{on}} =& m(R - D^{on}_1 + Y)\frac{de}{dK^{on}} - (p_g + me)\frac{dD^{on}_1}{dK^{on}} + q - c'(e)\frac{de}{dK^{on}} - q\alpha p_g\frac{dD^{on}_{2,3}}{dK^{on}} - q\alpha \\ =& \underbrace{\left[m(R - D^{on}_1 + Y) - c'(e)\right]}_{>0} \underbrace{\frac{de}{dK^{on}}}_{<0} < 0\end{aligned} \tag{III.14}$$

In the case that the bank proposes $D^{on}_{0,3} = R - \frac{1}{p_g}$ and $Z^{on} = 0$, the area where the separation is available collapses to $\Pi_g = 0$ and $\frac{dD^{on}_{2,3}}{dK^{on}} = -\frac{1}{p_g}$, shown as Fig. III.5. Thus, the bank profit increases with the signalling cost decreases. From Fig. III.5, the signalling cost can be minimised to 0 when creditor rights are strong and $K^{on}_L = 1 - p_g\mu R$ when creditor rights are weak. Therefore, the bank can maximise its profit by minimising the signalling cost $K^{on} = \max\{0, K^{on}_L\}$.

Lemma III.9. *If the bank finances the first project through the debt contract. The bank's optimal effort choice is* e^{on*}*, where* $c'(e^{on*}) = m(R - \frac{1-Y+qmax\{0,K^{on}_L\}-q\alpha(p_gR-1)}{p_g+me})$.

III.3.3 Bank's problem

The bank decides the financing mode at $t = 0$ to maximise its profit. Through the off-balance sheet financing mode, the bank expects a profit Π^{off*}_1, which varies with the payoff

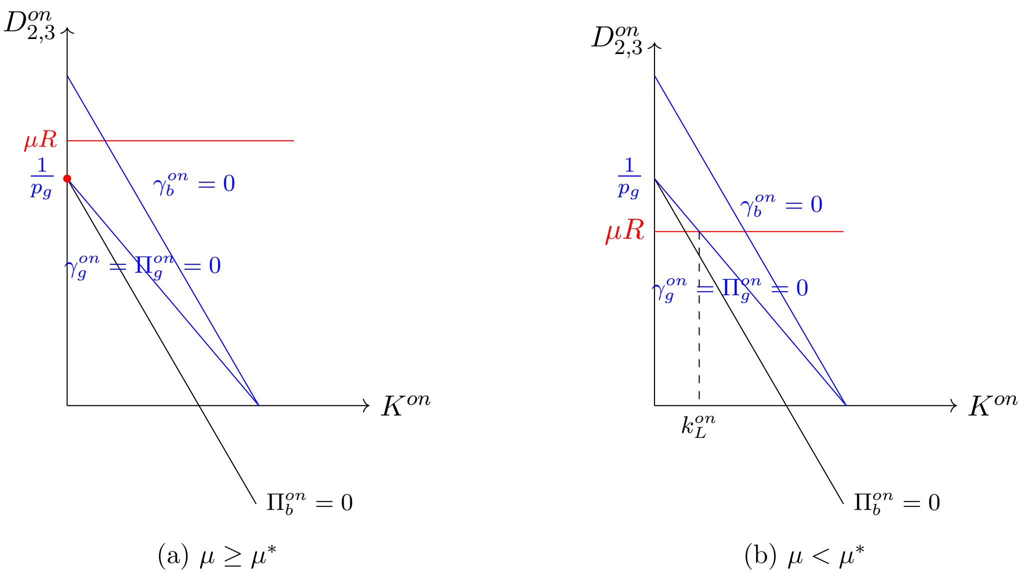


Figure III.5: In the case of $D_{0,3}^{on} = R - \frac{1}{p_g}$ and $Z^{on} = 0$

Y.

$$\begin{aligned}\Pi_1^{off*} =&(p_g + me^{off*})R - c(e^{off*}) - 1 + Y \\ &+ q\alpha \cdot p_g(R - \max\left\{R - \frac{K^{off}}{p_b}, \frac{1}{p_g}\right\})\end{aligned} \tag{III.15}$$

If the bank can receive a higher payoff $Y \geq p_b(R-\frac{1}{p_g})$ at $t = 1$, it can voluntarily support more, leading a higher profit.

$$\Pi_1^{off*}|_{Y \geq p_b(R-\frac{1}{p_g})} = (p_g + me^{off*})R - c(e^{off*}) - 1 + Y + q\alpha \cdot (p_g R - 1) \tag{III.16}$$

If the payoff is lower $Y < p_b(R-\frac{1}{p_g})$, the signalling cost will be less, resulting in a smaller bank profit, caused by a combination of lower second project profit and less effort exerted in the first project.

$$\Pi_1^{off*}|_{Y < p_b(R-\frac{1}{p_g})} = (p_g + me^{off*})R - c(e^{off*}) - 1 + Y + q\alpha \cdot \frac{p_g}{p_b} Y \tag{III.17}$$

Through the on-balance sheet financing mode, the bank expects a profit Π_1^{on*}.

$$\Pi_1^{on*} = (p_g + me^{on*})R - c(e^{on*}) - 1 + Y + q\alpha \cdot (p_g R - 1) \tag{III.18}$$

$\Pi_1^{off*} < \Pi_1^{on*}$, since the adverse selection problem can be solved by the off-balance sheet financing with an implicit condition of strong creditor right $\mu \geq \mu^*$. Therefore, the on-balance sheet financing is optimal for the bank, and the equilibrium effort can be characterized as Lemma III.9.

III.4 Planner's problem

The objective of the planner is to maximise net social surplus. Under the condition that the adverse selection problem is alleviated through signalling, a higher effort level is crucial for the planner.

Under the off-balance sheet financing mode, the effort level can be maximised to $\overline{e}^{off*}$ when the payoff from bank's existing asset is big enough $Y \geq p_g R - 1$, where $c'(\overline{e}^{off*}) = m(R - \frac{1-q\alpha(p_g R-1)}{p_g+me})$.

While, under the on-balance sheet financing mode, the effort level can be maximised to $\overline{e}^{on*}$ when the creditor rights is strong $\mu \geq \mu^*$, where $c'(\overline{e}^{on*}) = m(R - \frac{1-Y-q\alpha(p_g R-1)}{p_g+me})$

It follows that the planner may also prefer the on-balance sheet financing mode, since $c'(e)$ is strictly increasing in e. This also suggests that strong creditor rights should be maintained to ensure that higher effort level can be achieved.

III.5 Discussion and conclusion

We present a model in which a bank has two investment opportunities. The first opportunity is subject to an effort moral hazard problem, while the second may encounter an adverse selection problem if the first investment fails due to systematic reasons. To resolve the potential adverse selection problem, banks need to retain some funds for signalling after asymmetric information arises, rather than compensating all funds to investors. There are two funding modes that could achieve this result: off-balance sheet financing and debt contract financing. We demonstrate that off-balance sheet financing with voluntary support signalling can resolve the adverse selection problem under the implicit condition of strong creditor rights, while debt contract financing with direct investment signalling is not restricted.

This result bridge the negative opinion on strong credit rights to the adverse selection hypothesis. When the creditor rights is strong, the off-balance sheet financing is functional in resolving the adverse selection problem. Thus, banks taken this approach moves the good project off the books, increasing bank risk-taking (Jayaraman and Thakor, 2013; Houston et al., 2010). This is also consist with González (2023) who find banks are more contestable with creditor rights increases more in countries with less stringent restrictions non-traditional bank activities.

Moreover, we indicate that debt contract financing dominates the off-balance sheet financing since the limited liability created by off-balance sheet financing weakens the banks' incentives to compensate investors after failure, worsening the moral hazard problem. Our results show that the bank would like to exert more effort to increase its profit, and the unregulated equilibrium contract can maximise the effort level to its extent. However, the maximum effort level under the on-balance sheet financing is restricted by the creditor rights. Our analysis favours to maintain it strong, as a strong creditor rights could result a greater social surplus. Jayaraman and Thakor (2013); Houston et al. (2010) appear prudential to strong creditor rights as it relates to greater bank risk taking and higher likelihood of financial crisis. However, we interpret this in terms of adverse selection hypothesis and state that it can be weakened when the on-balance sheet financing with cross-subsidization is adopted by banks.

Chapter IV

A Rationale for Minimum Bank Capital Requirements

IV.1 Introduction

Capital adequacy requirements have been emphasised since Basel II and have attracted further attention in the aftermath of the global financial crisis (Goodhart et al., 2023). Although imposing capital requirements may reduce a bank's ability to create liquidity (Van den Heuvel, 2008), some regulators impose more stringent capital requirements than the Basel accord (Rime, 2001). Some existing literature states that capital requirements are imposed to mitigate information frictions, based on the assumption that the regulator has superior skills in distinguishing bank types compared to the public (Morrison and White, 2005). Ahnert et al. (2021) relate the sensitivity of capital regulation to the accuracy of the superior information, thus interpreting the stringent capital requirement as a result of the regulator's strong ability to obtain accurate information. However, in this paper, we emphasize that good banks have their own incentive and ability to separate, demonstrating that regulatory intervention may not be essential to mitigate information frictions, thus relaxing the assumption of the regulator's superior information. We additionally propose another perspective to rationalise these stricter regulations, suggesting that they can be used to rectify the divergence arising from individual banks' and the regulator's different objectives, thereby improving upon the unregulated equilibrium.

In this paper, we construct a model in which a bank funds a project with uninsured deposits and costly capital, suffering from two information frictions. One is a moral hazard problem arising from the bank's choice of the probability of default. Considering the costlier capital, the bank may borrow more from investors to fund the project. However, if the bank funds the project primarily through borrowed funds, thereby risking little of its own capital, failure may be less threatening to the bank, and it may have less incentive to exert effort to control risk, resulting in a higher probability of default. Some literature thus rationalises risk-insensitive capital requirements. Restricted by this regulation, banks have enough skin in the game and may have a greater incentive to exert effort, since their profits are sufficiently tied to the success of the project. Ahnert et al. (2021) support the risk-insensitive capital requirement in the case that the regulator has inaccurate information about banks' types. They state that, although it has no effects on screening bad banks out, it can mitigate the moral hazard problem. They additionally support risk-sensitive capital requirements in the case of accurate information, which can be imposed to both rule bad banks out and mitigate the moral hazard problem. Comparing to Ahnert et al. (2021), our model emphasises that investors may have an incentive to preserve their interests and require a minimum level of capital provided by the bank, which may alleviate the moral hazard problem without regulatory intervention.

The other friction is an adverse selection problem stemming from the bank's type, referring to the project's loss given default. Some literature rationalises risk-sensitive capital requirements due to it, by arguing that investors are not able to distinguish good banks from bad ones, and relates the sensitivity of capital requirements to the accuracy of the regulator's superior information. Risk-insensitive capital requirements should be imposed to mitigate the moral hazard problem when the signal is inaccurate, while risk-sensitive capital requirements can be used to resolve both adverse selection and moral hazard problems when the signal is sufficiently accurate. However, we argue that good banks are capable of separating from bad banks since they dominate in the failure state and can signal investors by proposing higher repayments in that state, which is more costly for bad banks. Good banks also have an incentive to do so, as accommodating bad banks incurs a mispricing cost. When the cost of enforcing separation is lower than the mispricing cost, good banks pursue higher profits, leading to an unregulated separating equilibrium. Therefore, we show that regulatory intervention is not essential for mitigating information frictions. Comparing to Ahnert et al. (2021), our model emphasises good banks' own incentive to separate and allows a larger set of possible financing contracts. Good banks therefore can dominate and separate from bad bank without regulator intervention. Ahnert et al. (2021), however, ignores the incentive and possibility of investors and good banks to separate and state risk-sensitive capital requirements should be imposed by the regulator who has sufficient accurate information about banks' types. While the equilibrium state is determined by the simultaneous interplay of supply and demand. It is unable to foresee the financing decisions if it fails to take into account investors' and banks' portfolio decisions (Mossin, 1969).

Then, we present that both good banks and the regulator trade off the opportunity cost of separation against it benefit and prefer pooling bad banks rather than ruling them out as asymmetric information becomes mild, although focusing on different objectives. Good banks, considering their own profit, trade off the stable separation cost, against the mispricing cost, which decreases as the proportion of good banks increases. When the asymmetric information problem is severe, a unique separating unregulated equilibrium arises, located at the intersection of the binding participation constraints between bad banks and investors facing good banks, where bad banks can just be screened out, allowing good banks to extract the entire project profit without sharing with investors. When the asymmetric information problem is less severe and the mispricing cost is lower, good banks may be willing to pool with bad banks, but the unregulated equilibrium may be either separating or pooling, depending on the beliefs of depositors. There exists a feasible pooling equilibrium that lies at the intersection of the binding participation constraints between bad banks and investors facing weighted-average banks, where the good bank can extract higher profit than in any other equilibrium. Both bank types may profitably deviate from other pooling equilibria towards it. However, since both types can benefit from this deviation, the Intuitive Criterion has no bite. Investors observing this deviation cannot attach zero probability to this offer coming from the bad bank, and hence may reject the offer. These pooling equilibria cannot be eliminated. By the same argument, the separating equilibrium described above may also exist woithin this parameter range.

The regulator, focused on social surplus, does not take into account individual banks' profits. From the regulator's perspective, there is a social cost of accommodating value-destroying bad banks in the market, which decreases as the proportion of good banks increases. Meanwhile, separation impedes the banking sector's expansion, raising a social cost associated with costly capital. By trading off these two costs, the regulator prefers a separating equilibrium with a high borrowing rate when the asymmetric information problem is severe. This equilibrium undermines good banks' profits and is not preferred by them. As the asymmetric information problem becomes less severe, the regulator may be willing to accommodate bad banks and prefer a pooling equilibrium in which good banks compensate compensate investors for all scrap value, an outcome that cannot be pinned down in the unregulated equilibria.

Therefore, we introduce a novel rationale for imposing capital requirements, to rectify the divergence between the unregulated equilibrium and the regulator's aspiration, which arises from their different focuses. When the asymmetric information problem is severe, both the regulator and good banks prefer separation. A minimum collateral requirement should be imposed, transferring the project profit to investors, along with a minimum capital requirement to screen out bad banks. When the asymmetric information is mild, both the regulator and good banks prefer to accommodate bad banks in the market. A minimum leverage requirement should be imposed, forcing banks to achieve the pooling equilibrium with the maximum leverage.

The situation is complex when the asymmetric information problem is moderate. If the cost of capital is low, there may exist a situation in which the regulator prefers a pooling equilibrium, whereas good banks want to separate. In this case, the regulator can achieve pooling by setting minimal collateral requirements to reduce good banks' dominance in the failure state, thereby forcing them to accommodate bad banks. If the cost of capital is high, following Van den Heuvel (2008), a situation may arise in which the regulator prefers to separate, while good banks desire to pool. This divergence occurs because good banks, anticipating higher capital requirements required by investors in the unregulated separating equilibrium, overestimate the benefits of accommodating bad banks, especially with a multiple effects of the high cost of capital. In this case, minimum capital and collateral requirements should be imposed jointly to achieve the separation preferred by the regulator.

Related literature. Our paper is closely related to Ahnert et al. (2021), who develop similar a model. However, in their framework, good banks issue debt to finance the project, relinquishing their dominance in the failure state. Thus, good banks are unable to reveal their type without regulatory intervention and there is scope for risk-sensitive capital requirement to facilitate a separation when the regulator has sufficiently accurate superior information. Otherwise, when the information is inaccurate, the regulator cannot ascertain the type of bank and has no choice but to embrace bad banks. In this case, risk-insensitive capital requirements should be imposed to mitigate the moral hazard problem. However, this paper emphasises good banks' incentive and ability to signal to investors and show that information frictions may be mitigated without regulatory intervention, and the assumption about the regulator's superior information can be relaxed.

There is some existing literature investigating the rationale of capital requirements, also based on the assumption that the regulator has some superior information on banks' types. Vollmer and Wiese (2013) assume the regulator can receive an imperfect signal to analyse the imperfect substitution between bank resolution schemes and minimum capital requirements and suggest strengthening capital requirements during economic upswings. Ding et al. (2021) argue that the leverage constraint should be tighter when the regulator receives a signal with worse precision. Van den Heuvel (2008) focus on the welfare costs of bank capital requirements but also use their model to show that capital requirements are helpful in alleviating the moral hazard problem generated by the regulator's imperfect observability of each bank's riskiness, but only in conjunction with bank supervision.

We share the assumption that bank equity is costlier than deposits with Allen et al. (2015). However, in their model, they state that there are no benefits from regulating bank capital, since the market solution is efficient unless there are institutional distortions. Biswas and Koufopoulos (2022) rationalise this assumption and state that regulation may be relevant without resorting to institutional distortions. Thakor (2014) also states that regulatory capital requirements become germane because the socially efficient capital level may exceed banks' privately optimal capital levels. Although they find lower capital in banking leads to higher systemic risk and capital regulation reform should seek to increase bank capital, they also emphasise social costs entailed by requirements need to be considered. Despite the agreement on the positive effect of higher capital on banking stability (Thakor, 2018), there is a debate on whether capital requirements should be higher.

Repullo (2013) focuses on welfare-optimal capital requirements and offers a model to rationalise the cyclical adjustment of bank capital requirements. They believe capital requirements designed for good times would be expected to be too high in bad times. Posner (2015) agrees on and argues that higher bank capital is not always more socially desirable than lower capital and suggests to the regulators that there is a balance to be struck, which is supported by Le et al.'s result, showing that Australian bank performance is weakened as capital ratios rise. Morrison and White (2005) deeply explore and state a loose regulation policy will maximise the size of banks and allow the largest possible amount of funds to be channelled into profitable investments; however, it will decrease the quality of the banking sector. Alternatively, a tight regulation policy can raise the average quality of the banking system at the cost of reducing its size.

Tirole (2012) states that the regulator, through a mixture of buybacks and equity injections, reduces the adverse selection enough to let the market rebound, but not too much to limit the cost of intervention. Biswas and Koufopoulos (2022) further argue that the regulator may intervene not only to overcome adverse selection, but also sometimes to embrace it to improve the social efficiency.

The unregulated banking sector may be smaller than that expected by the social planner, as the presence of moral hazard in the banking system means that competent bankers must receive a rent to reward them for investing and monitoring other agents' deposits(Morrison and White, 2005). This coincides with the finding in Allen et al. (2011), that valuable banks find it optimal to use costly capital rather than the interest rate on the loan to commit to monitoring because it allows for a higher borrower surplus.

IV.2 Model

IV.2.1 Set-up

We consider a two-date economy in which agents are risk-neutral. There is a bank with access to a project that requires 1 at $t = 0$ and generates $R > 1$ with probability $p \in (0, 1)$ or a random scrap value at $t = 1$. The scrap value can be $S \in (0, 1)$ with probability $\alpha \in (0, 1)$ or 0 with probability $1 - \alpha$. The bank with a scrap value of S can be classified as a good bank, and one with no scrap value as a bad bank. Banks' types are their private information at $t = 0$.

During the investment, the bank can exert effort to increase the success probability p from p_L to p_H, incurring an effort cost $B > 0$. There are three assumptions characterising the effort. The first assumption ensures the effort is efficient,

Assumption IV.1. $\frac{B}{\Delta p} < R - S$, *where* $\Delta p = p_H - p_L$.

the second assumption restricts the project to a negative net present value without the bank's effort,

Assumption IV.2. $p_L R + (1 - p_L)S < 1$.

and the third assumption ensures that only the good bank can obtain a positive net present value when the bank exerts effort, while the bad one has a negative net present value.

Assumption IV.3. $p_H R < 1 + B < p_H R + (1 - p_H)S$.

Both the bank and investors have wealth 1 at $t = 0$. The bank prefers to raise funds from competitive investors due to the higher cost of its own capital. Suppose the capital can be invested in another profitable investment whose return rate is $z > 1$. We assume that z is not so large such that there exist a financing equilibrium.

Assumption IV.4. $z \leq \frac{p_L \frac{B}{\Delta p}}{p_L \frac{B}{\Delta p} - NPV} \equiv \bar{z}$.

IV.2.2 The game

We consider a standard two-stage signaling game:

- Stage 1: A bank proposes a contract (X_s, X_f, k) to investors, which consists of the repayment in the success state $X_s \leq R$ and that in the failure state $X_f \leq S$, and also the bank's own capital invested in the project $k \in [0, 1]$.

- Stage 2: After observing the bank's proposal, investors form a belief about the bank's type and its willingness to exert effort. Depending on these beliefs, investors decide to accept or reject this contract. If they accept the contract, when the project fails, investors can receive X_f if the bank repays or 0 if the bank defaults.

We look for the pure strategy Perfect Bayesian Equilibria of this game that satisfy the Intuitive Criterion of Cho and Kreps (1987) (the so-called "reasonable" equilibria).

IV.2.3 Benchmark: observed types

Consider first bank types are public known. Although the effort level remains unobservable, investors would build a belief about whether the bank exerts effort facing different contract terms.

A bank exerts effort when its incentive constraint is satisfied.[1]

$$p_L(R - X_s) + (1 - p_L)(S - X_f) \leqslant p_H(R - X_s) + (1 - p_H)(S - X_f) - B \tag{IV.1}$$

, shown in the contract as a small difference between repayments in the success and failure states:

$$\Delta X \leqslant R - S - \frac{B}{\Delta p} \tag{IV.2}$$

[1] Here, we use the good bank's incentive compatibility constraint, which is stricter.

, where $\Delta X = X_s - X_f$

According to Assumption IV.2, a bank cannot yield a positive NPV without exerting effort. Therefore, investors may refuse to provide funds, facing a contract that they believe the bank will not exert effort, regardless of the bank's type. That is, only contracts with sufficiently small repayment spread $\Delta X \leqslant R - S - \frac{B}{\Delta p}$ can be accepted by investors, such that the bank's incentive constraint can be satisfied.

Lemma IV.1. *A financing equilibrium contract specifies* $\Delta X \leq R - S - \frac{B}{\Delta p}$.

Proof. Suppose the contract specifies $\Delta X > R - S - \frac{B}{\Delta p}$. The good bank will not exert effort, since its incentive constraint Eq. IV.1 is violated. Without effort, the success probability will decrease to p_L, and the participation constraints of investors

$$p_L X_s + (1 - p_L) X_f \geq 1 - k$$

and good banks

$$p_L (R - X_s) + (1 - p_L)(S - X_f) - (1 - k) \geq zk$$

are conflict due to Assumption IV.2. Therefore, there cannot exist an equilibrium in which the bank obtains financing with the contract specifies $\Delta X > R - S - \frac{B}{\Delta p}$. □

Therefore, in a financing equilibrium, good banks have to exert effort and increase the success probability to p_H, and investors' expected profit is denoted as

$$\gamma(\hat{\alpha}) = p_H X_s + (1 - p_H)\hat{\alpha} X_f - (1 - k) \tag{IV.3}$$

, where $\hat{\alpha}$ is the probability of the bank is of type g in investors' belief.

In this benchmark scenario, investors identify and fund good banks. Their participation constraint can be denoted as $\gamma(\hat{\alpha} = 1) \geq 0$. It follows that the capital banks need to invest in this project can be minimised to $\underline{k} = p_L \frac{B}{\Delta p} - NPV$[2], when the repayments are maximised to their extent, that is $X_f^{max} = S$ due to limited liability and $X_s^{max} = R - \frac{B}{\Delta p}$ due to the incentive compatibility constraint Eq. IV.2.

[2],where $NPV = p_H R + (1 - p_H) S - B - 1$.

In the case of $p_L \frac{B}{\Delta p} \leq NPV$, $\underline{k} \leq 0$. There exist an equilibrium where banks could raise enough funds for the investment from investors through a contract satisfying its incentive compatibility constraint and do not need to provide its costly own capital. In this case, mitigating the moral hazard problem is costless for the bank, and it will have no hesitation in doing so.

In this paper, we focus on the other case of $p_L \frac{B}{\Delta p} > NPV$, where the bank needs to invest capital $\underline{k} > 0$ into the project, generating a cost in mitigating the moral hazard problem. In this case, a financing equilibrium requires a sufficiently small cost of capital $z \leq \bar{z}$, with which good banks would like to provide the capital and participate:

$$p_H(R - X_s^{max}) + (1 - p_H)(S - X_f^{max}) - B \geq z\underline{k} \tag{IV.4}$$

Otherwise, good banks' expected profit from this project will cover the opportunity cost of that capital. Consequently, there can be no financing. Therefore, we assume throughout that there is a sufficiently small cost of capital z, shown as Assumption IV.4.

IV.3 Equilibrium

The key date of strategic interaction between the bank and investors is $t = 0$. We solve for the equilibrium using backward induction. Below we list all the candidate equilibria.

1. A candidate separating equilibrium in which only the bad banks obtain financing.
2. A candidate separating equilibrium in which only the good banks obtain financing.
3. A candidate separating equilibrium in which both bank types obtain financing, but offer different contracts.
4. A candidate pooling equilibrium in which both bank types obtain financing.
5. A candidate pooling equilibrium in which neither type of bank obtains financing (market breakdown).

According to Lemma IV.1, a financing equilibrium contract specifies $\Delta X \leq R - S - \frac{B}{\Delta p}$, shown that banks exert effort to obtain finance and the success probability could increases to

p_H. Candidates 1 and 3 cannot exist, since investors will not fund the bank which is of type b with certainty in their belief, due to the negative net present value.

Lemma IV.2. *There cannot exist a separating equilibrium where only bad banks obtain financing, or where both good and bad banks obtain financing but under different terms.*

Proof. Suppose investors could identify bad banks, their participation constraint facing bad banks could update to $p_H X_s \geq 1-k$, which cannot be satisfied simultaneously with bad banks' participation constraint $p_H(R-X_s)-B \geq zk$ since $p_H R - B < 1$ (Assumption IV.2). Therefore, there cannot exist a separating equilibrium in which the bad bank obtains financing. □

In the case of $p_L \frac{B}{\Delta p} > NPV$ we considered, banks need to invest some own capital $k > 0$ in the project, resulting in an opportunity cost for them to undertake this investment. Thus, good banks participate when its expected profit from this project, net of effort cost, covers the opportunity cost of the capital $\Pi_g \geq zk$.

$$\Pi_g = p_H(R - X_s) + (1 - p_H)(S - X_f) - B \tag{IV.5}$$

Bad banks' participation constraint $\Pi_b \geq zk$ is more binding due to its zero scrap value, unless good banks commit to repay the entire scrap value after failure.

$$\Pi_b = p_H(R - X_s) - B \tag{IV.6}$$

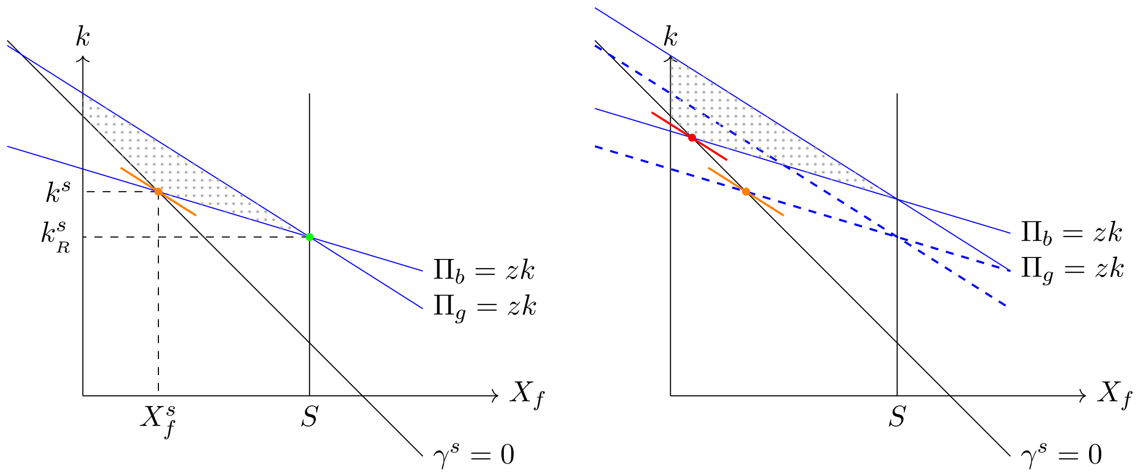
Lemma IV.3. *There cannot exist a "reasonable" equilibrium where the market breaks down.*

Proof. Suppose the market breaks down in the equilibrium. Due to the good bank's dominance in the failure state, it can profitably deviate from the market breakdown equilibrium by offering any contract which violates the bad bank's participation constraint Eq. IV.6. If this contract is accepted by the investors, the bad bank is worse off, while the good bank is better off. According to the Intuitive Criterion, investors have no doubt that it is the good bank offers this contract. Investors then accept the contract and finance the bank offering the contract since they can be better off. Therefore, the market breakdown equilibrium does not survive the Intuitive Criterion. □

IV.3.1 Separating equilibrium

This section considers whether a separating equilibrium in which only good banks obtain financing could exist. This separating equilibrium may exist under the following conditions: First, the bad banks' participation constraint is (weakly) violated $\Pi_b \leq zk$. Second, the good banks' participation constraint is satisfied $\Pi_g \geq zk$. Third, investors are willing to provide funds to good banks, shown as $\gamma^s = \gamma(\hat{\alpha} = 1) \geq 0$ and $\Delta X \leq R - S - \frac{B}{\Delta p}$.

We plot the binding participation constraints of banks (blue lines) and investors in the (X_f, k) space. Fig. IV.1 shows that the bad banks' binding participation constraint line lies under that of good banks until $X_f = S$.



(a) $\Delta X = R - S - \frac{B}{\Delta p}$ (b) $\Delta X < R - S - \frac{B}{\Delta p}$

Figure IV.1: Separating equilibrium

The candidate separating equilibria lie in the shaded area, where none of the constraints are violated. To exactly identify, we consider the good banks' problem. It can yield expected profit P_g, including the profit extracted from the project and the profit from the free capital.

$$\begin{aligned} \mathrm{P}_g =& p_H(R - X_s) + (1 - p_H)(S - X_f) - B + z(1 - k) - 1 \\ =& z + NPV - p_H \Delta X - X_f - zk \end{aligned} \tag{IV.7}$$

To maximise its profits, good banks may prefer a candidate equilibrium where both the bad banks' and investors' participation constraints are just binding. Otherwise, investors' participation constraint may be slack, requiring good banks to share some profit with them, or the bad banks' participation constraint may be too stringent, making it too costly to screen out bad banks.

Lemma IV.4. *The separating equilibrium may be located at the intersection of investors' and the bad bank's participation constraint lines.*

Proof. We provide a graphical proof and refer to Fig. IV.1a, where participation constraint lines of investors and the bad banks cross at (X_f^s, k^s) (the orange dot), and the good banks' indifference curves (e.g. the orange curve) have a slope of $-\frac{1}{z}$ (Eq. IV.7), which are flatter than the investors' zero-profit line.

In the case of $X_f \leq X_f^s$, the investors' zero-profit line lies above the bad banks' participation constraint line. Suppose that the equilibrium lies at any point on the investors' zero-profit line in this region, good banks may profitably deviate from that dot to the orange dot, since their indifference curve through the orange dot is closer to the origin, due to its flatter slope relative to the investors' zero-profit line. Observing the deviation, investors hold the belief that the deviation comes from good banks with certainty, as the bad banks' participation constraint is violated in this region. Hence, investors accept the offer and that point may not be a reasonable equilibrium. By the same argument, we can eliminate all other separating equilibria that lies in the shaded area above this segment.

In the case of $X_f > X_f^s$, investors' zero-profit line lies below the bad bank's participation constraint. Suppose that the equilibrium lies anywhere on the bad bank's participation constraint in this region. Compared to this point, good banks located at the orange dot can propose a contract with a lower X_f and higher k, implying a higher profit and still keeping bad banks out. Thus, good banks may profitably deviate. Observing the deviation, investors will hold the belief that the deviation comes from good banks with certainty, as either a lower X_f or higher k is better off to good banks and worse off to bad banks. Hence, this point is not a reasonable equilibrium. By the same argument, we can eliminate all other separating equilibria that lies in the shaded area above this segment. □

Also, good banks may propose a contract where the repayment difference is maximised to its extent, $\Delta X = R - S - \frac{B}{\Delta p}$, in order to raise more funds, rather than investing their costlier own capital.

Lemma IV.5. *The separating equilibrium contract may specify the repayment spread as* $\Delta X = R - S - \frac{B}{\Delta p}$.

Proof. We provide a graphical proof and refer to Fig. IV.1b, which shows the banks' binding participation constraint lines (blue solid lines) under the condition of a smaller repayment difference, while the dashes lines show the case when the repayment spread extends to its maximum, $\Delta X = R - S - \frac{B}{\Delta p}$.

As shown in the figure, the banks' binding participation constraint lines move upwards as the repayment difference increasing. As the bad banks' binding participation line shifts upwards, so does its intersection with the investors' zero-profit line (shown as moving from the orange dot to the red dot). Drawing the good banks' indifferent curves through these two intersections, we see that the orange curve is closer to the origin since the indifference curves are flatter than the investors' zero-profit line.

Suppose the equilibrium contract involves a smaller repayment spread, e.g. the equilibrium is at the red dot. Good banks may deviate from the red dot to the orange dot, where they can obtain more profit. Investors, observing the deviation, may accept this offer, as they may hold the belief that the deviation comes from good banks with certainty, since the bad banks' participation constraint is violated. Thus, the red dot may not be a reasonable equilibrium. By the same argument, we can eliminate all other separating equilibria with smaller repayment spreads. □

From Lemmas IV.4 and IV.5, the candidate separating equilibrium in which only good banks obtain financing can be characterised as follows:

$$\begin{aligned} X_s^s &= R - \frac{B}{\Delta p} - \frac{zNPV - (z-1)p_L \frac{B}{\Delta p}}{z - p_H} \\ X_f^s &= S - \frac{zNPV - (z-1)p_L \frac{B}{\Delta p}}{z - p_H} \end{aligned} \tag{IV.8}$$

, and

$$k^s = p_L \frac{B}{\Delta p} - NPV + \frac{zNPV - (z-1)p_L \frac{B}{\Delta p}}{z - p_H} \tag{IV.9}$$

, shown as the orange dot in Fig. IV.1.

Lemma IV.6. *Given the contract proposed by good banks, a separating equilibrium in which only good banks obtain financing may be possible, characterised as* (X_s^s, X_f^s, k^s).

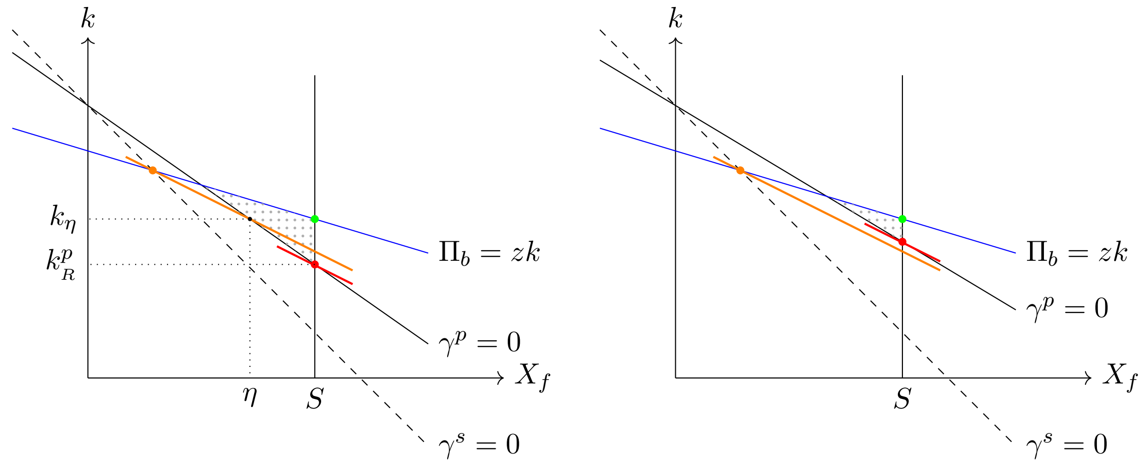
In this potential separating equilibrium, the good bank can earn expected profit P_g^s.

$$\begin{aligned}\mathrm{P}_g^s =& p_H(R - X_s^s) + (1-p_H)(S - X_f^s) - B + z(1-k^s) - 1 \\ =& \frac{1-p_H}{z-p_H}\left[zNPV - (z-1)p_L\frac{B}{\Delta p}\right]\end{aligned} \tag{IV.10}$$

IV.3.2 Pooling equilibrium

Next, considering the pooling equilibrium in which both good and bad banks obtain financing. This equilibrium may exist when both the good and bad banks' participation constraints are satisfied $\Pi_b \geq zk$[3] and investors are also willing to provide funds $\gamma^p = \gamma(\hat{\alpha} = \alpha) \geq 0$ and $\Delta X \leq R - S - \frac{B}{\Delta p}$.

We illustrate the binding participation constraints of the banks (blue lines) and investors in the pooling equilibrium in Fig. IV.2. It also includes the investors' zero-profit line in the separating equilibrium (dashed lines) for comparison. From the figure, it is evident that no constraints are violated in the shaded area.



(a) $\alpha > \alpha_g$ (b) $\alpha \leq \alpha_g$

Figure IV.2: Pooling equilibrium

To identify whether the candidate pooling equilibria in the shaded area are feasible, we consider the good banks' problem. Good banks may not want to accommodate bad banks if

[3] Here, we use the bad bank's participation constraint, which is stricter.

they cannot yield a higher profit than that from the separating equilibrium, shown as Fig. IV.2b that the good banks' indifferent curve through the separating equilibrium (orange curve) is closer to the origin than that through any dots in the shaded area.

Lemma IV.7. *When the good bank's proportion is small $\alpha \leq \alpha_g$, there exists a unique separating equilibrium, characterised in Lemma IV.6.*

From Fig. IV.2b to Fig. IV.2a, as the good banks' proportion α increases, $\gamma^p = 0$ becomes steeper. When the good banks' proportion is large enough $\alpha > \alpha_g$, their indifference curve in the separating equilibrium intersects $\gamma^p = 0$ in an effective region of the repayment, where $\eta \leq S$. From this point, the pooling equilibrium becomes possible.

$$\alpha > 1 - \frac{(z-1)[zNPV - (z-1)p_L \frac{B}{\Delta p}]}{(z-p_H)[z(1-p_H)S]} \equiv \alpha_g \in (0,1) \tag{IV.11}$$

Intuitively, good banks trade off the mispricing cost of accommodating bad banks to implement a pooling equilibrium against the separation cost ruling out bad banks. Since the mispricing cost decreases as the good banks' proportion increases, while the separation cost remains constant. A pooling equilibrium may be possible when the good bank's proportion is large enough, leading the mispricing cost lower than the separation cost.

Lemma IV.8. *When the good banks' proportion is large $\alpha > \alpha_g$, a continuum of pooling equilibria may be possible, where good banks obtains profit $P_g > P_g^s$, by proposing a contract specified as $X_b \in [\eta, S]$.*

Proof. We provide a graphical proof and refer to Fig. IV.2a.

Firstly, we show that candidate pooling equilibria at any point in the shaded region above or on the orange indifference curve are not reasonable. Consider a point in this region as a candidate pooling equilibrium. Good banks may profitably deviate towards the orange dot to pursue higher profits, by proposing a contract that separates them from bad banks. Investors, believing that this deviation comes from a good bank, may accept the offer, since a small repayment in the failure state X_f is better for good banks but worse for bad banks. Hence, any point in the shaded region above or on the orange indifference curve is not a reasonable pooling equilibrium.

There is a candidate pooling equilibrium at the intersection of the banks' binding limited condition and the investors' pooling participation constraint (red dot). This equilibrium is clearly feasible since no constraints are violated and no profitable deviations exist. The indifference curve of good banks through this dot (red curve) is the closest to the origin.

Consider points on the investors' pooling zero-profit line in the range of $X_f \in [\eta, S]$. Pick one point in this region as a candidate pooling equilibrium. Both good and bad banks may profitably deviate towards the red dot where both good and bad banks are strictly better off. Since both types are better off, the Intuitive Criterion does not have a bite. Thus, these feasible equilibria may not be eliminated and are reasonable.

Next, consider points on the banks' binding limited constraint in the shaded area below the orange indifference curve (vertically above the red dot) and suppose a candidate pooling equilibrium lies on one of them. Both good and bad banks may profitably deviate towards the red dot, where both types are strictly better off. Since both types are better off, the Intuitive Criterion does not have a bite. Thus, these feasible equilibria may not be eliminated and are reasonable.

By the same argument, no points in the shaded region below the orange indifference curve can be ruled out as unreasonable. Thus, the set of reasonable pooling equilibria lies anywhere in the shaded region below the orange indifference curve in Fig. IV.2a. □

IV.3.3 Unregulated equilibrium characterization

Good banks trade off the opportunity cost to separate against its benefit, and decide whether or not to implement a separating equilibrium. From Lemma IV.7, it is clear that a unique separating equilibrium exists when the proportion of good banks is small $\alpha \leq \alpha_g$, while the separating equilibrium also cannot be eliminated when $\alpha > \alpha_g$.

Lemma IV.9. *When the proportion of good banks is large $\alpha > \alpha_g$, a separating equilibrium, characterised as Lemma IV.6, may also be possible.*

Proof. We provide a graphical proof and refer to Fig. IV.2a.

When the proportion of good banks is large $\alpha > \alpha_g$, there are pooling allocations which make both types of bank better off, compared to the separating allocation (orange dot), shown as the shaded area below the orange indifference curve. Suppose the equilibrium lies at the orange dot. Both good and bad banks may profitably deviate towards those points in that shaded area, where both good and bad banks are strictly better off. Since both types are better off, the Intuitive Criterion does not have a bite and we can always find a strictly positive set of beliefs for which the orange dot is an equilibrium. Thus, the separating equilibrium at the orange dot cannot be eliminated and is the unique reasonable separating equilibrium. □

Combining Lemmas IV.7, IV.9 and IV.8, we characterise the unregulated equilibrium under asymmetric information in the following proposition:

Proposition IV.1. *The unregulated equilibria satisfying the Intuitive Criterion are as follows:*

i) For all values of α, there exists a separating equilibrium, in which only good banks obtain financing. The equilibrium contract is specified as (X_s^s, X_f^s, k^s) derived from Eq. IV.8 and Eq. IV.9.

ii) If $\alpha > \alpha_g$, there exist multiple pooling equilibria, where both types of banks invest, and good banks obtain profit $P_g \geq P_g^s$, by proposing a contract specified as $X_b \in [\eta, S]$.

IV.3.4 Capital regulation choice of regulator

Suppose that there exists a benevolent regulator whose objective is to maximise net social surplus. From his perspective, a higher profit good banks pursued is just a transfer between banks and investors, which is therefore not valued. Thus, the regulator may have different preferences in equilibrium choice, which gives a rationale for the regulator's intervention.

First, we show that the regulator may prefer a separating equilibrium which is eliminated in the unregulated situation, or a pooling one which cannot be pinned down. For the separating equilibrium, the regulator, considering social welfare

$$W^s = \alpha[NPV + (z-1)(1-k)] + (1-\alpha)(z-1) \quad \text{(IV.12)}$$

, may prefer one in which good banks can raise more funds from investors, reducing the costly capital k. The equilibrium located at the intersection of $\Pi_g = zk$ and $X_f = S$ is feasible, shown as the green dot in Fig. IV.1a. It can be characterised as follows:

$$\begin{aligned} X^s_{s_R} &= R - \frac{B}{\Delta p} \\ X^s_{f_R} &= S \end{aligned} \tag{IV.13}$$

, and

$$k^s_{_R} = \frac{p_{_L}\frac{B}{\Delta p}}{z} \tag{IV.14}$$

Among the candidate pooling equilibria, the regulator, considering social welfare

$$W^p = NPV - (1 - p_{_H})(1 - \alpha)S + (z - 1)(1 - k) \tag{IV.15}$$

, may prefer one in which the size of the banking sector can be maximised, shown as the intersection of $\gamma^p = 0$ and $X_f = S$ (red dot) in Fig. IV.2a, characterised as:

$$\begin{aligned} X^p_{s_R} &= R - \frac{B}{\Delta p} \\ X^p_{f_R} &= S \end{aligned} \tag{IV.16}$$

, and

$$k^p_{_R} = p_{_L}\frac{B}{\Delta p} - NPV + (1 - \alpha)(1 - p_{_H})S \tag{IV.17}$$

We then show that the regulator may prefer the pooling equilibrium from another threshold of the proportion of good banks $\alpha_{_R}$. From the regulator's perspective, the pooling equilibrium is desired when it can generate a higher social welfare $W^p(k = k^p_{_R}) > W^s(k = k^s_{_R})$, from which a threshold on the good bank's proportion can be derived.

$$\alpha > 1 - \frac{(z-1)[zNPV - (z-1)p_{_L}\frac{B}{\Delta p}]}{z[z(1-p_{_H})S] - [zNPV - (z-1)p_{_L}\frac{B}{\Delta p}]} \equiv \alpha_{_R} \tag{IV.18}$$

In a pooling equilibrium, there is a social cost of accommodating value-destroying bad banks, which decreases with the proportion of good banks. Meanwhile, accommodating bad banks may also increase the size of the banking sector. As the good banks' proportion increases to $\alpha_{_R}$, the social cost can be covered by the benefit of a larger banking sector, prompting the regulator's preference to shift from the separating equilibrium to the pooling equilibrium.

As shown in Section IV.3.2, good banks follow a similar process but consider the mispricing cost of accommodating bad banks and the separation cost to establish a different threshold α_g. Next, we compare the magnitudes of these two thresholds to identify the range of overlap between the good banks' and the regulator's preferences on equilibrium types, in order to determine when and how the regulator should intervene.

Lemma IV.10. *The magnitude of α_g and α_R depends on the value of z.*

- *α_g lies in the range $(0, \alpha_R)$ when $z > \underline{z}$*
- *α_R lies in the range $(0, \alpha_g)$ when $z < \underline{z}$*

Proof. From Eq. IV.18, $\alpha_R > 0$ if:

$$zNPV - (z-1)p_L \frac{B}{\Delta p} < z(1-p_H)S \Rightarrow z(p_H R - 1 - B) < (z-1)p_L \frac{B}{\Delta p} \quad \text{(IV.19)}$$

$z > 1$, and $p_H R - 1 - B < 0$ due to Assumption IV.2. Therefore, the above condition is always satisfied, and $\alpha_R > 0$.

From Eq. IV.11, $\alpha_g > 0$ if:

$$(z-1)(zNPV - (z-1)p_L)\frac{B}{\Delta p} < (z - p_H)z(1-p_H)S \quad \text{(IV.20)}$$

$z > 1 > p_H$, and $zNPV - (z-1)p_L \frac{B}{\Delta p} < z(1-p_H)S$ from above. Therefore, this condition is also always satisfied, and $\alpha_g > 0$.

Comparing these two, Eq. IV.18 and Eq. IV.11, we can get $\alpha_R > \alpha_g$ if:

$$zNPV - (z-1)p_L \frac{B}{\Delta p} > zp_H(1-p_H)S \Rightarrow z < \frac{p_L \frac{B}{\Delta p}}{p_L \frac{B}{\Delta p} - NPV + p_H(1-p_H)S} \equiv \underline{z} \quad \text{(IV.21)}$$

$\underline{z} < \bar{z}$. Therefore, the above condition is possible. And vice versa, $\alpha_R < \alpha_g$ if $z > \underline{z}$. □

Lemma IV.10 shows, depending on the magnitude of the cost of capital, there exists a situation where good banks prefer to pool while the regulator prefers to separate, or vise verse. As the cost of capital increases, the cost of maximising the banking sector also rises, reducing the regulator's incentive to pool with bad banks. Proposition IV.2 and Proposition IV.3 summarise when and how the regulator intervenes.

Proposition IV.2. *If the cost of capital is high* $z \in (\underline{z}, \bar{z}]$*, then*

i) for $\alpha > \alpha_R$*, the regulator prefers the pooling equilibrium with* $(S,\, k^p_R)$ *and can achieve it by imposing a leverage requirement on the banks.*

ii) for $\alpha \leq \alpha_R$*, the regulator prefers the separating equilibrium with* $(S,\, k^s_R)$ *and can achieve it by setting minimum collateral* $X_f = S$ *and capital requirement* $k = k^s_R$*.*

Proof. Suppose $z \in (\underline{z}, \bar{z}]$, that is $0 < \alpha_g < \alpha_R$.

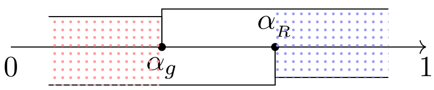


Figure IV.3: $z \in (\underline{z}, \bar{z}]$

When the proportion is large, $\alpha > \alpha_R$ (blue shaded area in Fig. IV.3), both good banks and the regulator are willing to accommodate bad banks. However, the regulator prefers a pooling equilibrium with $(S,\, k^p_R)$ (red dot in Fig. IV.2a), which is possible but cannot be pinned down in the unregulated equilibrium (Lemma IV.8). Despite there being no divergence between the attitudes of good banks and the regulator towards bad banks in this case, some inefficient equilibria cannot be ruled out due to off-equilibrium beliefs of investors. The regulator may then need to set a minimum leverage requirement to rule out those inefficient equilibria.

When the proportion is small, $\alpha \leq \alpha_g$ (red shaded area in Fig. IV.3), both good banks and the regulator are willing to separate. The regulator prefers a separating equilibrium located at $(S,\, k^s_R)$ (green dot in Fig. IV.1), however, the unregulated separating equilibrium is located at the orange dot with $(X^s_f,\, k^s)$. A minimum collateral requirement $X_f = S$ can effectively rule out the orange dot. However, this restriction may lead the good bank to prefer pooling with bad banks, pursuing lower capital to increase its own profit, making some pooling equilibria possible (e.g., red dot in Fig. IV.2b, which is closer to the origin than the green dot). To ensure the separation, a minimum capital requirement $k = k^s_R$ should be combined.

Consider the case of $\alpha_g < \alpha \leq \alpha_R$. Good banks prefer to pool with bad banks (shown as the case in Fig. IV.2a), while the regulator prefers the separating equilibrium with $(S,\, k^s_R)$ (green dot). A minimum capital requirement $k = k^s_R$ can rule out those pooling equilibria but may make the unregulated separating equilibrium (orange dot) possible. A minimum collateral requirement $X_f = S$ should also be imposed. □

Proposition IV.3. *If the cost of capital is low $z \in (1, \underline{z}]$, then*

i) for $\alpha \geq \alpha_g$, the regulator prefers the pooling equilibrium with $(S,\ k^p_R)$ and can achieve it by imposing a leverage requirement on the banks.

ii) for $\alpha_R \leq \alpha < \alpha_g$, the good bank prefers the separating equilibrium with $(X^s_f,\ k^s)$, but the regulator prefers the pooling equilibrium with $(S,\ k^p_R)$ and can achieve this by setting the minimum collateral $X_f = S$.

iii) for $\alpha < \alpha_R$, the good bank prefers the separating equilibrium with $(X^s_f,\ k^s)$, but the regulator prefers the separating equilibrium with $(S,\ k^s_R)$ and can achieve this by setting minimum collateral $X_f = S$ and capital requirement $k = k^s_R$.

Proof. Suppose $z \in (1, \underline{z}]$, that is $0 < \alpha_R < \alpha_g$.

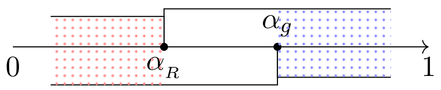


Figure IV.4: $z \in (1, \underline{z}]$

When the proportion is large, $\alpha > \alpha_g$ (blue shaded in Fig. IV.4), both good banks and the regulator prefer the pooling equilibrium. However, there is a continuum of pooling equilibria in the unregulated equilibrium. Similar to the above, the regulator needs to set a minimum leverage requirement to rule out inefficient equilibria and to locate the equilibrium at (S, k^p_R).

When the proportion is small, $\alpha \leq \alpha_R$ (red shaded in Fig. IV.4), both good banks and the regulator are willing to separate. However, they may favour different equilibria due to different objectives. Similar to the above, the regulator needs to impose a minimum collateral $X_f = S$ and capital requirement $k = k^s_R$, forcing good banks to implement the separating equilibrium at (X^s_f, k^s).

Considering the case of $\alpha_R < \alpha \leq \alpha_g$. The regulator prefers the pooling equilibria at $(S,$ $k^p_R)$, shown as the red dot in Fig. IV.2b, while the good bank prefers to separate (orange dot). After the regulator imposes a collateral requirement $X_f = S$, the good banks' dominance in the failure state is diluted, leaving it no choice but to pool with bad banks to earn more profit. $\square$

IV.4 Empirical implications

Our analysis implies that banks could mitigate adverse selection and moral hazard problems through specific financing contract. This may provide a rationale to banks' increasing use of the off-balance sheet funding mode with voluntary support. In the optimal contract above, $X_f^s < S$ the bank retains some equity in the case of default, which is difficult in a standard debt. While, it can be achieved if the bank finances the project off-balance sheet, and then provides k^s through a senior debt and commit to voluntary support other investors in the case of default. Consistent with this prediction, banks prefer to securitise better-quality assets in a setting with asymmetric information (Greenbaum and Thakor, 1987; Duran and Lozano-Vivas, 2013). However, our analysis also shows that a standard debt where banks compensate the whole scrap value to investors in the case of default is better for the social welfare.

Our analysis additionally suggests dynamic regulations in response to the composition of the financial system: as the economy becomes prosperous, leverage requirements may be more advantageous than capital requirements. In an economy prosperity, the proportion of good banks is high. Banks' equity can be retained under leverage requirements, which is conducive to expanding the banking sector. While, ruling bad banks out is more important if there are too many value-destroying bad banks in the market, and capital requirements is more appropriate in favour to separate.

IV.5 Conclusion

We consider a model involving two information frictions: an ex-post moral hazard problem related to the bank's choice of the probability of default, and ex-ante asymmetric information regarding heterogeneous losses given default. After emphasising agents' own incentives and abilities, we demonstrate that regulatory intervention may not be essential to mitigate these information frictions, which relaxes the assumption about the regulator's superior information regarding bank type. We also show that, from the perspectives of either good banks or the regulator, the desire to rule out bad banks and separate shifts to accommodate and pool as the asymmetric information problem becomes mild, though at different points due to their differing focuses. Therefore, we provide a novel rationale for imposing capital requirements, to correct the divergence between individual banks acting in their own self-interest and the aspirations of the regulator considering the overall social welfare. Our analysis implies that the regulator can improve upon the unregulated equilibrium through minimum capital requirements in conjunction with other regulations, even if he has no superior information.

Chapter V

Conclusion

Information frictions are pervasive in credit markets, leading to market inefficiencies. Banks act as intermediaries, playing a crucial role in the market by converting savings into investments and facilitating market development. The primary objective of this thesis is to better understand banks' behavior in the face of information frictions, contributing to the regulator to improve market efficiency. This thesis comprises three separate essays focused on banks suffering from adverse selection and effort moral hazard.

The first essay (Chapter II) constructs a model where a bank has two investment opportunities: the first suffers from an effort moral hazard problem and the second suffers from an adverse selection problem, and shows that through on-balance sheet funding with cross-subsidisation across projects, a full separating equilibrium arises, and the outcome is efficient (second-best) even when the bank is restricted from committing to borrowing from the same investor in both periods. In our solution, expected profits from projects associated with adverse selection are used to induce higher effort provision in projects subject to effort moral hazard. Thus, our analysis uncovers a novel channel through which banks can create value: cross-subsidisation across projects that relaxes the effort moral hazard constraint and boosts effort provision. Furthermore, it relates the emergence and rise of Private Debt funds in recent years with the advantages of the on-balance sheet funding mode.

The second essay (Chapter III) constructs a model where the bank's first investment suffers from an effort moral hazard problem, while the second one may suffer from an adverse selection problem if the asymmetric information arises after the first fails due to a systematic shock. In this essay, we introduce creditor rights associated with the highest repayment committed by banks and emphasise that the feasibility of off-balance sheet financing in mitigating the adverse selection problem is implicitly conditional on strong creditor rights, which provides a new perspective for interpreting the divergent empirical results on the adverse selection hypothesis for the off-balance sheet activities, shown in Duran and Lozano-Vivas (2013). We additionally show that debt contract financing works in alleviating the adverse selection problem under fewer conditions. Furthermore, if the regulator could encourage banks to link the financing of two investments together, debt contract financing dominates, since the limited liability created by off-balance sheet financing weakens the incentive of banks to compensate investors after failure, exacerbating the moral hazard problem. Moreover, although there are no implicit conditions for debt contract financing to function, we still argue for strong creditor rights, on which a greater social surplus could be achieved.

The essays above demonstrate that off-balance sheet financing is not optimal in resolving the given information frictions in the current setting. Therefore, my further research may continue to explore different combinations of frictions to provide a rationale for off-balance sheet funding with voluntary support.

The third essay (Chapter IV) focuses on capital requirements and provides a novel rationale for imposing them. Existing literature explores it based on the assumption that the regulator has superior information about the bank type, suggesting that risk-sensitive capital requirements should be imposed to mitigate information frictions, and that separation can be implemented when the regulator has sufficiently accurate bank type information. This part constructs a model where a bank funds a project using costly capital and borrowed funds, suffering from two information frictions: an ex-post moral hazard problem related to the bank's choice of the probability of default and ex-ante asymmetric information regarding heterogeneous loss given default. We emphasise agents' own incentives and abilities and present that these information frictions may be solved without regulatory intervention. Furthermore, we also show that, from the perspectives of the regulator and good banks, the desire to rule out bad banks shifts to accommodate and pool with them as the asymmetric information problem becomes mild, though at different points. This divergence provides a rationale for imposing regulations. Capital requirements can be imposed, in combination with other regulations, to rectify the divergence between individual banks acting in self-interest and the aspirations of the regulator.

This essay theoretically rejects risk-sensitive capital requirements based on the assumption that the regulator has no superior information. My further research may empirically examine regulatory effectiveness in countries where regulators have limited information, testing this model in real-world banking systems.

The models we have used in this thesis are simple, and the analysis conducted should be seen as an inspiration for future work. However, the character of our insights and analyses remain unchanged. In closing, we re-emphasise the incentive and flexibility of intermediaries in the face of information frictions as the basis for understanding their behaviours. We hope this could contribute to future theoretical research, placing greater emphasis on this.

Appendix A

Appendix to Chapter II

Limited liability constraint at t=2

In the main text, we consider the case the limited liability constraint of the bank at $t = 2$ is not binding. Below, we consider the case in which the limited liability constraint is binding (i.e., $D_{2,3} > R - D_{0,3}$). In this case, the participation constraint of an investor facing a type g bank becomes:

$$\gamma_g = p_g(R - D_{0,3}) - (1 - K) \geq 0 \tag{A.1}$$

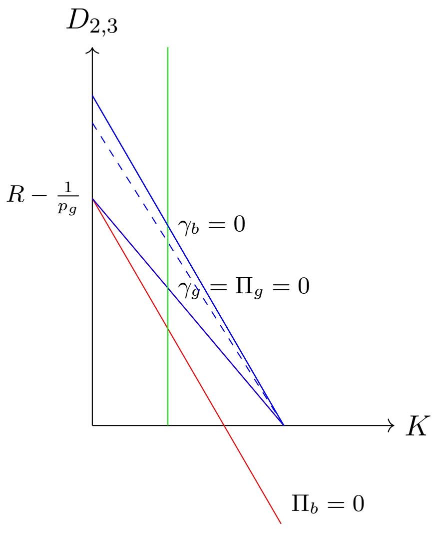


Figure A.1: Feasible equilibria $D_{0,3} > R - \frac{1-K}{p_g}$

When the participation constraint binds we get, $K \geq 1 - p_g(R - D_{0,3})$, which is the green vertical line in the $(K, D_{2,3})$ space in Fig. A.1. For an equilibrium to be feasible, it must lie on or to the right of this green vertical line. When the limited liability constraint is slack (see Fig. II.1a), this line is in the second quadrant and the green line intersects the horizontal axis at $K < 0$, and when it just binds (see Fig. II.1b), it is along the vertical axis. Thus, for $D_{0,3} \leq R - \frac{1-K}{p_g}$, this line does not affect the analysis. When the limited liability constraint is binding, the vertical line appears in the first quadrant, ruling out some of the equilibria. The set of feasible funding equilibria is along the $\Pi_g = \gamma_g = 0$ line, but on or to the right of the green line.

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