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Securitization, Bank Vigilance, Leverage and Sudden Stops

by

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Abstract

If securitization gives loan originators weaker incentives to screen borrowers, and thus hinders their ability to commit to better levels of efforts, then why would banks prefer it to traditional methods of finance, as one would expect in a principle-agent model?

This paper addresses this puzzle with a model in which banks choose the volume of lending, a variable level of effort in screening potential borrowers, and the method of finance. Securitization allows banks to communicate more information to investors, which increases screening efforts at fixed leverage, but also incentivises banks to increase leverage, which in turn degrades the screening effort.

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1 Introduction

In the aftermath of the recent financial crisis, many fingers have been pointed at the growth of the market for mortgage-backed securities (MBS) as a central source of instability. Through these inscrutable investment vehicles, the argument goes, banks have found a way to disguise risky assets as safe, and to be insufficiently vigilant in monitoring their borrowers since someone else is bearing most of the risk (e.g. Caprio et al., 2010; Gorton, 2009; Ashcraft and Schuermann, 2008; Mian and Sufi, 2009). Empirical evidence that has emerged since supports the claim that securitization leads to higher default rates, and suggests that this might be due to lax screening of borrowers (Keys et al., 2009, 2010, 2012; Elul, 2016; Purnanandam, 2011). These observations raise an important question: if securitization indeed exacerbates agency problems between a bank and its investors, why would banks prefer this method of finance?

To explicate this question, recall that in a typical principle-agent problem, it would be in the best interest of the agent to specify a contract that would make it incentive-compatible for himself to behave as close as possible to the first-best. Thus, if banks behave more responsibly when they raise funds via traditional deposits, then they should not want to switch to securitization. Indeed, the whole idea behind securitization (DeMarzo, 2005) is that it allows the bank to design a more general contract with investors, which should reduce agency problems, rather than exacerbate them.

In this paper I propose a theory of securitization, in which securitization emerges as an equilibrium outcome even though it leads to lower vigilance in screening borrowers. I introduce a model in which banks make loans to households, choosing the volume of loans they make, the effort they exert in screening households, and whether to finance these loans through eliciting deposits or selling securities. The difference between securitization and deposits in the model is that the first allows the bank to communicate information about borrowers to the buyers of securities, while depositors do not have access to such information. The key finding is that while securitization allows the bank to commit to a *higher* level of effort at fixed leverage, it also leads to a higher equilibrium leverage, which in turn leads to lower effort. Thus, it is not that securitization transfers risk from the bank to the investor in a way that disincentives the bank from exerting sufficient effort directly (in fact, the banks end up taking more risk), but rather it is the indirect effect of motivating the bank to leverage up that generates the lower effort. Paradoxically, the method of finance that allows for more transparent information leads to that information being less valuable.

This conclusion bares relevance for other financial innovations as well, as it points out how financial technologies that are intended to mitigate frictions, might lead to unintended consequences through the leverage channel.[1] In fact, this model exhibits a number of the phenomena discussed in Gertler et al. (2016): the financial innovation (securitization) increases both the credit supplied and the appetite for risk, and a small deterioration in economic conditions can lead to a large collapse and a financial crisis. Therefore, this paper can be considered as a possible micro-foundation for the financial sector in Gertler et al. (2016), since the advantage of the innovation is modeled explicitly here (rather than assumed as an exogenous proficiency advantage).

The model assumes that the bank screens potential borrowers by generating a signal about the probability that they default. The accuracy of the signal is chosen by the bank at a cost, and is unobservable to investors. The signal itself – but not its accuracy – can be reliably communicated to investors when the bank chooses to sell securities. The idea here is that the signal is composed of objectively verifiable information about which the bank cannot lie, but which can be obtained with variable accuracy (e.g. value of the

[1] See also Iachan et al. (2015) for a general discussion.

asset, income of the borrower).[2] As usual in such models, as the leverage ratio increases, the bank's incentive to invest in the signal decreases, so that in equilibrium the level of investment in the signal is lower than the first-best.

When banks choose to finance by using deposits there is no way to communicate the value of the signals to the depositors. Thus, in addition to the above asymmetric information problem, there is the danger that the bank will find it optimal to make out loans to borrowers regardless of the value of the signal. While lending to a potential borrower with a bad signal is socially undesirable, it may be profitable for the bank at high enough leverage ratios. The result is that financing through deposits leads to both a lower leverage ratio than securities, and as mentioned previously, this in turn implies that securitization is characterized by lower lending standards.

Beyond reproducing the observed association between securitization and default rates, this paper also explains the empirical observation that securitized loans are more likely to default than non-securitized loans, even after controlling for credit ratings (Keys et al., 2010, 2012; Purnanandam, 2011). Unlike previous literature, which suggests that this is due to banks using private information to securitize only lower-quality loans (An et al., 2009; Downing et al., 2009), in my model this is due to banks screening less accurately when securitizing. In the consumer credit market, where lending decisions are often made automatically based on mechanical analysis of information provided by the borrower, the reader may find this new interpretation more plausible.

Obviously, it is possible that there are other advantages to securitization that lead banks to use this method of finance even if it leads to lower lending standards. Such advantages can be circumventing regulation, tax benefits, and others (Gorton and Metrick, 2012).

[2] Mian and Sufi (2017) provide evidence that during the years 2002-2005 there was an increase in income overstatement, suggesting that the reliability of the information about borrower is a choice variable for banks or other originators.

The existence of other advantages notwithstanding, this paper point out that even without them, financial innovations that aim to mitigate agency problems might lower investment quality through an increase in leverage.

An additional advantage of my model is that it leads naturally to abrupt stops in securitization activity. Formally, the choice between funding through securitization or through deposits is a matter of determining which of two local maxima is the global maximum, which is a binary function of continuous parameters of the model. Thus, when, for example, the unconditional quality of potential borrowers drops below a critical threshold, securitization stops, and the overall volume of lending drops discontinuously. This helps address other puzzles about the MBS market, namely, why originators refrain from securitizing below a certain cutoff of credit scores (Keys et al., 2010), and why this market came to an abrupt stop in 2007.

This paper is organized as follows: section 2 gives a brief background on securitization and reviews the relevant literature; the model is presented in section 3, and the solution is analyzed in section 4; in section 5 I demonstrate how the model leads to sudden stops; and conclusions are summarized in section 6; appendix A. expands on a technical result. Finally, in appendix B. I consider the effects of bailouts in an extention of the basic model. Bailouts are represented as a commitment by the government to guarantee the face value of securities in some states of the world. The bailout promise relaxes the investors' participation constraint, and therefore gives the bank more flexibility. This, in turn, allows the bank to leverage up, and, as a result, might further lower the level of screening effort. The welfare effect of a bailout promise is ambiguous.

2 Background

The market for securities backed by bank loans was created in 1970 and has been growing rapidly until it collapsed before the financial crises of 2008 (Gorton and Metrick, 2012).[3] The emergence of this market has lead researchers to study the advantages that motivate financial intermediaries to choose securitization,[4] and had identified many such advantages. For example, the financial intermediary might simply wish to normalize cash flows (James, 1988; Cumming, 1987). Alternatively, it might sell its claims on the original assets and purchase the pool security in order to share risk with similar agents holding similar assets. Assets of low quality (as well as over-collateralization) may be repackaged to create an instrument with a higher credit rating (tranching), attracting investors that would otherwise refrain from investing in the underlying asset due to risk aversion or regulatory restrictions. Additional possible advantages include reducing asset-liability mismatch (Franke and Krahnen, 2007), circumventing regulatory restrictions, and tax planning (Han et al., 2015), amongst others (cf. Pennacchi, 1988; Flannery, 1989; Kareken, 1987; Schipper and Yohn, 2007).

A number of papers propose models to formalize some of the conjectured advantages of securitization listed above (Greenbaum and Thakor, 1987; Benveniste and Berger, 1987; Gorton and Pennacchi, 1995; Parlour and Plantin, 2008), all these papers employ some form of information asymmetry and show how securitization helps overcome the agency problem. However,these models do not imply that securitization would lead to lower lending standards; in fact, the increased flexibility in choosing the structure of the SPV allows banks to commit to higher levels of effort (DeMarzo, 2005; Fender and Mitchell, 2009).

The main goal of this paper is to explain how securitization leads to lower lending

[3] See Gorton and Souleles (2007) for a review of the institutional details of this market.

[4] Gorton and Metrick (2012) is a comprehensive review of this literature.

standards. We therefore focus on the bank's lending decision and how it is influenced by the relationship between the bank and the investors. The only aspects of securitization that are important in the model presented here are the ability to communicate information about the borrower to investors and the ability to flexibly choose the tranching structure. The other advantages of securitization are surely important, but do not enter this analysis.

The failure of mortgage-backed-securities in the recent crisis has lead researchers to reexamine securitization. Empirical studies by Mian and Sufi (2009), Keys et al. (2009), and Dell'Ariccia et al. (2008) showed that default rates were higher for securitized loans. Keys et al. (2009, 2010, 2012) additionally consider default rates as a function of credit ratings, and find a discontinuity around the value of FICO 620: borrowers whose credit rating is just above this value default more frequently than those whose rating is just below. Since loans to individuals with credit ratings below FICO 620 are difficult to securitize, the authors suggest that banks anticipate that they will have to hold such loans on the balance sheet, and thus screen such borrowers more carefully. As noted above, the results of my model explain these observed phenomena. Purnanandam (2011) uses the disruption to the MBS market in 2007, and also finds higher default rates of securitized mortgage loans, which is more severe at banks with lower capital, which is again consistent with my model.

3 The Model

3.1 Overview

The model consists of borrowers, investors, and a bank, and has two time periods $t = 0, 1$. Borrowers are passive: they simply request a loan at some constant interest rate, and have no knowledge about the probability that they will be able to return it. The bank has the technology to generate a signal in order to estimate this probability. The accuracy of the signal is chosen by the bank at a cost and is unobservable by others. The bank finances its lending by either eliciting deposits from or selling securities to risk-neutral investors; the advantage of securitization is that the bank is able to credibly communicate the value of the signal to these investors.

3.2 Borrowers and Signal

At time $t = 0$ there are infinitely many potential borrowers each seeking a loan of size L. There are two types of borrowers: a fraction $(1 + q)/2$ are *good* and will repay $W > L$ at $t = 1$, and a fraction $(1 - q)/2$ are *bad* and will default and repay nothing. We assume that $q \in (0, 1)$ so the majority of potential borrowers are good, but also that $(1 + q)W/2 \leq L$, so lending to a random borrower without knowing his type is not profitable.

The potential borrowers do not know their own type and cannot learn about it; only the bank has the technology to learn about the quality of a potential borrower. This structure is appropriate for the consumer loan market, where creditors are likely better equipped than borrowers to estimate the probability of a negative turn of events. Furthermore, this paper focuses on the interaction between the banks and the investors, so the interaction with borrowers is kept very simple: borrowers passively request loans at constant rate of return, and the bank is making all the decisions.

The bank can learn about potential borrowers by producing a signal that takes two values: *high* and *low*, denoted $S \in \{S_H, S_L\}$. The joint distribution of the signal with the borrower's type is

Signal/Borrower type	Good	Bad
$S = S_H$	$(1 + q)(1 + \alpha)/4$	$(1 - q)(1 - \alpha)/4$
$S = S_L$	$(1 + q)(1 - \alpha)/4$	$(1 - q)(1 + \alpha)/4$

,

and the parameter $\alpha \in [0,1]$ is a measure of the accuracy of the signal. Notice that at $\alpha = 1$ the signal fully reveals the type of the borrower, and at $\alpha = 0$ the signal carries no information at all. The bank chooses α at a cost $c(\alpha)$ per borrower screened, where

$$c(0) > 0, \qquad c(1) = +\infty, \qquad c'(\bullet) > 0, \qquad c''(\bullet) > 0.$$

The choice of α is unobservable to anyone but the bank.

The parameter α is simply a linear transformation of the covariance between the type of the borrower and the signal, and since we leave the cost function general, the underlying assumption is that the bank only gets to choose the correlation between the signal and the return. Limiting the bank's choice to a one-parameter family of possible signals is essential to the results and is also standard in macroeconomics: for example, a similar situation would result if the signal was distributed normally around the actual return, and the bank could only choose the variance of the signal. This structural assumption can be interpreted to mean that the signal is a result of a widely understood method of screening borrowers, where increasing the effort (e.g. gathering more information about the borrower) necessarily reduces both the probabilities of a type I and type II errors.

3.3 Investors

There is a large number of investors in the economy, all of whom are are risk-neutral and have access to a perfect storage technology. Thus, investors generate a perfectly elastic supply of funds as long as the net expected return is nonnegative. Investors can provide funds to the bank in two ways: they can either make deposits or buy securities. The difference between the two methods will be discussed in 3.4.3.

3.4 The Bank

A single profit-maximizing bank starts out with an exogenous amount of resources $X > 0$ (this can be thought of as inside equity or bank capital). The bank has a few decisions to make on both the lending and financing sides. On the lending side, the bank must decide how many potential borrowers to screen at what accuracy (α), and then set a policy for lending based on the signal obtained. On the finance side, the bank also chooses how much funds to raise and whether to do this by eliciting deposits or selling securities. When eliciting deposits, the bank also chooses the interest rate it offers depositors, and when securitizing, it chooses the structure of the securities.

3.4.1 Lending Decision

The lending decision of the bank has three components: how many borrowers to screen, what $\alpha \in [0, 1]$ to use, and for each possible value of the signal $\{S_H, S_L\}$, whether or not to make out a loan.

Notice that it is never profitable for the bank to make out a loan to an individual that was screened with $\alpha > 0$ if the signal obtained was $S = S_L$. The reason is that the bank can always do better by dropping that individual and lending to a new individual who was not screened at all: lending to the unscreened individual avoids the screening costs, and the probability of default is strictly lower. Thus, we can limit attention to cases where the bank chooses to make out loans to n_H high-signal individuals who were screened with accuracy $\alpha > 0$, and n_{NS} individuals who were not screened at all. In order to find n_H borrowers with a high signal at accuracy α, the expected number of potential borrowers that must be screened is $2n_H/(1 + q\alpha)$, so the total expected cost of lending is

$$C(\alpha, n_H, n_{NS}) = \frac{2n_H c(\alpha)}{1 + q\alpha} + (n_H + n_{NS})L. \tag{1}$$

The first term is the cost of screening, and the second is the sum lent. It is worth noting that $C(\alpha, n_H, n_{NS})$ is increasing in α: since

$$c(\alpha) = \int_0^\alpha c'(\tilde{\alpha})d\tilde{\alpha} \leq \alpha c'(\alpha),$$

we have

$$\partial_\alpha C(\alpha, n) = \frac{2nc(\alpha)}{1+q\alpha}\left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha}\right) \geq \frac{2nc(\alpha)}{(1+q\alpha)^2\alpha} > 0.$$

In principle one could imagine a more complex setting where the bank is allowed to screen different borrowers with different accuracies, but one can show that since all borrowers are *a-priori* identical and due to the convexity properties of the problem, there is never any reason to do so, so this simplification is without loss of generality.

3.4.2 A Simplifying Assumption or Mortgage Agents

Equation (1) is slightly at odds with the description of the model as it represents the expected cost of lending (before the screening is preformed). To avoid the complication of having to deal with a stochastic decision-rule, I shall assume that (1) is simply the cost. However, this can easily be modeled by assuming that there are *mortgage agents* who find potential borrowers, fill out applications on their behalf, and submit it to the bank. The bank charges the agents a non-refundable application fee equal to the cost of screening. This moves all uncertainty about screening to the agents and makes (1) precise.

3.4.3 Financing Decision

The bank raises funds by either eliciting deposits or selling securities. Financing by securitization works as follows: the bank announces the amount of of high- and low-signal loans it intends to make, and the amount of funds it plans to raise $y_0 > 0$. The bank then pools the loans together (in an SPV), and promises investors a payoff at $t = 1$ that depends of the total revenue from the loans in the pool. For the sake of this paper it is sufficient to limit attention to the following set of payoff schedules, which is parameterized by the single variable T:

$$\delta(Y) = \begin{cases} Y & Y \leq T, \\ T & Y > T. \end{cases} \tag{2}$$

This defines a two-tranche structure where the bank holds the upper tranche, and is the one most frequently observed. In Appendix A. we consider a a model where the bank is allowed to optimally design the contract offered and show that the structure in (2) is a approximately optimal.[5]

The critical assumption about securitization is that the bank is able to credibly communicate the value of the signal S for each borrower to the investors buying the securities. The signal should be thought of as composed of hard information like a credit rating, the location of the borrower, etc., so that the bank would incur some serious penalty if it were caught falsely reporting. The implication is that when securitizing, the bank's declaration of the number of high- and low-signal borrowers is enforceable. However, investors cannot see the bank's choice of α.

Deposits are simple debt contracts.[6] As with securitization, the bank announces the

[5]It should be noted that the analysis in this paper can be carried out with the optimal structure, and that this has no qualitative effect on the results. Splitting the lower tranche into a few tranches is also inconsequential: it may be desirable to do so if the bank is facing investors with different risk attitudes, but since the bank's decisions only depend on its own payoff schedule, this will not play a role in our analysis.

[6]Deposits in this model are not insured. If deposits were insured, the bank would not need to pay an interest to the risk-neutral investors, but it would need to pay a premium to the insurer. If one then assumes that the premium is such that the insurer's budget is balanced, then the entire analysis remains invariant.

how many loans it plans to make, the amount of funds it plans to raise y_0, and the interest rate paid on that sum; however, notice that here the bank has no way of committing that the loans made will be to high-signal individuals. If we denote the value promised to depositors at $t = 1$ by T, the payoff schedule to investors is precisely (2).

The different assumptions about the information structures between securities and deposits is motivated by empirical observations: securities always specify to the buyer a short list of characteristics of the underlying assets. In the case of consumer credit, this information typically includes the credit ratings of the borrowers. While it is hard to imagine a bank providing false information about such characteristics, it is virtually impossible for investors to know how much effort the bank puts into generating that information. This is precisely the difference between the value of the signal S and its accuracy α. Depositors, on the other hand, typically do not have easy access to information about the bank's assets.

3.5 Large n approximation

When the bank's lending plan is (α, n_H, n_{NS}), the expected revenue in $t = 1$ is

$$\mu(\alpha, n_H, n_{NS}) = \mathbb{E}[Y] = \frac{1+q}{2}\left[\frac{1+\alpha}{1+q\alpha}n_H + n_{NS}\right]W. \tag{3}$$

If the borrowers were statistically independent, then the revenue would be distributed as a sum of two binomial distribution, which for a large number of borrowers can be approximated by a normal random variable $Y \sim \mathrm{N}(\mu, \sigma^2)$, where

$$\sigma^2 = \frac{1-q^2}{4}\left[\frac{1-\alpha^2}{1+q\alpha^2}n_H + n_{NS}\right]W^2.$$

However, we do not wish to make the assumption of statistical independence. Since banks are using the same algorithm to screen all borrowers, it stands to reason that getting a high signal on a borrower of a certain type may be correlated with getting a high signal on another borrower of the same type. Rather than making micro-level assumptions about the specific structure of the correlations between borrowers, we keep the approximation $Y \sim \mathrm{N}(\mu, \sigma^2)$, but modify the variance to

$$\sigma^2 = \frac{1-q^2}{4}\left[\frac{1-\alpha^2}{(1+q\alpha)^2} n_H^{1+\zeta} + n_{NS}^{1+\zeta}\right] W^2, \qquad \zeta \in [0,1]. \tag{4}$$

The parameter ζ is a reduced form alternative to specifying the exact correlation between any two borrowers. The value $\zeta = 0$ represents statistical independence, and $\zeta = 1$ represents perfect correlation. Basically, we are assuming that there are some underlying correlations that make σ^2 grow with n at some rate between independence and perfect correlation, and drop all but the leading order term.

4 Analysis

To analyze the equilibrium of this system, it is instructive to consider separately the equilibria that would arise in the cases where the bank was forced to use either securities or deposits. For both cases we denote the bank's expected share of the revenue at $t = 1$ by $G(\alpha, n_H, n_{NS}; T)$, where

$$\begin{aligned} G(\alpha, n_H, n_{NS}; T) = \mathbb{E}[Y - \delta(Y)] = \int_T^\infty (Y - T) d\Phi\left(\frac{Y-\mu}{\sigma}\right) = \\ = \sigma\phi\left(\frac{T-\mu}{\sigma}\right) + (\mu - T)\left[1 - \Phi\left(\frac{T-\mu}{\sigma}\right)\right]. \end{aligned} \tag{5}$$

Note that the dependence on (α, n_H, n_{NS}) enters through μ and σ, which were defined in (3)-(4). The investors' share is simply $\mu - G$, therefore the investors' participation constraint in both cases is

$$y_0 = \mu(\alpha, n_H, n_{NS}) - G(\alpha, n; T), \tag{6}$$

where y_0 is the amount that investors transfer the banks at $t = 0$.

4.1 Securitization

Securitization allows the bank to specify in advance how many high-signal and how many low-signal borrowers will be included in the pool. Since making out loans to borrowers with a low signal always reduces the surplus, the bank always prefers to commit to not making out loans to such borrowers. Thus, the bank's plan when securitizing is always to commit to n_H high-signal borrowers. The cost of that was calculated in (1) to be

$$C(\alpha, n_H, 0) = \frac{2n_H c(\alpha)}{1 + q\alpha} + n_H L.$$

The bank's eventual choice of α is made after the contract is finalized, so it is determined by setting the marginal cost of increasing α equal to the marginal revenue, i.e.

$$\frac{2n_H c(\alpha)}{1 + q\alpha} \left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1 + q\alpha} \right) = \partial_\alpha G(\alpha, n_H, 0; T). \tag{7}$$

The above is the bank's incentive-comparability constraint. The bank needs to raise $y_0 = C(\alpha, n_H, 0) - X$, which plugged into (6) gives the investors' participation constraint:

$$\frac{2c(\alpha)}{1 + q\alpha} n_H + n_H L - X = \mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T). \tag{8}$$

For fixed n_H, solving (7)-(8) together determines $\alpha(n)$ and $T(n)$. The optimal n is given by solving the Lagrangian

$$\mathcal{L} = G(\alpha, n_H, 0; T) - \lambda \left[\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T) - \frac{2c(\alpha)}{1+q\alpha} n_H - n_H L + X \right] + \\ + \tau \left[\partial_\alpha G(\alpha, n_H, 0; T) - \frac{2n_H c(\alpha)}{1+q\alpha} \left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha} \right) \right].$$

Substituting the first constraint into the objective function allows us to rewrite the Lagrangian and leads to the following proposition:

Proposition 1. *In the subgame where the bank is constrained to finance through securitization, the bank chooses $n_{NS} = 0$, and α, n_H and T are given by the solution to the lagrangian system:*

$$\mathcal{L} = \mu(\alpha, n_H, 0) - C(\alpha, n_H, 0) - \\ - \lambda \left[\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T) - \frac{2c(\alpha)}{1+q\alpha} n_H - n_H L + X \right] + \\ + \tau \left[\partial_\alpha G(\alpha, n_H, 0; T) - \frac{2n_H c(\alpha)}{1+q\alpha} \left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha} \right) \right], \quad (9)$$

together with the additional requirement that the solution satisfies the positive profits condition

$$\mu(\alpha^*, n_H^*, 0) - C(\alpha^*, n_H^*, 0) \geq 0.$$

The economic interpretation of the above is that the bank is maximizing the total surplus $\mu - C$, subject to (7) and (8).

4.2 Deposits

When using deposits, the bank announces how many loans n it plans to make out, how much it plans to raise y_0, and what depositors would be paid T. The bank then chooses α, n_H and n_{NS} to maximize expected revenue, subject to $n_H + n_{NS} = n$. The bank's eventual choice of α is determined exactly as in securitization by setting the expected marginal revenue equal to the marginal cost:

$$\frac{2n_H c(\alpha)}{1+q\alpha}\left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha}\right) = \partial_\alpha G(\alpha, n_H, n - n_H; T).$$

The investors' participation constraint is derived from (6):

$$\frac{2c(\alpha)}{1+q\alpha} n_H + nL - X = \mu(\alpha, n_H, n - n_H) - G(\alpha, n_H, n - n_H; T).$$

The essential difference between deposits and securitization is that the bank cannot commit in advance to a fixed number of n_H and n_{NS}. This creates an additional moral hazard problem to take care of, namely, that the bank may try to cut costs by increasing the proportion of non-screened borrowers. However, it is straightforward to verify that the expected revenue function $G(\alpha, n_H, n_{NS}; T)$ is convex in (n_H, n_{NS}), and since $C(\alpha, n_H, n_{NS})$ is linear in the same variables, it follows that the bank will always choose a corner solution: either $(n_H, n_{NS}) = (n, 0)$ or $(n_H, n_{NS}) = (0, n)$. When the bank chooses the first option, the above equations collapse to precisely (7)-(8), and when it chooses the latter, the expected revenue μ is negative, so the investors' participation constraint can never be satisfied.

Consider a solution to (7)-(8) for a fixed $n_H = n$, and denote it by $\alpha_s(n)$ and $T_s(n)$. We know that this is an equilibrium of the subgame where the bank is forced to make out exactly n loans and securitize them. The bank could also use deposits to reach the exact same equilibrium if and only if the revenue from choosing $\alpha_s(n)$, and $(n_H, n_{NS}) = (n, 0)$ is greater than the revenue from choosing $\alpha = 0$ and $(n_H, n_{NS}) = (0, n)$ (keeping $T_s(n)$ fixed). Thus, the condition that allows this to be an equilibrium of the deposit subgame is

$$G(\alpha_s(n), n, 0; T_s(n)) \geq G(0, 0, n; T_s(n)) + \frac{2nc(\alpha_s(n))}{1 + q\alpha_s(n)}. \tag{10}$$

The above is summarized in the following proposition:

Proposition 2. *In the subgame where the bank is constrained to finance through deposits, the bank chooses $n_{NS} = 0$, and α, n_H and T are given by the solution to the Lagrangian system* (9) *together with the inequality constraint* (10)*.*

4.3 The Equilibrium

To illustrate our method of finding the equilibrium, it is useful to fix n and think about the bank's optimal choice of α when financing through securitization. In Figure 1 the lower panel shows $\alpha_s(n)$ (the solid line). The function $\alpha_s(n)$ is decreasing for an obvious reason: the higher the n (and consequentially the leverage), the higher the share of the eventual revenue that the bank must pay to investors, so its incentive to screen borrowers accurately diminishes. Next, the upper panel in 1 shows the bank's profits plotted against n (again, the solid line). Increasing n linearly increases the surplus at fixed α, but since α decreases with n, the profits initially grow until some optimal $n = n_s^*$ after which the decreasing α dominates. We denote the level of accuracy at the optimal leverage as $\alpha_s^* = \alpha_s(n_s^*)$.

We now turn our attention to deposits. The dashed red line in Figure 1 represents the profits that the bank would make if after finalizing the securitization contract it would decide to lend to n unscreened borrowers instead of choosing $(n_H, n_{NS}) = (n, 0)$. This is given by the right-hand-side of (10). (When securitizing the bank does not have this

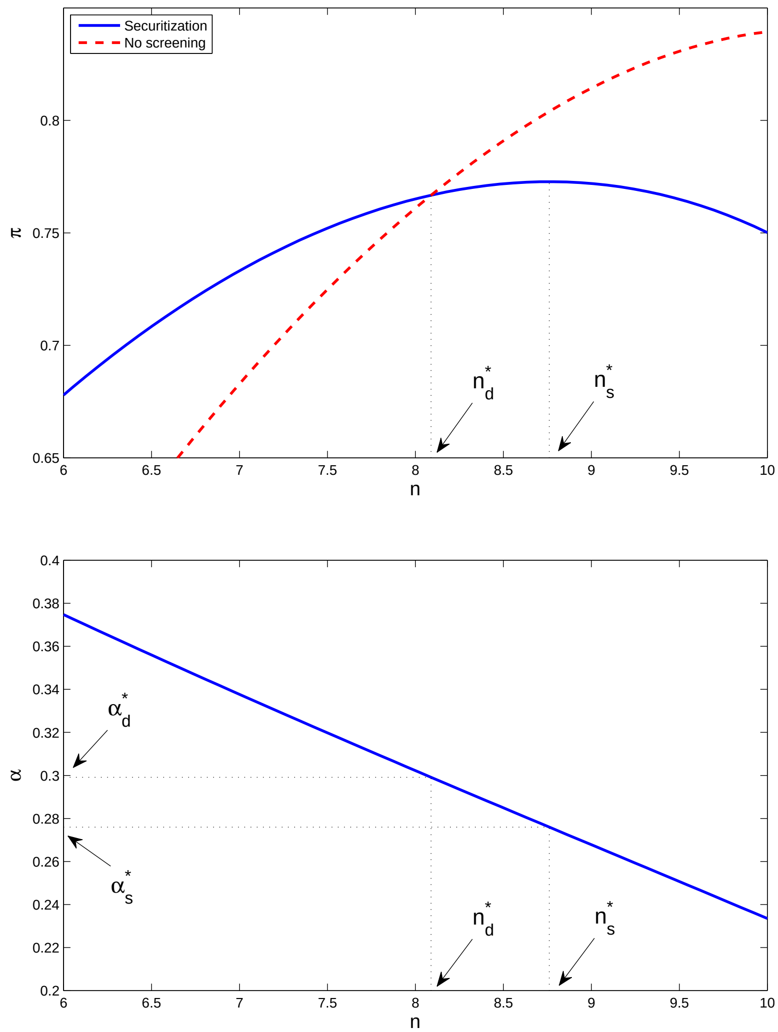

Figure 1: In the upper panel, the solid line is the bank's profits for fixed volume of loans n, and the dashed red line is the bank's potential potential profit from shirking and not screening potential borrowers at all. The optimal value of n is the point where the solid line is maximized (n_s^*), and the maximum value of n that can be obtained using deposits is where the two lines meet (n_d^*). The lower panel shows the equilibrium level of accuracy of screening α for fixed n. The optimal level of screening when securitizing is lower than when restricted to using deposits.

option, and so the dashed line is irrelevant, but when using deposits the bank does have this option, which puts an upper bound on the level of n.) In Figure 1 the dashed line crosses the solid line at the point $n = n_d^*$, which is to the left of n_s^*, implying that this upper bound is binding. A bank choosing to use deposits will thus choose $n = n_d^*$, and make lower profits than when securitizing. However, it also would choose $\alpha = \alpha_d^* = \alpha_s(n_d^*) > \alpha_s^*$, meaning that if limited to using deposits, the bank would have chosen a higher quality signal.

Imagine that the bank is initially only allowed to use deposits, and then at some point this limitation is lifted: what would be the result? In the case illustrated in Figure 1, after the limitation is lifted the bank would increase the volume of lending from n_d^* to n_s^*, and simultaneously decrease the effort of screening from α_d^* to α_s^*. However, notice that the lower accuracy of screening is entirely due to the higher n: if the bank was allowed to securitize but its leverage ratio was restricted by the regulator, there would be no difference between securitization and deposits.

Finally, there is one other case that can arise, as is illustrated in Figure 2. In this case the dashed red line is to the right of n_s^*. Since the inequality constraint (10) is not binding at $n = n_s^*$, the bank can reach that volume of lending whether it is securitizing or using deposits. Therefore, the bank can use either method, and its choice of (n, α) would be the same. This analysis is summarized by the following two propositions:

Proposition 3. *Securitization weakly dominates deposits, and the equilibrium of the full game is the equilibrium of the securitization subgame as described in Proposition 1. If the values defined by the securitization equilibrium* $(\alpha_s^*, n_{Hs}^*, T_s^*)$ *satisfy the inequality*

$$G(\alpha_s^*, n_{Hs}^*, 0; T_s^*) < G(0, 0, n_{Hs}^*; T_s^*) + \frac{2n_{Hs}^* c(\alpha_s^*)}{1 + q\alpha_s^*}, \tag{11}$$

then securitization <u>strictly</u> dominates deposits.

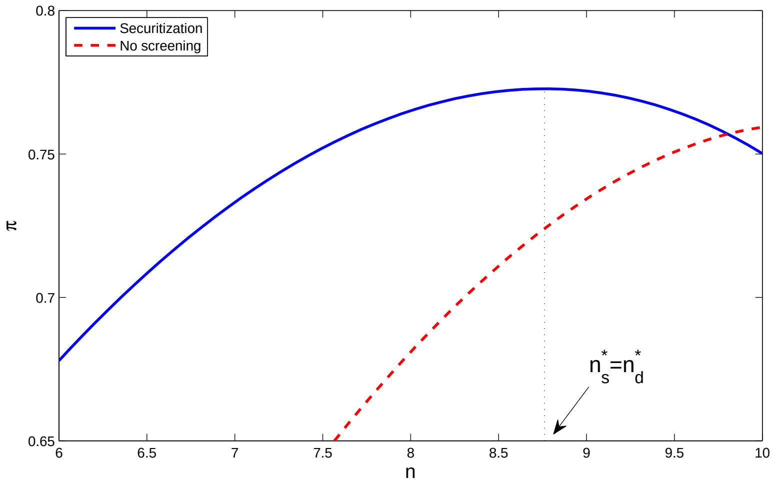

Figure 2: As in figure 1, the solid line is the bank's profits for fixed volume of loans n, and the dashed line is the potential profits from shirking and not screening borrowers. Here the dotted line is below the solid line.

Proposition 4. *Comparing securitization to a situation where the bank is limited to using deposits, with securitization the bank makes out a larger number of loans and screens borrowers less accurately:*

$$n^*_{Hd} \leq n^*_{Hs}, \qquad \alpha^*_d \geq \alpha^*_s.$$

If the inequality (11) *holds, then the above relationships are strict.*

Proposition 4 also implies that leverage and default rates are higher with securitization.

5 Sudden Stops

In this section we modify the model by assuming that investors demand a higher interest on securities than on deposit. This can be naturally interpreted as deposits providing some liquidity or other services that produce a convenience yield. We continue to normalize the interest on deposits to zero and define the convenience yield to be $\rho > 0$, thus, the participation constraint for security buyers is now

$$\frac{2c(\alpha)}{1+q\alpha} n_H + n_H L - X \leq \frac{\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T)}{1+\rho}. \tag{12}$$

There is no other change to the model: the lagrangian for the deposits subgame remains unchanged, and the securitization lagrangian is modified to:

$$\mathcal{L}_S(\rho) = G - \lambda \left[\frac{\mu - G}{1-\rho} - \frac{2c(\alpha)}{1+q\alpha} n_H - n_H L + X \right] + \\ + \tau \left[\partial_\alpha G - \frac{2n_H c(\alpha)}{1+q\alpha} \left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha} \right) \right].$$

The convenience yield has the simple effect of making securitization more costly to the bank at any choice of leverage and effort, and thus breaks the tie in favor of deposits whenever the no-screening constraint (10) does not bind.

The equilibrium is determined as follows: If the no-screening constraint (10) is not binding at the maximum of the deposits subgame, the it is the global maximum and the bank chooses to finance using deposits; otherwise, one must compare the local maximum of the securitization subgame to the point where the no-screening constraint becomes binding for the deposits subgame. The latter case is illustrated in figure 3. The choice between securitization and deposits is a tradeoff between paying lower yields and taking advantage of the improved technology of the securitization contract.

Let us focus on how the choice between securitization and deposits depends on the unconditional quality of potential borrowers, q. This exogenous parameter can either represent the overall state of the economy, or the credit-worthiness of a particular sub-market (like a FICO credit score). Figure 3 illustrates the profit function for a few values of

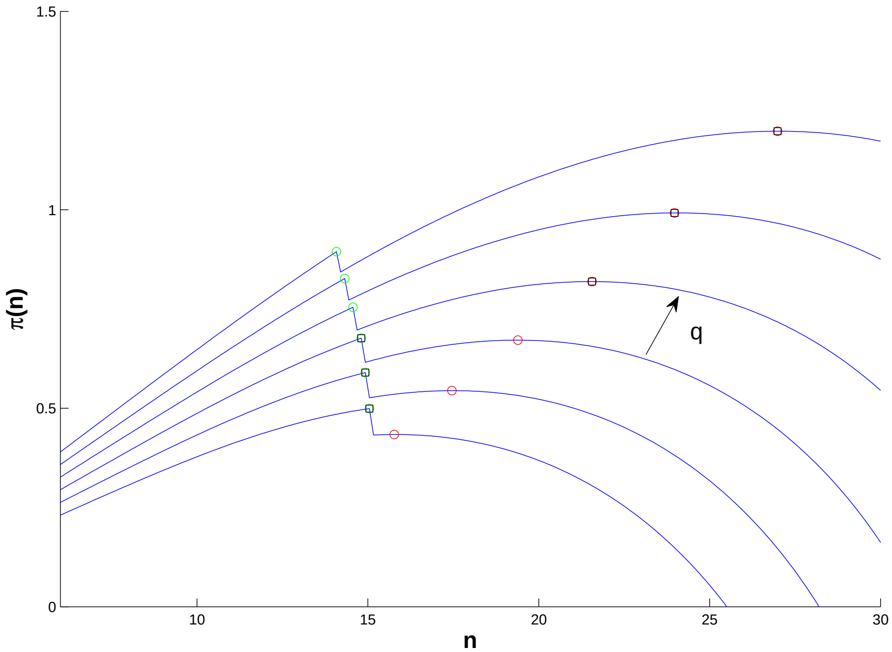

Figure 3: The profit function of the bank as a function of leverage is plotted when the convenience yield $\rho > 0$ and for a few values of q. The arrow shows the direction at which q is increasing. For each value of q, the maximum of the deposits (securitization) subgame is denoted by a green (red) circle, and the global maximum is denoted by a square.

q. One can see that there is a critical value q_c below which the deposit-subgame dominates, and above which the securitization subgame dominates.

As the economy crosses the threshold, the bank switches from deposits to securitization, and as a result, at the threshold there is a discontinuous drop in the effort level α, and an increase in the leverage n/X and in the rate of mortgages that default. This is illustrated in figure 4. This result relates directly to the empirical literature: as shown in Keys et al. (2009), the observed rate of default is generally decreasing as a function of the FICO score, however, there is a threshold (FICO=620) below which no securitization occurs, and the

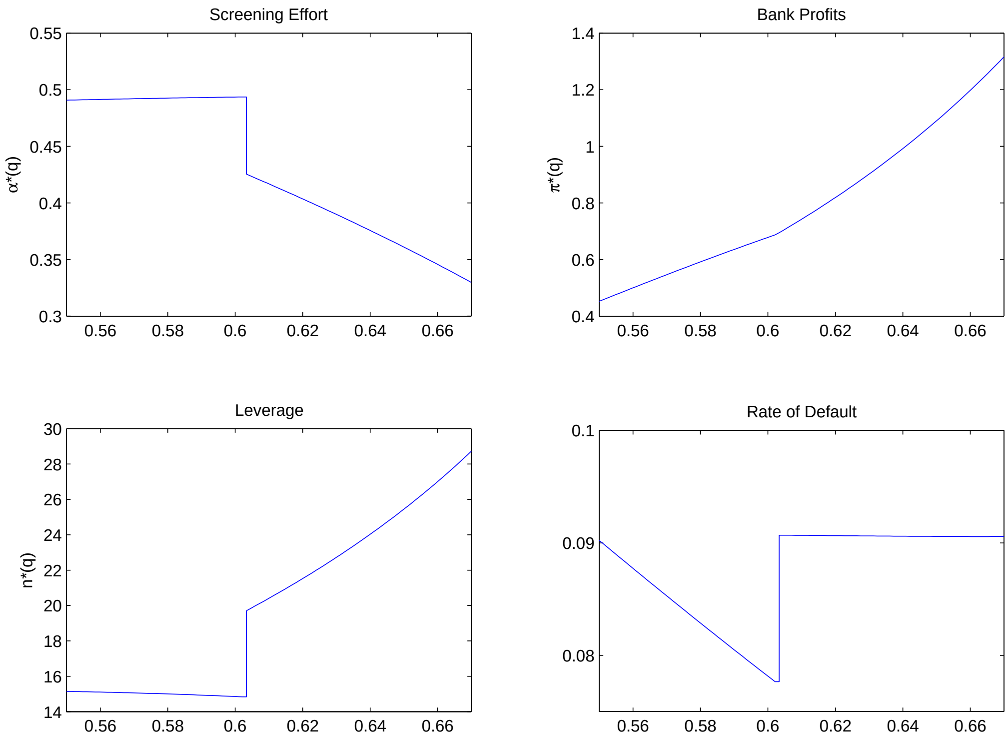

Figure 4: The behaviour of the screening effort α, the leverage n/X and the rate of mortgages that default as a function of the exogenous parameter q.

rate of default discontinuously increases across the threshold.

The model, therefore, explains two phenomena: first, why despite credit-worthiness being a continuous variable, there exists a sharp boundary under which no securitization occurs (as opposed to securities being offered at a lower price for low-credit-score population); and second, how it may happen that a decrease in overall economic conditions naturally leads to no new securitization activity.

6 Conclusions

Researchers who have analyzed loan data have found that securitization is associated with higher default rates (Keys et al., 2009, 2010; Elul, 2016). That same phenomenon happens in this model, but the mechanism is different than the one suggested. Securitization allows the bank to commit to lending only to individuals with a high enough credit rating ($S = S_H$ in the model), which alleviates agency problems between the bank and its investors. However, the improved contracting environment makes it possible for the bank to increase leverage, and it is the increased leverage that eventually leads to lower effort in obtaining information about potential borrowers.

Keys et al. (2010) also find that a loan that was securitized is more likely to end in default even controlling for credit rating. Past literature has suggested that banks have additional private information about borrowers, and that they select to securitize the lower quality loans while holding the others. In our model this happens for a different reason: when securitizing, the banks simply put less effort into screening, and so the same signal about a lender is less informative. As such, this paper reproduces the observed facts about securitization and lending standards in a way that is consistent with banks and investors being rational profit-maximizing agents, and with security and deposit contracts having the structure that is most common in the real world. It also suggests a testable hypothesis: that default rates or other measures of loan quality should depend on the method of finance only through the leverage ratio.

Regarding policy implications, this work demonstrates that securitization is welfare-enhancing. If the rate of default is of concern to the government, it would be best to limit leverage rather than to curtail the sale of securities. We also show that the bailouts have an *ex-ante* positive effect on welfare, as long as the states of the world where bailouts are required occurs with low enough probability. The analysis in section B. can be used to calculate the optimal bailout policy.

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A. On the Optimal Contract

In Subsection 3.4.3 we have postulated that when banks securitize, they form an SPV with two tranches, selling the entire safer tranche and keeping the equity tranche. Additionally, we defined deposits as simple debt contracts. The main motivation for making these assumptions is that they correspond to the contracts most frequently observed empirically, however, we have not made the claim that these are the optimal contracts. In this appendix we describe the optimal contract, and demonstrate that for reasonable values of the parameters, the contract structure assumed in the model is a good approximation of the optimal contract.

Let us consider what would happen if instead of limiting the contracts between the bank and investors to have the form defined in (2), we allowed it to be completely general.

The analysis would still lead us to the Lagrangian in (9),

$$\begin{aligned}\mathcal{L} &= \mu(\alpha, n_H, 0) - C(\alpha, n_H, 0) + \\ &+ \lambda\left[\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T) - \frac{2c(\alpha)}{1+q\alpha} n_H - n_H L + X\right] + \\ &\qquad + \tau\left[\partial_\alpha G(\alpha, n_H, 0; T) - \frac{2n_H c(\alpha)}{1+q\alpha}\left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha}\right)\right],\end{aligned}$$

only that the function G defined in (5), would now take the more general form:

$$G(\alpha, n_H, n_{NS}; T) = \mathbb{E}[Y - \delta(Y)] = \int (Y - \delta(Y)) d\Phi\left(\frac{Y-\mu}{\sigma}\right).$$

Recall that $\delta(Y)$ denotes the payoff to investors as a function of the eventual revenue and must satisfy $0 \leq \delta(Y) \leq Y$. An important feature of the Lagrangian is that it is linear in δ, therefore for any Y, $\delta(Y)$ must be at one of the boundaries: $\delta(Y) = 0$ or $\delta(Y) = Y$. We calculate

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial \delta(Y)} &= -(\lambda - \tau\partial_\alpha)\frac{\partial G}{\partial \delta(Y)} = (\lambda - \tau\partial_\alpha)\phi\left(\frac{Y-\mu}{\sigma}\right) \\ &= \left[\frac{\tau(-\partial_\alpha \sigma)}{\sqrt{2\pi}\sigma^4} Y^2 + h_1(n_H, \alpha, \tau, \lambda) Y + h_0(n_H, \alpha, \tau, \lambda)\right]\phi\left(\frac{Y-\mu}{\sigma}\right),\end{aligned}$$

where $h_i(n_H, \alpha, \tau, \lambda)$ are independent of Y. The sign of the above expression is determined by the sign of the term in brackets, which is a quadratic polynomial in Y. The leading coefficient is positive since $\partial_\alpha \sigma < 0$ (see equation (4)) and $\tau > 0$.[7] From this we can conclude that the optimal contract can be defined in terms of two parameters (T_1, T_2) as

[7] The variable τ is the Lagrange multiplier on the incentive-compatibility constraint of the bank's eventual choice of α. The bank would benefit from being able to commit to a higher α, which would make the constraint that τ multiplies negative. Thus, thinking of τ as a shadow price, it is clear that it must be positive.

follows:

$$\delta(Y) = \begin{cases} 0 & Y \in [T_1, T_2], \\ Y & \text{otherwise.} \end{cases}$$

To gain intuition about this conclusion, recall that both the bank and the investors are risk-neutral in our model. Thus, the only criterion to compare contracts is the degree to which they allow the bank to commit to a higher α. Increasing α has two effects: it increases the expected outcome μ and decreases the variance σ^2. In Figure 5 the distribution density function is plotted for two values of α. Since increasing α increases the probability of the outcomes between the points denoted by Y_1 and Y_2 on the graph, the best way for the bank to commit to the higher level of α is by agreeing that the bank collects all the revenue if $Y \in [Y_1, Y_2]$ and the investors collect all the revenue otherwise. However, the contract also needs to satisfy the investors participation constrain, and the expected revenue restricted to $Y \notin [Y_1, Y_2]$ is typically not sufficient. Thus, the set $[T_1, T_2]$ that defines the actual contract must be wider than the values that appear in the graph (i.e. $T_1 < Y_1 < Y_2 < T_2$).

The form of the optimal contract is rather extreme: investors get nothing in the most likely states of the world. Such contracts are not observed in reality and also cannot be achieved through the technology of securitization. In reality, contracts always specify a payoff to investors that is nondecreasing in the revenue, and the technology of tranching additionally requires that $\delta'(Y) \leq 1$. There is no motivation for this restriction in our model, but it is well known how to explain this empirical phenomenon, e.g. by adding costly state verification to the model (Townsend, 1979). Since this is not the focus of this paper, we do not wish to complicate the model by adding an assumption of costly state

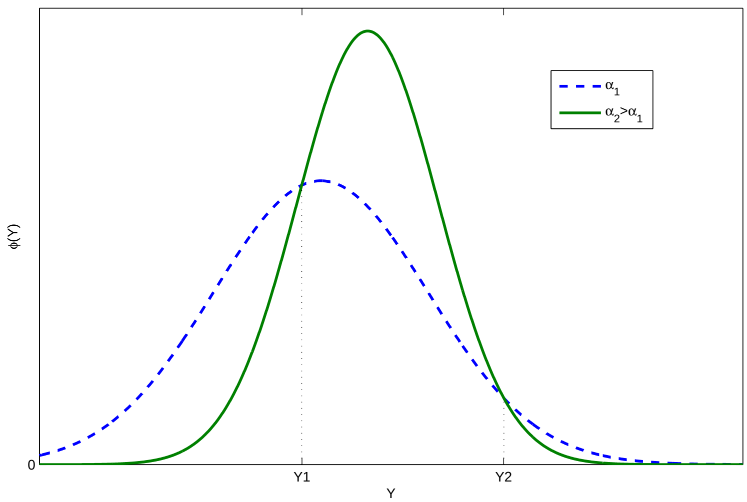

Figure 5: The distribution density function of revenue is illustrated for two values of α. The higher value of α is the solid green line. The higher α produces higher probabilities of the outcomes between T_1 and T_2.

verification, so we simply impose the additional requirement that $0 \leq \delta'(X) \leq 1$.[8]

With the additional constraints on the derivative, the problem of finding the optimal contract remains a linear planning problem, so the solutions is still obtained at the boundary. The optimal contract can always be written as:

$$\delta(Y) = \begin{cases} Y & Y \leq T_1 \\ T_1 & T_1 \leq Y \leq T_2 \\ T_1 + Y - T_2 & Y > T_2 \end{cases} . \tag{13}$$

The above describes the structure of an SPV with three tranches, where the bank sells the entire upper and lower tranche and keeps the mezzanine tranche. This same optimal

[8]More accurately, we require that $\delta(Y)$ is differentiable everywhere except for finitely many kink points, and that $\lim_{Y-} \delta'(Y), \lim_{Y+} \delta'(Y) \in [0, 1]$.

structure was found in Fender and Mitchell (2009), and for similar reasons: with this structure the bank does not get paid in extreme events (either good or bad), and that helps the bank commit the higher levels of vigilance.

In the body of this paper we have assumed that the bank does not use the optimal structure of the SPV described above, but rather a simpler two-tranche structure where the bank only sells the lower tranche. This was done both to simplify the calculations, and since it is the structure which is most frequently observed in reality. However, it should be emphasized that the entire analysis can be preformed using the optimal three-tranched structure without affecting the results qualitatively. The reason is that the parameter T_2 defined in (13) is typically so large that the probability of the event $Y > T_2$ is very small. As explained above, T_2 must be greater than Y_2, which is depicted in Figure 5, and defined as the larger of the two roots of the equation

$$\frac{\partial}{\partial \alpha}\phi\left(\frac{Y_2-\mu}{\sigma}\right) = 0 \qquad \Rightarrow \qquad Y_2 = \frac{(1+q)(1+\alpha)}{2(q+\alpha)} W n_H + o(n_H).$$

Therefore,

$$\frac{Y_2-\mu}{\sigma} \approx \frac{\sqrt{(1-q^2)(1-\alpha^2)}}{q+\alpha} n_H^{(1-\zeta)/2},$$

and since the number of loans, n_H, is typically very large, Y_2 will be many standard deviations larger than the mean. In other words, while the optimal contract requires that investors get the entire revenue in some very good states of the world, the cutoff is practically so high that one can safely ignore this. This both justifies our approximation and explains why the structure (13) is not frequently observed in the real world.

B. Bailouts

Before the financial crisis of 2008, asset-backed securities were often used as collateral to back various other financial transactions (Gorton and Metrick, 2012). As a result, in an event when securities lose value, the government might feel forced to intervene and guarantee their value. We consider the implications of such policy, by assuming that if the securities do not pay their face value T, there is a probability $b \in (0,1)$ that the government will pay investors T instead of the bank. Notice that the bank is not getting anything directly from the government so its incentive compatibility constraint (7) remains unaltered. The bailout promise does change the investors' expected share of the revenue to

$$\begin{aligned}
&\int_{-\infty}^{T} [bT + (1-b)Y]dF(Y) + \int_{T}^{+\infty} TdF(Y) = \\
&= bT\left[\int_{-\infty}^{T} dF(Y) + \int_{T}^{+\infty} dF(Y)\right] + (1-b)\left[\int_{-\infty}^{T} YdF(Y) + \int_{T}^{+\infty} TdF(Y)\right] = \\
&\qquad = bT + (1-b)[\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T).
\end{aligned}$$

Therefore, the investors' participation constraint (8) is modified to

$$\frac{2c(\alpha)}{1+q\alpha} n_H + n_H L - X = (1-b)[\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T)] + bT. \tag{14}$$

The securitization problem in the presence of bailouts is thus a solution to the Lagrangian problem

$$\begin{aligned}\mathcal{L} = \mu(\alpha, n_H, 0) - \frac{1}{1-b} C(\alpha, n_H, 0) + \frac{b}{1-b} T - \\ - \lambda \left[bT + (1-b)[\mu(\alpha, n_H, 0) - G(\alpha, n_H, 0; T)] - \frac{2c(\alpha)}{1+q\alpha} n_H - n_H L + X \right] + \\ + \tau \left[\partial_\alpha G(\alpha, n_H, 0; T) - \frac{2n_H c(\alpha)}{1+q\alpha} \left(\frac{c'(\alpha)}{c(\alpha)} - \frac{q}{1+q\alpha} \right) \right]. \end{aligned} \quad (15)$$

The expected cost of the bailout program to the government is

$$\begin{aligned}-GS = b\int_{-\infty}^{T} (T-Y)dF(Y) = b\int_{-\infty}^{+\infty} (T-Y)dF(Y) + b\int_{T}^{+\infty} (Y-T)dF(Y) = \\ = b[T - \mu(\alpha, n_H, 0) + G(\alpha, n_H, 0; T)].\end{aligned}$$

Calculating the effects of a bailout promise is a straightforward exercise in monotone comparative statics. One simply starts with the Lagrangian (15), and calculates how the various quantities change as b increases. Since this calculation is rather cumbersome, we simply report the results and follow with some intuition.

1. If the government forced the bank to keep n fixed, the introduction of a bailout promise would lead to a higher choice of α.

2. Without leverage restrictions, a bailout promise leads to a higher equilibrium choice of n. The overall effect on the choice of α is ambiguous.

3. If an increase in b increases α, then increasing b is locally welfare-improving. Otherwise, welfare is concave in b, and there exists an optimal $b = b^*$ where welfare is maximized.

The anticipation of a bailout relaxes the investors' participation constraint. Since investors get bailed out in some bad events, the bank can offer them a lower share of the revenue. Since the bank's share of the revenue is therefore larger, the bank finds it optimal to be more vigilant about screening borrowers, i.e. to choose a higher α, which explains the first result above. However, relaxing the bank's constraints also allows the bank to choose a higher n, which in turn leads to lower α. The overall effect on α depends on the parameter values.

When the overall effect on α is negative, a promise of a bailout is welfare-enhancing for small enough values of b. Initially, the increase in lending activity more than compensates for the lower α; however, as b is increased, the bank's choice of n also increases and as a result α decreases, until after some critical value b^* the effect of lower accuracy in screening dominates.