Securitization, Implicit Recourse and Investment Efficiency*

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Abstract

A widespread feature of securitzation is the implicit recourse provided by the originator banks. We develop a model of a bank's decision to finance investments either with traditional on-balance sheet debt or through securitization with implicit recourse. When a project failure may lead to asymmetric information about the quality of future investments, the flexibility associated with voluntarily providing recourse improves investment efficiency in the future, because it grants a good bank signaling opportunities in addition to skin-in-the-game. Yet, recourse provision requires the bank to carry spare resources on its balance sheet, which increases the funds raised from external investors above those necessary for investment. We show that securitization with implicit recourse arises when the cost of external funds is not too high. In these cases, the introduction of a ban on implicit recourse decreases the expected surplus in the economy.

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Introduction

Securitization is an important means of funding for banks. Securitization transactions are structured to transfer the credit risk of the underlying assets from the originator bank's balance sheet to that of outside investors. Yet, the *voluntary* provision of recourse to the originator's balance sheet constitutes a widespread feature of securitization (see, e.g. Higgins and Mason, 2004, Gorton and Souleles, 2007, Vermilyea et al., 2008, Acharya et al., 2013), that has been attributed by regulators and practitioners to the reputational concerns of the originating institutions.[1] The numerous instances of voluntary support during the financial crisis, including but not restricted to securitization instruments,[2] have brought renewed interest to the regulation of implicit recourse.[3] However, a better understanding of the rationale for implicit recourse is necessary in order to evaluate the impact of regulatory interventions. In this paper we address the following questions. First, what determines banks' incentives to voluntarily provide recourse ex-post, and how does this affect ex-ante their decisions to originate securitization instruments? Second, what are the consequences of policy interventions that limit the provision of implicit recourse?

This paper develops a model of a bank's optimal decision to finance investment either with *traditional funding,* that consists of the issuance of on-balance sheet debt, or through *securitization,* in which debt funding is raised by an off-balance sheet vehicle. We focus on the following key difference between the two funding modes: When the bank relies on traditional funding and the investment fails, it must use resources on its balance sheet

[1] An example of the rating agency view is: "In effect, there is moral recourse since the failure to support the securitization may impair future access to the capital market." FitchIBCA (1999). The following quote on HSBC's rescue of its two Structured Investments Vehicles (SIVs) during the past financial crisis provides another illustration: "A huge SIV failure, especially if it triggered losses for the holders of its commercial paper, would be a reputational black eye."Financial Times, November 28, 2007.

[2] The most prominent case of implicit recourse to securitization instruments was sponsor banks' rescue of their SIVs in December 2007 (see, e.g. Acharya et al., 2013). Sponsor support in the money market industry was relevant (Brady et al., 2012, and Kacperczyk and Schnabl, 2012). The rescue by Bear Stearns of two of its hedge funds in July 2007 was widely covered by the media.

[3] Following the G20's initiative to strengthen the oversight and regulation of the shadow banking system, the Basel Committee on Banking Supervision has issued in October 2017 guidelines on the identification and management of banks' "step-in risk" in securitization (BCBS, 2017). Note that there were regulatory restrictions on the provision of implicit recourse before the crisis (e.g. Fed Board, SR 02-15, 2002), whose oversight was not sufficient as demonstrated by the widespread provision of implicit recourse clearly shows (Higgins and Mason, 2009, and Fein, 2013).

to satisfy the debt promise. By contrast, when the bank relies on securitization and the investment fails, it is not contractually obliged to repay the vehicle's debt *but* it might nevertheless voluntarily decide to provide recourse to its balance sheet to satisfy (part of) that promise. We show that, when a project failure may lead to asymmetric information about the quality of future investments, the flexibility associated with voluntarily providing recourse enlarges the signaling opportunities of a bank with good projects and improves investment efficiency in the future. Yet, the provision of recourse requires the bank to maintain spare resources on its balance sheet, which must be raised from external investors, in addition to what is necessary to undertake investments. Securitization with implicit recourse thus arises in equilibrium when the cost of external funds is not too high and improves investment efficiency relative to that under traditional funding. In these cases, the introduction of a ban on implicit guarantees decreases the expected surplus in the economy.

We develop a model of a bank with access to two consecutive investment projects. At the initial date the bank can invest in a good project that has a positive net present value (NPV), but there could be asymmetric information when the bank needs to finance the second project. More precisely, we assume that if the first project fails, the second investment opportunity becomes bad with some probability, in which case its NPV is negative. The second project quality is private information of the bank when the payoff of the first investment is realized. Following the return of the first project but before investment in the second project takes place, there may be a publicly observable aggregate shock that renders the bank's investment opportunity negative NPV regardless of its quality.

In order to finance the investments and to manage its on-balance sheet resources, the bank can obtain funds at each of the investment dates from competitive investors who require a positive net return. We assume that external funds can be obtained via two financing modes. The bank may use traditional funding in which it keeps the project on-balance sheet and issues short-term debt. Alternatively, the bank may rely on securitization funding. Namely, the bank creates a new legal entity, a vehicle, which holds the right to the project payoffs and issues short term debt against them. The proceeds from issuing the vehicle's debt are paid to the bank in exchange for the project transfer, and the bank is the residual claimant of the vehicle. In either case, the bank maintains spare funds on-balance sheet if it decides to raise more funds at the initial date than those necessary for investment. The two financing modes crucially differ in the flexibility they grant the bank to use these funds to signal strength should the first project fail and asymmetric information become a concern: While traditional funding obliges the bank to use its on-balance sheet resources to repay debt, securitized funding "protects" the banks' funds and grants the bank discretion on how to use them. On the one hand, the bank can use its funds to signal strength by putting "skin-in-the-game"on the second investment, similarly as in Leland and Pyle (1977). On the other hand, the bank can voluntarily provide recourse to its balance sheet and repay the vehicle debt holders using its on-balance sheet resources (which subsequently leads the bank to raise more external funds for its second investment).

We first show that when the first projects fails and asymmetric information becomes a concern, voluntarily providing recourse constitutes a "money burning" signal of quality.[4] This result is consistent with the interpretation of commentators and regulators that voluntary recourse is driven by the banks' reputational concerns. The signaling properties of voluntary recourse in our model stem from the fact that the gains from signaling quality (in the form of better funding terms for the second investment should information asymmetry persists), relative to the cost of such an action (amounting to a reduction in the available resources that increases external funding needs for the second investment), are larger for a bank with a good second project. For this to be the case, it is crucial that when the bank faces the recourse decision the aggregate state has not yet realized and there is uncertainty regarding whether or not investors will be willing to provide financing for the second project. The intuition is that since no external funding is provided in the low aggregate state because all projects are negative NPV, providing voluntary recourse does not lead to any gains should the low state realize. This renders the action particularly costly for the bad bank. Note that an original feature of voluntary recourse as a money burning signal in the context of our model is that since in equilibrium investors anticipate the bank's recourse decisions, any money "burnt" to provide recourse ex-post is priced in when the securitization debt is issued at the initial date.

When the bank uses securitized funding and the first project fails, it can use its funds to

[4]For examples of money burning to credibly signal private information, see, e.g., Milgrom and Roberts (1986), Daniel and Titman (1995), and Bagwell and Bernheim (1996).

signal strength both by providing recourse to the investors in the first project and by putting skin-in-the game in the second investment. We show that voluntary recourse emerges when skin-in-the-game alone would not able to achieve full investment efficiency. In this case voluntary recourse improves the efficiency of investment in the second project by reducing the probability that a bad project is undertaken. The intuition is that providing recourse is a more costly signal than putting skin-in-the-game due to its money burning features. As a result, recourse is a stronger signal, but also one that is only used as a last resort.

We then study the bank's decisions at the initial date regarding its financing mode and the amount of funds to raise. These choices take into account two considerations. On the one hand, securitized funding protects the bank's on-balance sheet resources when the first project fails, which affords the bank discretion over how to use them and gives rise to signaling possibilities that can improve investment efficiency. By contrast, with traditional funding the bank must exhaust its on-balance sheet resources to repay its debt when the first project fails, leaving no signaling possibilities. On the other hand, in order for the bank to have spare resources to signal strength when it uses securitized funding and the first project fails, the bank must raise additional funds from external investors at the initial date. We show that when the cost of external funds is not too high, securitized funding emerges and improves investment efficiency. Moreover, whenever securitized funding is optimal, there is voluntary recourse with strictly positive probability. This is because it is not optimal for the bank to raise at the initial date a large enough amount of costly external funds to be able to achieve full investment efficiency in the second project only through skin-in-the-game. In fact, voluntary recourse, being a stronger signal than skin-in-the-game, allows the bank to achieve the same investment efficiency while raising a lower amount of external funds.

We use the model to shed novel light on the policy debate on the regulation of implicit recourse. In particular, we consider the ex-ante welfare implications of the introduction at the initial date of a ban on the provision of voluntary recourse. When the ban is introduced, a bank that relies on securitization funding can only put skin-in-the-game in the second investment to signal its quality to investors. We show that, although securitized funding may still dominate traditional funding in this context, the ban nevertheless reduces the expected surplus in the economy. The reason is that putting skin-in-the-game is a weaker signal than providing voluntary recourse, so that the ban on recourse forces the bank to raise a larger amount of costly external funds in order to achieve the same level of investment efficiency, reducing the expected surplus.

Even if allowing voluntary recourse is welfare improving from an ex ante perspective, a bank regulator might be concerned that the ex post provision of recourse reduces bank capitalization. Notice that from an ex ante perspective voluntary recourse has no direct effect on the bank's expected surplus since these transfers are anticipated and priced by the investors in securitized debt, but from an ex post perspective recourse amounts to money burning and has a direct negative effect on banks' net worth. We find that such direct negative effect is more than overcome by the investment efficiency gains induced by the possibility to provide voluntary recourse. Hence, an unexpected ex post introduction of a ban on recourse would reduce banks' expected surplus.[5] The results point to the absence of a time consistency problem in permitting banks to provide voluntary recourse to their securitizations.

Finally, our results are robust to allowing the bank to issue long-term funding. Specifically, we extend the model to allow the bank to obtain funds at the initial date by issuing equity, that is, by promising a fraction of the residual claims of the bank at the final date. We assume that there is no cost difference between equity and the other funding modes so that we can focus on how they affect investment efficiency. Equity funding is in fact similar to securitized funding when a ban on recourse is introduced as they both allow the bank to signal its strength when asymmetric information is a concern albeit only by putting skin-in-the-game in the second investment. The only difference between these two funding modes is that equity financing enables the bank to pledge the expected return of the second project and thus to augment the amount of funds that can be raised. Although the latter is valuable to increase investment efficiency, we show that it is never optimal a funding structure that relies exclusively on equity financing as it foregoes the possibility to use the stronger voluntary recourse signal embedded in securitized funding.

[5]This is in contrast to other signaling games, in which some equilibria are Pareto dominated by the outcome that arises when agents are not allowed to send signals. A classical example of this is a version of Spence (1973) in which education does not increase productivity.

Related literature The main intuition of this paper is related to Boot, Greenbaum and Thakor (1993), who show that unenforceable financial contracts grant the issuer discrretion on whether or not satisfy them, which fosters reputation building. The authors then show that this may lead in equilibrium to the emergence of unenforceable contracts in a context in which enforceable contracts are feasible. Similarly, our paper shows that funding an investment through securitization gives the originator bank discretion over whether or not to voluntarily provide recourse. This in turn allows the bank to signal information to outside investors and is valuable for the bank from an ex-ante perspective.

This paper belongs to the theoretical literature that analyzes the emergence of a shadow banking system that relies on voluntary support from sponsoring institutions.[6] Ordoñez (2014) develops a model of securitization booms and busts, in which providing voluntary recourse has reputation implications. In his paper, banks are restricted to providing voluntary recourse as the only means to signal the quality of their future investments while we focus on how voluntary recourse may emerge in a context in which banks can also put skin-in-the-game to signal quality.[7] There are other contributions in which voluntary support is not driven by signaling/reputational considerations. Gorton and Souleles (2006) and Kuncl (2015) show that voluntary support arises as a form of collusion between the originator banks and investors in securtized assets in a repeated interaction context. Kobayashi and Osano (2012) build a model in which banks voluntarily satisfy implicit guarantees on short-term funded vehicles to avoid the costly liquidation of their long-term assets in some states of the world. From an ex-ante perspective implicit guarantees dominate explicit ones because they lead the bank to liquidate the vehicle assets when it is efficient to do so. Parlatore (2016) builds a model of delegated portfolio management in which the sponsor obtains fees that are proportional to the market price of assets under management and the incentives to provide support depend on these fees.

Our paper is also related to the literature on the emergence of securitized instruments with explicit guarantees. Benveniste and Berger (1987) argue that securitization with explicit

[6]Other theories of shadow banking in which voluntary support considerations are absent include Parlour and Plantin (2008), Dang, Gorton and Holmström (2012) and Gennaioli, Shleifer and Vishny (2013).

[7]Segura (2017) develops a model in which a sponsor bank provides voluntary support to its vehicle in distress for signaling purposes to avoid that investors run on the bank's short-term. Yet, the paper does not analyze the bank's ex-ante decision to create a vehicle.

recourse improves risk sharing among investors with heterogeneous risk aversion. Greenbaum and Thakor (1987) explore the trade off between securitization with explicit credit enhancement, in which the flexibility in the ex-ante choice of the enhancement level allows the bank to alleviate information asymmetry, and deposit funding that allows more efficient risk sharing.

The rest of the paper is organized as follows. Section 1 presents the model set-up. Section 2 proceeds by backward induction to the determination of the optimal funding structure at the initial date. Section 3 analyzes the welfare implications of the introduction of restrictions on the voluntary provision of recourse. Section 4 extends the baseline model to allow long-term funding instruments. Section 5 presents the conclusions of our work. The proofs of the formal results of the paper can be found in the Appendix.

1 The model

There are two periods and two classes of risk-neutral agents: a bank and investors. There is no time discounting. The bank has an investment opportunity at the beginning of each period, whose pay-off realizes at the end of the period. We will henceforth refer to the beginning of the first (second) period,and the end of the first (second) period, as $t = 0, 1$ ($t = 2, 3$), respectively. The bank is endowed with internal funds w_0 at $t = 0$ that, for the sake of simplicity, we assume to be in the interval $0 \leq w_0 < 1$.[8] The bank has access to a zero return storage technology and, without loss of generality, we assume that the bank owners only value consumption at $t = 3$. The investors are deep-pocketed and competitive. The investors have an opportunity cost of funds $r > 1$ per period, i.e. between $t = 0$ and $t = 1$, and between $t = 2$ and $t = 3$.[9] This can stem from the investors' alternative investment opportunities and captures the cost of external financing for the bank.

[8]All the results and intuitions in the paper are valid in the case $w_0 \geq 1$ but some of the analytical expressions we derive might change. For the sake of simplicity we thus focus only on the $w_0 < 1$ case.

[9]The assumption is consistent with interpreting the time interval between $t = 1$ (end of the first period) and $t = 2$ (beginning of the second period) as short relative to the maturity of investment projects. Nevertheless, introducing a discount rate greater than 1 between dates $t = 1$ and $t = 2$ would not change our results. It would only constitute an additional cost for long-term sources of financing such as equity that would reinforce our results in Section 4.

Investment opportunities At $t = 0$, the bank's first investment opportunity requires 1 unit of funds, and pays off at $t = 1$ either $R_1 = R$ with probability p_g, or $R_1 = 0$ otherwise. The payoff of the investment at $t = 1$ is publicly observable. The first investment opportunity is of good (g) quality. That is, we assume that its expected payoff is large enough for the bank to be able to obtain external financing:

Assumption 1 $p_g R > r$

If the bank invests at $t = 0$, then it has a second investment opportunity at $t = 2$ that requires 1 unit of funds and pays off at $t = 3$ either $R_3 = R$ with probability p_2, or $R_3 = 0$ otherwise. The success probability of the second investment depends on the quality of the bank's investment opportunity $\theta \in \{g, b\}$, which is privately observed by the bank at $t = 1$, as well as the aggregate state of the world $\Omega \in \{H, L\}$, which is observed by all agents at $t = 2$. The success probability of a good (g) project is higher than that of a bad (b) project in all aggregate states, and the realization of the low aggregate state ($\Omega = L$) reduces the success probability of both types of projects.

The quality of the second project depends on the realization of the first project. If the first investment returns $R_1 = R$ at $t = 1$, the second project is good with certainty. However, if the first investment returns $R_1 = 0$ at $t = 1$, the second project is good with probability $\alpha \in (0, 1)$. The probability that the low aggregate state realizes at $t = 2$ is $q \in (0, 1)$, independently of the realization of R_1.

We characterize next the success probabilities of each bank's project for each aggregate state. In the high state ($\Omega = H$), a g investment succeeds with probability $p_2 = p_g$, whereas a b investment succeeds with probability $p_2 = p_b$, with $p_b < p_g$. We assume that a bank with a b project would not find it optimal to fund it with its own funds when $\Omega = H$, i.e.:

Assumption 2 $p_b R < 1$.

We also assume that:

Assumption 3 $\alpha < \overline{\alpha} \equiv \frac{r - p_b R}{p_g R - p_b R}$.

Note that $\overline{\alpha}$ is defined to satisfy the inequality $[\overline{\alpha}p_g + (1-\overline{\alpha})p_b]\,R = r$ and thus the assumption states that an imperfectly informed investor that believes a bank is good with probability α is not willing to entirely finance its project even in the high state.

In the low state ($\Omega = L$), on the other band, the bank's investment opportunities succeed with probability $p_2 = p_\theta - \Delta$, for $\theta \in \{g, b\}$. We assume that even a bank with a good project would not find it optimal to fund it with its own funds when $\Omega = L$, i.e.:

Assumption 4 $(p_g - \Delta)R < 1$.

Figure 1 describes the distribution of bank types and the probability of success of their projects at $t = 2$ for all the possible contingencies. Our assumptions are such that, on the one hand, investment at $t = 2$ only takes place in state H and, on the other, asymmetric information between the bank and investors arises at $t = 1$ if the first project fails. Since the bank needs external funds to invest in the second project, it has incentives to signal its quality. The bank can do so at $t = 1$ and/or at $t = 2$. Crucially, as we will see, attempts to signal quality at $t = 1$ face the risk of being useless, as the state of the economy could be L and no investments take place. This renders signals sent at $t = 1$ especially costly.

Financing choices In order to invest in the projects, the bank can use a combination of its own funds and external funds raised from investors. In the baseline model we restrict to short-term financing possibilities and we discuss in Section 4 the effect of allowing for alternative longer-term funding instruments such as equity.

To study the bank's choice to securitize, we allow the bank to raise external financing through either *traditional funding* or *securitization* at $t = 0$. If the bank uses traditional funding, it keeps the projects on its balance sheet, and issues one-period bank debts, backed by the returns of the projects and any other funds in the bank.

Alternatively, the bank raises external financing through securitization. To do so, the bank sets up an off-balance sheet vehicle, to which the project is transferred. The vehicle raises external financing by issuing one-period debts backed only by the project returns. The bank is the residual claimant of the vehicle. Crucially, should the project pay-off not be sufficient to repay the debt, the bank has discretion on whether or not to use its own funds

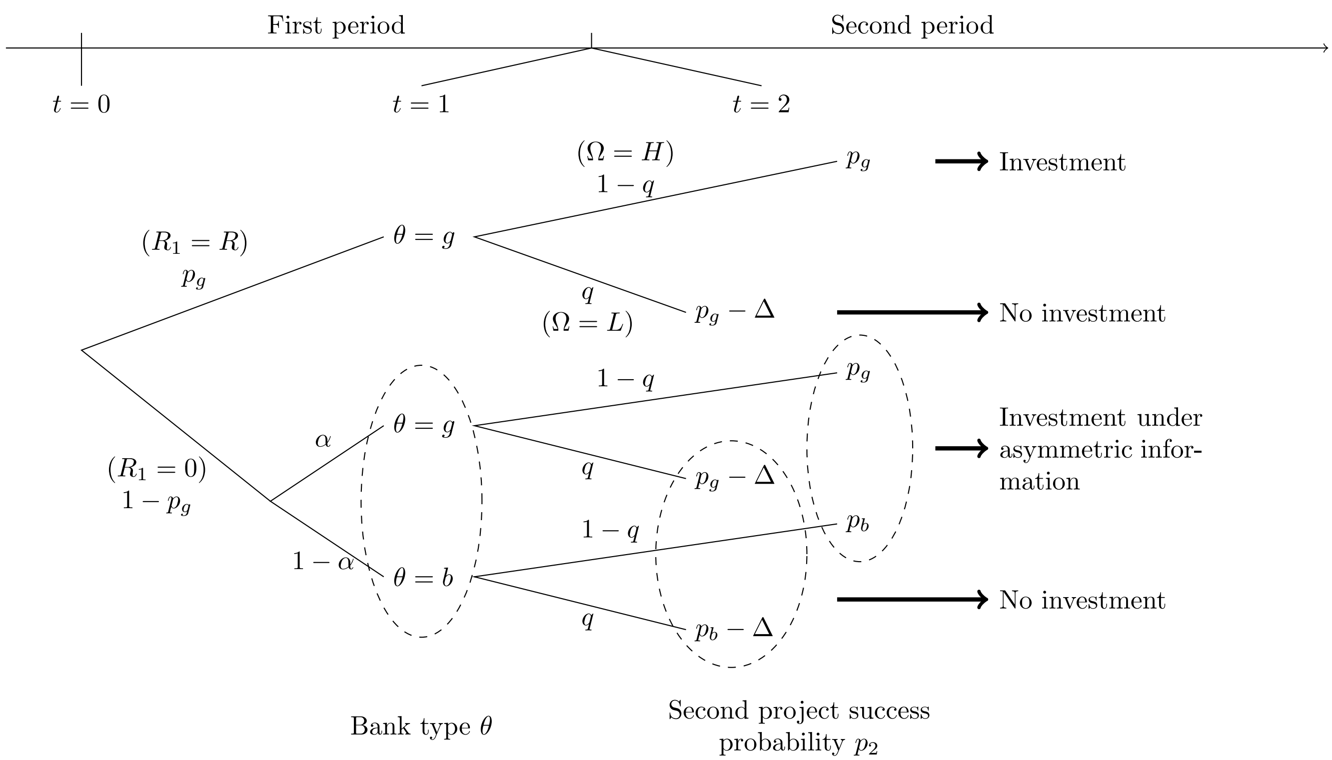

Figure 1: Distribution of the second project's success probability p_2. Dashed circles represent the information set of uninformed investors.

to support such repayment. That is, the bank may choose to *voluntarily provide recourse.* This contrasts with the case of traditional funding, where the bank is obligated to repay its creditors with its own funds (and, if they are not sufficient, with a claim on its future payoffs) when the project fails.

More precisely, the sequence of decisions is as follows. At $t = 0$, the bank first decides whether to finance its first investment through traditional funding or through securitization. The bank then chooses the promised repayment to outside investors $D_1 \in [0, R]$ contingent on investment. Competitive investors bid the amount of funds to contribute, d_0. Financing fails and the bank is unable to invest if $w_0 + d_0 < 1$. Assumption 1 ensures that it is optimal for the bank to invest in the project and that a sufficiently large promised repayment will allow the bank to obtain the required external funds. So we assume from now on that there is investment in the first project. It follows that the amount of funds held by the bank at the beginning of $t = 1$ is given by

$$w_1 = w_0 + d_0 - 1. \tag{1}$$

At $t = 1$, the return of the first investment realizes. If the first project returns $R_1 = R$, then the outside investors are paid in full. If the bank finances its first project through securitization, the residual payoff $R - D_1$ of the vehicle is paid to the bank. Then regardless of whether the bank uses traditional funding or securitization, the amount of funds held by the bank at the beginning of $t = 2$ is given by

$$w_2 = w_1 + R - D_1.$$

Instead, if the first project returns $R_1 = 0$, the debt repayment depends on whether the bank uses traditional funding or securitization. If the bank relies on traditional funding, it uses its own funds w_1 to repay D_1. If $w_1 < D_1$ the bank is not able to repay the debt in full and needs to roll-over an amount $D_1 - w_1 > 1$. Should investors not be willing to refinance the residual short-term debt the bank defaults and looses access to the second project. In either case, conditional on not defaulting at $t = 1$ the amount of funds held by the bank at the beginning of $t = 2$ is given by

$$w_2 = (w_1 - D_1)^+.$$

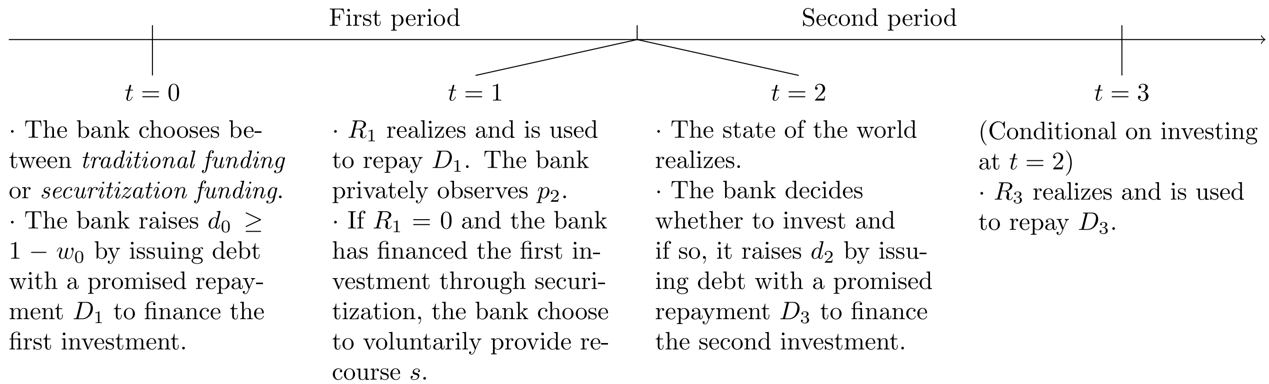

Figure 2: Sequence of decisions and events

If the bank uses securitization, the bank is not obliged to use its own funds w_1 to repay the vehicle's debt when the first project returns $R_1 = 0$. However, the bank can *voluntarily* provide recourse $s \in [0, \min\{w_1, D_1\}]$ to its own balance sheet, meaning that the bank uses s units of its own funds at $t = 1$ to repay the vehicle investors (part of) the D_1 promise. We assume that the recourse decision of the bank s is observable by all investors. It follows that the amount of funds held by the bank at the beginning of $t = 2$ is given by

$$w_2 = w_1 - s.$$

Suppose the bank has not defaulted at $t = 1$, then after the realization of the aggregate state Ω at $t = 2$, each type of bank decides whether to invest in its second project and chooses the financing mode. It is easy to prove that since the economy ends at $t = 3$ and there are no signaling incentives at that date, the two financing choices are equivalent. For the sake of concreteness we assume thus that the funding of investment at $t = 2$ is through securitization. If the bank decides to invest, it chooses the promised repayment to outside investors $D_3 \in [0, R]$ contingent on investment and backed by the project payoff. Competitive investors bid the amount of funds to contribute, d_2. Financing fails and the bank is unable to invest if $w_2 + d_2 < 1$. If investment is underaken and the project fails at $t = 3$ ($R_3 = 0$) then the bank does not provide recourse.

The sequence of decisions and events is summarized in Figure 2.

We use the concept of sequential equilibrium and the D1 refinement of Cho and Kreps

(1987) to refine off-equilibrium beliefs where possible.[10]

2 Equilibrium analysis

We proceed to solve the model by backward induction. We first consider the bank's investment and financing decisions at $t = 2$. We then analyze the bank's voluntary recourse decision at $t = 1$ when that possibility arises. Finally we analyze the bank's investment and financing decisions at $t = 0$.

2.1 The investment and financing decisions at $t = 2$

At $t = 2$ the bank has an investment opportunity. We take the bank's own funds at this date, w_2, as given. If the aggregate state is L then all projects are negative NPV and there is no investment. Let us henceforth focus on the H aggregate state. We can distinguish between two cases, depending on the return of the first project.

Consider first the case $R_1 = R$ at $t = 1$, which implies that the bank is good with certainty. Assumption 1 and the fact that external funds are costly immediately imply that:

Lemma 1 *Suppose $R_1 = R$ at $t = 1$ and the aggregate state at $t = 2$ is H. Then the bank invests in the project and finances the investment with as much internal funds as possible, i.e., with $\min\{w_2, 1\}$ own funds.*

Consider next the case $R_1 = 0$ at $t = 1$, so that at $t = 2$ there is information asymmetry on the quality of the bank. Let α_2 denote the investors' updated belief about the probability that the bank is good at $t = 2$ given all information available. The investment and financing decisions of each bank type are characterized in the following lemma.

Lemma 2 *Suppose $R_1 = 0$ at $t = 1$, the aggregate state at $t = 2$ is H, and $w_2 > 0$. Let α_2 be investors' belief about the bank quality. There exists a unique equilibrium which is characterized as follows:*

[10] This is a commonly used refinement. In the context of financing decision with asymmetric information, see, for example, Nachman and Noe (1994) and DeMarzo and Duffie (1999). We summarize how to apply this refinement at the beginning of the Appendix.

- *The good bank finances the investment with as much internal funds as possible, i.e., with* $\min\{w_2, 1\}$ *own funds and raises the remaining funds needed* $(1 - w_2)^+$ *from outside investors with a promised repayment* $D_3^*(w_2, \alpha_2)$*, where* $D_3^*(w_2, \alpha_2)$ *is decreasing in* w_2 *and in* α_2*.*

- *There exists* $\bar{w}_2 < 1$*, such that the bad bank mimics the good bank and invests with positive probability if* $w_2 < \bar{w}_2$*, and does not invest if* $w_2 \geq \bar{w}_2$*.*

$\bar{w}_2$ *is defined by*

$$p_g \left[R - \frac{r(1 - \bar{w}_2)}{p_g} \right] = \bar{w}_2 \tag{2}$$

As in Myers and Majluf (1984), a good bank is more willing to use its own funds in order to invest in the project than a bad bank. The reason is that by using internal funds a bank reduces the promised repayment to debt investors and increases the payoff to the bank conditional on project success, which is a more likely event for the good bank. As a result, putting "skin-in-the-game" is a signal of good quality and in equilibrium the good bank always invests and exhausts its internal funding capacity.[11]

In deciding whether or not to invest, the bad bank trades-off the costs of contributing its own wealth to fund a negative NPV project and the benefits from the overpricing of the debt issued to raise external funds. The cost of mimicking is greater if the bank must contribute a larger amount of own funds. When the bank has sufficient internal funds $w_2 \geq \bar{w}_2$, mimicking is unprofitable for the bad bank and only good projects are funded. Instead, when $w_2 \in (0, \bar{w}_2)$, the bad bank mimics the good bank with some probability, which leads to underpricing of the debt issued by the good bank. Such underpricing and the cost associated with it, decrease with investors perception on the bank's quality (that is, $D_3^*(w_2, \alpha_2)$ is decreasing in α_2). As we will see in the next section, voluntary recourse to a securitization structure at $t = 1$ will arise as a way for a good bank to improve investors perception of its quality at $t = 2$.

[11] Let us highlight that this result does not rely on the assumption that the cost r of external funds is above 1 but on the signaling properties of using own funds to invest in the project. In fact the result still holds for $r < 1$ provided that $p_g R \geq 1$.

We conclude the section with a final technical comment. Lemma 2 characterizes the unique equilibrium at $t = 2$ conditional on $R_1 = 0$ and $\Omega = H$ for any $w_2 > 0$. The limit of these equilibria as $w_2 \to 0$ is an equilibrium for $w_2 = 0$. However, there exists also a continuum of other welfare equivalent equilibria for $w_2 = 0$ in which $D_3^* = R$.[12] Without loss of generality, for the remainder of the analysis we focus for $w_2 = 0$ on the limit of the equilibria described in Lemma 2.

2.2 The recourse decision at $t = 1$

Suppose that the bank financed the first project through securitization with a promise $D_1 > 0$ and that at $t = 1$ the project returns $R_1 = 0$ so that the debt cannot be repaid out of the project payoff. Yet, the bank can use its own funds to *voluntarily* provide a recourse to its own balance sheet of amount $s \leq w_1$ that covers part of the D_1 promise to the investors. Why should a bank grant such a "gift" to the securitization debt investors? In this section, we study how the asymmetric information on bank quality that follows the failure of the first project provides signaling incentives for the banks to provide voluntary recourse and characterize the resulting equilibrium outcome.

Let w_1 be the bank's own funds at $t = 1$ and let us focus on the interesting case in which $w_1 > 0$. Recall that, conditional on the failure of the first project at $t = 1$, the bank has private information about the quality of its second investment, while imperfectly informed investors believe that the second investment is good with probability α. With probability $1 - q$, the aggregate state at $t = 2$ is $\Omega = H$. In this case, Lemma 2 states that if a good bank does not have sufficient own funds, it suffers from an underpricing in the issuance of the debt to finance the investment at $t = 2$. This underpricing is more severe the lower the investors' perception α_2 on the bank quality at $t = 2$. A good bank thus has incentives to take actions at $t = 1$ to improve its perceived quality.

[12] The limiting equilibrium is such that a good bank invests with certainty and i) if $\alpha > \bar{\alpha}$, then the bad bank mimics with certainty and ii) if $\alpha \leq \bar{\alpha}$, then the probability that the bad bank mimics is such that the promised repayment to debt investors is $D_3^* = R$, so that no bank obtains any surplus. There exist also a continuum of equilibria in which a good bank invests with probability less than one and the mimicking behaviour of a bad bank is such that the promised repayment to debt investors remains $D_3^* = R$. Finally, there exists also a pooling equilibrium in which no bank invests. All equilibria for $w_2 = 0$ and $\alpha_2 \leq \overline{\alpha}$ are characterized in the proof of Lemma 2. The limiting equilibrium Pareto dominates the other equilibria, and strictly so for $\alpha_2 > \bar{\alpha}$.

Does providing voluntary recourse $s > 0$ lead to an improvement on the perceived quality of the bank? That will be the case if investors assess that a good bank is "more willing" to provide recourse than a bad bank, or more formally, if the gains associated with such an action relative to its costs are higher for the good bank.

In order to demonstrate that is the case, let us denote by $\Pi_{j,t=1}(w_1, s, \alpha_2)$ the expected surplus as of $t = 1$ of a bank of type j that provides voluntary recourse $s < min\{w_1, D_1\}$ and whose perceived probability at $t = 2$ of being a good bank is α_2. Let us illustrate with the case where w_1, s and α_2 are such that the two bank types pool in their investment decisions if $\Omega = H$ at $t = 2$.[13] Then, using Lemma 1 and Lemma 2, we have that

$$\Pi_{j,t=1}(w_1, s, \alpha_2) = q(w_1 - s) + (1 - q)p_j \left[R - D_3^*(w_1 - s, \alpha_2)\right]. \tag{3}$$

The first term in the expression takes into account that if $\Omega = L$ at $t = 2$, the bank does not invest. The bank keeps its internal funds after the voluntary recourse at $t = 1$, given by $w_2 = w_1 - s$. The second term captures that if $\Omega = H$ at $t = 2$, both bank types invest using all their internal funds and raising additional external funds with a promised repayment of $D_3^*(w_1 - s, \alpha_2)$ (characterized in Lemma 2).

The benefits of providing voluntary recourse come from an increase in investors' perception α_2 that reduces the promised repayment to the investors if $\Omega = H$ at $t = 2$. For a bank of type $j \in \{g, b\}$, they amount to:

$$\frac{\partial \Pi_{j,t=1}(w_1, s, \alpha_2)}{\partial \alpha_2} = -(1 - q)p_j \frac{\partial D_3^*(w_1 - s, \alpha_2)}{\partial \alpha_2} > 0. \tag{4}$$

Notice that a bank benefits from improving its perceived quality at $t = 2$ only when there is a positive probability that $\Omega = H$ at $t = 2$, that is, when $q < 1$. Moreover, since debt is only paid when the project succeeds, the reduction on the required promised repayment $D_3^*(\cdot)$ associated to an increase in α_2 increases the expected surplus of a good bank more than those of a bad bank. In fact, if $q < 1$ the ratio of the marginal benefits to a good bank and a bad bank from improving its perception at $t = 2$ amounts to

$$\frac{\partial \Pi_{g,t=1}(w_1, s, \alpha_2)/\partial \alpha_2}{\partial \Pi_{b,t=1}(w_1, s, \alpha_2)/\partial \alpha_2} = \frac{p_g}{p_b} > 1. \tag{5}$$

[13] From the statement and proof of Lemma 2 we have that if $\Omega = H$ at $t = 2$ the two bank types pool in their investment decisions if $\alpha_2 \geq \bar{\alpha}$ and $w_2 \leq \underline{w}_2(\alpha_2)$, where $\underline{w}_2(\alpha_2)$ is defined in the proof of Lemma 2.

On the other hand, the costs of providing recourse result from a reduction in the bank's funds at $t = 2$. For a bank of type $j \in \{g, b\}$, they amount to:

$$\frac{\partial \Pi_{j,t=1}(w_1, s, \alpha_2)}{\partial s} = -q + (1-q) p_j \frac{\partial D_3^*(w_1 - s, \alpha_2)}{\partial w_2}. \tag{6}$$

A reduction in the bank's funds at $t = 2$ is costly in both aggregate states. Conditional on $\Omega = H$ at $t = 2$, the reduction in the bank's own funds leads to a higher promised repayment $D_3^*(w_1 - s)$, which the good bank repays more frequently than the bad bank. Indeed, conditional on the H state, the ratio of the marginal costs of providing recourse for a good bank and a bad bank amounts again to $p_g/p_b > 1$. Yet, conditional on $\Omega = L$ at $t = 2$, the cost of providing recourse is simply the reduction of the bank's payoff and is the same for the two bank types. Therefore providing recourse is *relatively more costly* for the bad bank in the L state than in the H state. We have thus that if $q > 0$ the ratio of the marginal cost of providing recourse for the good bank than for the bad bank satisfies

$$\frac{-\partial \Pi_{g,t=1}(w_1, s, \alpha_2)/\partial s}{-\partial \Pi_{b,t=1}(w_1, s, \alpha_2)/\partial s} < \frac{p_g}{p_b}. \tag{7}$$

It follows from (5) and (7) that the relative ratio of the marginal gain and cost of providing recourse is indeed greater for the good bank than for the bad bank. That is, the following single-crossing condition is satisfied for $q \in (0, 1)$:

$$\frac{\partial \Pi_{g,t=1}(w_1, s, \alpha_2)/\partial \alpha_2}{-\partial \Pi_{g,t=1}(w_1, s, \alpha_2)/\partial s} > \frac{\partial \Pi_{b,t=1}(w_1, s, \alpha_2)/\partial \alpha_2}{-\partial \Pi_{b,t=1}(w_1, s, \alpha_2)/\partial s} \quad \Leftrightarrow \quad \frac{p_g}{p_b} > 1. \tag{8}$$

It is worth noting that a necessary and sufficient condition for the good bank to have a strictly stronger incentive to provide recourse is that $q \in (0, 1)$. If $q = 1$, there is never investment at $t = 2$ and consequently there are no signaling concerns. If $q = 0$, although the bank has signaling needs, providing voluntary recourse is not a credible signal. In this case, there is always investment at $t = 2$, and both the benefits and the costs of providing recourse accrue to the bank due to the effects on the promised repayment $D_3^*(\cdot)$. As a result, the ratio of the marginal gain and cost of providing recourse is the same for the two bank types and voluntary recourse is not a signal of quality. It is only when $q \in (0, 1)$ and the aggregate state L, in which recourse is relatively more costly for the bad bank, is realized with positive probability that voluntary recourse is a signal of quality.

The properties described above suggest that a good bank will provide voluntary recourse to signal quality when its funds at $t = 1$ are not sufficient to achieve full separation by using skin-in-the game in investment at $t = 2$. By Lemma 2, this is the case for $w_1 < \bar{w}_2$. In this case, voluntary recourse may indeed render separation possible. To see this, suppose a good bank with funds w_1 provides recourse s. A bad bank will not mimic even if by doing so it is perceived as good if:

$$q(w_1 - s) + (1-q)p_b \left[R - \frac{r(1 - w_1 + s)}{p_g}\right] \leq w_1 \quad \Leftrightarrow \quad s \geq \overline{s}(w_1),$$

where the minimum recourse threshold $\overline{s}(w_1)$ leading to separation satisfies

$$\overline{s}(w_1) = \begin{cases} \frac{(1-q)p_b}{qp_g+(1-q)rp_b} \left[(p_g R - r) - \frac{p_g - rp_b}{p_b} w_1\right], & \text{if } w_1 < \bar{w}_2 \\ 0, & \text{if } w_1 \geq \bar{w}_2 \end{cases}. \tag{9}$$

We have that $\overline{s}(w_1)$ is strictly decreasing for $w_1 < \bar{w}_2$. The reason is that the more funds a good bank has, the closer it is to being able to avoid by putting skin-in-the-game that the bad bank invests at $t = 2$, so that the less funds the bank needs to "burn" by providing recourse in order to achieve separation. Also, $\overline{s}(w_1) = 0$ for $w_1 \geq \bar{w}_2$ because in that case separation can be obtained with skin-in-the-game at $t = 2$ alone.

Finally, whenever $w_1 < \bar{w}_2$ and $\overline{s}(w_1) \leq \min\{w_1, D_1\}$ a good bank is not able to achieve separation if it "waits" until $t = 2$ to put skin-in-the-game but can achieve it at $t = 1$ by providing recourse $s = \overline{s}(w_1)$,. This is feasible because amount of recourse required $\overline{s}(w_1)$ is below the natural constraints on maximum recourse, namely, the debt promise D_1 and the bank available funds w_1.[14]

Our arguments so far show that voluntary recourse provides a powerful signal that may enable separation of bank types when their funds at $t = 1$ are limited. The following proposition completes our informal arguments above by providing a characterization of the equilibrium of the voluntary recourse game at $t = 1$.

Proposition 1 *Suppose the bank has financed the first project through securitization with promised repayment $D_1 > 0$, and at $t = 1$ the bank has internal funds $w_1 > 0$ and the first*

[14]Note that the conditions $w_1 < \bar{w}_2$, $\overline{s}(w_1) \leq \min\{w_1, D_1\}$ are mutually satisfied in an interval of positive length because the function $\overline{s}(w_1)$ is continuous and $\overline{s}(\bar{w}_2) = 0$.

project returns $R_1 = 0$. There exists a unique equilibrium of the voluntary recourse game, characterized as follows:

- *The good bank voluntarily provides recourse $s_1^*(w_1, D_1) = \min\{D_1, w_1, \bar{s}_1(w_1)\}$ at $t = 1$ and subsequently invests with certainty if the aggregate state at $t = 2$ is H, where $s_1^*(w_1, D_1) > 0$ for all $w_1 < \bar{w}_2$.*

- *With probability $\pi_1^*(w_1, D_1)$, the bad bank pools with the good bank to provide recourse $s_1^*(w_1, D_1)$ at $t = 1$ and subsequently invest if the aggregate state at $t = 2$ is H. $\pi_1^*(w_1, D_1)$ is decreasing in w_1 and in D_1. $\pi_1^*(w_1, D_1) = 0$ if and only if $\min\{w_1, D_1\} \geq \bar{s}_1(w_1)$.*

The proposition shows that the good bank voluntarily provides recourse whenever its internal funds are insufficient to allow it to fully separate from the bad bank by putting skin-in-the-game in the $t = 2$ investments (that is, when $w_1 < \bar{w}_2$). In this case, the good bank attempts to achieve separation by providing voluntary recourse as this action is more costly relative to its benefits for the bad bank. Recall that, on the one hand, the bad bank is never willing to provide recourse $s \geq \bar{s}_1(w_1)$, and, on the other hand, the maximum amount of recourse a bank can provide is limited by both the promised repayment D_1 and the bank's available funds w_1. The proposition states that whenever $\min\{w_1, D_1\} \geq \bar{s}_1(w_1)$, the constraint on maximum recourse is not binding and the good bank provides recourse $s_1^*(w_1, D_1) = \bar{s}_1(w_1)$ that allows for full separation from the bad bank. Instead, when $\min\{w_1, D_1\} < \bar{s}_1(w_1)$, the maximum recourse constraint is binding and full separation is not feasible. In such a case the bad bank mimics the good bank' recourse and investment decisions with positive probability $\pi_1^*(w_1, D_1)$. As a higher amount of bank funds w_1 and a higher promised repayment D_1 through securitization relaxes such constraint and gives the good bank more capacity for providing voluntary recourse, the probability that the bad bank invests $\pi_1^*(w_1, D_1)$ is decreasing in w_1 and D_1.

We conclude this section with a final technical comment. Proposition 1 characterizes the unique equilibrium of the voluntary recourse game for $w_1 > 0$ and $D_1 > 0$. For $\min\{w_1, D_1\} = 0$, there is no possibility or need to provide recourse, and the bank arrives at $t = 2$ with funds $w_2 = w_1$. The equilibrium outcome in such a case is as described in Section 3.1 and coincides with the limiting equilibrium as $w_1 \to 0$ and/or $D_1 \to 0$ of the recourse game described in Proposition 1. For the sake of notational compactness, we define $s^*(w_1, D_1)$ and $\pi^*(w_1, D_1)$ for $w_1 = 0$ and $D_1 = 0$ as the limit of these equilibrium variables as $w_1 \to 0$ and $D_1 \to 0$, respectively.

2.3 The investment and financing decision at $t = 0$

We now turn to the analysis of the investment and financing decision at $t = 0$. The bank can invest in the first project either with traditional funding or with securitized funding. We analyze next each of the financing modes.

Traditional funding Suppose the bank uses traditional funding and issues debt with promised repayment $D_1 \leq R$. If the bank invests at $t = 0$, then it repays the debt in full if the first project returns $R_1 = R$ at $t = 1$. If instead the project fails and returns $R_1 = 0$, the bank must use its funds w_1 at $t = 1$ to repay the debt holders up to the promised amount D_1. Since the bank own funds at $t = 0$ are $w_0 < 1$, it has to be the case that $w_1 < D_1$. In order to get convinced of this, suppose, by contrast, that $w_1 \geq D_1$ so that the bank would have sufficient funds at $t = 1$ to repay D_1. This would imply that the debt promise D_1 is safe and its competitive price would be $\frac{D_1}{r}$. The inequality $w_1 \geq D_1$ could then be written as

$$w_0 + \frac{D_1}{r} - 1 \geq D_1,$$

which taking into account that $r > 1$ would imply that $w_0 > 1$, a contradiction.

Since for any choice of D_1 it is the case that $w_1 < D_1$, when the project returns $R_1 = 0$ the bank uses all its own funds at $t = 1$ to repay debt and still needs to refinance the unrepaid debt, which amounts to $D_1 - w_1$. Importantly, if the bank does not default at $t = 1$, it arrives at $t = 2$ with no internal funds and with a perceived quality α. If the aggregate state is H, Assumption 3 and Lemma 2 (and the discussion after it) imply that the quality of the project is so low that investors require the entire success pay-off R in order to provide the unit of funds the bank needs to undertake investment. The bank is therefore unable to refinance the $D_1 - w_1$ units of its unrepaid debt and thus defaults.[15]

[15]Notice that the bank default results in no deadweight costs. If we were to allow the bank to default on

It follows that, conditional on investment at $t = 0$, the rational expectations price of the debt is given by

$$d_0^T(D_1)r = p_g D_1 + (1 - p_g)(w_0 + d_0^T(D_1) - 1),$$

where $w_0 + d_0^T(D_1) - 1$ stands for the funds the bank has at $t = 1$ when $R_1 = 0$. Rearranging terms leads to

$$d_0^T(D_1) = \frac{D_1}{r} - \frac{1 - p_g}{r p_g}(1 - w_0). \tag{10}$$

Note that $d_0^T(D_1)$ increases in D_1 at a rate $\frac{1}{r} < 1$. From Assumption 1 it is easy to prove that the bank is able to raise enough funds to invest in the first project if and only if $D_1 \geq \underline{D}_1$ for $\underline{D}_1 \in (0, R)$ satisfying $d_0^T(\underline{D}_1) = 1 - w_0$.

Taking the previous into account and also that outside investors are competitive, the expected surplus of the bank as of $t = 0$, which we denote by $\Pi^T(D_1)$, can be written as:

$$\Pi^T(D_1) = w_0 + \underbrace{\left[\underbrace{(p_g R - 1)}_{\text{NPV first project}} + \underbrace{p_g(1-q)\,(p_g R - 1)}_{\text{NPV second project}} - \underbrace{A^T(D_1)(r-1)}_{\text{External funds cost}} \right]}_{\text{Surplus from } g \text{ projects}}. \tag{11}$$

The interpretation of the surplus decomposition is as follows. The first term captures the bank's initial wealth. The second big term in brackets includes the expected surplus the bank obtains from investment in good projects and is composed of three terms capturing the NPV of the first project, the expected NPV of the investment in good projects at $t = 2$ (that is only when $R_1 = R$ at $t = 1$ and $\Omega = H$ at $t = 2$), and the excess cost of the aggregate expected external funds raised to invest in good projects at $t = 0$ and $t = 2$, respectively. Note that such excess cost is equal to the aggregate expected external funds raised to invest in good projects, which we denote by $A^T(D_1)$, multiplied by the excess cost per unit of external funds, $r - 1$, where $A^T(D_1)$ is given by:

$$A^T(D_1) = d_0^T(D_1) + p_g(1-q)\left(1 - w_0 - d_0^T(D_1) + 1 - R + D_1\right). \tag{12}$$

The first term in the expression above captures the external funds raised for investment in the first project (that is good with certainty), and the second one includes the funds required

the unrepaid debt $D_1 - w_1$ and continue to $t = 2$ without any debt obligation nor any own funds, the bank earns an expected payoff of 0 by Assumption 3 and Lemma 2.

for investment in a good project at $t = 2$ in the H state conditional on first project success. Notice that in (11) and (12) we have used that conditional on failure of the first project the bank defaults and thus there is no investment in either g or b projects at $t = 2$.

The aggregate expected external funds raised to invest in good projects, $A^T(D_1)$, is strictly increasing in D_1. This is so because of two reasons. First, a higher D_1 increases the external funds raised for investment at $t = 0$. Second, since funds raised at $t = 0$ have to be paid back at $t = 1$ at an expected rate $r > 1$, an increase in D_1 leads to a decrease in the funds the bank carries until $t = 2$ conditional on success of the first project.

The surplus decomposition (11) shows that, while raising at $t = 0$ more funds than strictly necessary for investing in the first project reduces the expected surplus due to the excess cost of investors' funds (*external funds cost effect*), it does not allow to improve the efficiency of investment at $t = 2$ (*no investment efficiency effect*). We have thus that:

Lemma 3 *Suppose the bank invests in the first project with traditional funding. There exists* $\underline{D}_1 \in (0, R)$ *such that the bank can raise sufficient funds if and only if* $D_1 \geq \underline{D}_1$ *and the bank's expected surplus is maximized with* $D_1 = \underline{D}_1$.

The lemma states that if the bank invests in the first project using traditional funding then its expected surplus is maximized with the minimum promised repayment such that investment is feasible. This is because when traditional debt is used the contractual obligation to use funds (and, if necessary, future payoffs) to repay debt eliminates the possibility to use them to signal investment quality and improve its efficiency. Since external funds are costly, the bank finds optimal to raise just the minimum required amount to undertake investment at $t = 0$.

Securitized funding Suppose instead that the bank uses securitized funding to invest in the first project. To do so, it sets up a vehicle that issues debt with promised repayment $D_1 \leq R$ at a competitive price $d_0 \geq 1 - w_0$, and contributes its own funds meet any remaining financing needs.

As with traditional funding, if at $t = 1$ the first project returns $R_1 = R$ then the debt is repaid in full. In contrast to traditional funding, if the first project returns $R_1 = 0$, the bank has discretion over whether or not to use some of its resources w_1 to provide recourse for the debt holders. The recourse decisions as a function of the securitized debt promise D_1 and the bank funds w_1 at $t = 1$ is characterized by the recourse $s_1^*(w_1, D_1)$ provided by a good bank and the probability $\pi_1^*(w_1, D_1)$ that a bad bank mimics it at $t = 1$ and $t = 2$, as described in Proposition 1. Let us highlight that when competing at $t = 0$ to buy the vehicle debt promise D_1, investors anticipate the bank's voluntary recourse decisions, which in turn depend on the debt price d_0 via its effect on the bank funds $w_1 = w_0 + d_0 - 1$ at $t = 1$. A rational expectations competitive price $d_0^S(D_1)$ of the securitization debt promise D_1 satisfies the following break even condition for investors

$$d_0^S(D_1)r = p_g D_1 + (1 - p_g)\left[\alpha + (1-\alpha)\pi_1^*(w_0 + d_0^S(D_1) - 1, D_1)\right] s_1^*\left(w_0 + d_0^S(D_1) - 1, D_1\right). \tag{13}$$

The next lemma describes the main properties of securitized funding:

Lemma 4 *Securitization debt with a promised repayment D_1 raises sufficient funds to invest at $t = 0$ if and only if $D_1 \geq \underline{D}_1$. In this case the rational expectations debt price $d_0^S(D_1)$ is unique and strictly increasing in D_1. Moreover, the function $\pi^*(D_1) \equiv \pi_1^*(w_0+d_0^S(D_1)-1, D_1)$ describing the probability that conditional on $R_1 = 0$ a bad bank mimics a good bank in the recourse decision at $t = 1$ and in the investment decision at $t = 2$ in state H, is decreasing in D_1 and strictly so if $\pi^*(D_1) > 0$.*

The lemma states two results. First, the bank is able to raise enough funds to invest only if the debt promise D_1 is sufficiently large and in that case its price is increasing in the promise D_1. Second and more importantly, as the promise D_1 increases, $\pi^*(D_1)$ decreases and the investment efficiency at $t = 2$ is improved. This crucial property results from the bank's lack of contractual obligation under securitized funding to use its own funds at $t = 1$ to repay the debt when the project fails and thus the bank's discretion over how to use its own funds at $t = 1$. In state H following the failure of the first project, this flexibility provides the bank with the means to send signals to investors that improve investment efficiency. In particular, as D_1 increases the bank has more funds at $t = 1$, allowing the good bank to better separate from the bad bank by providing voluntary recourse and subsequently putting skin-in-the-game in the second investment.

The expected surplus of the bank as of $t = 0$, which we denote by $\Pi^S(D_1)$, can be written as:

$$\Pi^S(D_1) = w_0 + \underbrace{\left[\underbrace{(p_g R - 1)}_{NPV\ first\ project} + \underbrace{[p_g + (1-p_g)\alpha](1-q)(p_g R - 1)}_{NPV\ second\ project} - \underbrace{A^S(D_1)(r-1)}_{External\ funds\ cost} \right]}_{Surplus\ from\ g\ projects}$$

$$- \underbrace{(1-p_g)(1-\alpha)(1-q)\,\pi^*(D_1)\,(r - p_b R)}_{Losses\ from\ b\ projects}. \qquad (14)$$

The interpretation of the first two terms in the surplus decomposition expression is analogous to that in the traditional funding case (11). Notice that in contrast to the case with traditional funding, with securitization, conditional on $R_1 = 0$ the bank is able to invest in good projects if $\Omega = H$ at $t = 2$, which is captured by the new term $(1-p_g)\alpha(1-q)(p_g R - 1)$ within the second big term in brackets and also is included in the expression for the expected funds raised to invest in good projects, denoted by $A^S(D_1)$. Similar to the case with traditional funding, we can show that $A^S(D_1)$ is strictly increasing in D_1.[16] The reason is again twofold. First, a higher D_1 increases the external funds raised for investment at $t = 0$. Second, since the additional funds raised at $t = 0$ has to be repaid at $t = 1$ at an expected rate $r > 1$, an increase in the amount of funds raised at $t = 0$ in fact reduces the expected funds the bank carries until $t = 2$. This in turn implies that a higher D_1 also increases the expected amount of external funds required for investment at $t = 2$.

Finally, the last term in (14) includes the expected losses the bank suffers from investing in bad projects at $t = 2$. The factor $r - p_b R$ captures the losses per unit of investment in a bad project and takes into account that, conditional on $R_1 = 0$, if $\pi^*(D_1) > 0$ it is the case that the bank has no funds at $t = 2$ and thus the financing of b projects is entirely provided by outside investors. In addition, the factor $(1-p_g)(1-\alpha)(1-q)\,\pi^*(D_1)$ is the probability as of $t = 0$ that there is invesment in b projects.

The surplus decomposition in (14) thus illustrates the trade-off faced by the bank when deciding its optimal securitized funding debt promise D_1. On the one hand, an increase in D_1 increases the expected aggregate amount $A^S(D_1)$ of costly external funds raised from

[16] This claim as well as other unproven claims in this section are formally shown in the proof of Proposition 2.

investors to undertake g projects (*external funds cost effect*). On the other hand, an increase in D_1 reduces $\pi^*(D_1)$ and thus the expected costs associated with investment in bad projects at $t = 2$ (*investment efficiency effect*).

We can now state the main result of the paper:

Proposition 2 *There exists $\overline{r} > 1$ such that if $r < \overline{r}$, then in equilibrium the bank invests in the first project using securitized funding with promised debt repayment $D_1^* > \underline{D}_1$. Moreover, if the first project fails at $t = 1$ a good bank provides strictly positive recourse with probability one and a bad bank with probability less than one. Finally, the efficiency of investment decisions at $t = 2$ is improved relative to that under traditional funding of the first project.*

The proposition states that securitization with implicit recourse dominates traditional funding when the excess cost of outside funds is not too high. The intuition for this result is as follows. On the one hand, securitization funding enables the bank to maintain internal funds to signal strength through recourse at $t = 1$ and skin-in-the-game at $t = 2$. This improves the bank's investment efficiency at $t = 2$, which is valuable from a $t = 0$ perspective. On the other hand, the ability to signal strength when the first project fails requires the bank to maintain internal funds at $t = 1$, which must be raised at $t = 0$ from outside investors. Since external funds are costly, being able to send signals comes at its cost. The proposition then simply states that when the external funds are not too costly the benefits of being able to improve investment efficiency overcome its costs.

3 Ban on voluntary recourse

In this section we investigate the effects on aggregate welfare and investment efficiency of the introduction of a ban on voluntary recourse provision at $t = 1$. We conduct our analysis both from an ex ante perspective, that is, the impact of the introduction *at* $t = 0$ of a ban on voluntary recourse, and from an ex post perspective, that is, the effect of the unexpected introduction *at* $t = 1$ of a ban on voluntary recourse. Our results show that the limitation of the bank's signaling possibilites has detrimental effects for aggregate welfare and bank surplus both if it is introduced ex ante and if it is introduced ex post.

3.1 Ex ante ban on voluntary recourse

We consider the introduction at $t = 0$ of a ban on voluntary recourse provision at $t = 1$. Note that from an ex ante perspective, since investors are competitive, aggregate welfare coincides with the bank's expected surplus as of $t = 0$. To analyze the effect of the introduction of a ban on recourse on the economy, we first characterize the pricing of securitization debt and the investment efficiency it induces at $t = 2$.

Suppose the bank relies on securitized funding with promised repayment $D_1 \leq R$. In contrast to the case of securitized funding with no ban in the baseline model, if the first project returns $R_1 = 0$, the bank is prohibited from providing any recourse to the debt holders. The debt holders therefore receive a zero repayment. The competitive price $d_0^B(D_1)$, where B stands for "ban", of the securitization debt promise D_1 is simply

$$d_0^B(D_1)r = \frac{p_g D_1}{r} \tag{15}$$

We have the following lemma analogous to Lemma 4:

Lemma 5 *Suppose there is a ban on voluntary recourse. Securitization debt with promised repayment D_1 raises sufficient funds to invest at $t = 0$ if and only if $D_1 \geq \underline{D}_1$. In this case, the competitive debt price $d_0^B(D_1)$ is strictly increasing in D_1. Moreover, the function $\pi^B(D_1) = \pi_1^*(w_0 + d_0^B(D_1) - 1, 0)$ describing the probabiliy that conditional on $R_1 = 0$ a bad bank mimics a good bank in the investment decision at $t = 2$ when the state is H, is decreasing in D_1 and strictly so if $\pi^B(D_1) > 0$.*

Notice that, even when implicit recourse is prohibited, an increase in the securitization debt promise D_1 improves the efficiency of the bank's investment decisions at $t = 2$ by decreasing $\pi^B(D_1)$. Intuitively, a higher promised repayment allows the bank to raise more cash $d_0^B(D_1)$ at $t = 0$. This in turn increases the amount of internal funds the bank has at $t = 2$, $w_2 = w_0 + d_0^B(D_1) - 1$, and its capability to put skin-in-the-game and deter investment in bad projects.

The next formal result is crucial to assess the effects of the introduction of a ban on recourse on welfare in the economy:

Lemma 6 *For any securitization debt promise* $D_1 > \underline{D}_1$ *in an economy with a ban on voluntary support, there exists a securitization debt promise* $D_1' \in (\underline{D}_1, D_1)$ *of the economy without a ban on voluntary support, that leads to the same investment efficiency at* $t = 2$*, that is,* $\pi^*(D_1') = \pi^B(D_1)$*, and whose price* $d_0^S(D_1')$ *satisfies* $d_0^S(D_1') < d_0^B(D_1)$*.*

The lemma states that any investment efficiency level at $t = 2$ that can be achieved through securitization debt in the presence of a ban, can also be attained in absence of a ban with a lower issuance of securitization debt at the initial date. The reason is that voluntary recourse to the first project securitization being a more powerful signal than skin-in-the-game in the second investment (as shown in Proposition 1), it allows to achieve the same level of separation across bank types with a lower amount of funds at the bank at $t = 1$.

In addition, as in the baseline mode, a reduction in the funds raised at $t = 0$ (that have to be paid back at $t = 1$ at an expected rate $r > 1$) also reduces the expected amount of external funds required for investment at $t = 2$.[17] The following proposition thus follows.

Proposition 3 *If* $r < \bar{r}$*, where* $\bar{r}$ *is defined in Proposition 2, then the ex ante* $(t = 0)$ *introduction of a ban on voluntary recourse strictly reduces the expected surplus of the bank as of* $t = 0$*.*

The proposition states that when the cost of external funds is not too high, so that the bank finds convenient to maintain spare resources in its balance sheet to be able to signal its quality and improve investment efficiency at $t = 2$, the ban on recourse reduces the bank's expected surplus from an ex ante perspective. This is because the ban constrains the signaling possibilities of the bank and thus makes it costlier to achieve any given level of investment efficiency.

Notice that from an ex ante perspective, since the investors in securitization debt price in the anticipated voluntary recourse decisions of the bank at $t = 1$, providing recourse is only costly for the bank to the extent that the bank must maintain spare resources, increasing the external funds the bank raises. By contrast, when the effect on the bank's expected surplus of a ban on recourse is assessed from a $t = 1$ perspective, the money burning nature of the signal has to be taken into account. In other words, from an ex-post perspective

[17] This claim is formally shown in the proof of Proposition 3.

the fact that voluntary recourse enlarges the signaling possibilities for a good bank does not necessarily mean that the good bank benefits from such possibility. In fact, it is well known that the equilibria of signaling games may be Pareto dominated by the outcome in an economy in which agents cannot send signals.[18] Should an unexpected ban on recourse at $t = 1$ conditional on $R_1 = 0$ increase the expected surplus of banks from that date onwards, a bank regulator whose objective is to maximize the net worth of banks would suffer a time consitency problem. We address whether or not that is the case in the next section.

3.2 Ex post ban on voluntary recourse

Suppose $r < \bar{r}$, so that the optimal funding choice at $t = 0$ when agents expect recourse to be allowed is as described in Proposition 2. More precisely, the bank invests in the first project using securitized funding with a promised debt repayment $D_1^* > \underline{D}_1$. Following the failure of the first project at $t = 1$, the bank holds internal funds $w_1^* = w_0 + d_0^S(D_1^*) - 1$. If allowed to, the good bank provides voluntary recourse $s^*(w_1^*, D_1^*) > 0$ with certainty, whereas the bad bank mimics and provides voluntary recourse $s^*(w_1^*, D_1^*)$ with probability $\pi_1^*(w_1^*, D_1^*) \in [0, 1)$.

A regulator who is concerned with bank capitalization may wish to ban voluntary recourse at $t = 1$. Indeed, voluntary recourse leads to a transfer of the bank's funds to the securitization debt investors. If the L aggregate state realizes and the bank does not invest at $t = 2$, a ban on recourse provision preserves the bank's net worth. However, if the H aggregate state realizes, a ban on recourse provision strictly reduces investment efficiency (that is, $\pi_1^*(w_1^*, 0) > \pi_1^*(w_1^*, D_1^*)$), which reduces the surplus of an average bank.[19] The following proposition shows that the investment efficiency effect dominates:

Proposition 4 *If $r < \bar{r}$, where $\bar{r}$ is defined in Proposition 2, then the ex post unexpected introduction of a ban on voluntary recourse when $R_1 = 0$ at $t = 1$ strictly reduces the expected surplus (as of $t = 1$) of a good bank and has no effect on that of a bad bank.*

[18]A classical example of this arises in a simple version of the signaling model in Spence (1973) in which education does not increase productivity. When the probability that the worker has high productivity is sufficiently high, the separating equilibrium in which that worker type gets education is dominated by the pooling outcome that would result from a prohibition on investing in education.

[19]Notice that from an aggregate welfare perspective voluntary recourse amounts to a redistribution of wealth between the bank owners and the securitization debt investors, so that there is no trade off and banning ex post is aggregate welfare decreasing.

We discuss next the intuition for this result. Since external funds are costly, the optimal securitization debt promise D_1^* is such that, conditional on $R_1 = 0$ at $t = 1$, a bad bank is indifferent between providing recourse or not, so its expected surplus as of $t = 1$ amount to w_1^*.[20] If an ex-post ban on recourse were introduced, then condtional on the H state at $t = 2$ the bad bank would also be indifferent between using its w_1^* units of funds to invest or not doing so. The reason is that the probability that the bad bank invests in that contingnecy is given by $\pi_1^*(w_1^*, 0)$, and this probability satisfies, on the one hand $\pi_1^*(w_1^*, 0) > \pi_1^*(w_1^*, D_1^*) \geq 0$ and, on the other hand, $\pi_1^*(w_1^*, 0) < \pi_1^*(0, 0) < 1$ where the last inequality results from Assumption 3. The ex-post ban has thus no effect on the expected surplus of a bad bank, or putting it differently, a bad bank that is perceived as having quality α is indifferent between providing recourse $s = 0$ or providing recourse $s = s^*(w_1^*, D_1^*)$. The single-crossing condition we derived in (8) then implies that a good bank is strictly better off when providing recourse $s = s^*(w_1^*, D_1^*)$ than providing recourse $s = 0$. The introduction of an ex post ban thus reduces the expected surplus of a good bank. We conclude that the potential time consistency problem in the authorization of recourse provision faced by a bank regulator does not in fact not emerge.

4 Equity funding extension

Thus far we have only allowed the bank to issue short-term debt via traditional funding or securitization. In this section we extend the model to allow the bank some long-term financing options. Specifically, we allow the bank to issue equity at the initial date. The bank can promise to outside investors a fraction $\phi \in [0, 1)$ of itsresidual payoff at $t = 3$, in exchange for e_0 units of funds at $t = 0$. Because the equity investors provide funds for two investment periods (between $t = 0$ and $t = 1$, and between $t = 2$ and $t = 3$), the required rate of return for the competitive investors to supply equity financing is equal to r^2.[21] We

[20] Otherwise, since the equilibrium of the recourse game is not the pooling one (that is, $\pi_1^*(w_1^*, D_1^*) < 1$), we would necessarily have that the bad bank strictly prefers not to provide recourse. In that case the securitization debt promise at the initial date could be slightly reduced and the equilibrium of the recourse game following the failure of the first project would still be separating, and thus the bank's expected surplus would be larger than with the optimal choice D_1^*.

[21] Note that we assume that the time interval between $t = 1$ and $t = 2$ is sufficiently small, such the equity investors do not require a rate of return of r.

therefore do not assume any cost difference from the bank's point of view between equity funding relative to traditional or securitized funding.

Similarly to the case of securitization with a ban on voluntary recourse discussed in the previous Section, issuing equity does not allow to provide recourse at $t = 1$ but can be beneficial by increasing the amount of internal funds the bank is able to carry to put skin-in-the game at $t = 2$. Because long-term financing instruments such as equity also allow to pledge some of the return of the second investment when raising funds at $t = 0$, equity funding is able to raise more funds at the initial date than securitization with a ban is able to. In fact, we can show that the bank is able to raise through equity an amount of funds large enough to prevent any bad investment at $t = 2$:

Lemma 7 *There exists $\bar{\phi} \in (0, 1)$ such that if the bank issues equity at the initial date and promises investors a fraction $\phi \geq \bar{\phi}$ of its $t = 3$ payoffs, then there is no investment in bad projects at $t = 2$.*

While equity funding alone is always able to deter investment in bad projects, it does so by providing signaling possibilities only through skin-in-the-game. By contrast, off-balance sheet funding also provides stronger signaling possibilities through providing voluntary support at $t = 1$. As a result, there can be a role for combining the two funding options: equity may serve to overcome the limited pledgeability associated with short-term funding and allow to raise more funds at $t = 0$, while securitization with implicit recourse allows access to a stronger signal. It is possible to prove that whenever a mix of short-term debt funding and equity funding is allowed, then some positive amount of securitized funding with implicit recourse is always part of the optimal funding structure when the cost of external funds is not too large.

Proposition 5 *If $r < \bar{r}$, where $\bar{r}$ is defined in Proposition 2, it is never optimal to issue only equity financing at $t = 0$, and the optimal funding structure always exhibits a strictly positive amount of off-balance sheet debt.*

The proposition shows that the emergence of securitized funding with implicit recourse is not the result of our focus in the baseline model on short-term funding arrangements.

5 Conclusion

In light of the widespread feature in securitization, namely the implicit recourse provided by the originator banks, we develop a model of a bank decision to finance investments either with traditional on-balance sheet debt or through securitization with implicit recourse. When a project failure may lead to asymmetric information about the quality of future investments, the flexibility associated with voluntarily providing recourse enlarges the signaling opportunities of a good bank and improves investment efficiency in the future. Yet, recourse provision requires the bank to carry spare resources on its balance sheet, which increases the funds raised from external investors above those necessary for investment. We show that securitization with implicit recourse arises when the cost of external funds is not too high. In these cases, the introduction of a ban on implicit recourse decreases the expected surplus in the economy.

Appendix

The D1 refinement of Cho and Kreps (1987) We use the D1 refinement of Cho and Kreps (1987) to refine the set of sequential equilibria. A brief summary of how to apply this concept in our model in which there are only two types $j \in \{g, b\}$ is as follows. Given an equilibrium, for any off-equilibrium action a take by a bank of type j, let $\beta_j(a)$ denote the set of beliefs held by investors, such that their best response lead to a payoff for the bank at least as high as the equilibrium payoff. Then, if there exists a type $j' \in \{g, b\}$ and $j' \neq j$ such that the set $\beta_j(a)$ is strictly smaller than $\beta_{j'}(a)$, then the off-equilibrium belief associated with the action a must assign probability 1 to the j' type.

Proof of Lemma 1 Omitted.

Proof of Lemma 2 We consider the cases with $w_2 = 0$ and $w_2 > 0$ separately. For $w_2 = 0$, conjecture first an equilibrium in which $D_3 < R$. This implies that both the good bank and the bad bank invest and enjoy strictly positive payoffs. Such an equilibrium exists if and only if $\alpha_2 > \bar{\alpha}$, where $\bar{\alpha}$ is defined by in Assumption 3.

Next, conjecture an equilibrium in which $D_3 = R$ for $w_2 = 0$. For any $\alpha_2 \in (0, 1)$, this can be supported in a semi-pooling equilibrium in which the type j bank invests with probability $\pi_{2,j} \in [0, 1]$, such that the probability that the bank is good conditional on investment is equal to $\hat{\alpha}_2 = \frac{\alpha_2 \pi_{2,g}}{\alpha_2 \pi_{2,g} + (1-\alpha_2)\pi_{2,b}} = \bar{\alpha}$. Therefore for all α_2, there exists a continuum of payoff equivalent equilibria in which the bank of type j invests with probability $\pi_{2,j}$ and receives an equilibrium payoff of 0.

Finally, for $w_2 = 0$, there exists a pooling equilibrium in which no bank invests. The bank receives an equilibrium payoff of 0.

For $w_2 > 0$, we prove this lemma through a series of claims below.

Claim 1 *In any equilibrium that survives the D1 refinement, at $t = 2$, the good bank invests in the second project with probability* 1.

Proof. We prove this claim by contradiction. Suppose there exists an equilibrium in which the good bank invests at $t = 2$ with probability less than 1, when R_1 and the project quality p_2 remains private information. We will show that this equilibrium does not survive the D1 refinement.

Notice that in such an equilibrium, the expected payoff to the bank of both types at $t = 2$ is equal to w_2. To see this, consider first the good bank. In such an equilibrium, the good bank is either indifferent between investing or not, or strictly prefers not to invest. That is,

$$w_2 + d_2 - 1 + p_b(R - D_3) \leq w_2$$

Therefore the equilibrium payoff to the good bank is equal to w_2, the payoff when it does not invest. This also implies that in equilibrium, the good bank does not have sufficient capital and thus raises outside financing, $d_2 \geq 1 - w_2 > 0$, and suffers from underpricing $D_3 > \frac{rd_2}{p_g}$. Consider next the bad bank. For any given promised repayment D_3 and the corresponding best response by the investors d_2 in equilibrium, whenever a bank invests, it receives an expected payoff at most as high as the good bank would:

$$w_2 + d_2 - 1 + p_b(R - D_3) \leq w_2 + d_2 - 1 + p_b(R - D_3)$$

where the inequality is strict whenever $D_3 < R$. Therefore the bad bank also receives an equilibrium payoff of w_2.

We can now prune the supposed equilibrium by constructing a profitable deviation for the good bank under the D1 refinement. Consider a deviation by the bank to an off-equilibrium action $D_3' = D_3 - \epsilon$, where $\epsilon > 0$. Let $\hat{\beta} \in [0, 1]$ denote the belief held by the investors associated with the deviation D_3', where $\hat{\beta}$ is the probability that the bank who promises D_3' is of the good type. The best response of the invests to the deviation to D_3' given a belief of $\hat{\beta}$ is given by

$$\hat{d}_2(\hat{\beta}, D_3') = \frac{\hat{\beta} p_g + (1 - \hat{\beta}) p_b}{r} D_3' \tag{16}$$

Then the set of beliefs $\beta_j(D_3')$ such that the investors' best response lead to a payoff for the bank of type j at least as high as the equilibrium payoff is given by

$$\beta_j(D_3') = \{\hat{\beta} \in [0, 1] : \hat{d}_2(\hat{\beta}, D_3') - 1 + p_j(R - D_3') \geq 0 \text{ and } \hat{d}_2(\hat{\beta}, D_3') \geq 1 - w_2\}$$

For ϵ sufficiently small, this set is strictly larger for the good bank than for the bad bank. Therefore the D1 refinement requires that the belief associated with the off-equilibrium action of D_3' is to assign probability 1 to the good type. Given such belief, the good type has an incentive to deviate to $D_3' < D_3$, which gives it a payoff of strictly higher payoff than w_2, as

$$\begin{aligned} w_2 + \hat{d}_2(1, D_3') - 1 + p_g(R - D_3') &> w_2 + \hat{d}_2(1, D_3) - 1 + p_g(R - D_3) \\ &\geq w_2 + d_2 - 1 + p_g(R - D_3) = w_2 \end{aligned}$$

Therefore for $w_2 > 0$, the good bank invests with probability 1 in any equilibrium that survives the D1 refinement. ■

Claim 2 *In any (semi-)pooling equilibrium that survives the D1 refinement, at $t = 2$, a bank raises $d_2 = 1 - w_2$ from outside investors whenever it invests.*

Proof. We prove this claim by contradiction. Suppose there exists an equilibrium in which the bank of type j invests at $t = 2$ by raising $d_2 > 1 - w_2$ with positive probability $\pi_{2,j} \in (0, 1]$. We will show that this equilibrium does not survive the D1 refinement.

Notice that in such an equilibrium, the bank promises the investors a payoff of $D_3 = \frac{rd_2}{\hat{\alpha}_2 p_g + (1-\hat{\alpha}_2)p_b}$, where $\hat{\alpha}_2 = \frac{\alpha_2 \pi_{2,g}}{\alpha_2 \pi_{2,g} + (1-\alpha_2)\pi_{2,b}} \in [\bar{\alpha}, 1)$ is the probability that a bank who raises d_2 is of the good type. The equilibrium payoff to the bank of type j is given by

$$w_2 + d_2 - 1 + p_j(R - D_3)$$

We can now prune the supposed equilibrium by constructing a profitable deviation for the good bank under the D1 refinement. Consider a deviation by the bank to an off-equilibrium action $D_3' = D_3 - \epsilon$, $\epsilon > 0$. Let $\hat{\beta} \in [0, 1]$ denote the belief held by the investors associated with the deviation D_3', where $\hat{\beta}$ is the probability that the bank who promises D_3' is of the good type. The best response $\hat{d}_2(\hat{\beta}, D_3')$ of the invests to the deviation to D_3' given a belief of $\hat{\beta}$ is given by (16). Then the set of beliefs $\beta_j(D_3')$ such that the investors' best response leads to a payoff for the bank of type j at least as high as the equilibrium payoff is given by

$$\beta_j(D_3') = \left\{ \hat{\beta} \in [0, 1] : \hat{d}_2(\hat{\beta}, D_3') \geq d_2 - p_j(D_3 - D_3') \text{ and } \hat{d}_2(\hat{\beta}, D_3') \geq 1 - w_2 \right\}$$

For ϵ sufficiently small, this set is strictly larger for the good bank than for the bad bank. To see this, notice that, as $\epsilon \to 0$, $\hat{d}_2(1, D_3') = \frac{p_g D_3'}{r} > d_2 - p_g(D_3 - D_3')$ and $\hat{d}_2(0, D_3') = \frac{p_b D_3'}{r} < d_2 - p_b(D_3 - D_3')$, because $D_3 = \frac{rd_2}{\hat{\alpha}_2 p_g + (1-\hat{\alpha}_2)p_b} \in (\frac{rd_2}{p_g}, \frac{rd_2}{d_b})$. Therefore for ϵ sufficiently small, the set $\beta_g(D_3')$ is strictly larger than the set $\beta_b(D_3')$. The D1 refinement then requires that the belief associated with the off-equilibrium action of D_3' is to assign probability 1 to the good type. Given such belief, the good type has an incentive to deviate to D_3', which gives it a payoff of $w_2 + \frac{p_g D_3'}{r} - 1 + p_g(R - D_3') > w_2 + \frac{p_g D_3}{r} - 1 + p_g(R - D_3) > w_2 + \frac{[\hat{\alpha}_2 p_g + (1-\hat{\alpha}_2)p_b]D_3}{r} - 1 + p_g(R - D_3)$. Therefore in any (semi-)pooling equilibrium that survives the D1 refinement, at $t = 2$, $d_2 = 1 - w_2$. ■

Having shown Claims 1 and 2, we can now prove this lemma for $w_2 > 0$. Let us first characterize the separating equilibria. Conjecture a separating equilibrium, in which the good bank raises d_2. In such an equilibrium, $D_3 = \frac{rd_2}{p_g}$. This is an equilibrium if and only if the incentive compatibility constraint for the bad bank not to mimic is satisfied, i.e.

$$w_2 + d_2 - 1 + p_b(R - \frac{rd_2}{p_g}) \leq w_2$$

The above condition is most relax when d_2 is minimized at $d_2 = \max\{1 - w_2, 0\}$. When $d_2 = 1 - w_2$, the above condition is equivalent to $w_2 \geq \bar{w}_2$, where $\bar{w}_2$ is defined by (2). Since $\bar{w}_2 < 1$, a separating equilibrium exists if and only if $w_2 \geq \bar{w}_2$.

We now show that for $w_2 \geq \bar{w}_2$, there is a unique separating equilibrium such that $d_2 = (1 - w_2)^+$. To see this, conjecture a separating equilibrium in which the good bank promises $D'_3 > D_3$ to raises $d'_2 = \frac{p_g D'_3}{r} > d_2$. This cannot be an equilibrium, because the good bank can then deviate to promising $D''_3 \in (D_3, D'_3)$. Since the bad bank does not find it profitable to mimic, the investors contributes $d''_2 = \frac{p_g D''_3}{r}$. This deviation then gives the good bank a strictly higher equilibrium payoff $w_2 + \frac{p_g D''_3}{r} - 1 + p_g(R - D''_3) > w_2 + \frac{p_g D'_3}{r} - 1 + p_g(R - D'_3)$.

Let us next characterize the pooling equilibria. Conjecture a pooling equilibrium in which both the good bank and the bad bank invest with certainty by promising D_3. Using the results of Claims 1 and 2, in such an equilibrium, $d_2 = \frac{[\alpha_2 p_g + (1-\alpha_2) p_b] D_3}{r} = 1 - w_2$. This is an equilibrium if and only if the bad bank prefers to invest, i.e. $p_b(R - D_3) \geq w_2$. Therefore a unique pooling equilibrium exists if and only if $w_2 \leq \underline{w}_2(\alpha_2)$, where $\underline{w}_2(\alpha_2)$ is defined by

$$p_b\left(R - \frac{r(1 - \underline{w}_2(\alpha_2))}{\alpha_2 p_g + (1 - \alpha_2) p_b}\right) = \underline{w}_2(\alpha_2), \quad \forall \alpha_2 \geq \bar{\alpha} \tag{17}$$

Notice that $\underline{w}_2(\alpha_2)$ is increasing in α_2, $\underline{w}_2(\bar{\alpha}) = 0$ and $\underline{w}_2(1) = \bar{w}_2$.

Finally let us characterize the semi-pooling equilibria. Using the results of Claims 1 and 2, conjecture a semi-pooling equilibrium in which the bad bank invests with probability $\pi_b \in (0, 1]$ by raising promising D_3, and the good bank invests with certainty. Using the results of Claims 1 and 2, in such an equilibrium, $d_2 = \frac{[\hat{\alpha}_2 p_g + (1-\hat{\alpha}_2) p_b] D_3}{r} = 1 - w_2$, where $\hat{\alpha}_2 = \frac{\alpha_2}{\alpha_2 + (1-\alpha_2)\pi_2} \in [\bar{\alpha}, 1)$ is the probability that a bank who raises d_2 is of the good type. This is an equilibrium if and only if the incentive compatibility constraint for the bad bank holds with equality, i.e. $p_b(R - D_3) = w_2$. That is, the equilibrium probability that the bad bank invests, $\pi_{2,b}(w_2, \alpha_2) \in (0, 1)$ is given by

$$p_b\left(R - \frac{r(1 - w_2)}{\hat{\alpha}_2 p_g + (1 - \hat{\alpha}_2) p_b}\right) = w_2, \quad \text{where } \hat{\alpha}_2 = \frac{\alpha_2}{\alpha_2 + (1 - \alpha_2)\pi_{2,b}(w_2, \alpha_2)} \tag{18}$$

Such an equilibrium exists if and only if $w_2 < \bar{w}_2$ and $w_2 > \underline{w}_2(\alpha_2)$ for $\alpha_2 \geq \bar{\alpha}$. It follows from (18) that $\pi_{2,b}(w_2, \alpha_2)$ is increasing in α_2 and decreasing in w_2. As $\alpha_2 \to 0$, $\pi_{2,b}(w_2, \alpha_2) \to 0$.

To summarize, for $w_2 > 0$, there exists a unique equilibrium that survives the D1 refinement. For $w_2 \geq \bar{w}_2$, the equilibrium is separating. For $w_2 < \bar{w}_2$ and $w_2 > \underline{w}_2(\alpha_2)$ for $\alpha_2 \geq \bar{\alpha}$, the equilibrium is semi-pooling. For $w_2 \leq \underline{w}_2(\alpha_2)$, the equilibrium is pooling. In equilibrium, a bank raises $d_2^* = (1-w_2)^+$ to invest by promising outside investors $D_3^*(\alpha_2, w_2)$, where

$$D_3^*(\alpha_2, w_2) = \begin{cases} \frac{r(1-w_2)^+}{p_g}, & \text{if } w_2 \geq \bar{w}_2, \\ R - \frac{w_2}{p_b}, & \text{if } w_2 < \bar{w}_2 \text{ and either } \alpha_2 < \bar{\alpha} \text{ or } \alpha_2 \geq \bar{\alpha} \text{ and } w_2 > \underline{w}_2(\alpha_2), \\ \frac{r(1-w_2)}{\alpha_2 p_g + (1-\alpha_2) p_b}, & \text{otherwise} \end{cases} \tag{19}$$

The comparative statics then follows. $D_3^*(w_2, \alpha_2)$ is decreasing in w_2, and strictly decreasing for $w_2 < 1$. $D_3^*(w_2, \alpha_2)$ is decreasing in α, and strictly decreasing for $\alpha_2 > \bar{\alpha}$ and $w < \underline{w}_2(\alpha_2)$. ∎

Proof of Proposition 1 In this proof, we use the concept of sequential equilibrium as follows. If the updated belief at the end of $t = 1$ is $\alpha_2 = 0$ or $\alpha_2 = 1$, we restrict the equilibrium in the $t = 2$ subgame to be the limiting equilibrium as described in Lemma 2 as $\alpha_2 \to 0$ or $\alpha_2 \to 1$, respectively.

Since the support decision is only relevant if $w_1 > 0$, we focus on this case. We prove this proposition through a series of claims below.

Claim 3 *In any equilibrium, in which the bank provides voluntary support $s = w_1$ at $t = 1$, the good bank invests with certainty at $t = 2$ in state H following $R_1 = 0$.*

Proof. We prove this claim by contradiction. Suppose there exists an equilibrium in which the good bank provides voluntary support $s = w_1$ at $t = 1$, and subsequently invests at $t = 2$ with probability less than 1, when $R_1 = 0$ and $\Omega = H$.

By the reasoning at the beginning of the proof of Lemma 2, the good bank receives an equilibrium payoff of 0. We now show that the good bank strictly prefers to deviation to provide voluntary support $s' < w_1$ at $t = 1$, because this leaves the bank with a strictly positive equilibrium payoff, even when it does not invest at $t = 2$.

Therefore in any equilibrium that survives the D1 refinement, in which the bank provides voluntary support $s = w_1$ at $t = 1$, the good bank invests with certainty at $t = 2$ when $R_1 = 0$ and $\Omega = H$. ∎

Claim 4 *In any equilibrium that survives the D1 refinement, in which the bad bank provides voluntary support $s > 0$ at $t = 1$ with positive probability, $s = \min\{D_1, w_2\}$.*

Proof. We prove this claim by contradiction. Conjecture an equilibrium, in which the bad bank provides support $s \in (0, \min\{D_1, w_1\})$ at $t = 1$ with probability $\pi_{1,b} \in (0, 1]$. Notice first that, in this equilibrium, the bad bank subsequently invests with positive probability at

$t = 2$. This is because, otherwise the bad bank's equilibrium payoff is equal to $w_1 - s$, and the bad bank can profitably deviate to providing no support at $t = 1$ and not investing at $t = 2$. Second, this implies that, in this equilibrium, the good bank also provide support s with positive probability $\pi_{1,g} \in (0, 1]$. This is because, otherwise the investors hold a belief of $\alpha_2 = 0$ after observing a support s at $t = 1$, and the bad bank does not invest.

We will show that this equilibrium does not survive the D1 refinement. In this equilibrium, following a support of s, the investors update their belief to $\alpha_2 = \frac{\alpha\pi_{1,g}}{\alpha\pi_{1,g}+(1-\alpha)\pi_{1,b}} < 1$. The subsequent investment decision at $t = 2$ is as described in Lemmas 1 and 2. Since in equilibrium, both the good bank and the bad bank invest with positive probability at $t = 2$ in state H, the equilibrium payoff to the bank of type j is given by

$$q\left[w_1 - s + \max\{p_j R - 1, 0\}\right] + (1-q)p_j\left[R - D_3(\alpha_2, w_1 - s)\right]$$

The first term in the above expression is the expected payoff to the bank in state L (with probability q). The second term is the expected payoff to the bank in state H (with probability $1-q$), where $D_3(\alpha_2, w_2)$ is the outside investors' equilibrium response at $t = 2$ given by (19).

Consider now a deviation to provide support $s' = s + \epsilon$, $\epsilon > 0$. Let $\hat{\beta} \in [0, 1]$ denote the belief held by the investors associated with the deviation s', where $\hat{\beta}$ is the probability that the bank who provides voluntary support s' at $t = 1$ is of the good type. Then the equilibrium payoff to bank j after providing voluntary support s' is given by

$$q\left[w_1 - s' + \max\{p_j R - 1, 0\}\right] + (1-q)\left[R - D_3(\hat{\beta}, w_1 - s')\right]$$

Then the set of beliefs $\beta_j(s')$ such that the investors' best response lead to a payoff for the bank of type j at least as high as the equilibrium payoff is given by

$$\beta_j(s') = \{\hat{\beta} \in [0, 1] : D_3(\hat{\beta}, w_1 - s') \leq D_3(\alpha_2, w_1 - s) - \frac{q(s'-s)}{(1-q)p_j}\}$$

For ϵ sufficiently small, this set is strictly larger for the good bank than for the bad bank. To see this, notice that $D_3(\alpha_2, w_2)$ is decreaing in α_2, $D_3(\alpha_2, w_1 - s') > D_3(\alpha_2, w_1 - s)$, and, for $\epsilon \to 0$, $D_3(1, w_1 - s') < D_3(\alpha_2, w_2 - s)$. Therefore for $\epsilon \to 0$, there exists $\hat{\beta}_j \in (\alpha_2, 1)$ such that $\beta_j(s') = \{\hat{\beta} \in [0, 1] : \hat{\beta} \geq \hat{\beta}_j\}$, where $\hat{\beta}_j$ is defined by

$$D_3(\hat{\beta}, w_1 - s') = D_3(\alpha_2, w_1 - s) - \frac{q(s'-s)}{(1-q)p_j}$$

Notice that $\hat{\beta}_g < \hat{\beta}_b$, implying that the set $\beta_g(s')$ is strictly larger than $\beta_b(s')$.

Therefore the D1 refinement requires that the belief associated with a deviation to some s' is to assign probability 1 to the good type. Given such belief, the good type has an incentive to deviate to s', which gives it a strictly higher payoff than its equilibrium payoff as $\epsilon \to 0$:

$$w_1 - s' + (p_g R - 1) > q[w_1 - s + (p_g R - 1)] + (1-q)p_j(R - D_3(\alpha_2, w_1 - s))$$

Therefore in any equilibrium that survives the D1 refinement, in which the bad bank provides voluntary support $s > 0$ at $t = 1$ with positive probability, $s = \min\{D_1, w_1\}$. ■

Having shown Claims 3 and 4, we can now prove this lemma for $w_1 > 0$. Let us first characterize the separating equilibria. Conjecture a separating equilibrium, in which only the good bank provides voluntary support s at $t = 1$. In such an equilibrium, the good bank invests with certainty at $t = 2$, raising $d_2 = \max\{1 - w_1 + s, 0\}$. This is an equilibrium if and only if the incentive compatibility constraint for the bad bank not to mimic at $t = 1$ is satisfied, i.e.

$$q(w_1 - s) + (1-q)p_b\left[R - D_3(1, w_1 - s)\right] \leq w_1$$

This is the case if and only if $s \geq \bar{s}(w_1)$, where $\bar{s}(w_1)$ is defined by (9). Notice that $\bar{s}(w_1)$ is continuous and decreasing in w_1.

We now show that for $\min\{D_1, w_1\} \geq \bar{s}(w_1)$, there is a unique separating equilibrium such that $s = \bar{s}(w_1)$. To see this, conjecture a separating equilibrium in which the good bank provides voluntary support $s' > s$. This cannot be an equilibrium, because the good bank can then deviate to provide support $s'' \in (\bar{s}(w_1), s')$, while obtaining a strictly higher equilibrium payoff $w_1 - s'' + (p_g R - 1) > w_1 - s' + (p_g R - 1)$.

Let us next characterise the pooling equilibria. Using the result of Claims 3 and 4, conjecture a pooling equilibrium in which both the good bank and the bad bank provide voluntary support $s = \min\{D_1, w_1\}$ at $t = 1$. In such an equilibrium, the investors' belief at $t = 2$ is $\alpha_2 = \alpha$ and the equilibrium at $t = 2$ in state H is either pooling or semi-separating (by the proof of Lemma 2). The bad bank's expected payoff as of $t = 2$ in state H is thus equal to $w_1 - s$. This implies that the bad bank strictly prefers not to provide support s:

$$q(w_1 - s) + (1-q)(w_1 - s) < w_1$$

Therefore a pooling equilibrium does not exist.

Finally let us characterize the semi-pooling equilibria. Using the result of Claims 3 and 4, conjecture a semi-pooling equilibrium in which the bad bank provides positive voluntary support $s = \min\{D_1, w_1\}$ at $t = 1$ with positive probability $\pi_{1,b} \in (0, 1)$. This implies that the good bank provides support $s = \min\{D_1, w_1\}$ with certainty, as

$$q(w_1 - s) + (1 - q)p_g[R - D_3(\alpha_2, w_1 - s)] > q(w_1 - s) + (1 - q)p_b[R - D_3(\alpha_2, w_1 - s)] = w_1$$

where the last equality is the bad bank's indifference condition between providing support and not providing support.

In such an equilibrium, the investors' belief at $t = 2$ is $\alpha_2 = \frac{\alpha}{\alpha+(1-\alpha)\pi_{1,b}}$ and the bad bank invests with positive probability at $t = 2$. This is an equilibrium if and only if the incentive compatibility constraint for the bad bank holds with equality. That is, the equilibrium probability that the bad bank invests, $\pi_{1,b}(D_1, w_1) \in (0, 1)$ is given by

$$q(w_1 - \min\{D_1, w_1\}) + (1 - q)p_b[R - D_3(\alpha_2, w_1 - \min\{D_1, w_1\})] = w_1, \quad \alpha_2 = \frac{\alpha}{\alpha + (1 - \alpha)\pi_{1,b}} \tag{20}$$

Such an equilibrium exists if and only if $\min\{D_1, w_1\} < \bar{s}(w_1)$ and $\min\{D_1, w_1\} > \underline{s}(w_1)$ for $\alpha \geq \bar{\alpha}$. It follows from (20) that $\pi_{1,b}(D_1, w_1)$ is decreasing in D_1 and decreasing in w_2.

To summarize, for $w_1 > 0$, $D_1 > 0$ and $\alpha < \bar{\alpha}$, there exists a unique equilibrium that survives the D1 refinement, in which the good bank provides voluntary recourse $s^*(w_1, D_1) = \min\{w_1, D_1, \bar{s}(w_1)\}$ at $t = 1$ and subsequently invests at $t = 2$ with certainty. Let us distinguish between two cases:

1. $D_1 \geq w_1$. There exists $\bar{w}_1 < \bar{w}_2$ such that, the equilibrium is separating for$w_1 \geq \bar{w}_1$, and semi-pooling otherwise. $\bar{w}_1$ is defined by

$$\bar{w}_1 = \bar{s}(\bar{w}_1) \tag{21}$$

   For $w_1 < \bar{w}_1$, the probability that the bad bank mimics $\pi_1^*(w_1, D_1)$ is given by

$$(1 - q)p_b \left[R - \frac{r}{\alpha_2 p_g + (1 - \alpha_2)p_b}\right] = w_1, \quad \alpha_2 = \frac{\alpha}{\alpha + (1 - \alpha)\pi_1^*(w_1, D_1)}$$

   It follows that $\pi_1^*(w_1, D_1)$ is independent of D_1 and strictly decreasing in w_1.

2. $D_1 < w_1$. The equilibrium is separating for $D_1 > \bar{s}(w_1)$, and semi-pooling otherwise. For $D_1 < \bar{s}(w_1)$, the probability that the bad bank mimics $\pi_1^*(w_1, D_1)$ is given by

$$q(w_1 - D_1) + (1 - q)p_b \left[R - \frac{r(1 - w_1 + D_1)}{\alpha_2 p_g + (1 - \alpha_2)p_b}\right] = w_1, \quad \alpha_2 = \frac{\alpha}{\alpha + (1 - \alpha)\pi_1^*(w_1, D_1)}$$

   It follows that $\pi_1^*(w_1, D_1)$ is strictly decreasing in D_1 and decreasing in w_1.

∎

Proof of Lemma 3 This lemma follows from the preceding discussion. ∎

Proof of Lemma 4 We use extensively the results and notation in Proposition 1 and in its proof. The lemma is proven in a sequence of steps.

i) *The bank raises sufficient funds to invest at $t = 0$ if and only $D_1 \geq \underline{D}_1$ and in this case the rational expectations debt price $d_0^S(D_1)$ is unique.*

For $d_0 \geq 1 - w_0$ let us consider the function

$$\widehat{d}_0(d_0) = \frac{1}{r}\left[p_g D_1 + (1-p_g)\left[\alpha + (1-\alpha)\pi_1^*(w_0 + d_0 - 1, D_1)\right] s_1^*\left(w_0 + d_0 - 1, D_1\right)\right]. \tag{22}$$

Comparing with (13), we have that finding a rational expectation price of the promise D_1 is equivalent to finding a fixed point of $\widehat{d}_0(d_0)$ in the interval $d_0 \geq 1 - w_0$.

The function $\pi_1^*(w_1, D_1)$ is continuous and weakly decreasing in w_1 and the function $s^*\left(w_1, D_1\right)$ is continuous in $w_1$and its slope relative to this variable is at most 1. As a result, the function $\widehat{d}_0(d_0)$ is continuous and its slope is at most $\frac{1-p_g}{r} < 1$. We have that $\widehat{d}_0(1-w_0) = \frac{p_g D_1}{r}$ and hence if $D_1 \geq \underline{D}_1$,the function $\widehat{d}_0(d_0)$ has a unique fixed point in the interval $d_0 \geq 1 - w_0$. Moreover, if $D_1 < \underline{D}_1$, we have that $\widehat{d}_0(d_0) < d_0$ for all $d_0 \geq 1 - w_0$.

From now on we introduce the notation $w_1(D_1) \equiv w_0 + d_0^S(D_1) - 1$.

ii) $D_1 > w_1(D_1)$.

This is an immediate consequence of the fact that $w_0 < 1$ and $d_0^S(D_1) < \frac{D_1}{r} < D_1$

iii) $s_1^*(w_1(D_1), D_1) = w_1(D_1)$ *if* $\pi^*(D_1) > 0$ *and* $s_1^*(w_1(D_1), D_1) = \overline{s}(w_1(D_1))$ *if* $\pi^*(D_1) = 0$.

Immediate implication of Proposition 1 and step ii).

iv) $d_0^S(D_1)$ *is strictly increasing in* D_1.

Following steps i)–iii), for all D_1 such that $\pi^*(D_1) > 0$, the rational expectations price of the promise D_1 satisfies

$$d_0^S(D_1) = \frac{1}{r}\left[p_g D_1 + (1-p_g)\left[\alpha + (1-\alpha)\pi_1^*(w_1(D_1), D_1)\right] w_1(D_1)\right] \tag{23}$$

Let us implicitly differentiate the above expression w.r.t. D_1. After collecting terms, we have

$$\left(r-(1-p_g)\left[\alpha+(1-\alpha)\pi^*(D_1)\right]-(1-p_g)(1-\alpha)\frac{\pi_1^*(w_1(D_1),D_1)}{\partial w_1}w_1(D_1)\right)\frac{\partial d_0^S(D_1)}{\partial D_1}$$

$$=p_g+(1-p_g)(1-\alpha)\frac{\partial \pi_1^*(w_1(D_1),D_1)}{\partial D_1} \qquad (24)$$

It follows from the proof of Proposition 1 that $\frac{\pi_1^*(w_1(D_1),D_1)}{\partial w_1}<0$ and $\frac{\pi_1^*(w_1(D_1),D_1)}{\partial D_1}=1$ for $D_1>w_1(D_1)$. This implies that $\frac{\partial d_0^S(D_1)}{\partial D_1}>0$.

Following steps i) and iii), for all D_1 such that $\pi^*(D_1)=0$, the rational expectations price of the promise D_1 satisfies

$$d_0^S(D_1)=\frac{1}{r}\left[p_g D+(1-p_g)\alpha\bar{s}(w_1(D_1))\right] \qquad (25)$$

Let us implicitly differentiate the above expression w.r.t. D_1. After collecting terms,

$$\left(r-(1-p_g)\alpha\frac{\partial\bar{s}(w_1(D_1))}{\partial w_1}\right)\frac{\partial d_0^S(D_1)}{\partial D_1}=p_g \qquad (26)$$

It follows from (9) that $\frac{\partial\bar{s}(w_1(D_1))}{\partial w_1}<0$. This implies that $\frac{\partial d_0^S(D_1)}{\partial D_1}>0$.

v) $\pi^*(D_1)$ is decreasing in D_1 and strictly so if $\pi^*(D_1)>0$. Immediate implication of step iv) and Proposition 1.

∎

Proof of Proposition 2 We introduce the notation $w_1(D_1)\equiv w_0+d_0^S(D_1)-1$. The proposition is proven in a sequence of steps.

i) *The expected aggregate external funds $A^S(D_1)$ raised for investment in g projects are strictly increasing in D_1*

The expression for $A^S(D_1)$, analogous to that for $A^T(D_1)$ in (12), is given by

$$\begin{aligned} A^S(D_1) \;&=\; d_0^S(D_1)+p_g(1-q)\left(1-w_0-d_0^S(D_1)+1-R+D_1\right) \\ &\quad +(1-p_g)(1-q)\alpha\left(1-w_0-d_0^S(D_1)+1+s^*(D_1)\right) \qquad (27)\end{aligned}$$

where we denote $s^*(D_1)\equiv s_1^*\left(w_1(D_1),D_1\right)$. The term in the second line accounts for the fact that the good bank invests with certainty in equilibrium at $t=2$ in state H following the failure of the first project.

Lemma 4 states that the first term in (27) is strictly increasing in D_1. The proof of Lemma 4 also establishes that $\frac{dd_0^S(D_1)}{dD_1} \leq \frac{1-p_g}{r} < 1$. This implies that the second term in (27) is increasing in D_1. From step iii) of the proof of Lemma 4 we can distinguish two cases:

a- $s^*(D_1) = w_1(D_1)$. In this case the last term in (27) is constant and equal to $(1-p_g)\alpha$. Since the condition $s_1^*(w_1(D_1), D_1) = w_1(D_1)$ is satisfied in an open set we conclude that $A^S(D_1)$ is strictly increasing in D_1.

b- $s^*(D_1) = \overline{s}(w_1(D_1))$. In this case, using the rational expectations price $d_0^S(D_1) = \frac{1}{r}\left[p_g D_1 + (1-p_g)\alpha s^*(D_1)\right]$, we have

$$\begin{aligned} A^S(D_1) = d_0^S(D_1) + p_g(1-q)(1-w_0-d_0^S(D_1)+1-R) \\ + (1-p_g)(1-q)\alpha(1-w_0-d_0^S(D_1)+1) + r(1-q)d_0^S(D_1) \end{aligned} \tag{28}$$

The above expression is strictly increasing in $d_0^S(D_1)$, which is strictly increasing in D_1 by Lemma 4.

ii) *There exists $\overline{r}_1 > 1$ such that for $r \in (1, \overline{r}_1)$ it is optimal to invest in the first project with securitized funding and some $D_1^* > \underline{D}_1$*

We have $\Pi^T(\underline{D}_1) = \Pi^S(\underline{D}_1)$. Using (14) we have that

$$\frac{d\Pi^S(\underline{D}_1)}{dD_1} = -\frac{dA^S(\underline{D}_1)}{dD_1}(r-1) - (1-p_g)(1-\alpha)(1-q)\frac{d\pi^*(\underline{D}_1)}{dD_1}(r-p_b R). \tag{29}$$

By construction, when the bank chooses securitized funding with promise $D_1 = \underline{D}_1$, the bank's own funds at $t=1$ is equal to $w_1 = 0$. The assumption $\alpha < \overline{\alpha}$ implies that $\pi^*(\underline{D}_1) \in (0,1)$ and thus Lemma 4 implies that $\frac{d\pi^*(\underline{D}_1)}{dD_1} < 0$. In turn, step i) in this proof states that $\frac{dA^S(\underline{D}_1)}{dD_1} > 0$. From (29) we deduce that there exists $\overline{r}_1 > 1$ such that for $r \in (1, \overline{r}_1)$ we have $\frac{d\Pi^S(\underline{D}_1)}{dD_1} > 0$, which proves the claim.

iii) *If investing at $t=0$ with securitization funding with promised repayment $D_1^* > \underline{D}_1$ is optimal, then if the first project fails at $t=1$ a good bank provides strictly positive recourse with probability one and a bad bank with probability less than one.*

Suppose the claim is not true. Then, Proposition 1 implies that the bank funds w_1^* at $t=1$ when $R_1 = 0$ under the optimal funding structure satisfy $w_1^* \geq \bar{w}_2$.

We have thus that $\overline{s}(w_1(D_1^*)) = 0$. Moreover, using that $w_1(D_1^*) > 0$ and $D_1^* > 0$, Proposition 1 implies that for D_1 in a neighborhood of D_1^* we have $s^*(D_1) = \overline{s}(w_1(D_1))$ and that the equilibrium of the $t=1$ game is separating, i.e. $\pi^*(D_1) = 0$. Choosing

$D_1 < D_1^*$ and sufficiently close to D_1^*, we have then that $A^S(D_1') < A^S(D_1^*)$ and from (14) we conclude that $\Pi^S(D_1) > \Pi^S(D_1^*)$.

iv) *If investing at $t = 0$ with securitization funding with promised repayment $D_1^* > \underline{D}_1$ is optimal then the efficiency of investment decisions at $t = 2$ is improved relative to that under traditional funding of the first project.*

Recall that the optimal debt promise under traditional funding is $D_1 = \underline{D}_1$. By construction, since when the debt promise is $D_1 = \underline{D}_1$ the bank funds at $t = 1$ conditional on $R_1 = 0$ are $w_1 = 0$ regardless of the financing mode, we have that

$$\Pi^S(\underline{D}_1) = \Pi^T(\underline{D}_1).$$

Moreover, the investment efficiency at $t = 2$ when traditional funding is used at $t = 0$ is described by the fraction $\pi_2^* = \pi(\underline{D}_1)$ of bad banks that invest at that date. Using (14), the optimality of securitized funding with promised repayment $D_1^* > \underline{D}_1$ implies that

$$(1 - p_g)(1 - \alpha)(1 - q)[\pi^*(\underline{D}_1) - \pi^*(D_1^*)](r - p_b R) \geq \left[A^S(D_1^*) - A^S(\underline{D}_1)\right](r - 1) > 0,$$

so that we conclude that $\pi^*(\underline{D}_1) > \pi^*(D_1^*)$, which means the securitized funding with debt promise D_1^* improves investment efficiency relative to traditional funding.

∎

Proof of Lemma 5 Omitted.

Proof of Lemma 6 Consider any $D_1^B \geq \underline{D}_1$. It is immediate that $\pi^B(D_1^B) \geq \pi_2^*$, where the inequality is strict if and only if $D_1^B > \underline{D}_1$.

In the economy without a ban on voluntary support, the bad bank mimics the good bank with probability $\pi^*(D_1') = \pi^B(D_1^B)$ if and only if $d_0^S(D_1')$ satisfies

$$\pi^*(D_1') = \pi_1^*(w_0 + d_0^S(D_1') - 1, D_1') = \pi_1^*(w_0 + d_0^B(D_1^B) - 1, 0) = \pi^B(D_1^B)$$

Let us consider two cases separately. Consider first Case (i), in which $\pi^B(D_1^B) > 0$, i.e. $w_0 + d_0^B(D_1^B) - 1 > \bar{w}_2$. Suppose $D_1' = D_1^B$. Then $d_0^S(D_1') > d_0^B(D_1^B)$ and thus $\pi^*(D_1') < \pi_1^*(w_0 + d_0^B(D_1^B) - 1, 0)$, where the inequality is strict if and only if $w_0 + d_0^B(D_1^B) - 1 < \bar{w}_2$. Moreover, $\pi^*(\underline{D}_1) = \pi_2^* \leq \pi^B(D_1^B)$, where the inequality is strictly for all $D_1 > \underline{D}_1$. Because $\pi^*(D_1)$ is strictly decreasing in D_1 for all $\pi^*(D_1) > 0$, it follows that there exists $D_1' \leq D_1^B$ such that $\pi^*(D_1') = \pi^B(D_1^B)$, where the inequality is strict if and only if $D_1^B > \underline{D}_1$.

Consider next Case (ii), in which $\pi^B(D_1^B) = 0$, i.e. $w_0 + d_0^B(D_1^B) - 1 \geq \bar{w}_2$. Suppose $D_1' = D_1^B$. Then $d_0^S(D_1') = d_0^B(D_1^B)$ and thus $\pi^*(D_1') = \pi^B(D_1^B) = 0$. It follows immediately from the proof of Proposition 1 that there exists $D_1' < D_1^B$ such that $\pi^*(D_1') = \pi^B(D_1^B) = 0$. ∎

Proof of Proposition 3 Before we start this proof, let us denote the expected surplus as of $t = 0$ of the bank given a ban on voluntary recourse by $\Pi^B(D_1^B)$, where

$$\Pi^B(D_1^B) = w_0 + \underbrace{\left[\underbrace{(p_gR-1)}_{\textit{NPV first project}} + \underbrace{[(p_g + (1-p_g)\alpha](1-q)(p_gR-1)}_{\textit{NPV second project}} - \underbrace{A_g^B(D_1^B)(r-1)}_{\textit{External funds cost}}\right]}_{\textit{Surplus from g projects}}$$
$$- \underbrace{\left[\underbrace{(1-p_g)(1-\alpha)(1-q)\pi^B(D_1^B)(1-p_bR)}_{\textit{NPV second project}} + \underbrace{A_b^B(D_1^B)(r-1)}_{\textit{External funds cost}}\right]}_{\textit{Losses from b projects}} \tag{30}$$

The interpretation of the terms in the surplus decomposition expression is analogous to that for the baseline case of securitization with implicit recourse. Notice that the expression for the last term in E(30), which includes the expected losses the bank suffers from investing in bad projects at $t = 2$, differs from the last term in (14). In (30), we have separated the NPV of the bad projects from the cost of external funds raised to finance the bad projects. When voluntary recourse is allowed, the bank optimally exhausts its internal funds to provide recourse at $t = 1$, so that it raises the entire 1 units of funds required for investment at $t = 2$ through external funding. By contrast, when voluntary recourse is limited, the bank maintains a positive amount of internal funds at $t = 2$ and raises the remaining funds needed for investment from outside investors.

Given a ban on voluntary recourse, the external funding needs for the g and b projects are given by

$$A_g^B(D_1^B) = \underbrace{d_0^B(D_1^B)}_{t=0} + \underbrace{p_g(1-q)\left(1 - w_0 - d_0^B(D_1^B) + 1 - R + D_1^B\right)}_{t=2, R_1=R}$$
$$+ \underbrace{(1-p_g)\alpha(1-q)\left(1 - w_0 - d_0^B(D_1^B) + 1\right)}_{t=2, R_1=0}$$
$$A_b^B(D_1^B) = \underbrace{(1-p_g)(1-\alpha)(1-q)\pi^B(D_1^B)\left(1 - w_0 - d_0^B(D_1^B) + 1\right)}_{t=2, R_1=0} \tag{31}$$

The first term in $A_g^B(D_1^B)$ captures the external funds raised at $t = 0$ for investment in the first project (that is good with certainty). The second and the third terms include the funds raised at $t = 2$ for investment in a good project conditional on the success and the failure of the first project, respectively. The expression for $A_b^B(D_1^B)$ captures the external funds raised at $t = 2$ following the failure of the first project when information asymmetry persists.

In order to prove this proposition, we first show that the aggregate amount of external funds raised in order to achieve the same level of investment efficiency at $t = 2$ is higher with a ban on voluntary recourse than without. That is, for any $D_1^B > \underline{D}_1$ and D_1' such that $\pi^B(D_1^B) = \pi^*(D_1')$ as defined in Lemma 6, $A_g^B(D_1^B) + A_b^B(D_1^B) > A^S(D_1') + A_b^S(D_1')$, where

$$A_b^S(D_1) = (1-p_g)(1-\alpha)(1-q)\pi^*(D_1)\left(1 - w_0 - d_0^S(D_1) + 1 + s^*(D_1)\right) \tag{32}$$

Using the rational expectations pricing function for the debt given a ban on voluntary recourse (15), we have

$$\begin{aligned} A_g^B(D_1^B) + A_b^B(D_1^B) = {} & d_0^B(D_1^B)\left(1 + (1-q)\left(r - p_g - (1-p_g)\left[\alpha + (1-\alpha)(1-q)\pi^B(D_1^B)\right]\right)\right) \\ & - p_g(1-q)R \\ & + (1-q)\left(p_g + (1-p_g)\left[\alpha + (1-\alpha)(1-q)\pi^B(D_1^B)\right]\right)(2 - w_0) \end{aligned} \tag{33}$$

Using the rational expectations pricing function for the debt with voluntary recourse (27), we have

$$\begin{aligned} A^S(D_1') + A_b^S(D_1') = {} & d_0^S(D_1')\left(1 + (1-q)\left(r - p_g - (1-p_g)\left[\alpha + (1-\alpha)(1-q)\pi^*(D_1')\right]\right)\right) \\ & - p_g(1-q)R \\ & + (1-q)\left(p_g + (1-p_g)\left[\alpha + (1-\alpha)(1-q)\pi^*(D_1')\right]\right)(2 - w_0) \end{aligned} \tag{34}$$

$A_g^B(D_1^B) + A_b^B(D_1^B) > A^S(D_1') + A_b^S(D_1')$ therefore follows because $\pi^B(D_1^B) = \pi^*(D_1')$ and $d_0^B(D_1^B) > d_0^S(D_1')$.

We can now prove this proposition by contradiction. Suppose there exists $D_1^B \geq \underline{D}_1$, such that $\Pi^B(D_1^B) \geq \Pi^S(D_1)$ for all $D_1 \geq \underline{D}_1$. Consider two case. First, if $D_1^B = \underline{D}_1$, it is immediate that $\Pi^B(D_1^B) = \Pi^S(\underline{D}_1) < \Pi^S(D_1^*)$, a contradiction. Second, if $D_1^B > \underline{D}_1$, then it follows from the previous discussion that there exists D_1' such that $\Pi^B(D_1^B) < \Pi^S(D_1')$, a contradiction. ∎

Proof of Proposition 4 $\pi_1^*(w_1, D_1)$ is characterized at the end of the proof of Proposition 1.

In the case with voluntary recourse, $w_1^* < D_1^*$ and $\pi_1^*(w_1^*, D_1^*)$ satisfies

$$(1-q)p_b\left[R - \frac{r}{\alpha_2^S p_g + (1-\alpha_2^S)p_b}\right] = w_1^*, \quad \alpha_2 = \frac{\alpha}{\alpha + (1 - \alpha\pi_1^*(w_1^*, D_1^*)}$$

This implies that the bad bank's expected surplus is w_1^*, and the good bank's expected surplus in equilibrium is equal to

$$(1-q)p_g\left[R-\frac{r}{\alpha_2 p_g+(1-\alpha_2)p_b}\right]=w_1^*\frac{p_g}{p_b}$$

In the case with a ban on voluntary recourse, $\pi_1^*(w_1^*,0)$ satisfies

$$qw_1^*+(1-q)p_b\left[R-\frac{r(1-w_1^*)}{\alpha_2^B p_g+(1-\alpha_2^B)\pi_b}\right]=w_1^*,\quad \alpha_2=\frac{\alpha}{\alpha+(1-\alpha)\pi_1^*(w_1^*,0)}$$

This implies that the bad bank's expected surplus is w_1^*, and the good bank's expected surplus in equilibrium is equal to

$$qw_1^*+(1-q)p_g\left[R-\frac{r(1-w_1^*)}{\alpha_2^B p_g+(1-\alpha_2^B)\pi_b}\right]=qw_1^*+(1-q)w_1^*\frac{p_g}{p_b}<w_1^*\frac{p_g}{p_b}$$

Therefore an ex post ban on voluntary recourse strictly reduces the expected surplus of the bank, because it strictly reduces the expected surplus of the good bank, while keeping the expected surplus of the bad bank constant. ∎

Proof of Lemma 7 Similarly to the case with securitized funding, when the bank issues equity, the investors price the bank's equity anticipating the bank's investment decision at $t=2$. Let $e_0(\phi)$ denote the rational expectations competitive price for the fraction ϕ of equity issued by the bank at $t=0$. From Proposition 1, we have that $\pi_1^*(w_1,0)=0$ if and only if $w_1\geq\bar{w}_2$. Let us conjecture that this is the case. Then, for all ϕ such that $w_1\geq\bar{w}_2$, $e_0(\phi)$ is given by the following expression, where the RHS is the expected equity value of the bank, using the fact that any other claims issued at $t=2$ allows outside investors to break even and thus incurs a cost $(r-1)$ on existing equity holders.

$$\begin{aligned}&e_0(\phi)r^2=\phi\left[w_0+e_0(\phi)+(p_gR-1)+[p_g+(1-p_g)\alpha](1-q)(p_gR-1)-A_2^e(\phi)(r-1)\right]\\&\text{where}\quad w_1=w_0+e_0(\phi)-1,\ \text{and}\\&A^e(\phi)=(1-q)\left[p_g(1-w_0-e_0(\phi)+1-R)^+ +(1-p_g)\alpha(1-w_0-e_0(\phi)+1)^+\right]\end{aligned}\tag{35}$$

Therefore there exists $\bar{\phi}$ such that $e_0(\bar{\phi})=\bar{w}_2+1-w_0$ if and only if the above expression is satisfied when evaluated at $\bar{\phi}$ and $e_0=\bar{w}_2+1-w_0$, i.e.

$$\begin{aligned}(\bar{w}_2+1-w_0)r^2-\bar{\phi}\,[\bar{w}_2+1+(p_gR-1)+[p_g+(1-p_g)\alpha](1-q)(p_gR-1)\\-\left[p_g(1-\bar{w}_2-R)^+ +(1-p_g)\alpha(1-\bar{w}_2)\right](r-1)\big]=0\end{aligned}$$

Clearly the LHS of the above expression is positive for $\bar{\phi}=0$, negative for $\phi=1$. Therefore $\bar{\phi}\in(0,1)$ indeed exists. ∎

Proof of Proposition 5 First, we prove the first part proposition by contradiction. Suppose otherwise and under the optimal funding arrangement, the bank issues a fraction ϕ of equity to raise $e_0(\phi)$ and issues $D_1 = 0$ amount of off-balance sheet debt. The equilibrium probability that the bad bank mimics the good bank's recourse decision at $t = 1$ and the investment decision at $t = 2$ is given by $\pi^\phi = \pi_1^*(w_0 + e_0(\phi) - 1, 0)$.

We first show that, if $e_0(\phi) > 1 - w_0$, then for any $D_1 = \epsilon \geq 0$, there exists and $\phi' \leq \phi$, such that the mimicking probability remains equal to π^ϕ. For $\epsilon > 0$ and $\epsilon \to 0$, D_1' and ϕ' must satisfy

$$
\begin{aligned}
e_0(\phi', D_1)r^2 = \phi' \big[& w_0 + e_0(\phi', D_1) + d_0^S(w_1', D_1) + (p_g R - 1) + [p_g + (1-p_g)\alpha](1-q)(p_g R - 1) \\
& -(1-p_g)(1-\alpha)(1-q)\pi_1^*(w_1', D_1)(1 - p_b R) - A_2^e(w_1', D_1)(r-1)\big] \\
\text{where } w_1' &= w_0 + e_0(\phi', D_1) + d_0^S(w_1', D_1) - 1, \\
d_0^S(w_1', D_1)r &= \left(p_g + (1-p_g)[\alpha + (1-\alpha)(1-q)\pi_1^*(w_1', D_1)]\right) D_1, \text{ and} \\
A_2^e(w_1', D_1) &= (1-q)\,[p_g(1 - w_1' - R + D_1) \\
& \quad +(1-p_g)[\alpha + (1-\alpha)(1-q)\pi_1^*(w_1', D_1)](1 - w_1' + D_1)]
\end{aligned} \tag{36}
$$

We now show that, for any $\epsilon > 0$, as $\epsilon \to 0$, there exists ϕ' that satisfies the above equations. To see this, notice that for any D_1, there exists $w_1' < w_0 + e_0(\phi) - 1$, such that $\pi_1^*(w_1', D_1) = \pi^\phi = \pi_1^*(w_0 + e_0(\phi) - 1, 0)$. This implies that $e_0(\phi', D_1) = w_1' + 1 - w_0 - d_0^S(\phi', D_1)$. We now show that there exists $\phi' \leq \phi$ such that this is true. To see this, notice that the LHS of the first equation of the above expressions is less than the RHS for $\phi' = \phi$, and greater than the RHS for $\phi' = 0$.

We now show that the aggregate cost of external funds raised under the funding arrangement (D_1', ϕ') is strictly lower than that under the funding arrangement (D_1, ϕ). To see this, notice that the aggregate amount of external funds raided given the funding arrangement (D_1', ϕ') is given by

$$
\begin{aligned}
& e_0(\phi', D_1')(r^2 - 1) + \left[d_0^S(w_1', D_1') + A_2^e(w_1', D_1')\right](r-1) \\
= & \left[w_1' + 1 - w_0\right](r^2 - 1) - q d_0^S(w_1', D_1')r(r-1) \\
& + \left[p_g(1 - w_1' - R) + (1-p_g)[\alpha + (1-\alpha)(1-q)\pi_1^*(w_1', D_1')](1 - w_1')\right](r-1)
\end{aligned} \tag{37}
$$

It is now straightforward to see that, because $w_1' < w_1$, the aggregate cost of external funds raised under the funding arrangement (D_1', ϕ') is lower than that under the funding arrangement (D_1, ϕ), which is given by

$$
\begin{aligned}
& e_0(\phi, 0)(r^2 - 1) + A_2^e(w_1, 0)(r - 1) \\
= & \left[w_1 + 1 - w_0\right](r^2 - 1) \\
& \quad + \left[p_g(1 - w_1 - R) + (1 - p_g)[\alpha + (1 - \alpha)(1 - q)\pi_1^*(w_1, 0)](1 - w_1)\right](r - 1)
\end{aligned}
$$

Let $\Pi^e(\phi, D_1)$ denote the expected surplus of the bank given that it issues a fraction ϕ of equity and securitization debt with a promised repayment D_1 at $t = 0$. This implies that $\Pi^e(\phi', D_1') > \Pi^e(\phi, D_1)$.

We can now prove by contradiction that, for $r < \bar{r}$, it is never optimal to only issue equity at $t = 0$, and the optimal funding structure always exhibits a strictly positive amount of off-balance sheet debt. Suppose there exists ϕ^*, such that $\Pi^e(\phi^*, 0) \geq \Pi^e(\phi, D_1)$ for all (ϕ, D_1). Consider two cases. First, if $w_0 + e_0(\phi^*) - 1 = 0$, it is immediate that $\Pi^e(\phi^*, 0) = \pi^S(\underline{D}_1) < \pi^S(D_1^*)$, a contradiction. Second, if $w_0 + e_0(\phi^*) - 1 > 0$, it follows from the previous discussion that there exists $D_1' > 0$ and $\phi' < \phi$, such that $\Pi^e(\phi', D_1') > \Pi^e(\phi^*, 0)$. ∎

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