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A Shot at Regulating Securitization

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Abstract

In order to incentivize stronger issuer due diligence effort, European and U.S. authorities are amending securitization-related regulations to force issuers to retain an economic interest in the securitization products they issue. This paper contributes to the process by exploring the economics of equity and mezzanine tranche retention in the context of systemic risk, moral hazard and accounting frictions. It shows that screening levels are highest when the loan originating bank retains the equity tranche. However, most of the time a profit maximizing bank would favor retention of the less risky mezzanine tranche, thereby implying a suboptimal screening effort from a regulator's point of view. This distortion gets even more pronounced when the economic outlook is positive or profitability is high, implicitly making the case for dynamic and countercyclical credit risk retention requirements. Finally, the paper illustrates the importance of loan screening costs for the retention decision and thereby shows that an unanimous imposition of equity tranche retention might run the risk of shutting down securitization markets.

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1 Introduction

In the aftermath of the global financial crisis, European and U.S. authorities are putting in place new regulations that will force securitizers to retain economic exposure to the assets they securitize in order to better align their interests with those of investors. More specifically, the Article 122a of the European Capital Requirments Directive and Section 941 of the U.S. Dodd-Frank Wall Street Reform and Consumer Protection Act both impose a five percent minimum credit risk retention rate. Both allow for several options, including retaining just the equity tranche, or equal amounts of all tranches.[1]

However, a number of recent papers have shown that both the size and form of the retention are critical to incentivizing due diligence. They imply, for example, that the implementation should be flexible in order to achieve broad-based incentive alignments. Fender and Mitchell (2009) identify conditions under which mezzanine tranche retention best incentives loan screening but note that the best incentive mechanism depends on the size of the respective tranches, the quality of the loan pool and the economic conditions expected during the life of the securitization. Kiff and Kisser (2010) illustrate that even if the loan quality and the economic outlook are known, it is impossible to design specific policy recommendations in case tranche sizes are exogenous. The Board of Governors of the Federal Reserve System (2010) stresses the importance of considering the economics of the underlying assets and securitization structure and, along with IMF (2009), the potential for other incentive

[1]Securitization is a process in which different assets or portfolios of cash flow generating securities are pooled together and then sold to third parties. This paper focuses on structured finance which further implies that cash flows of the entire portfolio are tranched into several slices which differ with respect to their risk-return characteristics. Tranche holders are paid in a specific order, starting with the senior tranches (least risky) working down through various levels to the equity tranche (most risky). If some of the expected cash flows are not forthcoming (e.g., some loans default), then, after any cash flow buffers are depleted, the payments to the equity tranche are reduced. If the equity tranche is depleted, then payments to the mezzanine tranche holders are reduced, and so on up to the senior tranches.

alignment mechanisms to complement various forms of mandated risk retention.

This paper explores the economics of equity and mezzanine tranche retention in the context of systemic risk, moral hazard and accounting frictions. Specifically, it derives both the optimal screening activity and retention size of a loan originating and securitizing bank and thereby provides a clear characterization of its optimal policies. The paper shows that although equity tranche retention generates the highest screening effort, most of the time a profit maximizing bank would choose to retain the mezzanine tranche because it requires less loan screening costs and regulatory capital.

This distortion gets even more pronounced when the loan has a high promised return or the economy is expected to perform well. The intuition for this result is that a more favorable environment increases the opportunity costs of retaining funds and thereby makes equity tranche retention less desirable. Also, loan screening costs have a first order effect on the choice between equity and mezzanine tranche retention. The main public policy implication of these results is that credit risk retention requirements should be based on accurate estimates of potential screening and opportunity costs, and be conditioned on the economic outlook. Poorly designed retention schemes further run the danger of actually shutting down securitization markets.

Furthermore, the paper shows that vertical slice retention is unlikely to dominate equity tranche retention and that for all the cases analyzed in this paper, even mezzanine tranche retention is expected to generate higher screening activity. Finally, we present an alternative risk specification which isolates the impact of loan quality on default risk and thereby abstracts from the distortions stemming from the systemic risk component. Under this more simple setup, the difference in implied screening effort becomes even more extreme and equity tranche retention clearly better incentivizes due diligence. Put differently, the robustness check underlines the importance of considering the joint impact of systemic risk and loan quality on the incentives to screen loans.

The paper closely relates to literature dealing with principal agent problems and credit risk transfer (CRT). Innes (1990) models a principal-agent problem between a risk-neutral entrepreneur with access to an investment project and an outside investor. The entrepreneur can exert costly effort to influence the probability of success of the underlying project but this action is unobservable and thus non-contractible. Given limited liability of the entrepreneur, Innes (1990) shows that debt financing is the corresponding optimal contract. Chiesa (2008) models a loan originating bank which needs outside financing and extends the setup to allow for a systemic risk component. Because a high return does not necessarily mean that the bank has engaged in monitoring but instead can be the result of a favorable realization of the systemic risk factor, Chiesa (2008) is able to show that a pure debt contract is not optimal whereas CRT with limited credit enhancements enhances loan monitoring and expands financial intermediation.

Fender and Mitchell (2009) adapt the principal agent problem of Innes (1990) to the case of asset securitization and introduce a systemic risk component into the analysis. They derive optimal screening effort under various retention mechanisms and show that equity tranche retention does not necessarily maximize loan screening activity. Using a dynamic model, Hartman-Glaser, Piskorski, and Tchistyi (2012) focus on the optimal contract for mortgage backed securities beween an originator and outside investors. Under some technical assumptions, they are able to show that the optimal contract consists of a one time payment to the originator after having a observed a default-free waiting period.

The empirical evidence on the effect of securitization on screening behavior mostly reveals evidence of a decline in the quality of securitized loans prior to the recent crisis. Krainer and Laderman (2009) focus on mortgage loans originated in California for the period from 2000 to 2007. Using loan-level data, they show that underwriting standards for private label securitizations are worse than for U.S. non-securitized loans or securitizations conducted by the government sponsored entities. This is confirmed by Demyanyk and Van Hemert (2011) who analyze subprime mortgage loans issued between 2001 and 2007 and show that loan quality deteriorated in the years leading up to the financial crisis. Keys, Mukherjee, Seru, and Vig (2010) compare the performance of loans with credit scores just above or below a certain threshold and find that loans above the threshold suffer from a worse ex-post performance. Given that these loans had a higher likelihood of being securitized, the paper argues that securitization reduced the bank's loan screening incentives.

Another strand of literature relates to the effect of informational asymmetries, signaling and pricing of securities. The "lemons problem", as coined by Akerlof (1970), shows that markets may break down in the presence of informational asymmetries. Leland and Pyle (1977) use a signaling model to show how agency costs can be mitigated in the context of a partial firm sale. They model an entrepreneur with superior information regarding future prospects of assets in place who wants to sell part of his holdings to diversify risk. The entrepreneur can signal quality by retaining a larger fraction of the asset and thereby mitigate the agency problem.

Gorton and Pennacchi (1995) focus on the subsequent adverse selection problem a bank faces if it engages in loan sales. However, they show that implicit contract features such as retention of part of the loan and or implicit guarantees against default can make loan sales possible and thereby reduce agency problems. While Morrison (2005) illustrates that credit derivatives may destroy the signaling value of debt and thereby cause disintermediation and lower welfare, Niccolo and Pelizzon (2006) demonstrate that even in the context of credit risk transfer, banks may signal their own types by using first-to-default contracts. Similarly, DeMarzo (2005) shows that if assets are not only pooled but also tranched into different risk-return categories, banks can signal the quality of the sold loan portfolio by retaining interest in the equity tranche, thereby confirming optimality of a (standard) debt contract.[2]

This paper compares the effects of equity and mezzanine tranche retention and thereby builds on the model proposed by Fender and Mitchell (2009). Doing so, we contribute to the existing literature in several ways. By introducing accounting frictions into the principal agent problem, we are able to solve for both the optimal loan screening effort and the optimal level of tranche retention and thereby provide a clear characterization of the optimal retention policies. This has important implications as equity tranche retention continues to best incentivize loan screening. Furthermore, using the optimal solutions we are able to analyze the mismatch between maximizing due diligence and maximizing profits and thereby identify areas for policy intervention. Specifically, we show that the mismatch is highest when the underlying market is highly profitable and the economic outlook is positive.

[2]Note that this paper deals with the impact of moral hazard on securitization. The reason is that we are primarily interested in analyzing the impact of credit risk retention requirements on the incentives to screen loans in the context of accounting frictions and systemic risk.

The paper proceeds as follows. Section [2] introduces the model and Section [3] presents the numerical analysis. Section [4] presents results under two alternative model specifications. Section [5] finally concludes.

2 Optimal Retention and Screening Policy

The model centers around a profit maximizing bank which extends individual loans to borrowers and then has the option of securitizing the loan portfolio and selling different tranches to individual investors. The total loan portfolio is normalized to one, outside investors and the bank are assumed to be risk-neutral and the risk-free interest rate is set to zero. A performing loan returns $R > 1$ while there is zero recovery for a defaulting loan.

The simplified economy consists of a continuum of good and bad borrowers who differ in their ability to repay the loan. The proportion of "good" borrowers is captured by the parameter θ which is given exogenously. The bank can exert costly screening effort e to increase the probability of lending to a good quality borrower. Denoting α_G and α_B as the revised probabilities of lending to good and bad borrowers, it is assumed that

$$\alpha_G(e) = (\theta + e) \tag{1}$$

$$\alpha_B(e) = (1 - \theta - e) \tag{2}$$

Screening borrowers is costly, which is captured by the cost function $c(e)$ which is assumed to be increasing in e and convex, i.e. $c(0) = 0$, $c'(e) > 0$ and $c''(e) > 0$. Similar to Carletti (2004) and Duffie (2008), we assume a quadratic cost function, i.e. we set $c(e) = \frac{\phi}{2}e^2$ to

	Good Borrower	Bad Borrower
High State	0	PD
Low State	PD	1

Table 1: Default Probabilities in the context of systemic risk

account for the convexity in effort costs. It is further assumed that at the time when the loans are extended, the originator has already decided if and in what form the loan portfolio will be securitized. Effort level is chosen accordingly and then different tranches of the portfolio are sold to outside investors. Outside investors are only willing to make payments equal to the expected value of future cash flows conditional on the optimal effort level of the originator.

The setup also embeds a systemic risk component, i.e. it is assumed that the economy can be either in a high or a low state and that the corresponding probabilities are given by p_L and p_H. The state of the economy has a distinct impact on each borrower. In the high state, the good borrower is always able to repay the loan while the bad borrower may default with a probability PD. In the low state, the bad borrower always defaults with probability one while the good borrower only does so with a probability of PD. Table [1] summarizes the assumption.

Summing up, we can now define the expected cash flows of the entire loan portfolio in the low and the high state of nature of the economy.[3]

[3]Note that due to having assumed that there is a continuum of good and bad borrowers with corresponding subcontinua depending on their idiosyncratic default probabilities, it follows that expected and realized portfolio cash flows of the individual states of nature coincide.

$$P_L(e) \equiv [(1 - PD)(\theta + e)] R \tag{3}$$

$$P_H(e) \equiv [(\theta + e) + (1 - PD)(1 - \theta - e)] R \tag{4}$$

The bank has the option to create a structured product and sell different tranches to outside investors. It is assumed that the structured product consists of a senior tranche, a mezzanine tranche and an equity tranche. The size of the equity tranche is denoted as t and, in case the originator retains the mezzanine tranche, the thickness of mezzanine and equity tranche are identical. This assumption makes sure that in both cases the originator is flexible enough to ensure that the more senior tranches are risk-less, if required, and comparable. Senior and mezzanine tranche holders are promised a payment of $(1-2t)R$ and tR in non-default states. When pricing the tranches offered for sale, investors act rationally and consider the implied optimal screening effort of the bank and the observed size of credit retention. This is formalized in Assumption [1].[4]

Assumption 1 *Investors are rational and price different tranches according to their expected cash flow, taking into account both the optimal implied effort level e^* and the observed amount of retention t^*.*

[4]Note that there is no Special Purpose Vehicle (SPV) in our securitization chain. A reason why SPVs are usually employed is to separate the cash flows relating to the securitized assets from the overall cash flows and risk of the bank. Given that in our model the bank generates revenue through one line of business only, i.e. by lending funds to potential borrowers, the cash flows of the securitized assets and the bank itself coincide such that there is no need to introduce an additional intermediary into the securitization chain. In any case, when an SPV is involved, it is common practice for banks to retain an interest in the future cash flows associated with the securitized assets. Such retained interest includes interest-only strips receivable, retained subordinated security interests, the funding of cash-collateral accounts, or other forms of credit enhancements.

Due to the systemic risk component, the monotone likelihood ratio property does not always hold which is why debt financing, i.e. equity tranche retention, is not necessarily the optimal contract. While the optimal retention mechanism also depends on the systemic outlook and the idiosyncratic default probabilities, the thickness of the respective tranches is most relevant as has been illustrated by Kiff and Kisser (2010). Even more importantly, the systemic outlook, the quality of the loan pool and individual default probabilities are exogenous factors to the bank while the size of retention, or skin in the game, would be chosen by the bank.

In order to make the retention decision practically relevant, some market friction is needed. DeMarzo (2005) assumes that the source of market friction is superior valuation ability of banks which is why they profit from increasing volume, i.e. buying undervalued assets and selling them at market prices. However, if banks sell everything then they suffer from adverse selection as they are not able to signal the quality of their assets for sale. Alternatively, Fender and Mitchell (2009) discuss that banks can benefit from accounting loopholes as an upfront sale of the loan portfolio allows for early recognition of profits. This effect can create a market friction if managerial compensation is linked to it.

To capture this intuition, we assume that whenever the bank sells more senior tranches and those tranches are expected to be fully paid back, then it may be able to value the corresponding upfront payments at a premium to its notional amount. On the other hand, if the bank sells more risky tranches (i.e. sells equity and keeps the mezzanine tranche), then no premium can be realized with respect to the more risky tranche.

Assumption 2 *Banks benefit from accounting-related market imperfections and are thus able to value the proceeds received for selling risk-less senior claims at a premium to the* *notional amount. Under equity tranche retention, the bank values the sale of a risk-less senior tranche* $S_E(t) = (1 - t^2)R$*. Under mezzanine tranche retention, the senior tranche is valued at* $S_M(t) = (1 - 4t^2)R$*.*

The choice of the specific functional form allows us to capture a benefit of securitization in a reduced form. This effect is illustrated in Figure [1]. The solid blue line plots the fixed upfront payment $(1-t)R$ for different values of t in case R is set to 1.1. The dashed green line displays values corresponding to the concave function $(1 - t^2)R$. It can be seen that starting with a fully retained loan portfolio, i.e. $t = 1$, the initial marginal benefit of securitizing is very high and it subsequently decreases if a larger fraction of the loan portfolio is sold to outside investors. We can also see that if the entire portfolio is sold to outside investors, i.e. $t = 0$, the benefits from securitization are zero such that the originator only values the upfront payment at its notional value.[5]

From a practical perspective, equity and mezzanine tranche retention have very different profitability implications due to the fact that the Basel framework attaches different risk weights, and thereby costs, to them. We therefore specifically introduce capital charges into the model and assume a linear cost function for capital requirements.

Assumption 3 *To capture the various capital charges associated with each of the retention mechanisms, we assume the following linear cost function*

$$k_i(t) = k_i \cdot t \tag{5}$$

[5] The argument that managerial compensation creates an incentive for management to increase short-term profits requires a certain degree of intransparency within the firm. In the case of zero retention, transparency is likely to be high which is why we assume that the benefit of securitization is zero. Also, adding an additional constant excess benefit would not change the optimal policies discussed later and would only distort the profitability level.

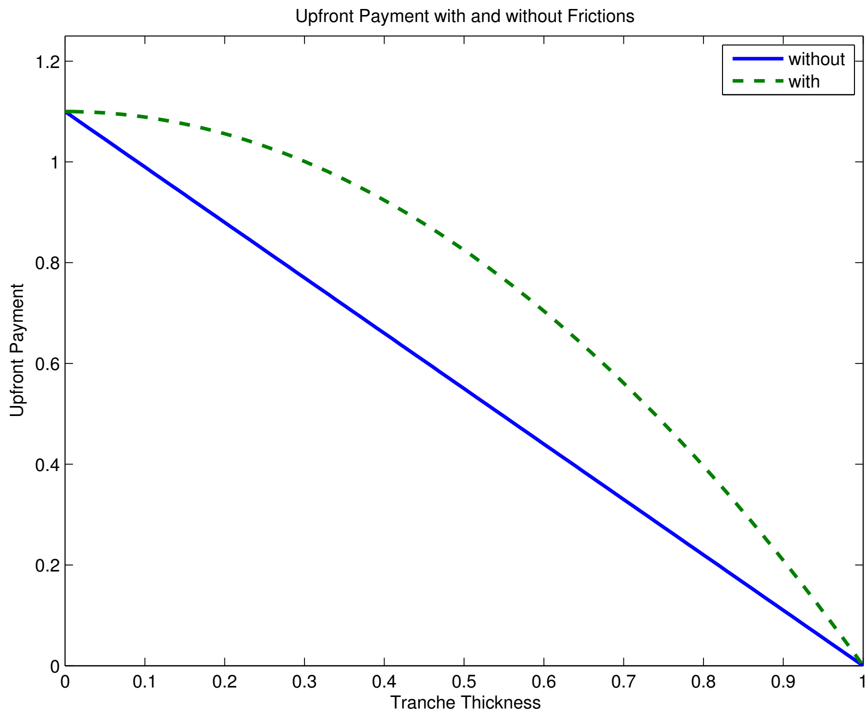

Figure 1: **Visualizing the Intuition of Assumption [2]:** The figure displays the value of the upfront payment received for selling a riskless senior claim with a promised payment of (1 - t)R. The solid blue line plots the fair value of the fixed upfront payment for different values of t in case R is set to 1.1. The dashed green line displays values corresponding to the concave function $(1-t^2)R$.

where k_i *captures capital charges, conditional on the specific retention mechanism. Specifically we assume that* $k_i = CAR \times RW_i \times (R-1) \times \delta$ *where* CAR *is the capital adequacy ratio as implied by the Basel II framework,* RW_i *denotes the risk weight under equity or mezzanine retention,* $(R-1)$ *captures the opportunity costs of the capital charges and* δ *is a parameter capturing the distortions between equity and debt financing.*[6]

[6]In fact, if there were no market frictions such that the capital structure choice was irrelevant, then δ would be equal to zero and capital requirements would not matter. In reality, frictions such as the tax deductibility of interest payments and, in case of banks, the implicit bailout guarantee given by governments, tend to make debt financing a less costly option.

Combining above, we are now able to write down the following general maximization problem.

$$\max_{e,t} \Pi_i(e,t) = S_i(t) + F_i(e,t) - c(e) - k_i(t) - 1 \tag{6}$$

where $i \in (E, M)$ denotes either equity or mezzanine tranche retention and $F_i(e,t)$ are the cash flows relating to the retained credit exposure. The subsequent analysis investigates how optimal screening effort and tranche size differ depending on whether the bank retains the equity or the mezzanine tranche.

2.1 Equity Tranche Retention

In case the bank retains interest in the equity tranche, the payoff structure is similar to holding a call option on the performance of the loan portfolio with a strike price equal to the promised payments to senior and mezzanine tranche holders. Specifically, expected profits of the retained credit exposure are given by

$$F_E(e,t) = p_L \max\{P_L(e) - B_E(t), 0\} + p_H \max\{P_H(e) - B_E(t), 0\} \tag{7}$$

where $B_E(t) = (1-t)R$ is the strike price of equity tranche holders and denotes the promised payments to mezzanine and senior tranche holders. From a practical perspective, the bank can either issue riskless senior claims or claims which are expected to default in the low state of nature.[7] Propositions [1] and [2] summarize the corresponding profit maximization problems.

[7] In principle, one would also need to check whether it is optimal for the bank to sell debt which is risky in the high state of nature. Because this scenario is economically not interesting, we abstract from this case.

Proposition 1 *If the bank sells riskless senior claims, the maximization problem is given by*

$$\begin{aligned}
\max_{e,t}\ \Pi_{E_1}(e,t) &= (1-t^2)R + p_L\left[P_L(e) - B_E(t)\right] + p_H\left[P_H(e) - B_E(t)\right] \\
&- \frac{\phi}{2}e^2 - k_E t - 1 \qquad (8)\\
s.t.\ B_E(t) &\leq P_L(e) \qquad (9)\\
e &\leq 1-\theta \qquad (10)\\
e &\geq 0 \qquad (11)
\end{aligned}$$

where [9] is the positive payoff constraint of equity tranche holders in the low state of nature and the minimum and maximum effort constraints [11] and [10] consider the fact that the probability of making a good loan is bounded by zero and one.

It can be seen that in case the bank sells riskless debt, it has to make sure that the payoff in the low state of nature is sufficient to cover promised payments to senior claim holders. This is guaranteed by imposing equation [9] which will be referred to as the positive payoff constraint. Other relevant constraints include the maximum effort constraint, given by equation [10] and the fact that optimal effort is non-negative. As can be seen, the bank can benefit from market imperfections for the entire fraction of the loan portfolio sold to outside investors when the equity tranche is not expected to be exhausted.

However, once it allows the equity tranche to get exhausted in the low state of nature, then it will only benefit from market frictions in the high state of nature. Furthermore, because the expected value of the senior claim in the low state of nature is less than the promised payment, outside investors will rationally take this into account and therefore only offer to pay the amount $p_L P_L(e^*)$ upfront. That is, outside investors will consider the optimal effort level of the originator when deciding about the upfront payment.[8] This is summarized by Proposition [2].

Proposition 2 *If the equity tranche is expected to be exhausted in the low state of nature, the maximization problem is given by*

$$\begin{aligned} \max_{e,t} \ \Pi_{E_2}(e,t) &= p_L P_L(e^*) + p_H(1-t^2)R + p_H\left[P_H(e) - B_E(t)\right] - \frac{\phi}{2}e^2 \\ &- k_E t - 1 \qquad (12) \\ s.t.\ B_E(t) &\leq P_H(e) \qquad (13) \\ e &\leq 1-\theta \qquad (14) \\ e &\geq 0 \qquad (15) \end{aligned}$$

where [13] is the positive payoff constraint of equity tranche holders in the high state of nature and the minimum and maximum effort constraints [15] and [14] consider the fact that the probability of making a good loan is bounded by zero and one.

Depending on whether expected profit is higher by selling riskless or risky debt, the bank will choose effort and tranche size accordingly. The optimal solution thus depends on the choice between riskless and risky senior claims and on whether the imposed constraints are individually or jointly binding. Due to the complexity of the corresponding optimal policy

[8] Put differently, the value of the senior tranche in the low state is given by $\min[(1-t)R, P_L(e)]$ which equals $P_L(e)$ in case of default. Because the effort level is non-contractible, outside investors will only make an upfront payment of $p_L P_L(e^*)$ for the expected value of the senior claim in the low state of nature. The bank in turn will not maximize its effort level over the upfront payment as it is not able to contract upon this effort.

functions, the presentation of the closed form solutions to Propositions [1] and [2] is limited to the the Appendix whereas the corresponding interpretation of the results is deferred to Section [3].

2.2 Mezzanine Tranche Retention

In case the bank retains the mezzanine tranche of the structured product, the corresponding payout structure is similar to holding subordinated or junior debt. The downside risk is lower due to the fact that the equity tranche serves as a first buffer to absorb losses whereas, the upside potential is limited and equal to the promised payments. Specifically, the payoff structure is given by

$$\begin{aligned} F_M(e,t) &= \min\left[\max\left\{P_L(e) - B_M(t), 0\right\}, tR\right] p_L \\ &+ \min\left[\max\left\{P_H(e) - B_M(t), 0\right\}, tR\right] p_H \end{aligned} \tag{16}$$

where $B_M(t) = (1-2t)R$ is the strike price of mezzanine tranche holders and denotes promised payments to senior tranche holders. Because the maximum payment mezzanine tranche holders can receive is capped at tR, they will only exert so much screening effort as to guarantee this payoff in the low state of nature. This in turn implies that the equity tranche will be exhausted in this case.

Combining above together with the fact that the payoff in the high state of nature is always larger than the payoff in the low state, i.e. $P_H(e) > P_L(e)$, the expected value of the equity tranche, and thus the value of the upfront payment for selling the equity tranche, is given by $p_H\left(P_H(e^*) - B_E(t)\right)$.[9] Using this together with Assumptions [1] to [3], Proposition [3] is as follows.

Proposition 3 *Under mezzanine tranche retention, if the bank sells riskless debt and the equity tranche is not expected to be exhausted in the high state of nature, the maximization problem is given by*

$$\max_{e,t}\ \Pi_M(e,t) = p_H\left(P_H(e^*) - B_E(t)\right) + (1-4t^2)R + p_L\left(P_L(e) - B_M(t)\right) + p_H tR - \frac{\phi}{2}e^2 - k_M t - 1 \qquad (17)$$

$$s.t.\ B_M(t) \leq P_L(e) \qquad (18)$$

$$P_L(e) \leq B_E(t) \qquad (19)$$

$$e \leq 1-\theta \qquad (20)$$

$$e \geq 0 \qquad (21)$$

where [18] is the positive payoff constraint of mezzanine tranche holders in the low state of nature, [19] is the maximum payoff constraint of mezzanine tranche holders in the low state of nature and the minimum and maximum effort constraints [21] and [20] consider the fact that the probability of making a good loan is bounded by zero and one.

It can be seen that in addition to the positive payoff constraint which is necessary to guarantee that the senior tranche is riskless, there is an additional constraint given by equation [19]. This condition considers the fact that it is not optimal for mezzanine tranche

[9] The intuition for the upfront payment is similar to Proposition [2]. Investors rationally take into account that the bank has no incentive to consider the upfront payment (it receives for selling the equity tranche) in the maximization problem and therefore offer an upfront payment which conditions upon the optimal anticipated effort level, i.e. they pay $p_H\left(P_H(e^*) - B_E(t)\right)$ upfront.

holders to exert more effort than to guarantee its promised payment and will therefore be referred to as the maximum payoff constraint.

Clearly, the maximization problems for equity and mezzanine tranche retention provide different incentives to screen loans and although we obtain the optimal screening effort and tranche size as closed form solutions, it is practically impossible to judge which retention mechanism dominates the other due to the various kinks in the payoff functions. The next section will therefore present numerical examples using the solutions to Propositions [1] to [3] which are provided in the Appendix.[10]

3 Numerical Analysis

This section analyzes whether equity or mezzanine tranche retention results in higher loan screening effort and it compares the profitability of the two retention mechanisms. We start our analysis by focusing on the stylized case of a market with high systematic and idiosyncratic risk, having in mind a proxy for the subprime market. We then perform a variety of robustness checks by varying the impact of screening costs, capital requirements and loan profitability as well as macroeconomic factors such as the systemic risk component and the fraction of good quality borrowers.

3.1 Baseline Scenario

For the baseline scenario, it is assumed that three out of 10 borrowers in the economy are classified as good ($\theta = 0.3$) and that the probability of entering a downturn is equal to 80

[10] Again, in principle one would also need to check whether it is optimal for the bank to make use of the limited liability option in the high state of nature. For the same reason as before, we abstract from this case.

percent. Furthermore, the gross return R is set to 1.1, ϕ and δ to 1. Following the Basel II framework, the capital adequacy ratio is equal to 8 percent, risk weights for equity tranche retention are set to 1250 percent while those of mezzanine tranche retention are equal to 100 percent.

We start our analysis by calculating implied screening effort for the case of equity and mezzanine tranche retention. All effort levels will be displayed relative to the amount of effort the bank would exert in case it retained the entire loan portfolio.[11] Results are presented for all default probabilities for which securitization is profitable for at least one of the two retention mechanisms.

The left panel in Figure [2] displays the amount of screening effort for both retention mechanisms. It can be seen that for default probabilities of up to 12 percent, equity tranche retention best incentivizes diligent loan screening and the bank would exert the same level of due diligence as if it retained the entire loan portfolio. Mezzanine tranche retention, on the other hand, implies a lower level of screening activity due to the fact that the maximum payoff constraint is binding. That is, given that the maximum payoff the bank receives is capped, it has no incentives to engage in more screening than necessary to guarantee this amount. At the same time, the right panel of Figure [2] shows that substantially more credit exposure is retained in the case of equity tranche retention.

From the perspective of a policy maker, the main interest lies in analyzing whether a profit maximizing securitizer would actually choose equity or mezzanine tranche retention. Figure [3] therefore displays profit levels under both retention schemes. It can be seen that the

[11]For a derivation of the corresponding optimal screening level, see Appendix.

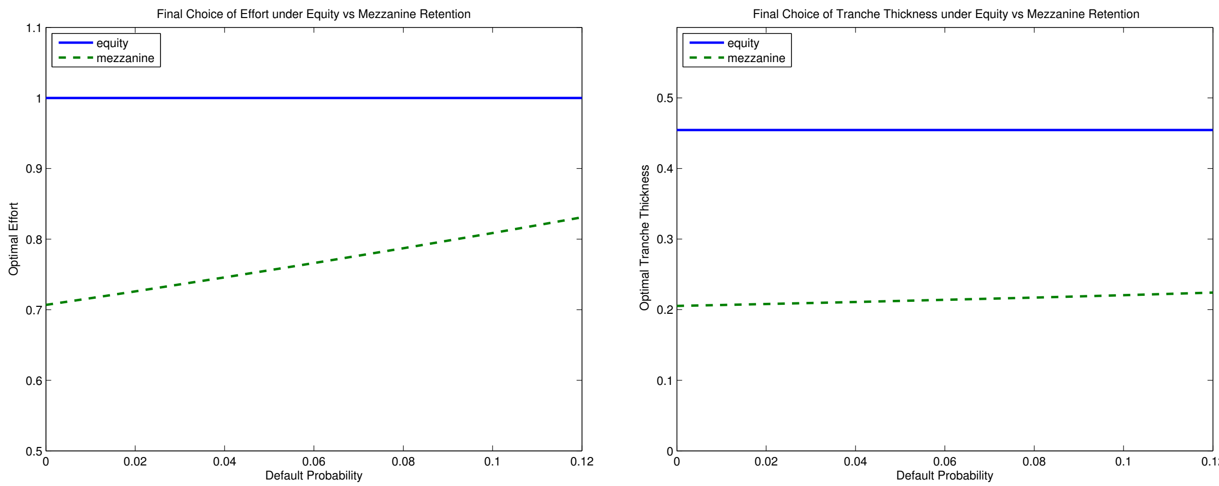

Figure 2: **Optimal Policies for Baseline Scenario:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. The baseline scenario is characterized by assuming that $R = 1.1$, $\phi = 1$, $p_H = 0.2$, $\theta = 0.3$, $\text{CAR} = 0.08$, $RW_E = 1250\%$ and $RW_M = 100\%$.

securitizer would choose equity tranche retention as long as the default probability is less than roughly 5% and mezzanine tranche retention otherwise. Intuitively, this is because the equity tranche is the first to suffer any losses which is why expected profits decline if the default probability is increased.

This simple example shows that for the stylized case of a low quality market, i.e. high fraction of bad borrowers and high chances of economic downturn, equity tranche retention would not necessarily be the preferred choice of a profit maximizing bank even though it best incentivizes loan screening.

Before discussing any potential policy implications, it is essential to obtain a rich understanding for how different scenarios affect results. We therefore vary the magnitude of

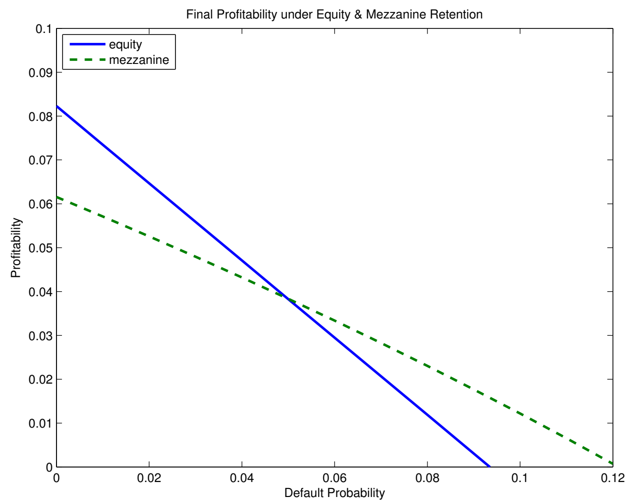

Figure 3: **Profitability for Baseline Scenario:** The figure displays expected profits under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) for different default probabilities. The baseline scenario is characterized by assuming that $R = 1.1$, $\phi = 1$, $p_H = 0.2$, $\theta = 0.3$, $\text{CAR} = 0.08$, $RW_E = 1250\%$ and $RW_M = 100\%$.

screening costs, capital charges and loan profitability and assess its implications for expected profits and screening activity. Then, we investigate the influence of the macroeconomic environment, as measured by the fraction of good and low quality borrowers and the systemic risk component on retention policy.

3.2 The Profit Drivers

3.2.1 The impact of loan screening costs

As a first step, we analyze the impact of screening costs on the retention decision. Instead of setting ϕ equal to one, we assume a value of 5% reflecting the intuition that for some credit markets it might be easier to screen borrowers than for others.[12]

[12]In a different context, the Corporate Finance literature relating to agency costs of free cash flow frequently assumes a value of 0.05 for the severity of the agency costs parameter. See for example Eisfeldt and Rampini (2009).

It turns out that due to the low costs of screening, the bank will exert maximum screening effort under both equity and mezzanine tranche retention for default probabilities of approximately 15% and higher which is visualized in the left panel of Figure [4]. For portfolios with lower risk, mezzanine tranche retention leads again to less screening activity due to the fact that the maximum payoff to mezzanine tranche holders is capped.

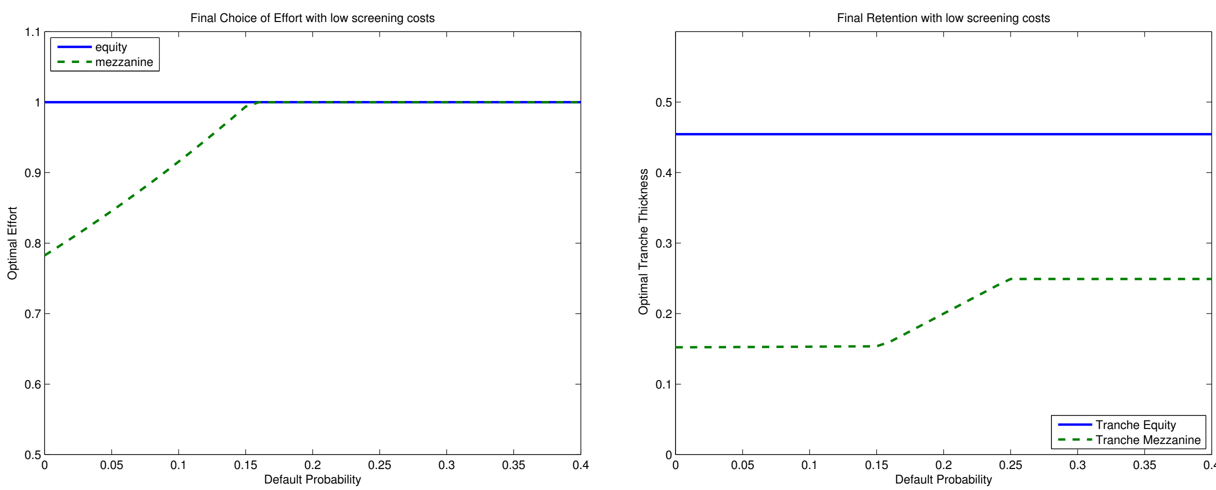

Figure 4: **Optimal Policies for Case of Low Screening Costs:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. All parameter values are as in the baseline scenario except for the screening cost parameter ϕ which is set to 0.05.

The right panel of Figure [4] visualizes that implied retention when holding the equity tranche is considerably higher than under mezzanine tranche retention. Also, it can be seen that the optimal level of skin in the game under mezzanine tranche retention is piecewise linear with respect to the default probability. First, the maximum payoff constraint is binding for default probabilities of up to 15%. At this threshold, also the maximum effort constraint becomes binding such that the cash flow in the low state of nature decreases with higher default probabilities. The bank responds by optimally increasing the retention rate. Only for default probabilities of 25% and higher, the maximum payoff constraint becomes slack such that the bank can keep the optimal retention level constant.

Finally, given the low costs of loan screening, securitization becomes more profitable than under the benchmark case. Figure [5] shows that equity tranche retention generates higher expected profits than mezzanine tranche retention for default probabilities of up to 15%. Beyond that, mezzanine tranche retention becomes the preferred choice for default probabilities of up to 40 percent.

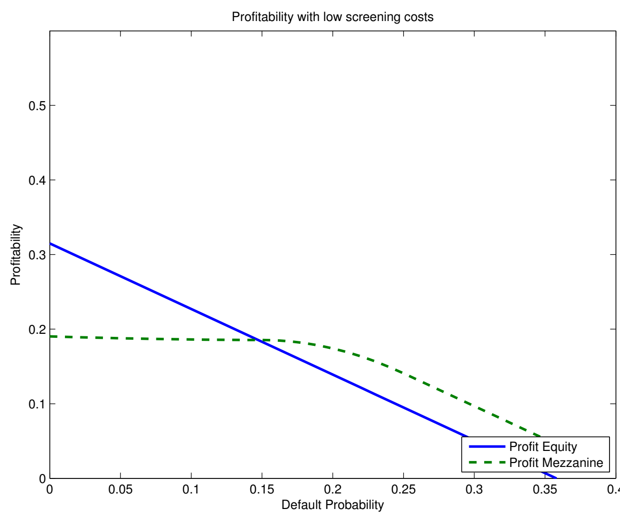

Figure 5: **Profitability for Case of Low Screening Costs:** The figure displays expected profits under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) for different default probabilities. All parameter values are as in the baseline scenario except for the screening cost parameter ϕ which is set to 0.05.

Comparing this result with the benchmark case illustrates how crucial it is that policymakers have a good estimate of potential screening costs across different securitization markets before designing any active policy recommendation. If the costs of performing due diligence are prohibitively high, then an unanimous imposition of equity tranche retention might not lead to a higher level of screening activity but could just simply shut down certain credit markets as equity tranche retention might not be profitable in this case.

3.2.2 The impact of capital requirements

Capital requirements have a direct impact on the profitability of securitization but they affect equity and mezzanine tranche retention in a different way. To analyze the sensitivity of the results with respect to capital charges while preserving their asymmetric influence, we therefore reduce their influence in the profit function.

Figure [6] displays optimal screening effort and retention policy in case the distortion parameter θ is reduced to 0.10. The left panel shows that screening effort is largely unaffected by the costs of retaining funds and thus similar to the benchmark case. Focusing on the implied retention rate, it can be seen that it becomes optimal to increase the amount of skin in the game under equity tranche retention whereas the impact of lower capital charges on mezzanine tranche retention is negligible.

Figure [7] shows that the region for which projects are financed using equity tranche retention more than doubles (with respect to the baseline scenario) to default probabilities of up to 14% whereas again there is basically no impact on the profitability under mezzanine tranche retention. This is due to the fact that the initial risk weight under mezzanine tranche retention is rather small which makes its impact negligible. Most importantly, equity retention delivers both the highest expected profit and the highest level of loan screening activity. While we do not argue that regulators should decrease the cost of retaining the

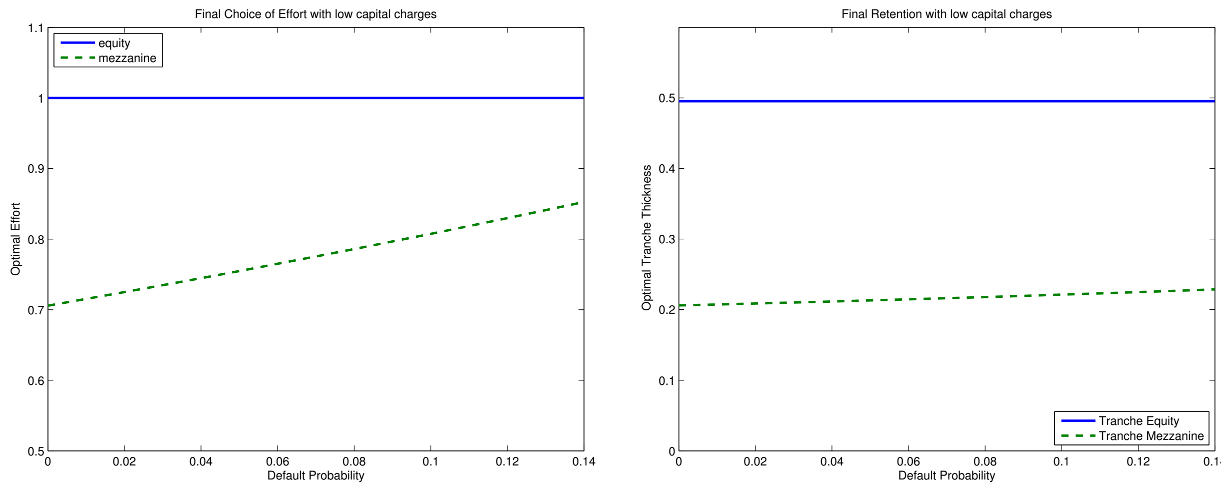

Figure 6: **Optimal Policies for Low Capital Charges:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. All parameter values are as in the baseline scenario except for the capital cost parameters k_E and k_M which are set to one tenth of its original value.

most risky asset, we want to emphasize the possible feedback effect on the incentives to retain credit exposure.

3.2.3 The impact of loan profitability

Finally, we analyze the effect of loan profitability on implied screening and retention levels. Increasing the gross return R to 1.4, Figure [8] shows that for default probabilities between roughly 20% and 40%, mezzanine tranche retention leads to the same level of loan screening as retention of the equity tranche.

The intuitive reason is that both the maximum effort and maximum payoff constraint are binding such that mezzanine tranche retention generates the full screening effort. However,

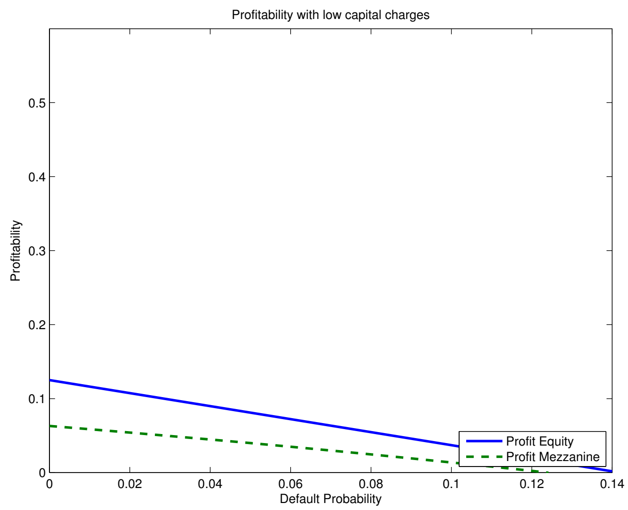

Figure 7: **Profitability for Low Capital Charges:** The figure displays expected profits under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) for different default probabilities. All parameter values are as in the baseline scenario except for the capital cost parameters k_E and k_M which are set to one tenth of its original value.

for default probabilities of 37% and higher, both constraints become slack and thereby reveal less due diligence under mezzanine tranche retention. At the same time, it can be seen that higher profitability allows the originator to optimally sell a larger fraction of the loan portfolio under both equity and mezzanine tranche retention, relative to the benchmark case.

Finally, it turns out that mezzanine tranche retention always generates higher profits than retaining the equity tranche. The reason is that equity tranche retention becomes increasingly costly as the opportunity cost of capital charges are positively related to the gross return R. Thus, because retention is more costly under equity tranche retention, the bank optimally chooses to retain the mezzanine tranche in case loans promise a high expected return. Nevertheless, it should be noted that in absolute values also equity tranche retention becomes more profitable than under the benchmark case. All effects are visualized in Figure [9].

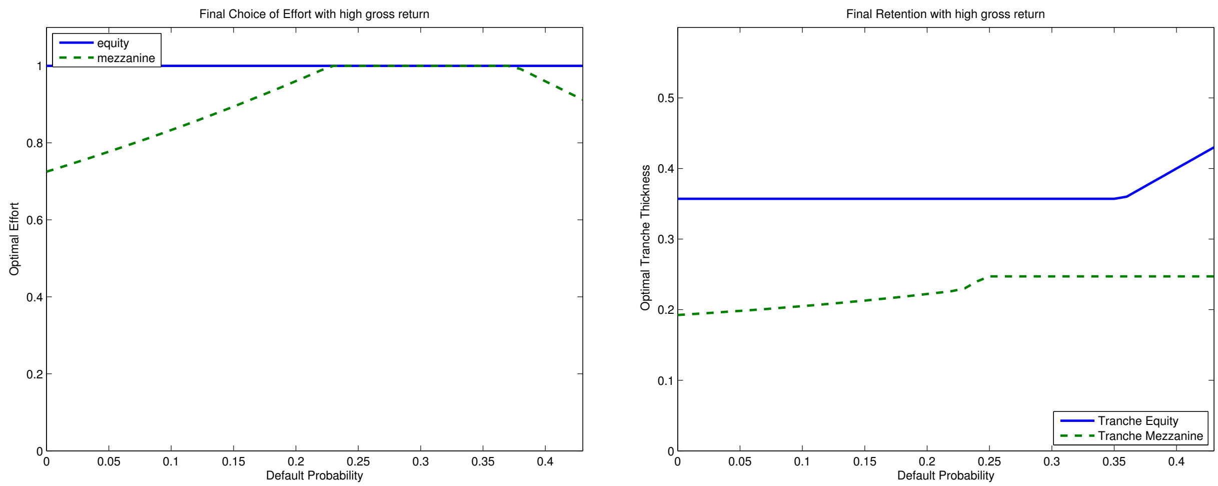

Figure 8: **Optimal Policies for Case of High Profitability:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. All parameter values are as in the baseline scenario except for R which is set to 1.40

3.2.4 Intermediate Summary

Summing up, we have seen that capital charges have a strong impact on the incentives to diligently screen loans and borrowers. This can be explained by the fact that in order for equity retention to be effective, a profit maximizing bank has to ensure that the next risky tranche is safe and this is achieved by increasing the thickness of the equity tranche. While this leads to the highest possible screening effort, it also reduces expected profits compared to the case of mezzanine retention due to the comparably much higher capital charges. This feedback effect even gets more pronounced in case gross profit is high as the opportunity costs of retaining funds become increasingly expensive in this case. While we do not argue that capital costs should be reduced to restore banks' incentives to retain the equity tranche,

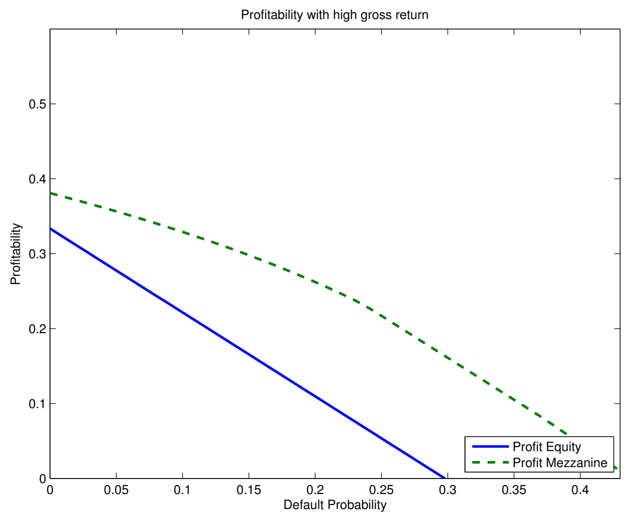

Figure 9: **Profitability for Case of High Profitability:** The figure displays expected profits under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) for different default probabilities. All parameter values are as in the baseline scenario except for R which is set to 1.40

it is important to consider this negative feedback effect when giving regulatory advice.

Another factor influencing the retention decision is the magnitude of loan screening costs. We have seen that once it becomes cheaper to screen, more projects receive financing. However, at the same time this makes high screening effort under mezzanine tranche retention also much more likely.

It is therefore crucial that regulators have a good estimate of loan screening costs and the relative profitability of the different credit markets in order to avoid any of the above mentioned undesired effects.

3.3 The Effect of the Macroeconomic Environment

The results presented so far have focused on a stylized credit market characterized by a large fraction of low quality borrowers and a high chance of an economic downturn. We now relax this assumption and present results for different levels of systematic risk and varying fractions of good and low quality borrowers.

3.3.1 The impact of the future state of the economy

Figure [10] displays optimal screening activity, tranche retention and profit levels for equity and mezzanine retention under different economic scenarios. Under the first one, we assume that the economy will enter a recession with 90% probability, under the second one we make no directional assumption regarding the future state of the economy and finally we set the probability of entering an upturn equal to 70 percent.

It can be seen that if an economic downturn is expected, then only projects with default probabilities of up to 8% would receive financing and equity tranche retention would be the preferred choice both in terms of screening effort and profitability. On the other hand, if chances of an economic upturn are 50% or higher, then more projects are financed and a profit maximizing bank would always choose to retain the mezzanine tranche, even though equity tranche retention becomes more profitable in absolute terms. The main reason is that the positive economic outlook allows the bank to save on screening costs in case the less risky mezzanine tranche is retained.

The same effect can be observed in case the economy is expected to perform well. The lower left panel of Figure [10] shows that the optimal level of due diligence under mezzanine

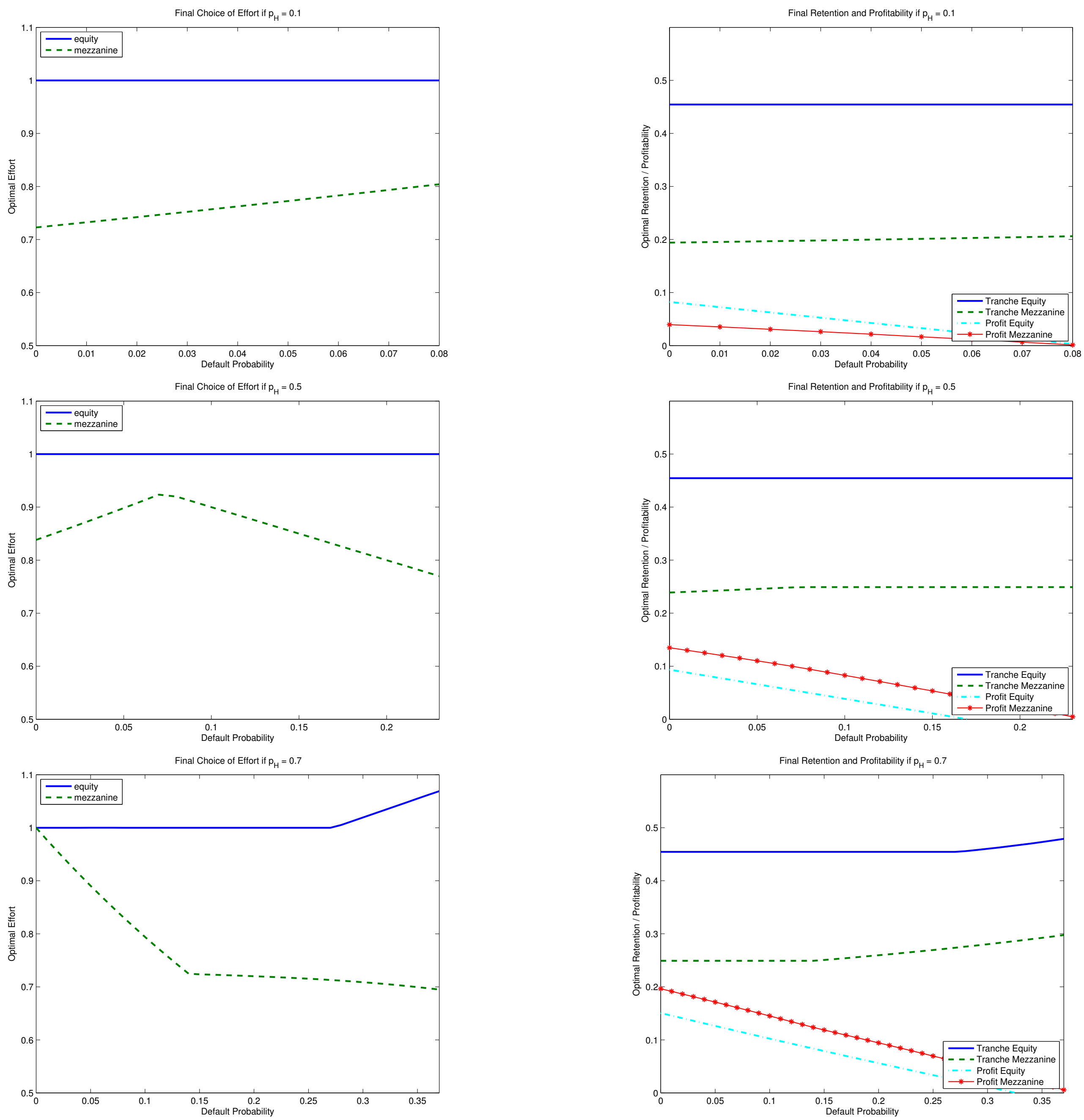

Figure 10: **Optimal Policies For Different Economic Outlooks:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line), mezzanine tranche retention (dashed green line) as well as profits under equity tranche retention (red with asterisk) and mezzanine tranche retention (dashed-dotted turquoise). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. The first row displays results in case $p_H = 0.1$, the second row in case $p_H = 0.5$ and the third row in case $p_H = 0.7$. All other parameter values are as in the baseline scenario.

tranche retention is considerably below the amount implied by retaining the equity tranche. At first, the effort level is downward sloping as none of the constraints are binding. Only when default probabilities are higher than approximately 15%, the bank starts to increase the level of retention and keeps the amount of loan screening constant. While a profit maximizing bank would favor mezzanine tranche retention, equity tranche retention also generates profits for a wider range of parameter values. A potential policy implication would be to advocate equity tranche retention in times when expectations regarding the future state of the economy are good in order to avoid that banks systemically save on screening costs and capital charges.

3.3.2 The impact of loan quality

We now assess how the quality of a given credit market influences loan screening activities and therefore change the fraction of high quality borrowers in the economy. Figure [11] displays optimal screening effort, retention policy and profitability when the parameter θ is set to 50% or 80%. We can see that for both cases, equity tranche retention delivers the highest screening effort but it would only be chosen by the originator if default probabilities are relatively low. One can thus observe a similar pattern as for the benchmark case.

3.3.3 A high quality market

Finally, we investigate how the combination of higher loan quality and less systematic risk affects screening effort and retention. We therefore display optimal policies and profit levels for the case of a high quality market, i.e. we set the parameter θ equal to 60% and assume that the chances of entering an economic up- or downturn are equal.

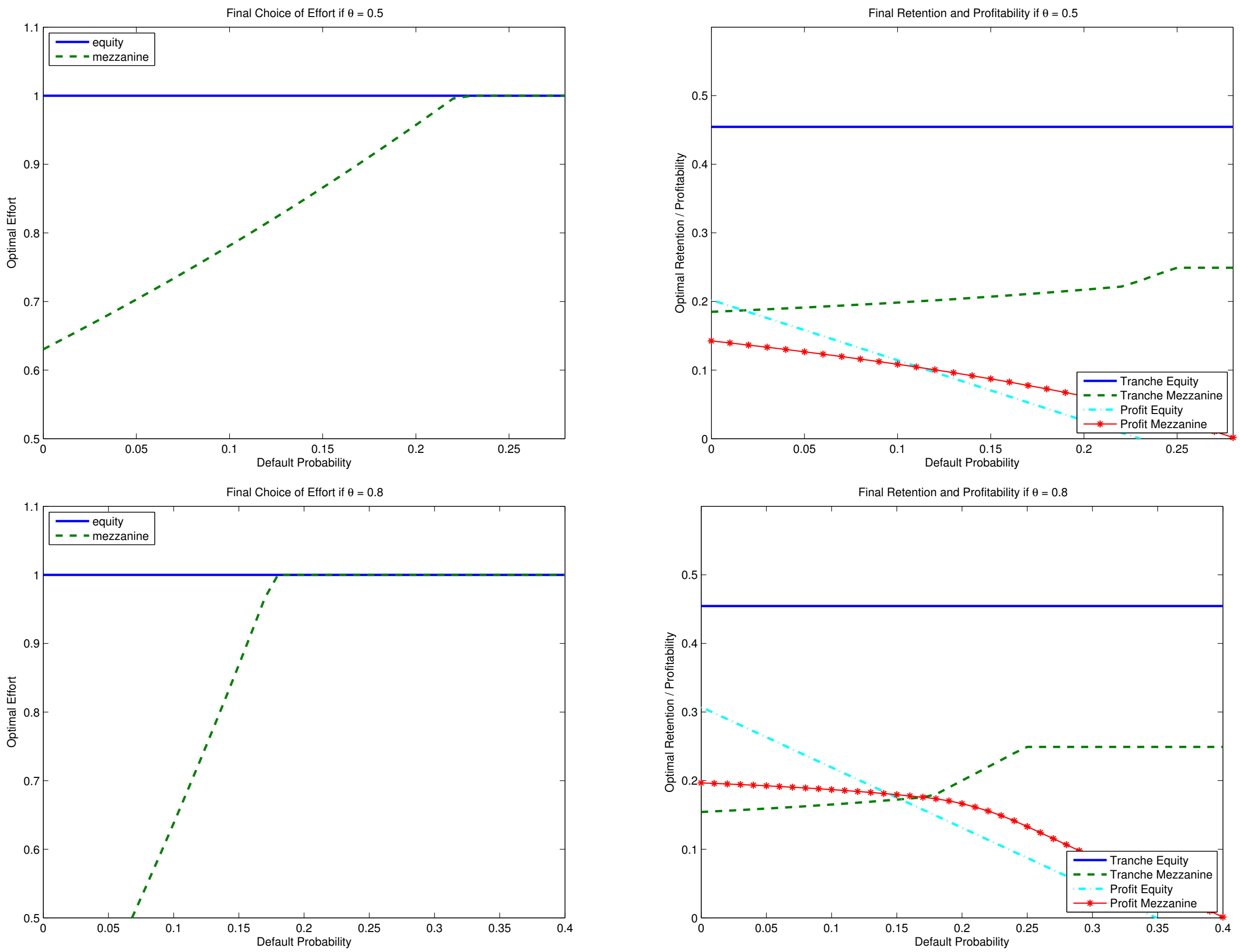

Figure 11: **Optimal Policies For Different Loan Quality:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line), mezzanine tranche retention (dashed green line) as well as profits under equity tranche retention (red with asterisk) and mezzanine tranche retention (dashed-dotted turquoise). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. The first row displays results in case $\theta = 0.5$ and the second row in case $\theta = 0.8$. All other parameter values are as in the baseline scenario.

Figure [12] displays corresponding results. It can be seen that for nearly all levels of default risk, a profit maximizing bank would choose to retain the mezzanine tranche. At the same time, the implied screening level is considerably below the one implied by equity tranche retention. Similar to before, this is because first the maximum payoff constraint is binding and then the bank maximizes screening effort according to its unconstrained solution. Besides, the right panel of Figure [12] shows that the optimal retention size when holding the mezzanine tranche is considerably lower than under equity tranche retention. Thus it seems again that once the expected outlook is of neutral to good quality, mezzanine retention would be the preferred choice due to a combination of lower screening costs and capital charges.

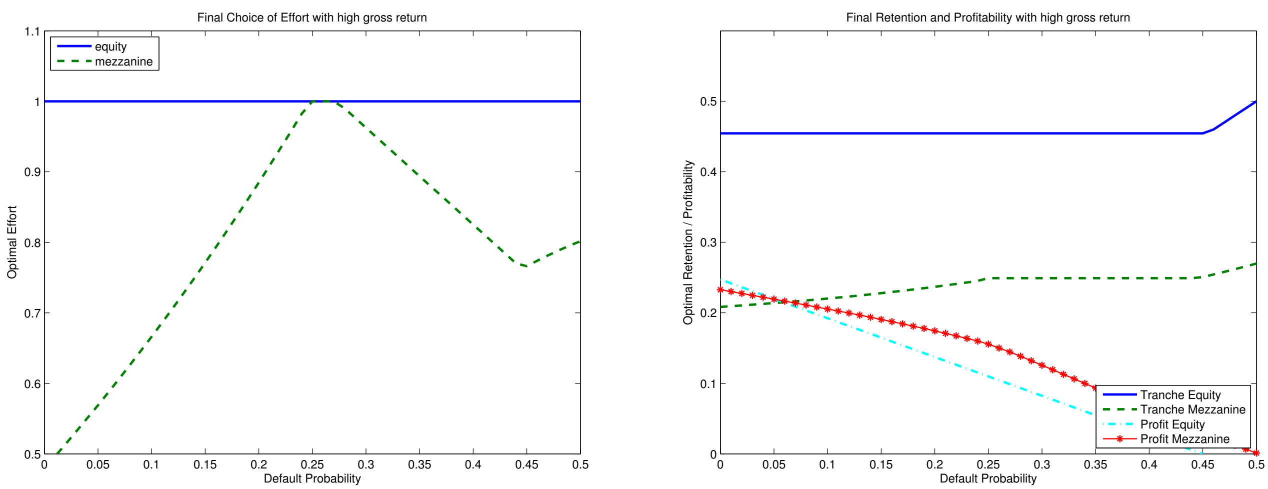

Figure 12: **Optimal Policies For High Quality Market:** The left panel displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. The right panel shows optimal tranche size for equity tranche retention (solid blue line), mezzanine tranche retention (dashed green line) as well as profits under equity tranche retention (red with asterisk) and mezzanine tranche retention (dashed-dotted turquoise). Results are displayed for different default probabilities as long as securitization is profitable for at least one of the two retention mechanisms. All parameter values are as in the baseline scenario except for p_H and θ which are set to 0.5 and 0.6.

4 Alternative Specification

This section presents two additional robustness checks. First, we show that retention of a vertical slice is unlikely to incentivize the originator to exert higher screening effort than implied under equity and mezzanine tranche retention. Second, we consider an alternative and simpler risk specification which isolates the effect of the low quality borrower's default risk. This further weakens the incentives to perform due diligence under mezzanine tranche retention.

4.1 Vertical Tranche Retention

The objective of this section is to briefly demonstrate that vertical slice retention is unlikely to adequately incentivize the originator to perform due diligence. While the mathematical arguments follow Fender and Mitchell (2009), it should be noted that the implications are profoundly different in combination with the results presented in Sections [2] and [3].

From a practical perspective, retaining a vertical slice of the loan portfolio implies that the originator retains equal amounts of each single tranche. It has been shown that the payoff structure of equity tranche retention is given by

$$F_E(e,t) = p_L \max\{P_L(e) - B_E(t), 0\} + p_H \max\{P_H(e) - B_E(t), 0\}$$

whereas for the case of mezzanine tranche retention it follows that

$$
\begin{aligned}
F_M(e,t) &= \min\left[\max\left\{P_L(e) - B_M(t), 0\right\}, tR\right] p_L \\
&+ \min\left[\max\left\{P_H(e) - B_M(t), 0\right\}, tR\right] p_H
\end{aligned}
$$

Similarly, the payoff structure of retaining the senior tranche can be written as

$$
F_S(e,t) = p_L \min\left[B_E(t), P_L(e)\right] + p_H \min\left[B_E(t), P_H(e)\right] \tag{22}
$$

Recognizing that the total cash flow of retaining a vertical slice with thickness t_V is given by holding a fraction t_V of the equity, mezzanine and senior tranche, it follows that

$$
F_V(e) = t_V\left[p_L P_L(e) + p_H P_H(e)\right] \tag{23}
$$

where $F_V(e)$ denotes the cash flow stemming from vertical slice retention. In other words, the cash flow of retaining a vertical slice of thickness t_V corresponds to retaining a pro-rata fraction t_V of the entire loan portfolio.

To show that vertical slice retention leads to a lower level of screening activity than retention of the equity tranche, it suffices to solve the following general maximization problem.

Proposition 4 *Under vertical tranche retention, the maximization problem of the originator is given by*

$$\max_e \Pi_V(e) = t_V [p_L P_L(e) + p_H P_H(e)] - \frac{\phi}{2} e^2 - k_V t_V - 1 \tag{24}$$

$$e \leq 1 - \theta \tag{25}$$

$$e \geq 0 \tag{26}$$

Expected profits are maximized by choosing e^* *such that*

$$e^* = \min \left[t_V [(2p_H - 1)PD - p_H + 1] \frac{R}{\phi}, 1 - \theta \right] \tag{27}$$

where $\min \left[[(2p_H - 1)PD - p_H + 1] \frac{R}{\phi}, 1 - \theta \right]$ *corresponds to the screening level when fully retaining the loan portfolio.*

Proof: See Appendix.

The derivation shows that the optimal screening level under vertical slice retention is proportional to the effort level exerted when fully retaining the loan portfolio. This implies that retaining a vertical slice with a thickness of 10 percent would induce the originator to exert (only) 10 percent of the amount implied when retaining the entire loan portfolio. It should be noted that this result is quite general and unless one assumes a benefit function of securitization which penalized securitization and implied full retention, the effort level under vertical slice retention will always be less than under full retention. Put differently, as long as there is some benefit to securitization, vertical slice retention will always generate less screening effort than full loan retention.

Given the analysis presented in Section [3], this result has important practical consequences. First, equity tranche retention always dominates vertical slice retention as under all cases considered, it induced the originator to exert as much effort as under full loan retention. Second, even mezzanine tranche retention is likely to dominate vertical slice retention as the implied effort level was constantly larger than 50 percent of the amount exerted under full loan retention. In fact, the average effort level under mezzanine tranche retention was around 70-80 percent of the amount of due diligence exerted under full loan retention, thereby implying that the size of the vertical slice should be around 70-80 percent in order to similarly incentivize loan screening.

4.2 A Simplified Model

This section presents a simplified model in which default risk only matters in the low state of nature. Specifically, it is assumed that there are no defaults in the high state of nature and that only the bad quality borrower faces a probability of defaulting in the low state of nature. This allows us to separately analyze the impact of borrower specific default risk on the incentives to perform due diligence and thereby get a richer understanding for the dynamics of the full model.

Focusing on the baseline scenario presented in Section [3], Figure [13] displays optimal screening effort for the case of equity and mezzanine tranche retention. It can be seen that equity tranche retention best incentivizes loan screening as the originator would exert the same amount of screening effort as in the case of full loan retention. This is to be expected given that the simplified model removes the potentially disturbing impact of the systemic risk factor such that high performance states become fully indicative of screening effort.[13] Focusing on the case of mezzanine tranche retention, it can be seen that the optimal

[13]That is, if anything, the effort level under equity tranche retention should be at least as high as in the context of systemic risk.

screening level is more extreme than in the case of systemic risk. That is, as long as the mezzanine tranche is safe, it is optimal for the originator not to screen any loans and to avoid the cost of performing due diligence. At some threshold it becomes optimal to start performing due diligence, but the amount of effort is considerably below the case of equity tranche retention.[14] This is different from the full model in which the presence of systemic risk influences the probability of default in both states of nature.

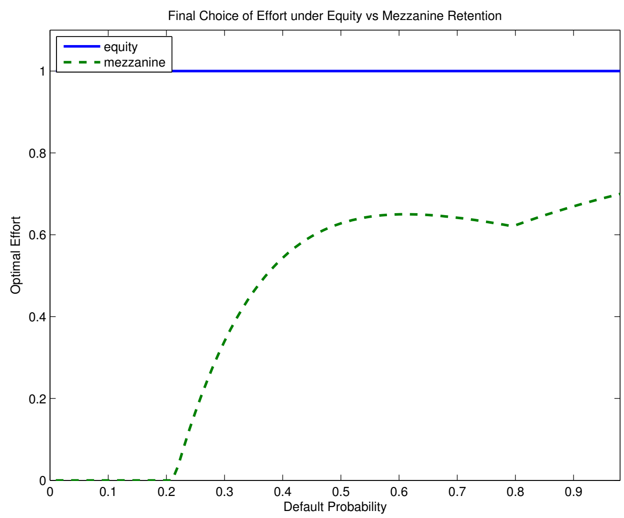

Figure 13: **Optimal Screening Effort under Alternative Risk Specification for Baseline Scenario:** This figure displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. All parameter values are as in the baseline scenario but it is assumed that (1) default does not matter in the high state of nature and (2) only the bad borrower faces default risk in the low state of nature.

The distortion becomes even more apparent in case the probability of the low state is reduced. Figure [14] displays optimal screening level in case the probability of the high state is equal to 70 percent. In that case, mezzanine tranche retention would only incentivize any

[14]Note that the lower effort level results from the fact that the maximum effort constraint is binding, i.e. the originator does not receive the full upside potential in case of mezzanine tranche retention.

screening activity in case the default probability exceeds approximately 30 percent. This is inherently different to the behavior implied by the full model in which mezzanine tranche retention induced the originator to exert high screening effort for low default probability states. The reason is that for the full model the originator chooses screening effort according to its unconstrained solution and then has to make sure that the mezzanine tranche is safe whereas in the case presented here, the optimal strategy switches from no screening to exerting a positive and significant amount of due diligence.

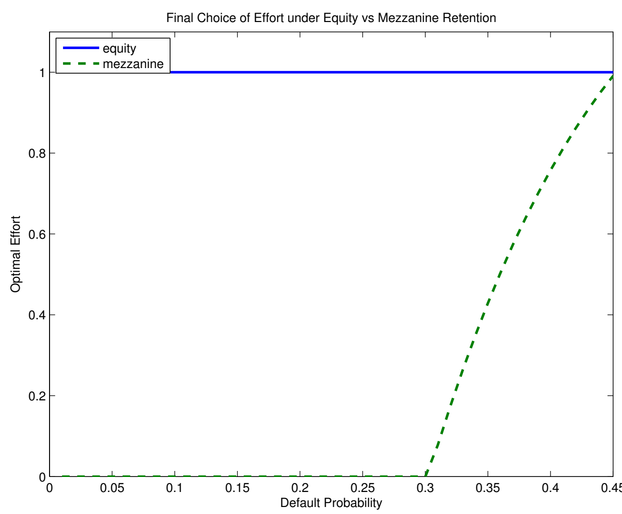

Figure 14: **Optimal Screening Effort under Alternative Risk Specification in case $p_H = 0.7$:** This figure displays screening effort under equity tranche retention (solid blue line) and mezzanine tranche retention (dashed green line) relative to the case of full loan retention. All parameter values are as in the baseline scenario except for p_H which is set to 0.7 and it is assumed that (1) default does not matter in the high state of nature and (2) only the bad borrower faces default risk in the low state of nature.

Concluding, it can be seen that the relation between default risk and screening is much simpler without considering systemic risk. In this case, higher default probabilities are associated with higher screening activities whereas in the case of systemic risk this is not necessarily the case. This is because the optimal screening level has a different exposure to the systemic risk factor across the two retention mechanisms which is why the optimal behavior is different and more complex.

5 Conclusion

This paper compares the effects of equity and mezzanine tranche retention by investigating the corresponding incentives of a loan securitizing bank to screen loans and retain skin in the game. The analysis accounts for systemic risk, moral hazard and accounting frictions.

We find that equity tranche retention generates the highest possible screening effort but, most of the time, a profit maximizing bank will choose to retain the mezzanine tranche and therefore exert less screening effort. The intuitive reason is given by the fact that both screening costs and capital charges are higher under equity retention than in case the mezzanine tranche was retained.

The paper also illustrates the importance of obtaining accurate estimates of loan screening costs for risk requirement regulations. In that light, an unanimous imposition of equity tranche retention in case of high loan screening costs might run the danger of shutting down certain areas of securitization markets. Regulators should also be aware that while higher profitability generally makes securitization more profitable, it also reduces banks' incentives to retain the equity tranche due to higher implied opportunity costs associated with capital requirements.

Finally, it is also shown that a more positive economic outlook allows the bank to save on screening costs in case the less risky mezzanine tranche is retained. That is, a profit maximizing bank would choose to retain the mezzanine tranche even though the implied screening level is only suboptimal from a regulator's point of view. The analysis therefore suggests that a more dynamic and countercyclical risk retention requirement policy could vary with the business cycle by, for example, requiring equity retention during boom periods.

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A Appendix

A.1 Proof of Proposition [1]

Proof.

[Proof] The maximization problem is as follows

$$\begin{aligned}\max_{e,t}\ \Pi_{E1}(e,t) &= (1-t^2)R + p_L\left[P_L(e) - B_E(t)\right] + p_H\left[P_H(e) - B_E(t)\right] \\ &- \frac{\phi}{2}e^2 - k_E t - 1 - \lambda_1\left[P_L(e) - B_E(t)\right] - \lambda_2\left[e+\theta-1\right] - \lambda_3(-e)\end{aligned} \tag{28}$$

If $\lambda_1 = \lambda_3 = 0$ and $\lambda_2 \geq 0$, the solution is given by

$$\begin{aligned} e^* &= \min\left[\left[(2p_H - 1)PD - p_H + 1\right]\frac{R}{\phi}, 1-\theta\right] \\ t^* &= \frac{1}{2} - \frac{k_E}{2R} \end{aligned} \tag{29}$$

If $\lambda_1 > 0$, $\lambda_2 \geq 0$ and $\lambda_3 = 0$, the solution is given by

$$\begin{aligned} e^* &= \min\left[\frac{k_E(1-PD) - \left[2PD^2\theta - 2\left(p_H + 2\theta - 1\right)PD + p_H + 2\theta - 2\right]R}{2\left(PD^2 - 2PD + 1\right)R + \phi}, 1-\theta\right] \\ t^* &= 1 - (1-PD)\left(\theta + e^*\right) \end{aligned} \tag{30}$$

Finally, if $\lambda_1 = \lambda_3 > 0$ and $\lambda_2 = 0$ then

$$\begin{aligned} e^* &= 0 \\ t^* &= 1 - (1 - PD)\theta \end{aligned} \tag{31}$$

Note that $\lambda_2 = \lambda_3 > 0$ is not possible. Also, $\lambda_1 = \lambda_2 = 0$ and $\lambda_3 > 0$ is not possible for PD $\in [0, 1]$.

■

A.2 Proof of Proposition [2]

Proof.

[Proof] The maximization problem is as follows

$$\begin{aligned} \max_{e,t} \Pi_{E2}(e,t) &= p_L P_L(e^*) + p_H(1-t^2)R + p_H\left[P_H(e) - B_E(t)\right] - \frac{\phi}{2}e^2 \\ &- k_E t - 1 - \lambda_1\left[P_H(e) - B_E(t)\right] - \lambda_2\left[e + \theta - 1\right] - \lambda_3(-e) \end{aligned} \tag{32}$$

If $\lambda_1 = \lambda_3 = 0$ and $\lambda_2 \geq 0$, the solution is given by

$$
\begin{aligned}
e^* &= \min\left[p_H PD\frac{R}{\phi}, 1-\theta\right] \\
t^* &= \frac{1}{2} - \frac{k_E}{2Rph}
\end{aligned}
\tag{33}
$$

If $\lambda_1 > 0$, $\lambda_2 \geq 0$ and $\lambda_3 = 0$, the solution is given by

$$
\begin{aligned}
e^* &= \min\left[\frac{k_E PD - 2(p_H\theta - p_H)PD^2R}{2PD^2Rp_H + \phi}, 1-\theta\right] \\
t^* &= (1-\theta-e^*)\,PD
\end{aligned}
\tag{34}
$$

Finally, if $\lambda_1 = \lambda_3 > 0$ and $\lambda_2 = 0$ then

$$
\begin{aligned}
e^* &= 0 \\
t^* &= (1-\theta)\,PD
\end{aligned}
\tag{35}
$$

Note that $\lambda_2 = \lambda_3 > 0$ is not possible. Also, $\lambda_1 = \lambda_2 = 0$ and $\lambda_3 > 0$ is not possible for PD $\in [0, 1]$.

■

A.3 Proof of Proposition [3]

Proof. The maximization problem is given as follows.

$$\begin{aligned}\max_{e,t}\ \pi_M(e,t) &= p_H\left(P_H(e^*)-B_E(t)\right)+(1-4t^2)R+p_L\left(P_L(e)-B_M(t)\right)+p_H tR-\frac{\phi}{2}e^2-k_M t\\ &- 1-\lambda_1\left[B_M(t)-P_L(e)\right]-\lambda_2\left[P_L(e)-B_E(t)\right]-\lambda_3\left[e+\theta-1\right]-\lambda_4(-e)\end{aligned} \tag{36}$$

If $\lambda_1=\lambda_2=\lambda_4=0$ and $\lambda_3\geq 0$, the solution is given by

$$\begin{aligned} e^* &= \min\left[\left((p_H-1)PD-p_H+1\right)\frac{R}{\phi},1-\theta\right]\\ t^* &= \frac{1}{4}-\frac{k_M}{8R}\end{aligned} \tag{37}$$

If $\lambda_1>0$, $\lambda_3\geq 0$ and $\lambda_2=\lambda_4=0$, the solution is given by

$$\begin{aligned} e^* &= \min\left[\frac{k_M(1-PD)-2\left(2PD^2\theta-(p_H+4\theta-2)PD+p_H+2\theta-2\right)R}{4(PD^2-2PD+1)R+2\phi},1-\theta\right]\\ t^* &= \left[1-(1-PD)\left(\theta+e^*\right)\right]\frac{1}{2}\end{aligned} \tag{38}$$

If $\lambda_2>0$, $\lambda_3\geq 0$ and $\lambda_1=\lambda_4=0$, the solution is given by

$$e^* = \min\left[\frac{k_M(1-PD) - \left(8PD^2\theta - (p_H + 16\theta - 7)PD + p_H + 8\theta - 7\right)R}{8(PD^2 - 2PD + 1)R + \phi}, 1 - \theta\right] \quad (39)$$

$$t^* = 1 - (1 - PD)(\theta + e^*) \quad (40)$$

If $\lambda_1 = \lambda_4 > 0$ and $\lambda_2 = \lambda_3 = 0$, the solution is given by

$$e^* = 0 \quad (41)$$

$$t^* = [1 - (1 - PD)\theta]\frac{1}{2} \quad (42)$$

If $\lambda_2 = \lambda_4 > 0$ and $\lambda_1 = \lambda_3 = 0$, the solution is given by

$$e^* = 0 \quad (43)$$

$$t^* = [1 - (1 - PD)\theta] \quad (44)$$

Note that $\lambda_4 = \lambda_3 > 0$ is not possible. Also, $\lambda_1 = \lambda_2 = \lambda_3 = 0$ and $\lambda_4 > 0$ is not possible for PD $\in [0, 1]$.

■

A.4 Full Loan Retention

Letting the subscript R denote the case of full loan retention, the maximization problem is as follows

$$\begin{aligned}\max_e \ \Pi_R(e) &= p_L P_L(e) + p_H P_H(e) \\ &- \frac{\phi}{2}e^2 - k_R - 1 - \lambda_1 \left[e + \theta - 1\right] - \lambda_2(-e)\end{aligned} \tag{45}$$

The optimal screening effort is given by

$$e^* = \min\left[\left[(2p_H - 1)PD - p_H + 1\right]\frac{R}{\phi}, 1 - \theta\right]$$

A.5 Proof of Proposition [4]

Proof.

[Proof] The maximization problem is as follows

$$\begin{aligned}\max_e \ \Pi_V(e) &= t_V \left[p_L P_L(e) + p_H P_H(e)\right] \\ &- \frac{\phi}{2}e^2 - k_V t_V - 1 - \lambda_1 \left[e + \theta - 1\right] - \lambda_2(-e)\end{aligned} \tag{46}$$

The optimal screening effort is given by

$$e^* = \min\left[t_V\left[(2p_H - 1)PD - p_H + 1\right]\frac{R}{\phi}, 1 - \theta\right]$$

■