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Detrimental Effects of Retention Regulation: Incentives for Loan Screening in Securitization under Asymmetric Information

Masazumi Hattori* and Kazuhiko Ōhashi**

Abstract

We consider an economy in which a lender finances his loans to borrowers by issuing a securitized product to investors, and where the credit quality of the product may depend on whether the lender screens the borrowers. In the presence of asymmetric information between the lender and the investors about the credit quality of potential borrowers, overvaluation of the low-quality securitized product may occur, inducing lender to not screen the borrowers and hence to issue a securitized product of low credit quality. This is likely to occur when the investors finds it difficult to distinguish the good state from the bad state, or when the seed of recession creeps toward the booming economy. A retention regulation that requires the lender to hold a minimum ratio of his own securitized products is not necessarily effective in solving this incentive problem. Even worse, in a certain situation, the retention regulation discourages the lender's screening effort and reduces welfare.

Keywords: originate-to-distribute; securitization; asymmetric information; financial regulation; screening; verification; retention

JEL classification: G14, G21, G24

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1 Introduction

Securitization, or more generally the originate-to-distribute (OTD) business model, is expected to improve the efficiency of financial markets: financial institutions make loans to borrowers, tranche and sell their cash flows to investors who value them most, and thus achieve efficient allocation. There are theoretical justifications for this expectation as long as the price mechanism in the process works properly. However, the financial crisis that began in 2007 revealed serious incentive problems in the process of securitization. Solutions are now being sought.

One plausible remedy for the incentive problems that has gained recent attention is the retention of securitized products by the issuers. The reasoning is as follows: a massive number of securitized products with low credit quality was created before the crisis because the issuers had too few incentives to improve quality. The issuers should be motivated to create higher-quality products if they incur losses when their products default. One way to ensure this is to have the issuers retain a portion of their products.

This view has won wide support, and regulation requiring issuers to hold a portion of their products has been called for. However, we conjecture that forcing retention on the issuers incurs a cost to them and may not necessarily work in all circumstances. Thus, the purpose of this paper is to supply a caveat regarding naive enforcement of the retention requirement by showing a detrimental effects of the retention regulation.

More specifically, in this paper, we consider intermediaries that make loans to borrowers and finance them by securitizing these loans to investors. While such intermediaries are simultaneously lenders to borrowers and issuers to investors, for convenience we call them just lenders in the following. We explicitly model the link between the market price of securitized products and loan activities, and analyze how pricing of securitized products affects lenders' incentives to screen potential borrowers and to improve the credit quality of their loan assets. We then examine the potential inefficiencies in such an OTD business model, and discuss the efficacy of the retention regulation to solve inefficiencies resulting from the low screening motivation of lenders.

The basic setup of the model is as follows: given costly screening and verification technologies, a lender decides whether to screen borrowers' credit quality when making loans. There is asymmetric information between the lenders and the investors regarding the distribution of the borrowers' credit quality. There are two types of lenders of potential loan asset portfolios. We call them "good" and "bad" lenders for short. All potential borrowers for "good" lenders are of high credit quality and non-defaultable. In contrast, certain borrowers for "bad" lenders are borrowers of low credit quality and defaultable. The lender knows his own type, that is, the quality of his potential borrowers, but the investors do not. The investors cannot observe the lender's screening activity, either. Given this asymmetric information, the lender can verify the credit quality of the securitized product. The presence or absence of screening affects the credit quality of the loan asset portfolio backing the securitized product. This factor, in conjunction with verification, affects the price that the investors are willing to pay for the securitized product. In turn, the price of the securitized product affects whether the lender undertakes such costly screening and verification.

With this basic setup in place, we first demonstrate that there exists an equilibrium in which the pricing of the securitized product may distort the lender's incentive to conduct costly screening of borrowers. Indeed, we show that a securitized product that is unscreened and of low credit quality can be overpriced from the lender's perspective. When such a low-quality product is sufficiently overpriced, the lender will choose not to screen borrowers and securitize the unscreened loan asset portfolio. This happens because the lender's gain from issuing a high-quality product backed by screened loan asset at a higher price does not exceed the cost of screening and verification borne by the lender. We derive the conditions for the emergence of such equilibrium pricing and show that low-credit-quality securitized products are likely to be created when the probability is low that the average credit quality of potential borrowers is low.

Given the equilibrium with low-quality securitized products, we then investigate the effect of the retention regulation, which is often claimed to be effective in motivating the lenders to make suitable efforts in screening and monitoring the borrowers. The retention regulation, in the securitization process, requires the lender to keep a certain portion of his loan portfolio backing the securitized product on his balance sheet through the maturity of the securitized product. The idea for the regulation is that a mechanism (regulation) in which the lender incurs a loss from the loan asset will motivate him to increase the effort of screening. The results of our analysis, however, cast doubt on such a view. The retention regulation may discourage the lender from conducting screening activity. Even worse, the effect of the regulation can be welfare reducing. That is, the retention regulation can be detrimental.

This can be seen as follows. Conventional wisdom says that retention is good because it provides lenders with incentives to make better loans since they must retain a portion of them. However, there is a cost to the retention: the lenders can sell a smaller portion of the loans due to retention, and thus have a smaller incentive to screen the loans, verify the quality of the securitized products, and sell them at a higher price to the investors. Moreover, the regulation affects not only the target lenders but also other lenders: when the good lenders are discouraged by the cost of the retention regulation and decide not to verify the quality of their products, through strategic interaction between both types of lenders, the bad lenders also lose the incentive to conduct costly screening and verification. Thus, to design a financial regulation, we must understand its intrinsic cost and differential effects on a certain motivation for each type of player involved in the business in question.

This paper is organized as follows. Section 2 discusses related papers. Section 3 introduces a general formulation of the OTD business model and analyzes the model without the retention regulation. Section 4 derives the results for the model without the retention regulation. Section 5 derives the results for the model with the retention regulation and discusses its effect from the viewpoint of the lender's motivation and welfare. Section 6 provides discussion and concluding remarks.

2 Related Papers

Well before the OTD business model obtains its recognition, Gorton and Pennacchi (1995) study incentive-compatible loan sale contracts by a bank (a lender) and investigate circumstances in which a bank originates loans after a costly screening of borrowers' credit quality and sells a portion of the loans to outside investors. They examine the optimal levels of screening efforts and loan sales by the originating bank.[1] In the wake of the subprime loan crisis, closely related to Gorton and Pennacchi (1995), several literatures emerge analyzing incentives for lenders to screen or monitor borrowers in the OTD business model and related financial regulation measures. Acharya and Richardson (2009) and Dewatripont et al. (2010) are in this strand; they discuss the issues from the viewpoint of concrete policy proposals. Fender and Mitchell (2009) and Kiff and Kisser (2010) also analyze how different types of retention regulation affect the lenders' incentives to conduct screening and improve the credit quality of securitized products.

While sharing the interest of these papers, our paper contains some differences. The most notable one is that we analyze the case with heterogeneous lenders in terms of potential loan asset quality, which is outside the scope of Fender and Michell (2009) and Kiff and Kisser (2010), which assume homogeneous lenders. We show that such heterogeneity affects the efficacy of the retention regulation on the motivation of screening. Moreover, our work differs from theirs in the treatment of funding aspect in the OTD business. They pay virtually no attention to the funding aspect: lenders are supposed to hold assets to be securitized, but how they finance the purchase of the assets is not discussed. The model in our paper explicitly describes it: lenders finance the asset purchase by tapping investors' funds in the securitized product market. This explicit inclusion of the funding aspect in the OTD business is not only in line with real practice but also enables us to analyze the effect of the funding constraint when we pin down the equilibrium. We think that this point has not received sufficient attention in the preceding literature despite its importance for analysis of the OTD business.

Holmstrom and Tirole (1997) is another closely related work. In their model, the investors' required rate of return should affect the intensity of monitoring by intermediaries and hence the quality of investment projects. A key in the linkage is the effects of wealth distribution between capital-constrained firms and intermediaries on the intensity of monitoring by the intermediaries. In our paper, the price that investors are willing to pay for a securitized product affects the lender's incentive to screen borrowers and the credit quality of the loan pool. However, unlike in Holmstrom and Tirole (1997), the heterogenous lenders need to consider the strategy of the lenders of other types and information is asymmetric between the lender and the investors on loan asset quality.

In the literature on security design, Allen and Gale (1988) are closely related to this paper. They analyze security innovations by producers who maximize profits from selling securities

[1] Gorton and Pennacchi (1995) point out that their model can also be interpreted as a costly monitoring model.

backed by their production to consumers. Our model can be regarded as an extension of Allen and Gale (1988) to the specific context of loan screening, in which asymmetric information between lenders and investors yields a complex relationship between the state of the loan market, the market price of securitized products, and loan screening incentives. As for the issue of information structure in the securitization process, DeMarzo (2005) and DeMarzo and Duffie (1999) are closely related works. They analyze the optimal payoff design of securitized products, given asymmetric information between originators and investors. In these papers, the credit quality of securitized products is determined by tranching of the underlying loan pool. We analyze the case of the pass-through securitized product that is backed by the entire loan pool whose credit quality is determined by lenders' screening activity.

Our paper also closely relates to the strand of studies of loan standard determinants. For example, Jimenez and Saurina (2006) on Spanish banks and Dell'Ariccia et al. (2008), Mian and Sufi (2009), and Keys et al. (2010) on the recent U.S. mortgage loan markets report empirical findings. Berger and Udell (2004) on the screening skill level of loan officers, Rajan (1994) on the incentive mechanisms for bank managers set by reward and punishment schemes, and Shin (2008, 2009) on the loan capacity of the intermediary sector discuss theoretical frameworks for understanding the determinants of loan standards and report supporting evidences for the theories. Plantin (2011) develops a model of securitization under asymmetric information and analyzes the conditions under which excessive and inefficient securitization may occur. In general, these works point to low lending standards in boom times and high lending standards in recessions. The results in this paper are consistent with the literatures: when the average quality of potential borrowers is bad with high probability, efforts in screening and verification are more likely to reward the lender, since investors price high-quality securitized products much higher than low-quality securitized products, and an equilibrium with screening and verification is likely to obtain.

3 The Model

We consider an economy with two periods, 0 and 1. There are borrowers, lenders, and investors, all of whom live for two periods. The borrower takes a loan from the lender in period 0 by promising to repay in period 1. The lender makes loans to the borrowers in period 0 and collects repayments in period 1. The lender finances the loans by selling a securitized product backed by these loans to the investors in period 0. The investors buy the securitized products issued by the lenders in period 0 and consume their proceeds in period 1.

The borrower is of either high or low credit quality. The high-quality borrower can repay the loan with certainty, but the low-quality borrower may default. By undertaking costly screening, the lender can screen the borrowers, lend only to the high-quality borrowers, and improve the credit quality of his loan pool. There are two types of lenders; one with a good lending opportunity in the sense that all of his potential borrowers are of high credit quality, and the other facing a bad lending opportunity in the sense that some of his potential borrowers are of low credit quality. The lender knows his own type, but the investors cannot. The investors cannot observe the lender's screening activities, either. With this asymmetric information, the lender can verify the credit quality of his securitized product through costly verification. The lender can also retain a part of his securitized product, which the investors observe.

The presence or absence of screening affects the credit quality of the loan pool backing the securitized product. This factor, in conjunction with verification and retention, affects the information that the investors possess and hence the price that they are willing to pay for the securitized product. In turn, the price of the securitized product affects whether the lender undertakes such costly screening/verification and retention.

3.1 Borrowers and Loan Opportunities

There is a continuum of borrowers who have no endowments. Each borrower borrows D (< 1) amount of a loan and invests all of it in period 0 by promising to repay 1 amount in period 1. The borrowers are of either high or low quality. The high-quality borrower has an investment opportunity that produces 1 for certain in period 1, and hence can repay her loan with probability 1. The low-quality borrower has an investment opportunity whose payoff is z ($0 \leq z < 1$) with probability α and 1 with probability $1 - \alpha$ in period 1, and hence may default with probability α by making only partial repayment z to the lender, while with probability $1 - \alpha$ making full repayment 1.[2] For simplicity, we assume that the defaults of the low-quality borrowers are perfectly correlated. We also assume that each borrower obtains the same amount u_B of utility by borrowing D from the lender, regardless of whether the borrower is of high or low credit quality.

3.2 Investors

The investors are risk-neutral, have no discount between periods 0 and 1, and face no wealth constraint in both periods. The investors purchase the securitized products in period 0, and consume the proceeds from their investments in period 1.[3]

The investors do not know the true type of the lenders. They do not observe the lenders' screening activities, either. However, the investors observe whether the lenders carry out verification as well as the result. They also observe the lenders' retention level. The investors set the prices of securitized products to be equal to their expected payoff conditional on this information about the lenders.

[2] As in Fender and Mitchell (2009) and Kiff and Kisser (2010), we assume that the lender can extract rents (here all rents) from his borrowers.

[3] We will assume that the lenders discount payoffs in period 1.

3.3 Lenders and Securitization

There is a continuum of lenders with mass 1. Each of them has his own lending opportunity, the pool of potential borrowers, makes loans to the borrowers in period 0, and collects repayments in period 1. The lender finances the loans by selling a securitized product backed by these loans to investors in period 0. Thus, the lender is the originator of the loans and the issuer of the securitized product.[4] The payoff of the securitized product is equal to the total amount of repayment by the borrowers in period 1. We normalize the nominal amount of the loan asset, and hence that of the securitized product issued by the lender, to be 1. The lender may retain some portion of the securitized product and sell the rest in period 0. However, the retention is costly, so the payoff from the retained portion in period 1 is discounted by the factor β $(0 \leq \beta \leq 1)$.[5]

There are two types of lenders with differing quality of lending opportunities; we call them "good" or "bad" lenders for short. The good lender has the lending opportunity in which all potential borrowers are of non-defaultable high credit quality. That is, all potential borrowers for the good lender repay 1 for certain in period 1. In contrast, the bad lender has the lending opportunity in which some of the potential borrowers are of defaultable low credit quality. That is, the ratio q of potential borrowers for the bad lender default and repay only z $(0 \leq z < 1)$ with probability α, while repaying 1 with probability $1 - \alpha$, and the ratio $1 - q$ of potential borrowers repay 1 for certain. We assume that the ratio of good lenders is $1 - p$, and that of bad lenders is p.

The lender can screen the borrowers and lend only to the borrowers of high credit quality, if he bears screening cost $\gamma_s > 0$. Note that such screening can be meaningful only for the bad lender, since all potential borrowers for the good lender are of high quality. Thus, whether the bad lender carries out the costly screening or not determines the credit quality of his loan asset pool, and hence that of his securitized product. If the bad lender pays the screening cost, he can make loans only to the borrowers of high quality and issue a securitized product backed solely by the high-quality loans. If the bad lender chooses not to pay the screening cost, he can still issue the securitized product by making loans without screening, but the product is now backed by a mix of high- and low-quality loans.

For a lender $k \in [0, 1]$, let y_k be the payoff of k's loan asset pool in period 1. Note that y_k depends on the presence/absence of screening as well as the type. If k is a good lender, all of his potential borrowers are of high credit quality and $y_k = 1$. That is, the securitized product backed by the high-quality loan pool is risk-free. If k is a bad lender and k carries out the costly screening, all borrowers to whom k makes loans are of high credit quality and $y_k = 1$. However, if k is a bad lender and does not carry out the costly screening, the ratio q of borrowers in k's loan pool are of low credit quality and the rest are of high quality. Note that the bad borrower pays back 1 with probability $1 - \alpha$ and

[4]A non-bank MBS originator is the example for the lender in this paper. Ashcraft and Schuermann (2008) provide an overview of the subprime mortgage securitization process and problems arising from informational frictions between players in the process.

[5]See DeMarzo and Duffie (1999) and DeMarzo (2005).

z with probability α, while the good borrower pays back 1 for certain. Thus, in this case, y_k is a random variable that takes the value 1 with probability $1-\alpha$, and $(1-q)+qz$ with probability α; that is, the securitized product backed by the low-quality loan pool is vulnerable to defaults. We denote the expected payoff of the bad lender's loan pool without screening by $x \equiv (1-\alpha)1 + \alpha\{(1-q)+qz\}$.

The lender knows his own type, but the investors cannot know the type of lenders. The investors cannot observe the lender's screening activities, either. Given this asymmetric information, we assume that there is a costly verification technology with which the lender can verify the credit quality of the securitized product for the investors. The cost of verification is $\gamma_v > 0$ and is borne by the lender. We assume that this verification is so accurate that the investors are assured that the credit quality is verified.

We also assume that the lender can retain a part of his securitized product. Denote by b the ratio of securitized product that the lender retains from date 0 to date 1. The lender can choose b, but it should be no less than the minimal retention ratio $\underline{b}$ set by the regulatory authority. (Note that $\underline{b}=0$ implies no retention regulation.) The investors observe b chosen by the lender.

The presence or absence of screening affects the credit quality of the loan asset pool backing the securitized product. This factor, in conjunction with verification and retention, affects the price that the investors are willing to pay for the securitized product. In turn, the price of the securitized product affects whether the lender undertakes such costly screening/verification and retention.

Let us denote by γ the cost to the lender in screening and/or verification. That is, $\gamma = 0$ if the lender does neither screening nor verification, $\gamma = \gamma_s$ if he does only screening, $\gamma = \gamma_v$ if he does only verification, and $\gamma = \gamma_s + \gamma_v$ if he does both. Depending on the type of lender, the cost and the retention, the credit quality of the securitized product may or may not be known to the investors, which affects the price of securitized product.[6]

Knowing his own type and taking account of the effects on the price, the lender $k \in [0,1]$ decides the cost γ that he pays for screening and/or verification and chooses retention level b to maximize his expected profit from securitization. That is, the lender solves the following problem:

$$\begin{aligned} &Max_{\gamma,b}(1-b)S(\gamma,b) + \beta b E_k[y_k(\gamma)] - \gamma - D \\ &s.t.\ \ \gamma = 0,\ \gamma_s,\ \gamma_v,\ \text{or}\ \gamma_s+\gamma_v \\ &\qquad b \geq \underline{b} \\ &\qquad (1-b)S(\gamma,b) - \gamma \geq D, \end{aligned}$$

[6]For example, if k is a good (respectively bad) lender and carries out verification (respectively screening and verification), that is, $\gamma = \gamma_v$ (respectively $\gamma = \gamma_s + \gamma_v$), then the investors learn that the credit quality of the securitized product is high, and hence its price becomes high. On the other hand, if k does not verify (i.e., $\gamma = 0$ or γ_s), the investors learn nothing about the credit quality of the securitized product, and hence its price may not be high.

where β denotes the discount factor by which the lender discounts his date 1 payoff, $y_k(\gamma)$ denotes the date 1 payoff of the lender k's loan asset pool when he spends the cost γ for screening and/or verification, which depends on whether the lender k is good or bad, and $E_k[y_k(\gamma)]$ is the lender k's expectation of $y_k(\gamma)$. $S(\gamma, b)$ is the price of securitized product at which the lender k can sell his product at date 0 when he spends the cost γ for screening and/or verification and retains b.[7] Finally, $(1-b)S(\gamma, b) \geq D$ requires that the lending D be financed solely by the sales of the securitized product.

3.4 Price of the Securitized Product

Let S_h be the price given by the investors to a high-quality securitized product whose expected payoff in period 1 is 1 when the investors know the securitized product is of high quality. Let S_l be the price given by the investors to a low-quality securitized product whose expected payoff in period 1 is x when the investors know the securitized product is of low quality. Note that $S_h = 1$ and $S_l = x$. We denote their average over the population of lenders by $\bar{S} \equiv (1-p)S_h + pS_l = (1-p)1 + px$.

If the good lender carries out costly verification, the price of his securitized product becomes S_h. Also, if the bad lender carries out costly screening and verification, the price of his securitized product becomes S_h. On the other hand, if the bad lender undertakes neither screening nor verification, while the good lender carries out verification, the price of the bad lender's securitized product becomes S_l. Finally, if neither the good lender nor the bad lender undertakes verification (and hence the bad lender does not carry out screening), the price of securitized product becomes $\bar{S}$.

3.5 Maintained Assumptions

To facilitate the analysis, we assume that the following conditions hold throughout this paper.

Assumption 1 (Participation of bad lenders)

$$1 - \gamma_s - \gamma_v \geq D.$$

That is, the bad lender can make at least non-negative profits by screening borrowers, verifying the quality of the securitized product, and selling the product at a high price.

Assumption 2 (Value enhancement of screening and verification)

$$1 - \gamma_s - \gamma_v \geq x.$$

[7] Note that the price $S(\gamma, b)$ is set by the investors and depends on the strategies that all lenders adopt on screening/verification and retention, though we suppress this dependence.

That is, it is more profitable for the bad lender to screen borrowers, verify the quality of the securitized product, and sell the product at a high price than to do nothing and sell the product at a low price.

Assumption 3 (Myopia of lenders)

$$\beta < Min[\frac{\gamma_s}{1-x}, 1-\gamma_v].$$

This is a technical condition. The former part $\beta < \frac{\gamma_s}{1-x}$ is a sufficient condition under which the good lender chooses verification with cost γ_v rather than retention to prove the high quality of his securitized product to the investors when the bad lender chooses screening and verification.[8] The latter part $\beta < 1-\gamma_v$ is a sufficient condition under which the (pooling) price in a non-screening equilibrium is high enough for the good lender not to retain his product when the ratio of bad lenders is small, that is, $\bar{S} > \beta S_h$ holds when $p < \gamma_v/(1-x)$.[9] Both are satisfied if β is small enough, in other words, if the lenders are myopic enough. Thus, this assumption accords with the widespread view regarding the behavior of financial institutions before the subprime crisis.

4 Equilibrium and Welfare without a Retention Regulation ($\underline{b} = 0$)

In this section, we consider the case in which no retention regulation exists, that is, $\underline{b} = 0$.

4.1 A Benchmark Case in Which Investors Know the True Type of Lenders

As a benchmark, we consider a case in which the investors know the true type of each lender, – good or bad – before purchasing the securitized products in period 0. We assume, however, that the investors cannot observe whether the lender screens borrowers.

In this case, since the investors know the type of lenders, the price of the securitized product that the good lender issues is S_h. For the bad lender, the price of his securitized product is S_h if screening and verification take place, and is S_l if they do not. Since we assume that $S_h - \gamma_s - \gamma_v \geq S_l$, the bad lender screens the borrowers, makes loans only to high-quality borrowers, verifies the high credit quality, and sells the high-quality securitized product to the investors at price S_h. Thus, in equilibrium, the lenders issue only securitized products of high credit quality.

[8] See Lemma A in the Appendix.

[9] See Proposition 1.

Note that since each borrower obtains the same amount u_B of utility from borrowing and the lenders extend the same amount of loans to the borrowers, the welfare of the borrowers remains the same. Additionally, since the investors are risk-neutral, the net gain of their expected utility, or the expected payoff less the price of the securitized product, is always zero *ex ante*. Hence, the net *ex ante* gain of welfare in this economy can be measured by the sum of the lender's profits, that is, the sum of the values of securitized products less the amount of loans and screening and verification costs.

Since the profit is $S_h - D$ for the good lender and $S_h - D - \gamma_s - \gamma_v$ for the bad lender, the net *ex ante* gain of welfare is $(1-p)(S_h - D) + p(S_h - D - \gamma_s - \gamma_v)$ in the benchmark case where the investors know the true type of lenders but cannot observe whether the lenders screen borrowers.

4.2 Equilibrium without Retention Regulation

In the following, we analyze the symmetric equilibrium in which the same type of lenders choose the same strategy.

Note that as in the benchmark case, whenever the good lender verifies the high quality of his securitized product, it is more profitable for the bad lender to carry out screening and verification and to sell his high-quality securitized products at the high price S_h. Also, note that without verifying the high-quality, the good lender cannot sell his securitized product at the high price S_h, since otherwise the bad lender will imitate the good lender and sell his low-quality products without screening at the high price S_h. Knowing this, the investors do not pay S_h for the securitized product: S_h is not attainable for the good lender without verification.

Hence, in our simple model, there are two types of equilibria. One is the screening equilibrium in which the bad lender carries out screening and verification, and the good lender verifies the quality of his product. The other is the non-screening equilibrium in which the bad lender does neither screening nor verification, and the good lender does not do verification, either. In the screening equilibrium, both the good and bad lenders issue the high-quality securitized products at the price S_h. In the non-screening equilibrium, the good lender issues the high-quality securitized product while the bad lender issues the low-quality one, and all securitized products receive the same pooling price $\bar{S}$.

We investigate under what conditions these equilibria emerge. For this purpose, let us consider the non-screening equilibrium. Denote by b^* the optimal retention ratio of the good lender in the non-screening equilibrium. Note that under Assumption 3, $\beta < 1$. Hence, $S_h > \beta S_h > \beta S_l$ and both good and bad lenders set b^* as small as possible in the screening equilibrium. Then, under the assumptions above, the non-screening equilibrium emerges if and only if the following conditions hold.

$$\begin{aligned} S_h - \gamma_v &\leq (1-b^*)\bar{S} + \beta b^* S_h && (1) \\ S_h - \gamma_s - \gamma_v &\leq (1-b^*)\bar{S} + \beta b^* S_l && (2) \\ (1-b^*)\bar{S} &\geq D. && (3) \end{aligned}$$

The first inequality is the incentive compatibility condition for the good lender to choose the non-screening equilibrium. Likewise, the second inequality is the incentive compatibility condition for the bad lender to choose the non-screening equilibrium. Note that the bad lender chooses the same retention ratio b^* as the good lender in the non-screening equilibrium. Otherwise, the bad lender's securitized product is revealed to be of low quality and the investors buy it only at the low-quality price S_l. The third inequality is the funding constraint showing that the lender can finance his loans by selling the securitized products at the non-screening price $\bar{S}$.

From these conditions, we obtain the following proposition for the existence of the non-screening and screening equilibria.[10]

Proposition 1

> Under the assumptions above, if $p \leq \frac{\gamma_v}{1-x}$, there exists a non-screening equilibrium. Otherwise, there exists a screening equilibrium. In both equilibria, the optimal retention ratio is zero.

Proof of Proposition 1

> See the Appendix.

In the non-screening equilibrium, since the investors cannot distinguish the high-quality securitized products from the low-quality ones, all securitized products receive the same average pooling price. When the ratio of the bad lenders is small, in other words, when the possibility is low that a securitized product is issued by the bad lender, the average price becomes relatively high. If the average price is high enough, it becomes more profitable for the bad lender to sell his low-quality product at the average price than to create the high-quality product and sell it at the high price by incurring screening and verification costs. The bad lender then loses the incentive to improve the quality of his securitized product. Likewise, if the average price is high enough, it becomes more profitable for the good lender to sell his high-quality product at the (lower) average price than to sell it at the high price

[10] This proposition is an extension of those in Hattori and Ōhashi (2009) to the case where $\beta > 0$ and the lender can retain his securitized product.

by incurring the verification cost. The good lender loses the incentive to verify the quality of his securitized products. Consequently, the non-screening equilibrium emerges with a low average quality of securitized products.

On the other hand, when the ratio of the bad lenders is high, that is, when the possibility is high that a securitized product is issued by the bad lender, the average price becomes low. In this case, the bad lender is better off by creating the high-quality securitized product with screening and verification costs, and the good lender is better off by verifying the high quality of his securitized product with verification cost. Consequently, the screening equilibrium emerges with a high quality of securitized products.

Note that the average quality of securitized products is lower when a small portion of lenders is bad, and high when most of the lenders are bad. Thus, it is when the small ratio of lending opportunities turns bad, or when the the booming economy begins to enter a recession, that the average quality of securitized products is likely to be low. This is because in such a situation, the securitized product of low credit quality without screening, commingled with the high-quality products, is overpriced from the bad lender's viewpoint. Such overvaluation of securitized products distorts not only the bad lender's incentive to improve the quality of his own securitized product, but also the good lender's incentive to prove the quality of his securitized product.

Note also that such reduction in average credit quality of securitized products occurs despite the assumption that verification is perfect. Hence, the result shows that even though the rating of securitized products has perfect precision, the quality of the products may not be revealed accurately and low-quality products may be issued.

Finally, it is worth noting that the condition $p \leq \frac{\gamma_v}{1-x}$ is equivalent to $S_h - \gamma_v \leq \bar{S}$, which is the good lender's incentive compatibility condition. That is, Proposition 1 shows that in equilibrium the bad lender's incentive of screening and verification depends on the good lender's incentive of verification. Hence, in this economy, a regulation that attempts to control the bad lender's incentive also affects the good lender's incentive, which in turn influences the bad lender's. Thus, it is important to know how the regulation affects the good lender's incentive even when its purpose is to control the bad lender's. This point will be the main focus of the next section.

4.3 Welfare Losses in Equilibria

Recall that the net gain of *ex ante* welfare of the benchmark case is

$$(1-p)(S_h - D) + p(S_h - \gamma_s - \gamma_v - D).$$

We obtain the net *ex ante* gains of welfare and losses compared to the benchmark in non-screening and screening equilibria as follows:

Proposition 2

The net *ex ante* gain of welfare in the non-screening equilibrium is

$$(1-p)(\bar{S}-D)+p(\bar{S}-D)$$

and its welfare loss compared to the benchmark is

$$p(S_h-\gamma_s-\gamma_v-S_l).$$

The net *ex ante* gain of welfare in the screening equilibrium is

$$(1-p)(S_h-\gamma_s-D)+p(S_h-\gamma_s-\gamma_v-D)$$

and its welfare loss compared to the benchmark is

$$(1-p)\gamma_v.$$

The welfare loss in the non-screening equilibrium comes from the failure of the bad lender to improve the credit quality of securitized products with costly screening and verification, even though it is value enhancing. As explained above, such inefficient securitization occurs because in the non-screening equilibrium the price is pooling in the sense that both the high- and low-quality securitized products have the same price, and hence the low-quality securitized product is overvalued from the bad lender's viewpoint. Due to this overvaluation, the bad lender has fewer incentives to screen borrowers than when the low-quality product is correctly priced low.

It is worth noticing that there is also welfare loss in the screening equilibrium, which stems from the good lender's need to undertake costly verification; to verify the quality of his product, the good lender must pay verification cost γ_v. Because of this welfare loss, it is not obvious that the welfare level is higher in the screening equilibrium than in the non-screening equilibrium.

5 Effects of the Retention Regulation

We define the retention regulation in this analysis such that each lender is required to retain at least the minimum ratio $\underline{b}$ of his own securitized product. Thus, we consider the case of a "vertical slice," that is, *pro rata* retention of the securitized product.[11] We assume that the regulator cannot distinguish the good lenders from the bad, so that the regulation is imposed on all lenders equally. We also assume that the regulation is set before all events occur in the economy and hence cannot depend on parameter values of the economy.

[11] See Fender and Mitchell (2009) and Kiff and Kisser (2010).

In the following, we focus on the case where $\bar{S} \geq \beta S_h$ by assuming

$$p \leq \frac{1-\beta}{1-x}.$$

In this case, similar to Proposition 1, we can show that the lenders choose the least retention ratio allowed by the regulator, $\underline{b}$, given the pooling price $\bar{S}$.

5.1 Non-Screening Equilibrium with a Retention Regulation

As is the case without retention regulation, the non-screening equilibrium with a retention regulation emerges if and only if the following conditions hold.[12]

$$\begin{aligned}
(1-\underline{b})S_h + \beta\underline{b}S_h - \gamma_v &\leq (1-\underline{b})\bar{S} + \beta\underline{b}S_h && (4)\\
(1-\underline{b})S_h + \beta\underline{b}S_h - \gamma_s - \gamma_v &\leq (1-\underline{b})\bar{S} + \beta\underline{b}S_l && (5)\\
(1-\underline{b})\,\bar{S} &\geq D. && (6)
\end{aligned}$$

The first inequality is the incentive compatibility condition for the good lender to choose the non-screening equilibrium, which we call GIC$_N$. The second inequality is the incentive compatibility condition for the bad lender to choose the non-screening equilibrium, which we call BIC$_N$. The third inequality is the funding constraint, which we call FC$_N$, showing that the lenders can finance their loans by selling the securitized products at the non-screening price $\bar{S}$ while retaining $\underline{b}$.

These conditions can be rewritten as

GIC$_N$:

$$p \leq \frac{\gamma_v}{(1-\underline{b})\,(1-x)}$$

BIC$_N$:

$$p \leq \frac{\gamma_v + \gamma_s - \underline{b}\beta(1-x)}{(1-\underline{b})\,(1-x)}$$

FC$_N$:

$$p \leq \frac{1-\underline{b}-D}{(1-\underline{b})\,(1-x)}.$$

We obtain the following proposition.

[12] See also Lemma A in the Appendix.

Proposition 3

Suppose that the lenders are required to retain at least $\underline{b}$ of their own securitized products. Suppose also that $p < (1-\beta)/(1-x)$. Then, under the assumptions above, there exists a non-screening equilibrium if

$$p \leq \frac{1}{(1-\underline{b})(1-x)} Min\left\{\gamma_v, 1-\underline{b}-D\right\}.$$

There exists a screening equilibrium if

$$\frac{\gamma_v}{(1-\underline{b})(1-x)} < p \leq \frac{1-\underline{b}-D}{(1-\underline{b})(1-x)}$$

as long as $1-\gamma_v-\gamma_s-D \geq \underline{b}$.

The result is similar to the one without the retention regulation, and the non-screening equilibrium emerges when p is small, in other words, the ratio of the bad lenders is small. Note that the result corresponds to the one without a retention regulation if $\underline{b} = 0$.[13]

5.2 Equilibrium and Welfare with the Minimum Retention Ratio $\underline{b}$

In this subsection, we analyze the equilibrium and welfare implication of the retention regulation in the economy considered above. Recall that we have assumed $p \leq (1-\beta)/(1-x)$ (i.e., $\bar{S} \geq \beta S_h$) so that the lenders retain as little as possible given the pooling price $\bar{S}$. Also, by Assumption 3, $\beta < (\gamma_s + \gamma_s)/(1-x)$, which implies that the BIC$_N$ curve, drawn in the ($\underline{b}$, p) plane, is increasing in $\underline{b}$. The GIC$_N$ curve is increasing in $\underline{b}$, too.

This feature of GIC$_N$ is crucial for realization of a certain equilibrium for a set of ($\underline{b}$, p) and it is the background for the case in which a minimum retention regulation can result in an outcome counter-productive to its aim of ensuring that the lenders exercise screening in their lending. The shape of BIC$_N$, either increasing or decreasing in $\underline{b}$, does not matter in the derivation of this interesting result. We will explain why this is so in this sub-section.

5.2.1 Effect of the retention regulation on the non-screening equilibrium

Before we move to analytical expansion concerning a welfare comparison between different equilibria, we provide a visual discussion of the case characterized by the two inequality

[13] When the retention ratio $\underline{b}$ is too large, the lenders cannot finance their loans and the results vary depending on the parameter values. We omit the details and show only the relevant results here.

conditions above.[14] Figure 1 shows the pair $(\underline{b}, p)$ corresponding to different kinds of equilibrium. The intercept of FC_N on the vertical axis is $\frac{1-D}{1-x}$ and it is larger than the one for BIC_N, $\frac{\gamma_s+\gamma_v}{1-x}$, because of Assumption 1 $(1-\gamma_s-\gamma_v-D>0)$. The areas marked as A_1 and A_2 are under all curves for BIC_N, GIC_N, and FC_N. Therefore, for the pair $(\underline{b}, p)$ in these areas, the non-screening equilibrium holds. Outside area A_1 and A_2, either GIC_N or FC_N for the non-screening equilibrium is violated.

The reason we show the non-screening equilibrium area separately as A_1 and A_2 is that the peculiarity of area A_1 is worth mentioning. Suppose p is marginally above the intercept of GIC_N on the vertical axis, that is, $\frac{\gamma_v}{1-x}$. Without retention, in other words, when $\underline{b}=0$, the set $(\underline{b}, p)$ is outside A_1 and A_2 and the equilibrium is a screening one. If the regulatory authority implements a minimum retention ratio regulation and forces the lenders to set the retention ratio to be a positive value, the realized set of $(\underline{b}, p)$ falls into area A_1 and the equilibrium changes to a non-screening equilibrium as long as the retention ratio does not violate FC_N. As in this example, for a given p, the equilibrium turns from a screening one to a non-screening one due to the minimum retention ratio regulation. In other words, area A_1 is the area in which the pair $(\underline{b}, p)$ for the non-screening equilibrium expands for a given value of p.

We can elaborate on the effect of the minimum retention ratio regulation and its welfare implication by discussing the characteristics of example points in Figure 2 and 3. In these, four points show how the minimum retention ratio may change the equilibrium for a certain value of p that we interpret as the state of the loan market. *Point 1* and *Point 3* are the equilibrium for a certain value of p when the minimum retention ratio regulation is not implemented: the realized retention ratio is zero in these cases.

When the minimum retention ratio regulation is implemented, the authority can force the lenders to set the retention ratio at least at the regulatory minimum retention ratio. In the current setup, it is optimal for the lenders to make the regulatory minimum retention ratio the actual retention ratio. *Point 2* and *Point 4* are examples of the case of a certain minimum retention ratio for a certain value of p.

Now, we focus on Figure 2 to see the effect of the retention regulation on the non-screening equilibrium specifically. Suppose that the equilibrium without the minimum retention ratio regulation is *Point 1*. When the regulation is implemented and the minimum retention ratio is set corresponding to *Point 2*. *Point 1* is surely a non-screening equilibrium. However, *Point 2* can be neither a screening nor a non-screening equilibrium: the funding constraint under the non-screening equilibrium is violated, and the funding constraint for the bad lenders under the screening equilibrium that is $\underline{b} < 1-\gamma_s-\gamma_v-D$ in Proposition 3, shown as FC_S in Figure 2, is also violated. Actually, we arrive at the rather strong claim that the minimum retention ratio regulation can never change a non-screening equilibrium to a screening equilibrium. This is contrary to the much discussed and expected result of the regulation. In our setup, this conclusion stems from the fact that the funding

[14] In the following, we consider the case where β is so small that the condition $p < \frac{1-\beta}{1-x}$ does not affect the discussion.

constraint for the screening equilibrium ($\underline{b} < 1 - \gamma_s - \gamma_v - D$) becomes binding before the funding constraint for the non-screening equilibrium becomes binding, as $\underline{b}$ increases when the equilibrium without the minimum retention ratio regulation is in the area for the non-screening equilibrium, that is, on the vertical axis with $p < \frac{\gamma_v}{1-x}$.

We analytically derive the change in welfare as a result of the minimum retention ratio regulation for this case. The *ex ante* welfare for a non-screening equilibrium with a certain $\underline{b}$ is

$$\begin{aligned} & (1-p)\left((1-\underline{b})\,\bar{S} + \beta\underline{b}S_h\right) + p\left((1-\underline{b})\,\bar{S} + \beta\underline{b}S_l\right) - D \\ = \; & (1-(1-x)\,p) - \underline{b}\,((1-\beta)\,(1-p(1-x))) - D. \end{aligned}$$

This is decreasing in $\underline{b}$. When there is no minimum retention ratio regulation, the lenders choose no retention ratio and the welfare is $(1-(1-x)\,p) - D$. This value is the welfare level attained at *Point 1.* As the minimum retention ratio under the regulation increases, the attained welfare level decreases. Because the equilibrium continues to be a non-screening one when $p < \frac{\gamma_v}{1-x}$, as long as the funding constraint for the non-screening equilibrium holds, the welfare effect of the minimum retention ratio regulation is simply welfare decreasing in the area.

We summarize the arguments above as Proposition 4.

Proposition 4

> Suppose that the equilibrium without the minimum retention ratio regulation is a non-screening equilibrium. Then, under the assumptions above, implementation of the minimum retention ratio regulation does not change the non-screening equilibrium to a screening one. Moreover, it has welfare-reducing effect.

5.2.2 Effect of the retention regulation on the screening equilibrium

Next, we discuss the effect of the minimum retention ratio regulation on the screening equilibrium. An example is depicted in Figure 3. Suppose the equilibrium without the minimum retention ratio regulation is *Point 3.* Then, the regulation is implemented and the minimum retention ratio is set corresponding to *Point 4.* In this case, the equilibrium changes from a screening equilibrium (*Point 3*) to a non-screening one (*Point 4*). The minimum retention ratio regulation changes the equilibrium from a screening to a non-screening one. Therefore, in this case, the regulation affects lenders' motivation in a way that is counter-productive to the aim of the regulation. As long as the minimum retention ratio is predetermined regardless of the state of the loan market, that is, p, such a possibility cannot be excluded. Although one way to eliminate the possibility is for the regulatory authority to determine the minimum retention ratio after it assesses the state of the loan market, such a practice does not occur in reality.

We can analytically derive the change in welfare for this case, too. Solving out the *ex ante* welfare at *Point 3* and *Point 4* and subtracting the value for the former from the one for the latter, we obtain the difference as

$$(\gamma_v + p\gamma_s) - p(S_h - S_l) - \widehat{b}(1-\beta)\left(1 - p(1-x)\right). \tag{7}$$

Here $\widehat{b}$ is a certain minimum retention ratio set by regulation corresponding to *Point 4*. The difference consists of three terms: the cost of financial technologies incurred in the non-screening equilibrium, the increase in value by screening, and the cost of retention.

We investigate whether this welfare effect is positive or negative. Equation (7) is negative if and only if

$$p < \frac{\widehat{b}\,(1-\beta) - \gamma_v}{\gamma_s - (S_h - S_l) + \widehat{b}\,(1-\beta)\,(1-x)}. \tag{8}$$

We first check if the right-hand side of the inequality is increasing or decreasing in $\widehat{b}$. Taking the derivative in terms of $\widehat{b}$, we get

$$\frac{(1-\beta)\,(\gamma_s + \gamma_v - 1 + (1-\gamma_v)\,x)}{\left(\gamma_s - (S_h - S_l) + \widehat{b}\,(1-\beta)\,(1-x)\right)^2}.$$

The denominator is positive and the numerator is negative if

$$\gamma_s + \gamma_v - 1 + (1-\gamma_v)\,x < 0,$$

that is, if

$$1 - \gamma_s - \gamma_v > (1-\gamma_v)\,x.$$

This inequality always holds true under Assumption 2 ($1 - \gamma_s - \gamma_v > x$). Therefore, the derivative is negative and the right-hand side of the inequality is decreasing in $\widehat{b}$. The second derivative in terms of $\widehat{b}$ is negative because $\widehat{b}$ is only in the denominator with a positive sign in the first derivative.

The value of the right-hand side when $\widehat{b} = 0$ is $\frac{\gamma_v}{1-x-\gamma_s}$ that is larger than the intercept of GIC_N, $\frac{\gamma_v}{1-x}$, in Figure 1. Therefore, when we plot the right-hand side as a function of $\widehat{b}$ in the figure, the line crosses GIC_N from above. The locus is shown as the dashed-curved line in Figure 3. Thus, transition from a screening equilibrium to a non-screening equilibrium exemplified by the move from *Point 3* to *Point 4* for the range of p between $\frac{\gamma_v}{1-x}$

and $\frac{\gamma_v}{1-x-\gamma_s}$ can be welfare reducing. Note that the transition can also be welfare increasing: this happens when the equilibrium corresponding to a certain minimum retention ratio $\widehat{b}$ like *Point 4* has a position beyond the line expressing the right-hand side of the inequality (8) (and before FC_N).

Contrary to the case of Proposition 4, we cannot decisively determine its welfare effect. However, what is notable is that implementation of the minimum retention ratio regulation can affect the incentive of the lenders in the way that changes the equilibrium from a screening to a non-screening one, and the effect can be welfare decreasing. In such a case, the minimum retention ratio regulation has an effect counterproductive to its aim of motivating the lenders to undertake screening and at the same time has a negative welfare effect.

We summarize the arguments above as Proposition 5.

Proposition 5

> Suppose that the equilibrium without the minimum retention ratio regulation is a screening equilibrium. Then, it is possible that implementation of the minimum retention ratio regulation changes the screening equilibrium to a non-screening one and reduces welfare.

6 Discussion and Concluding Remarks

In this paper, we analyze the interaction between the price of a securitized product and the lender's incentive to improve the credit quality of the product in the OTD business model. We show that with asymmetric information between the lender and the investors, the lender may lose the incentive to screen the borrowers and hence issue a low-credit-quality securitized product. The mechanism underlying this result is that in the OTD business model the lender decides whether to screen the borrowers to maximize the expected profit by comparing the price of the low-quality securitized product backed by unscreened loans with that of the high-quality product backed by screened loans, less screening and verification costs. Due to asymmetric information, the investors cannot distinguish the low-quality product from the high-quality one, and give an average price to both low- and high-quality products, which yields a relative overvaluation of the low-quality securitized product from the lender's perspective. This overvaluation reduces the lender's incentive to improve the credit quality of his product through costly screening.

Motivated by arguments about financial regulatory reform in the wake of the subprime loan crisis, we then analyze the effect of the minimum retention ratio regulation on the lender's incentive and the welfare gain/loss. Contrary to the widespread view that the retention regulation is effective to motivate the lender to improve the lending standard in the OTD business model, we find that implementation of the minimum retention ratio regulation may discourage the lender from conducting screening activity. Moreover, the welfare effect of the regulation is ambiguous and can be negative in a certain situation. Thus, the minimum retention ratio regulation can be counterproductive to, or even detrimental for, its aim of inducing the lender to carry out more screening and thereby improve welfare. This result stems from the fact that the lender discounts future cash flows. Forcing retention delays the timing of gains, reduces the profit from improving credit quality, and hence may discourage the lender from conducting costly screening and verification.

These results have several implications worth mentioning. First, the accuracy of rating (i.e., verification) may not be sufficient to give the lender an incentive to improve the credit quality of the securitized product. Even if the rating of the securitized product is perfect, the lender may decide not to conduct costly screening of borrowers. This is because under asymmetric information the investors may overprice the low-quality securitized product, which reduces the price difference between the high- and low-quality products and hence makes it less profitable for the lender to improve the credit quality of his product with the costs of screening and verification and sell it at a higher price.

Second, the low-quality securitized product is more likely to be issued when there are fewer low credit-quality potential borrowers in the loan market.[15] This is because in such a situation the price of the securitized product without verification, set by the investors as the average between the true value of the high-quality product and that of the low-quality one, increases. This exacerbates the relative overvaluation of the low-quality product, and hence discourages the lender from improving the quality of the securitized product. Thus, in the OTD business model, the low-quality product tends to be issued just after an economic boom hits its peak, or when lending opportunities start deteriorating, but not in a recession when a large portion of the lending opportunities has already turned bad.

Third, regulation is costly and affects not only the target agent but also other agents, which may lead to an unintended result. The minimum retention ratio regulation intends to motivate the bad lender to screen borrowers by affecting his incentive. However, the regulation also affects the good lender's incentive and indeed discourages him from conducting costly verification. Through strategic interaction between the good and bad lenders, this in turn reduces the bad lender's incentive of screening. Consequently, the minimum retention ratio regulation may give the bad lender less incentive to screen, cost both types of the lenders, and reduce welfare without improving the quality of securitized products. Accordingly, in the design of financial regulation, its intrinsic cost and differential effects on different types of agents should be carefully considered.

There are also several points that this paper leaves for possible extension in future research. First, while this paper considers a "vertical slice," different types of retention, for example, equity and mezzanine, are also utilized in the real business. As Fender and Mitchell (2009) and Kiff and Kisser (2010) did in investigating the effects of different retention types on incentives to improve the credit quality, it would be interesting to analyze how different types of retention affects the results above.

[15] Except, of course, the case in which all potential borrowers are of high credit quality.

Second, this paper focuses on the case where the lenders are myopic, that is, β is small. While this condition reflects the widespread view about the behavior of financial institutions before the subprime crisis, it is also natural to ask how the results can change when the lenders are patient, that is, when β is large and close to 1.

Finally, although this paper considers a model with rational investors under asymmetric information to analyze the interaction between the (mis)pricing of the securitized product (perceived by the lender) and the lender's incentive to improve the credit quality of the product, a similar incentive problem in the OTD business model can be addressed in a model with "irrational" investors whose behavior generates mispricing of securitized products. For example, suppose that the ratio of bad lenders perceived by the irrational investors is given by the subjective $\hat{p}$, not by the objective p. Suppose that the lenders are rational and maximize their expected profits from their OTD business. Then, if the investors irrationally believe that the bad lenders are fewer than exist in reality, that is, $\hat{p} < p$, the non-screening (average) price of the securitized products will rise, the lenders' gains from improving the credit quality of their products through screening and verification costs will decrease, and the low-credit-quality securitized products will be issued as shown in this paper. The interaction between price and incentive in a behavioral setting seems an important issue for future investigation.

Appendix

Lemma A

> If $\beta < \frac{\gamma_s}{1-x}$, then the good lenders never choose retention to prove the high-quality of their securitized products to the investors when the bad lenders create high quality products with screening and verification.

Proof of Lemma A

Denote by $\underline{b}$ the minimum retention ratio required by the regulation. Suppose that the good lenders can prove, without verification, the high quality of their securitized products to the investors by retaining ratio b_{GS} of their products and can sell their products at the high price S_h.

Since the price cannot be a pooling one in this case, for such b_{GS} to exist in an equilibrium, the following conditions are necessary:

$$\begin{aligned}
(1-b_{GS})S_h + \beta b_{GS} S_h - D \quad &\geq \quad (1-\underline{b})S_h + \beta \underline{b} S_h - \gamma_v - D \\
(1-b_{GS})S_h + \beta b_{GS} S_l - D \quad &\leq \quad (1-\underline{b})S_h + \beta \underline{b} S_h - \gamma_v - \gamma_s - D \\
\underline{b} \leq \quad b_{GS} \quad &\leq 1.
\end{aligned}$$

The first inequality is the good lenders' incentive compatibility condition under which the good lenders prefer retaining b_{GS} to costly verification to prove the high quality of their products. The second inequality is the bad lenders' incentive compatibility condition under which the bad lenders have no incentive to imitate the good lenders by retaining b_{GS}. The last inequality requires the retention ratio b_{GS} to comply with the regulation and be less than one.

It is now easy to see that there is no b_{GS} that satisfies these conditions if $\beta(1-x) < \gamma_s$. Thus, under Assumption 3, the good lenders never choose retention to prove the high quality of their securitized products to the investors. ||

Proof of Proposition 1

Note first that by Assumption 3, as shown in Lemma A, both good and bad lenders choose screening/verification rather than retention in a screening equilibrium. As explained just before inequalities (1)-(3), since $S_h > \beta S_h > \beta S_l$, both good and bad lenders set the retention ratio as small as possible in the screening equilibrium.

Note also that $p \le \frac{\gamma_v}{1-x}$ is equivalent to $S_h - \gamma_v \le \bar{S}$. In addition, by Assumption 3, $\beta < 1 - \gamma_v$. Hence, $\beta S_h < \bar{S}$ if $p \le \frac{\gamma_v}{1-x}$, since $S_h = 1$.

Suppose that there is a non-screening equilibrium with an optimal retention ratio $b^* > 0$. In a non-screening equilibrium, inequalities (1)-(3) hold and it is most profitable for the bad lender to choose the same retention ratio as the good lender. However, as shown above, $\bar{S} > \beta S_h$. Hence, it is most profitable for the good lender to choose as small a retention ratio as possible, as long as this behavior is imitated by the bad lender. Thus, $b^* > 0$ cannot be the optimal retention ratio, and $b^* = 0$ is necessary for a non-screening equilibrium.

Now, if $p \le \frac{\gamma_v}{1-x}$, then $S_h - \gamma_v \le \bar{S}$, which clearly implies $S_h - \gamma_v - \gamma_s \le \bar{S}$. Hence, given the argument above, the IC conditions of both good and bad lenders are satisfied. Moreover, by Assumption 1, $S_h - D > \gamma_v$. Hence, together with Assumption 3, $p < \frac{1-D}{1-x}$, which is equivalent to $\bar{S} > D$, in other words, the funding condition is satisfied. Thus, there exists a non-screening equilibrium.

Alternatively if $p > \frac{\gamma_v}{1-x}$, then $S_h - \gamma_v > \bar{S}$. On the other hand, by Assumption 3, $1 - \gamma_v > \beta$, which implies $S_h - \gamma_v > \beta S_h$. Hence, $S_h - \gamma_v > (1-b^*)\bar{S} + \beta b^* S_h$ for all b^*, and the good lenders choose verification. Then, the pooling price $\bar{S}$ cannot emerge, and since $S_h - \gamma_v - \gamma_s > S_l$ by Assumption 2, the bad lenders cannot help choosing screening and verification. By Assumption 1, $S_h - \gamma_v \ge S_h - \gamma_v - \gamma_s > D$, and the funding conditions are satisfied. Thus, there exists a screening equilibrium. ||

Proof of Proposition 3

By Assumption 3, $\beta(1-x) < \gamma_s$. Hence,

$$\frac{\gamma_v}{(1-\underline{b})\,(1-x)} < \frac{\gamma_v + \gamma_s - \underline{b}\beta(1-x)}{(1-\underline{b})\,(1-x)}.$$

Thus, GIC_N implies BIC_N and if

$$p \leq \frac{1}{(1-\underline{b})(1-x)} Min\left\{\gamma_v, 1-\underline{b}-D\right\},$$

then all conditions (4)-(6) for a non-screening equilibrium are satisfied.

On the other hand, if

$$\frac{\gamma_v}{(1-\underline{b})(1-x)} < p \leq \frac{1-\underline{b}-D}{(1-\underline{b})(1-x)},$$

then GIC_N is violated so that $(1-\underline{b})S_h + \beta\underline{b}S_h - \gamma_v > (1-\underline{b})\bar{S} + \beta\underline{b}S_h$ while FC_N (i.e., (6)) is satisfied so that $(1-\underline{b})\bar{S} \geq D$. Hence, the good lenders choose verification, and $(1-\underline{b})S_h - \gamma_v > D$, that is, the good lenders' financing constraint for verification is satisfied. Finally, since $S_h = 1$ and $1 - \gamma_v - \gamma_s - D \geq \underline{b}$ is equivalent to $(1-\underline{b})S_h - \gamma_v - \gamma_s \geq D$, the bad lenders' financing constraint for screening and verification is satisfied. Thus, there exists a screening equilibrium. ||

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Figure 1

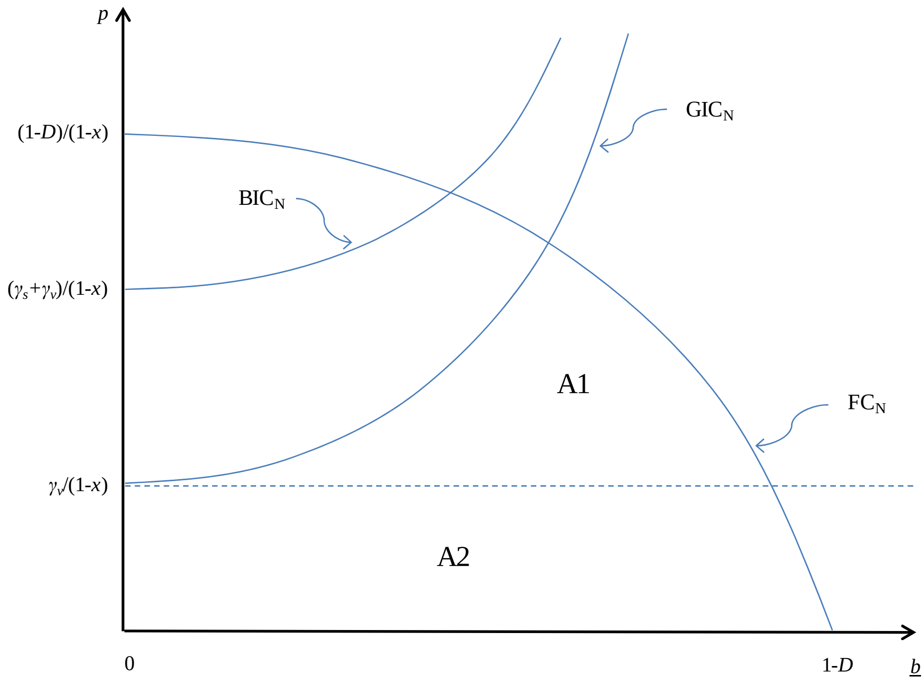


Figure 2

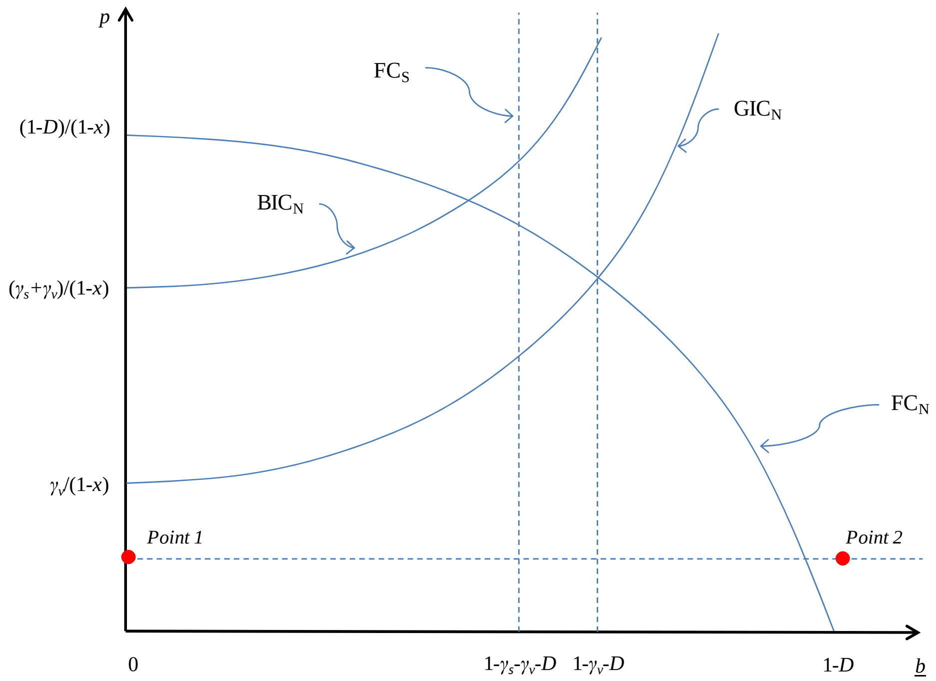
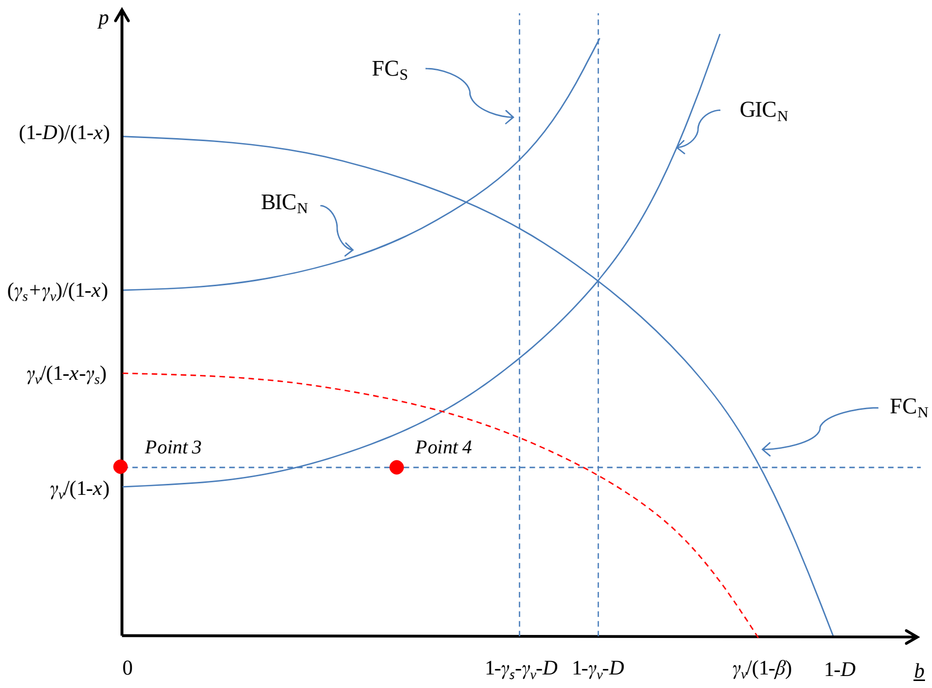


Figure 3



p
(1-D)/(1-x)
(γs+γv)/(1-x)
γv/(1-x-γs)
γv/(1-x)
FCS
GICN
BICN
FCN
Point 3
Point 4
0
1-γs-γv-D
1-γv-D
γv/(1-β)
1-D
b