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Optimal Design and Governance of Asset-Backed Securities*

Timothy J. Riddiough†

Massachusetts Institute of Technology, Building W31-310, Cambridge, Massachusetts 02139-4307

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A model of asymmetric asset value information and nonverifiability of liquidation motives is developed to examine the optimal design and governance of asset-backed securities. Because of adverse selection risk, the liquidation option of whole loan sale results in external price discounting of composite cash flows. The alternative liquidation option of senior/subordinated security design is shown to dominate whole loan sale, since cash flow splitting allows the issuer to internalize some or all of the lemons-related liquidation costs. Security subordination levels must increase relative to full information levels, however, to protect uninformed outside investors. Pool diversification and loan bundling are shown to be packaging strategies that can soften the lemons-related subordination effect and therefore increase liquidation proceeds. With respect to security governance, we show that it is the junior securityholder who should control the debt renegotiation process with pooled debt structures. Better asset value information and a first loss position are the reasons for junior securityholder control in our model. Numerous empirical implications of the model are also identified and discussed. *Journal of Economic Literature* Classification Numbers: D46, D81, D82, G13, G21, G24, G32, G33. © 1997 Academic Press

I. INTRODUCTION

Asset-backed securities market growth has exploded in recent years. Once dominated by the residential mortgage-backed security, this market now includes securities backed by car loans, manufactured housing loans,

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† E-mail: tjridd@mit.edu.

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credit card receivables, commercial real estate debt, various types of leases, franchise debt, and student loans. Distinguishing features of many of these assets are that they have risky debt or debt-like cash flow characteristics and that there is virtually no secondary whole asset market. In addition, they tend to be relatively homogeneous with respect to contracting characteristics while also being informationally intensive when originated.

Why has the asset-backed securities market grown so rapidly and what is it about the pooling and reengineering of cash flows that has created so much liquidity? From a supply-side perspective, Boot and Thakor (1993) provide a compelling rationale for senior/subordinated security design in asset markets characterized by adverse selection.[1] They show that a value maximizing liquidation strategy may be to split cash flows into ''informationally insensitive'' and ''informationally sensitive'' securities when investors are asymmetrically informed as to asset value. Informed investors are well suited to hold the informationally sensitive security, since they better understand the true investment risks and therefore may more highly value the security. Alternatively, uninformed investors are the preferred target for the riskless security, since acquisition of the risky security by uninformed buyers would result in it being discounted from its fundamental value.

In this paper, we reformulate and then extend this basic cash flow splitting insight to address certain other important features of asset-backed security design and governance. These other features include addressing why asset pooling is commonplace, since (in the absence of cost-saving economies of scale) liquidation objectives could be accomplished by cash flow splitting on an asset-by-asset basis. A related feature is the phenomenon of asset bundling, in which cash flows are tied together contractually with the express purpose of eliminating certain state-contingent payoff outcomes (e.g., borrower default). In addition, we recognize that costs as well as benefits can result from financial innovation. For example, multiclass asset-backed securities must be governed with respect to addressing borrower financial distress situations, which introduces control issues and the potential for conflicts between investment classes. When information sensitivity is a concern, adverse selection as well as moral hazard may contribute to principal–agent frictions.

This paper specifically examines security design, loan pooling and bundling incentives, and security governance in asset markets characterized by adverse selection problems. As a starting point in our analysis, we consider an investor who holds a portfolio of risky seasoned debt. The

[1] Gorton and Pennacchi (1990) provide similar insight in the general context of liquidity creation and financial intermediation. Other well-known rationales for security tailoring include risk sharing with short-sale restrictions (e.g., Allen and Gale, 1989), cost efficiencies of intermediation (Ross, 1989, Merton, 1990), and agency and the market for corporate control (Harris and Raviv, 1989).

investor (the insider) is motivated to liquidate at least part of the debt portfolio to outsiders. The insider is better informed about asset values than outsiders, and outsiders are unable to verify the insider's liquidation motives. Subject to satisfying capital constraint requirements, the insider's problem is to determine a liquidation strategy that maximizes total portfolio value.

We examine two possible liquidation channels: whole loan sale and securitization. Whole loan sale results in the marketing of composite cash flows, which are discounted below their fundamental value due to adverse selection concerns of outsiders. Alternatively, debt cash flows can be reengineered into riskless and risky securities. Marketing the riskless security to outsiders, while retaining the risky security internally, may result in a realized portfolio value that is equal to its fundamental value. If liquidation requirements are such that a portion of the informationally sensitive security must be sold to outsiders, securitization will still be preferred to whole loan sale since at least some of the adverse selection risk can be internalized through partial retention of the junior security.

Although securitization may allow the issuer to internalize lemons-related liquidation costs, security design is not immune to the effects of asymmetric asset value information. To ensure that the senior security is risk free given adverse selection incentives, a "lemons-protected" level of subordination is set higher than is needed given actual collateral quality. This will reduce issuance proceeds, which is costly if risky debt must be issued to satisfy the capital constraint. These basic results therefore establish a financing "pecking order" that is broadly consistent with that identified by Myers and Majluf (1984). First, the inside debtholder will generally prefer to "internally finance," by not having to market to outsiders at all. Given that at least a portion of the portfolio must be liquidated, it is preferable to raise capital by issuing riskless debt to outsiders. Least preferable is the sale of risky debt to outsiders.

Although Boot and Thakor (1993) and DeMarzo and Duffie (1996) consider similar issues with respect to security design and issuance incentives under asymmetric information, there are several basic differences between our model and theirs. Boot and Thakor utilize a noisy rational expectations model with competition among informed traders to examine who benefits the most by ownership of a particular security. We generate similar ownership results, but with a more primitive model of asymmetric value information that is not explicitly competition-based. Another basic difference is that Boot and Thakor do not directly address the security retention issue. DeMarzo and Duffie do address the retention question, and go further to examine how security design can be used to signal asset quality. In contrast, we do not examine signaling, and instead emphasize incentives to issue multiple asset pools as well as consider the interaction of security governance and security design.

Indeed, a unique feature of our model is that we analyze a multiple asset pool in which correlation structure among collateral assets is arbitrary. It is well known that pool diversification is an important structural consideration in asset-backed security design (e.g., Childs *et al.*, 1996). When adverse selection incentives are present, lower cash flow volatility that results from pool diversification may be quite valuable, since it is the lower tail of the asset price distribution that leads to the external pricing discounts.[2] We also examine a related risk management device—the cross-default clause—which results in multiple assets being tied together through the debt contract. This bundling mechanism further reduces the variance in the debt payoff distribution. In our model, variance reduction through the pooling and bundling of assets substitutes for costly information production, which suggests that lower quality (i.e., more opaque) assets are relatively more likely to be bundled together and placed into well diversified asset pools.

A second unique element is our analysis of security governance and control as it impacts the optimal design of asset-backed securities. That is, we ask the question of who—the senior or junior securityholder—should optimally control ex post liquidation/renegotiation policy decisions given borrower financial distress. In contrast to corporate structures in which the senior debtholder typically exerts strong control over the renegotiation process, our model supports the notion of junior securityholder control. This result is consistent with private information rationales for control, where it has been argued that the debtholder with superior asset value information is typically best suited to maximize total security payoffs from debt renegotiation (e.g., Fama, 1985). Superior information is not sufficient to guarantee value maximizing renegotiation decisions, however. It is the combination of *better* asset value information and a *first-loss position* that suggests junior securityholder control. In contrast, senior securityholders lack both the information and incentives to maximize proceeds from debt renegotiation.

Asymmetric asset value information complicates security design when the junior securityholder controls the debt renegotiation process. Given a borrower default, the junior securityholder will generally prefer to extend

[2] Glaeser and Kallal (1997) make a similar point when analyzing the variance of cash flows in a single-asset pool. A basic difference between our approach and theirs is that we hold individual asset variance constant and achieve reductions in total pool cash flow volatility through asset diversification. This leads to rather different model implications, where increases to pool value can be achieved through decreasing the probability of low value outcomes in our model. This is not possible in the Glaeser and Kallal model. Indeed, because of the convexity of their liquidity function, their model produces the opposite prediction of lower pool value given lower probability of extreme value outcomes.

the loan term in lieu of accepting a terminating workout payoff or immediately liquidating. The ‘‘volatility increasing’’ action of loan extension creates the potential for an ex post wealth transfer from the senior to the junior securityholder.[3] Thus, the senior security may become state payoff sensitive and, as a result, may be discounted relative to its fundamental value. To prevent price discounting from occurring, the security can be redesigned. Redesign involves increasing the level of security subordination to eliminate extension-related default risk. Higher subordination levels reduce the proceeds from senior security issuance, however, and may ultimately result in the issuance of risky (i.e., discounted) junior debt. As a consequence, issuers may instead find it advantageous to impose restrictions on loan extension in order to reduce subordination levels, and therefore to improve issuance proceeds.

To develop these ideas further, the main body of the paper is organized as follows. In Section II the basic model is explained. Inside (fundamental) and outside (discounted) debt values are determined. Securitization as an alternative to whole loan sale is analyzed and lemons-protected credit support levels are established. The multiple-asset security is analyzed in Section III. Pool diversification and loan bundling are shown to be variance reduction techniques that are particularly valuable in the presence of lemons-related price discounting. The governance question is examined in Section IV. Renegotiation incentives, establishment of control by the junior securityholder, and subsequent modification to security design are addressed. A conclusion and summary of empirical implications can be found in Section V.

II. THE FUNDAMENTAL LIQUIDATION PROBLEM, THE SECURITIZATION ALTERNATIVE, AND SECURITY DESIGN

Debt Valuation and Liquidation Motives

Consider the following stylized investment situation. An investor holds a standard debt claim with current face value L. Principal and interest are due in one period, where the given contract interest rate is ι, $\iota \geq 0$. The debt is secured by a single asset whose value at time 0 is P, $P \geq L$. Asset value is uncertain, either increasing or decreasing in value by a proportional factor of σ per period, $\sigma > 0$. To ensure the debt is risky we require that,

[3] Bulow and Shoven (1978) were the first to recognize the incentive to form coalitions when there are more than two classes of risky securityholders. Also see Longstaff (1989), who considers valuing the option to extend in a general context. Franks and Torous (1989) apply this concept to explain corporate yield spreads when corporate reorganization is an option. Cornell *et al.* (1996) examine extension decisions with defaultable whole loans.

at maturity, the debt either pays off as promised (a good state outcome) or default occurs (a bad state outcome). Thus, $P(1 - \sigma) < L(1 + \iota) \leq P(1 + \sigma)$ for the given loan rate ι.

Assume universal risk neutrality and normalize the risk-free rate of interest to be zero. The resulting equilibrium probability of an up state in asset value is $p = 1/2$. Internal valuation of the debt claim, D, given current asset value, P, depends on state-contingent collateral asset value outcomes and the respective probabilities of these outcomes. Consequently, (inside) debt value is

$$D = \frac{L(1+\iota) + P(1-\sigma)}{2}. \tag{1}$$

Now suppose that the investor is motivated to liquidate a portion of her asset "portfolio." As DeMarzo and Duffie (1996) discuss, liquidation incentives may be due to a preference for receiving cash over holding risky assets or perhaps due to a desire to pursue new investment opportunities given constraints on the ability to raise new capital. The incentive to sell risky assets may be particularly strong given the imposition of strict capital adequacy requirements (Dewatripont and Tirole, 1995).

From a modeling perspective, the liquidation incentive can be motivated in several ways. These include imposing a high internal discount rate on existing investments (as in DeMarzo and Duffie, 1996) or by imposing a total capital investment constraint that is less than the current investment value. As either of these two mechanisms satisfy similar objectives, for simplicity we choose to impose an explicit capital constraint. Thus, suppose the investor is newly capital constrained such that $0 \leq D^C < D$, where D^C denotes the size of the constraint. The constraint is internally imposed and is nonverifiable to outsiders.

Also assume that asset value, P, and therefore debt value, D, are known to the current debtholder but are unobservable to outsiders and that the insider is unable to credibly transmit asset value information at any cost. Information is therefore asymmetric with respect to debt value, thus presenting a lemons marketing problem to the seller. More precisely, assume that the characteristics of the asset price distribution (i.e., the values of p and σ) are common knowledge at time 0, but that information is asymmetric with respect to current collateral asset value. Outsiders must therefore place a probability distribution on the unobserved value of P. The support for this distribution is assumed to be bounded from below by $P^L < P$. Because of adverse selection incentives and the nonverifiability of the capital constraint, an outsider will value the debt at D^L, where

$$D^L = \frac{L(1+\iota) + P^L(1-\sigma)}{2} < D \tag{2}$$

given the additional requirement that $P^L(1 + \sigma)$ exceeds the promised loan payoff of $L(1 + \iota)$. Thus, the insider could satisfy the capital constraint by selling the debt claim whole, with external value D^L and a lemons-related liquidation loss of $D - D^L$.

Securitization and Optimal Design

As an alternative to whole loan sale, cash flows can be prioritized and split between investment classes. As Boot and Thakor (1993) recognized, in this case the security should be designed to prioritize cash flows into "informationally insensitive" securities and "informationally sensitive" securities. This partitioning pushes investment risk—and hence the adverse selection risk—into the informationally sensitive security. The issuer, by retaining a risky security, can therefore internalize at least some of the lemons-related liquidation costs.

With senior/subordinated security design, the basic objective is to determine a minimum security subordination level such that the senior security is riskless. A minimum subordination level is desirable because it maximizes the size of the senior security and hence maximizes the likelihood of meeting the capital constraint. However, because of adverse selection incentives, the minimum subordination level will be set higher than the "full information" subordination level to ensure that a riskless senior security obtains regardless of actual asset quality. Consequently, although the senior security is externally priced at its fundamental value to result in no information-related liquidation losses, lower issuance proceeds are obtained relative to proceeds obtained under full information.

Formally, a lemons-protected credit support level is determined such that

$$P^L(1 - \sigma) = L\alpha + L(1 - \alpha)i_J, \tag{3}$$

where $1 - \alpha$, $0 < \alpha < 1$, is the proportion of the pool subordinated to the senior security and i_J is the yield promised to the junior securityholder. The securities are issued as a proportion of loan face value, L, which conforms with usual practice. Convention also results in the junior securityholder receiving interest at time 1 regardless of state-contingent payoff outcomes.[4] Subject to this interest payment guarantee requirement, the relationship specified in (3) determines a minimum proportion, $1 - \alpha$, such that the outside senior securityholder receives a riskless return (which equals zero by assumption) regardless of actual asset quality.

For a given i_J, it is clear that α can easily be determined from Eq. (3).

[4] $P^L(1 - \sigma) > \iota L$ is therefore required given this interest payment guarantee. This restriction is benign given most realistic parameter value combinations.

Alternatively, if i_j were a choice variable to the issuer, there might be circumstances in which the issuer would prefer to specify i_J to improve issuance proceeds from the senior security. Endogenizing i_J in a strategic manner would, however, introduce additional complications to the model while not significantly affecting fundamental liquidation motives and resulting security design. Instead, to provide a self-adjusting benchmark with which to compare alternative security structures, we will assume that i_J is determined endogenously such that the junior security prices at par (based on the issuer's valuation). Therefore, the resulting (internally derived) par value expected payoff to the junior securityholder is

$$D - L\alpha = \frac{L(1-\alpha)(1+i_J) + [P(1-\sigma) - L\alpha]}{2}. \tag{4}$$

Note that, because senior securityholders require relatively high subordination levels to compensate for adverse selection risk, return of principal will accrue to the junior securityholder even if a default state occurs. Also note that, although i_J is determined endogenously by the issuer, outsiders will take i_J as given due to the unobservability of P and the nonverifiability of the capital constraint, D^C.

By using Eq. (1) and solving Eqs. (3) and (4) simultaneously for α and i_J, a lemons-protected level of subordination is determined. The following lemma summarizes the outcome.

LEMMA 1 (Single-asset security credit support). *Full risk partitioning can be accomplished with two security classes. Optimal partitioning and the resulting promised yield to the junior securityholder are*

$$1 - \alpha_S = 1 + \iota - \frac{P^L(1-\sigma)}{L}; \; i_J = \frac{\iota L}{L(1+\iota) - P^L(1-\sigma)}.$$

Relevant comparative static results are as follows. For a given P, proportional credit support $(1 - \alpha_S)$ decreases as the information asymmetry in asset value decreases (i.e., as P^L increases). Alternatively, subordination increases as the exogenous loan rate, ι, increases. This is due to the concavity of the senior securityholder's payoff function in P, which, when ι increases, produces a lower default-state payoff relative to the nondefault payoff of $L(1 + \iota)$. Also observe that the promised yield to the junior tranche, i_J, will be greater than ι when $\iota > 0$. This follows because the promised yield to the total security is ι, whereas the promised yield to the senior securityholder is the risk-free rate (which is zero by assumption). For the weighted average security yield to equal ι (i.e., for $(1 - \alpha_S)i_J$ to equal ι), the promised yield to the junior security must therefore be greater than ι

when $\iota > 0$. Related to this result is the fact that $\partial i_J / \partial P^L > 0$. As P^L increases, a greater proportion of the total security can be designated as senior, which results in increased default loss risk to the junior securityholder. When $\iota > 0$, a higher required promised yield to the junior tranche is therefore required.

Consider now how the capital constraint, $D^C < D$, impacts liquidation strategy. If the capital constraint is not binding once the senior debt value is subtracted from total debt value—i.e., if $D - L\alpha_S \leq D^C$—then the current debtholder will issue a riskless senior security and retain the risky junior piece. This allows the issuer to fully internalize lemons-related marketing costs that would otherwise be realized given a whole loan liquidation strategy.[5] Alternatively, if the capital constraint is still binding after issuing a senior security, optimal liquidation strategy is such that two risky junior securities are created: one that is issued to outsiders at a discount to its fundamental value and one that is retained internally.[6] Proposition 1 formally states the optimal liquidation strategy depending on the severity of the capital constraint.

PROPOSITION 1 (Optimal liquidation strategy, single-asset security). *Liquidation strategy and optimal security design will depend on the severity of the capital constraint, D^C. If the issuer is mildly capital constrained (i.e., if $D - L\alpha_S \leq D^C$), two security classes are created as specified in Lemma* 1. *The senior security will be issued at a price of $L\alpha_S$ and the junior security will be retained by the issuer with internal value of $D - L\alpha_S$. Total internal security value is therefore D, with no information-related liquidation losses incurred by the issuer. Alternatively, if the issuer is severely capital constrained (i.e., if $D - L\alpha_S > D^C$), she will consider issuing two securities to outside investors. If issued, the senior security will still be priced at $L\alpha_S$. In addition, a risky junior security will be issued at a price of $\pi(D^L - L\alpha_S)$, where*

$$\pi = \frac{D - L\alpha_S - D^C}{D - L\alpha_S}, 0 < \pi \leq 1.$$

A third risky security will be retained by the issuer with internal value of

[5] We implicitly assume that the senior security is issued in its entirety when $D - L\alpha_S < D^C$, since it can be sold at its fundamental value. If the issuer wanted to issue the minimum amount necessary to satisfy the constraint, part of the senior security could be sold and part of it could be retained. This latter option provides a rationale for the existence of multiple same-rated senior securities.

[6] This is not required. Instead of issuing a single riskless and a single risky security, one risky composite security could be issued that satisfies the capital constraint. A preference for finer tranche structure may nevertheless result due to, for example, risk-sharing or asset/liability matching needs of investors (factors that are exogenous to this model).

$(D - L\alpha_S)(1 - \pi) = D^C$. *Total security value to the issuer is* $D(1 - \pi) + D^L\pi < D$, *with resulting liquidation loss of* $\pi(D - D^L)$.

Positive benefits to securitization lie in the issuer's ability to internalize lemons-related marketing costs by retaining at least some of the risky security. It is worth noting that, if additional fixed or variable issuance costs were to be incurred from securitization, or if a costly asset value revelation technology existed, it might be possible that the whole loan sale alternative would be at least weakly preferred to the securitization alternative.[7]

Observe that our results suggest a "pecking order" like that in Myers and Majluf (1984). In the absence of the capital constraint, the insider will generally prefer to "internally finance" by continuing to hold the investment and therefore avoid lemons-related liquidation costs. Similarly, if financial slack were introduced in terms of reducing the size of an existing capital constraint, and if the issuer is severely capital constrained, she would prefer to use this slack to internally finance by reducing the issuance size of the risky security. In the absence of other transaction costs, issuing a riskless security also avoids incurring information-related marketing costs. Least desirable is issuing risky securities, since information sensitivity results in external values that are discounted relative to their fundamental values.

The results of this subsection offer several empirical predictions regarding loan portfolio liquidation strategies, security design, and the ratings of issued securities. First, the model predicts that issuers will often retain low-rated security tranches to internalize information-related liquidation costs. The model also predicts the possible existence of multiple same-rated securities, both at the senior and the junior level. Further, the potential for adverse selection suggests subordination levels may be set higher than the issuer would prefer. The size of the subordination "wedge" is predicted to increase as asset opaqueness increases (i.e., as the difference between P and P^L increases). After issuance, however, and as information is revealed as to true asset quality, our model suggests an upward migration (on average) in risky security quality—as perhaps certified by an external credit rating agency or as measured by security price change and security liquidity. The speed of this upward migration is predicted to be positively related to the degree of asset opaqueness at the time of security issuance.

[7] If a costly information revelation technology were feasible at finite cost, a comparison would have to be made between lemons-related liquidation costs and information revelation costs. If information revelation costs were low enough, the insider may prefer to incur these costs and sell the assets whole.

III. LOAN BUNDLING AND THE MULTIPLE-ASSET POOL

Asset-backed security pools are typically composed of many assets. Although individual loan flows may only depend on single collateral asset value realizations, cash flows that are aggregated and then split among various investment classes will depend on *all* collateral asset values that back the pooled loans. Because collateral-asset value changes are, in general, neither perfectly correlated nor completely independent of one another, it is important to recognize the correlation structure of underlying assets (Childs *et al.*, 1996).

In addition, a contracting feature that is sometimes of keen interest in the multiple asset portfolio is the *cross-default* clause. When multiple loans have been issued to a particular borrower, a cross-default clause can be used to bundle the debt such that default on any individual loan constitutes default on all of the loans included in the arrangement. The bundled debt is therefore a contingent-claim whose value depends on multiple underlying asset values. This codependency is relevant even without consideration of debt securitization, which provides a further rationale for analyzing asset value interaction. In this section of the paper, we develop conditions under which the capital constrained debtholder will be motivated to cross-collateralize previously unbundled loans. We show that benefits to bundling the debt and subsequently structuring a senior/subordinated security may accrue in terms of higher net issuance proceeds relative to leaving the loans unbundled as well as in terms of wider ranges over which these higher net issuance proceeds are realized.

When collateral assets are imperfectly correlated, multiple asset securitization and loan bundling can be recognized as cash flow variance reduction strategies. This variance reduction effect may strongly impact debt pricing and portfolio liquidation strategy, even under the assumption of risk neutrality. Asset diversification decreases the probability of low total asset value outcomes, which is especially important when adverse selection incentives exist. Thus, the pooling and bundling of imperfectly correlated assets partially substitutes for provision of asset value information in markets characterized by adverse selection risk.

The Multiple Asset Pool: Preliminaries

As a starting point in our analysis, consider two identical risky loans issued to the same borrower. Assume that these debt claims were initially issued independently and that they are individually collateralized by identical, but imperfectly correlated, assets. As in the single loan portfolio case, information is asymmetric with respect to debt value. In the absence of a cross-default clause, payment decisions are made independently on the two loans. For ease of comparison, we scale loan size so that the internal two-loan portfolio value is

$$D = \frac{L(1+\iota) + P(1-\sigma)}{2},$$

as in Eq. (1). Similarly, the discounted external value of the whole loan portfolio is

$$D^L = \frac{L(1+\iota) + P^L(1-\sigma)}{2}$$

as stated in Eq. (2).

Before analyzing loan-bundling incentives and the impact of diversification on pooled-asset security design, the single-asset contingent-claim approach employed in the previous section must be extended to handle multiple state variables. Given a two-asset pool as described above, there are four potential up–down (U or D) state outcomes in each period: U–U, U–D, D–U, and D–D. We will refer to these as state outcomes 1 through 4, respectively, and denote the probability of each outcome as p_1, p_2, p_3, and p_4, $p_1 + p_2 + p_3 + p_4 = 1$. Thus, the probability of an up state with asset 1 is $p_1 + p_2 = 1/2$ and the probability of an up state for asset 2 is $p_1 + p_3 = 1/2$. Given that asset values may be imperfectly correlated, uniquely determining these four probabilities requires specifying additional equilibrium relationships. The needed relationships can be obtained by using characteristics of the first and second moments of each respective asset price distribution as well as the correlation structure between the two assets. The following lemma summarizes these relationships and the unique solutions for p_1 through p_4.

LEMMA 2 (Valuing 2-asset discrete contingent-claims). *Assuming that the risk-free rate is zero and that the volatility of the two underlying assets are equal, the following equilibrium relationships must hold when valuing discrete-time contingent-claims:* (*i*) $p_1 + p_2 - p_3 - p_4 = 0$ (*expected return to asset 1*), (*ii*) $p_1 - p_2 + p_3 - p_4 = 0$ (*expected return to asset 2*), *and* (*iii*) $p_1 - p_2 - p_3 + p_4 = \rho$ (*correlation between assets 1 and 2*). *Using these three equalities plus the fact that* p_1 *through* p_4 *must sum to one, the resulting probabilities for each respective state outcome are:*

$$p_1 = p_4 = \frac{1+\rho}{4}, p_2 = p_3 = \frac{1-\rho}{4},$$

where ρ *denotes the correlation between returns to assets 1 and 2.*

This result shows that the probability of extreme value outcomes (i.e., either U–U or D–D) decreases as correlation decreases. Also note that when two loans with imperfectly correlated collateral assets—but with otherwise identical characteristics—comprise the portfolio, the debt security payoff state space is reduced to only three different outcomes at time 1: either both loans pay off as promised (state U–U obtains), one pays off and the other defaults (either state U–D or D–U obtains, with identical state payoffs regardless of which loan defaults), or both loans default (state D–D obtains).

Loan Bundling, Pool Diversification, and Implications for Design

Consider now the costs and benefits of bundling previously unbundled loans through a cross-default clause. Loan bundling further reduces the state-contingent debt payoff space from three to two possible outcomes, since the borrower will either default on both loans at the same time or pay off both loans as promised. For simplicity, assume that $P > L(1 + \iota)$. This assumption implies that the borrower will not default in states U–D or D–U at time 1, which makes the cross-default clause particularly effective in reducing the frequency of borrower default.[8]

From Lemma 2, a D–D state realization occurs with probability $p_4 = (1 + \rho)/4$; otherwise, the loans pay off as promised. As a result, the internal value of the bundled loan portfolio is

$$D_B = L(1 + \iota)(1 - p_4) + P(1 - \sigma)p_4. \tag{5}$$

Because $p_4 < 1/2$ when $\rho < 1$, it is clear that $D_B > D$. The borrower will require compensation for surrendering equity value by agreeing to cross-collateralize the loans. The cost of loan bundling is simply the difference between loan value with and without the cross-default clause. Denote this difference as Δ, where

$$\Delta = D_B - D = p_3[L(1 + \iota) - P(1 - \sigma)], \tag{6}$$

and where $p_3 = (1 - \rho)/4$ as described in Lemma 2.

From an internal valuation perspective, loan bundling is a zero-sum game. However, a benefit to the issuer of bundling the loans is that lemons-related

[8] That is, the cross-default clause under this assumption will result in a lower probability of default at time 1 as compared to the single-asset case. The alternative assumption of $P \leq L(1 + \iota)$ would result in a higher frequency of default at time 1 relative to the single-asset case, but with a lower loss severity. Thus the benefits to a cross-default clause more obviously accrue when $P > L(1 + \iota)$.

liquidation costs are reduced. This follows because the probability of a default state—in which the outsider assumes P^L is recovered—declines relative to the unbundled loan case. The resulting external value of the cross-collateralized loan is

$$D_B^L = L(1 + \iota)(1 - p_4) + P^L(1 - \sigma)p_4, \tag{7}$$

which implies that the net external benefit to loan bundling is

$$\Delta^L = D_B^L - D^L = p_3[L(1 + \iota) - P^L(1 - \sigma)]. \tag{8}$$

Δ^L is clearly positive for $\rho < 1$.

Before considering optimal liquidation strategy vis-à-vis the asset-backed security, we first analyze loan bundling incentives under the assumption of whole loan sale.

LEMMA 3 (Incentive to bundle loans). *Consider the whole loan liquidation option only. If $D/2 \leq D^C < D$, then a single loan will be sold whole and the other will be retained by the original debtholder. Otherwise, if $D^C < D/2$, loan bundling and complete liquidation is preferred to complete liquidation through independent whole loan sale.*

The basic result is that, if it is feasible to market just one loan to meet the capital constraint, the insider will prefer to do this. Advantages to loan bundling in this case are not high enough to offset the cost of the unneeded liquidation of the second asset. However, if the capital constraint is more severely binding such that both loans must be sold, loan bundling is preferred.

The proof of this lemma shows that the external benefits from bundling the loans always exceeds the internal costs; i.e., that

$$\Delta^L - \Delta = p_3(P - P^L)(1 - \sigma) > 0 \tag{9}$$

for $\rho < 1$. The relative value to bundling the debt increases as asset diversification benefits increase ($\rho \downarrow$) and as perceived asset quality decreases ($P^L \downarrow$). This suggests that capital constrained debtholders may be especially motivated to bundle low correlation assets that are of particularly low quality.

We now examine securitization as an alternative to liquidating the portfolio whole. As with the single-asset security, a lemons-protected subordination level is established such that

$$P^L(1 - \sigma) = L\alpha + L(1 - \alpha)i_{J,B}, \tag{10}$$

where $1 - \alpha$ is the subordination level to be determined and $i_{J,B}$ is the promised yield to the junior securityholder. It is important to recognize that the expected payoff to the junior securityholder differs from the single-asset case, since the loan pool is now composed of (imperfectly correlated) multiple assets that are bundled together through a cross-default clause. This par-value junior security payoff can be expressed as

$$D - L\alpha = (1 - p_4)L(1 - \alpha)(1 + i_{J,B}) + p_4[P(1 - \sigma) - L\alpha]. \tag{11}$$

Note that the internal value of the junior security is $D - L\alpha$, and not $D_B - L\alpha$. This is because the cost of loan bundling exactly offsets the increased loan value to result in a net internal total debt value of D.

The resulting level of subordination required to create a lemons-protected senior security is stated in Lemma 4.

LEMMA 4 (Multiple asset/cross-defaulted credit support level). *Full risk partitioning in the multiple asset security/cross-defaulted loan case can be achieved with two security classes. The optimal subordination level is*

$$1 - \alpha_B = \frac{2}{3 - \rho}[1 + \iota] - \frac{(1 - \sigma)\,[P^L - P((1 - \rho)/(3 - \rho))]}{L}.$$

This subordination level is less than that required in the otherwise equivalent single asset case. That is, $1 - \alpha_B < 1 - \alpha_S$.

As compared to the single-asset security, loan bundling combined with structuring a senior/subordinated security may result in a lower level of subordination and hence a higher likelihood of meeting the capital constraint. In addition, it is straightforward to show that the required level of subordination declines as asset diversification increases (i.e., $\partial(1 - \alpha_B)/\partial\rho > 0$). This is due to the concavity of the senior security's payoff function and the fact that the probability of borrower default declines as ρ decreases.

Before stating the optimal liquidation strategies, one additional lemma is needed to establish the benefits of securitization versus whole loan sale.

LEMMA 5 (Strong dominance of the securitization alternative). *Given that loan bundling is feasible, payoffs to securitization dominate payoffs to whole loan sale.*

Dominance holds even when the sale of a single whole loan satisfies the capital constraint. This follows because the security is structured such that lemons-related liquidation costs are minimized, while also satisfying the capital constraint. Whole loan sale cannot do better than this, because it is likely that "too much" adverse selection risk is packaged and sold relative to minimally satisfying the capital constraint and because the lack of a cross-default clause on the whole loan results in relatively higher default risk.

Multiple asset/loan bundling liquidation strategies can now be stated depending on the magnitude of the capital constraint.

PROPOSITION 2 (Optimal liquidation strategy, multiple asset/cross-collateralized security). *The multiple asset/cross-collateralized security generates equivalent or higher net liquidation proceeds than the otherwise identical single asset security. Major results can be summarized as follows.* $D - L\alpha_B < D - L\alpha_S$. *This implies that, by bundling the loans together in a multiple-asset security, the issuer is less likely to be capital constrained after issuing the senior security. If the issuer indeed goes from being capital constrained to noncapital constrained in the multiple asset/cross-defaulted loan case, net liquidation proceeds increase. If* $D - L\alpha_B > D^C$, *a junior security is issued like that described in Proposition 1, with proportional issuance parameter* π_B, $\pi_B < \pi$. *This latter inequality implies that, relative to the single-asset case, the lower bound of the moderately capital constrained region decreases and that a smaller proportion of junior security issuance is required to satisfy the capital constraint. Moreover,* $(1 - \pi_B)D + \pi_B D_B^L > (1 - \pi)D + \pi D^L$, *which implies that liquidation proceeds are greater in this case than in the single-asset case.*

Benefits to pooling and bundling imperfectly correlated assets derive from equivalent or higher realized issuance proceeds as compared to the single-asset security. Thus, in addition to previously discussed empirical implications, our model suggests that clear incentives may exist for the capital constrained debtholder to create a well diversified pool of assets and to recontract with borrowers to bundle loans through a cross-default clause—even though such recontracting may be costly. Furthermore, relative benefits to securitization grow as asset quality declines (i.e., as P^L decreases).

These findings relate to well known results on information disclosure and corporate capital structure. Admati and Pfleiderer (1986), Diamond and Verrechia (1991), and Fishman and Hagerty (1995), among others, suggest a role for the strategic disclosure of information as it relates to security valuation. Glaeser and Kallal (1997) go further to examine the simultaneous effects of information disclosure and asset pooling on total security value. In comparison, although there is no role for credible information disclosure in our model, we do show that asset pooling and loan bundling partially substitute for provision of information by lowering the likelihood of extreme value outcomes.[9] In a corporate capital structure setting, Stulz and Johnson (1985) recognize that issuance of secured debt may be preferred to unsecured debt issuance when asset substitution or underinvestment are relevant concerns. In contrast, we provide a value-increasing role for unsecured debt when information asymmetries exist and for firms who hold imperfectly correlated assets. Because it reduces the number of possible default state realizations, unsecured debt issuance may result in higher proceeds than could be obtained from separate secured debt issuance's.

IV. SECURITY GOVERNANCE

Thus far we have focused on the optimal design of securities when information asymmetries affect liquidation value of the underlying assets. An important assumption has been that borrower default results in immediate liquidation and that these ex post liquidation costs are zero. In this section we extend the model to analyze ex post control issues when debt renegotiation is an alternative to immediate liquidation. The interdependence of *security governance* and *security design* therefore becomes relevant, since conflicts of interest between securityholders may arise with respect to preferred liquidation versus renegotiation policy decisions and because anticipation of these ex post outcomes will affect how the security is designed to achieve ex ante liquidation objectives.

Before examining the control issue in the context of the asset-backed security, it is relevant to briefly review rationales for corporate debt structures in which banks, rather than the public bondholders, typically control renegotiation with equityholders. First, it is generally agreed that banks have informational-, technological-, and incentive-based advantages relative to public bondholders, which provides them with efficient decision-making incentives and superior bargaining power (e.g., Fama, 1985, Diamond, 1984, Chemmanur and Fulghieri, 1994). Moreover, the lack of "cohesiveness" of public bondholders suggests that banks are better suited to address financial distress situations (e.g., Bulow and Shoven, 1978, Thakor and Wilson, 1995). It has also been argued that splitting debt claims by maturity—where the "short termism" of the senior bank debt is of strategic

[9] This result also relates to Diamond (1984), who analyzes the role of diversification in reducing ex post information production costs. In contrast to his emphasis on moral hazard, we focus on asset diversification as it relates to adverse selection costs. Furthermore, whereas significant information cost reductions can only be achieved by holding large pools of imperfectly correlated assets in the Diamond model, we show how asset diversification together with security tailoring can be used with small asset pools to fully substitute for costly information production.

value—hardens the incentive of the equityholder to renegotiate efficiently ex post (e.g., Berglöf and von Thadden, 1994).

In comparison, we argue that it is the junior securityholder who should control the debt liquidation/renegotiation decision with multiclass asset-backed securities. Because of ex ante liquidation motives, the well-informed investor is junior in our model. Superior asset value information strengthens the junior securityholder's ability to extract concessions from the borrower given a default state outcome. The uninformed senior securityholder, who believes that the underlying asset value is less than the true asset value, is ill positioned to extract bargaining surplus from a better informed borrower. Superior asset value information alone does not ensure value maximizing renegotiation outcomes, however. It is the additional element of a first-loss position that hardens the junior securityholder's incentives to maximize the renegotiation payoff. The senior securityholder does not necessarily have a similar incentive, since he is typically well protected from default loss. Note that, in contrast to models of Berglöf and von Thadden (1994) and Diamond (1993), the strategic use of staggered debt maturity plays no role in our model. Instead, security value maximization incentives are channeled through the combined informed "trader"/first-loss position of the junior securityholder.

Although junior securityholder control may be advantageous from an ex post security value maximization perspective, it complicates up-front security design. Because the junior securityholder's claim has equity-like payoff characteristics, she will generally prefer to "play for time" by extending the loan term. This, in turn, may generate an ex post wealth transfer from the senior securityholder to the junior securityholder and therefore reintroduce information sensitivity into senior security valuation. In response to this combined moral hazard/adverse selection problem, the security can be redesigned. Doing so results in adjusting subordination levels upward to eliminate the preference for loan extension. The remaining section formally develops the intuition for junior claimholder control and security design in the case of the asset-backed security.

Ex Post Liquidation, Workout, and Loan Extension

In this subsection we impose additional structure on the previously developed model. This additional structure includes positing deadweight ex post liquidation costs to the debtholder, how those deadweight costs are split from renegotiation, and the exact form of debt renegotiation that can occur. Then, to establish a base case with which to compare optimal security design and governance structure, we examine renegotiation incentives given that the debt portfolio cash flows are marketed whole.

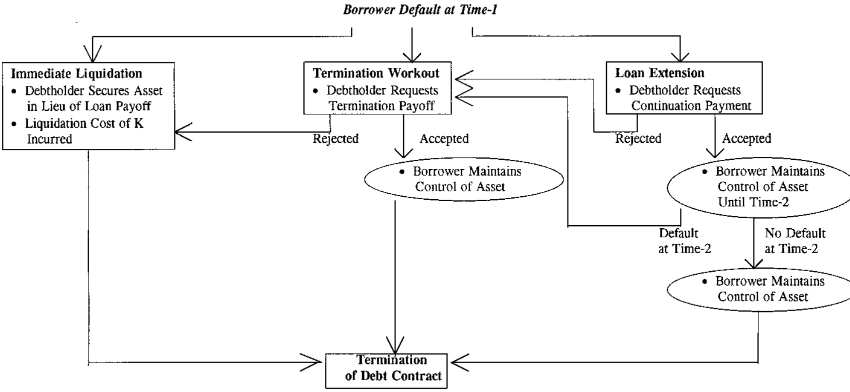

FIG. 1. Alternative liquidation/renegotiation policy outcomes.

The model developed in Section II is augmented as follows, where timing aspects of the liquidation versus renegotiation process are summarized in Fig. 1. For simplicity, assume a single-asset portfolio. Given that a default state occurs at time 1, liquidation or debt renegotiation can occur. If liquidation occurs, the debtholder secures the asset value in lieu of debt repayment as well as incurs a liquidation cost of $K > 0$. The liquidation cost can be avoided entirely if the debt is renegotiated.[10] Two types of renegotiation are considered. First, the debtholder may require a discounted payoff at time 1, in which the borrower is allowed to maintain control of the collateral asset. If the borrower rejects the discounted payoff request of the debtholder, liquidation occurs. We will refer to a successful outcome of this first type of debt renegotiation as a "termination workout."

A second alternative is for a one-period "loan extension" to occur. Given a default at time 1, the controlling debtholder demands an endogenously determined continuation payment in lieu of receiving the promised interest payment. If the borrower refuses to make the payment, a termination workout process occurs instead. Given that the borrower accepts the continuation payment terms, the loan is extended for one period with $L(1 + \iota)$ due at time 2. No additional extensions are allowed; thus, if default occurs again at time 2, a terminating workout process occurs.

Given a prioritized security structure, we wish to address whether the senior or the subordinated debtholder should control the renegotiation

[10] Thus the debtholder is assumed to have full bargaining power with respect to these costs. This assumption is made to abstract from strategic default incentives on the borrower's part. Note that this assumption does not imply that the debtholder always maximizes the bargaining surplus from renegotiation, only that the borrower is unable to extract the liquidation costs through the renegotiation process.

process—where the choice between liquidation, terminating workout, or loan extension is endogenous to the model. To provide a foundation for this more complicated case, consider first the termination workout versus loan extension payoffs given that the debt was sold whole to an outsider. Although the insider would request and receive a termination workout payoff of $P(1 - \sigma)$ at time 1 given a default state outcome, the outsider requests only $P^L(1 - \sigma)$ in order to avoid incurring liquidation costs of K. This follows because of the nonverifiability of the insider's capital constraint, which forces the outsider to value the collateralized asset (and therefore the debt) as a lemon. Consequently, the borrower (gladly) accepts the repayment terms, retains control of the asset, and the debt contract is terminated.

Loan extension in the whole loan case is somewhat more involved. True collateral asset value at time 1 given borrower default is $P(1 - \sigma)$. A one period loan extension results in a true collateral asset value of either $P(1 + \sigma)(1 - \sigma) = P(1 - \sigma^2)$, or $P(1 - \sigma)^2$ at time 2, $P(1 - \sigma^2) > P(1 - \sigma)^2$. However, the outsider presumes a time 2 state-contingent asset value outcomes of either $P^L(1 - \sigma^2)$ or $P^L(1 - \sigma)^2$ given an asset value realization of $P^L(1 - \sigma)$ at time 1. For simplicity assume that $P^L(1 - \sigma^2) \geq L(1 + \iota)$, which implies that a full loan payoff is expected (and indeed occurs) at time 2 given a high state value outcome. Hence, the outside debtholder places the following value on the payoffs from loan extension:

$$\mathscr{E}^L = \frac{L(1 + \iota) + P^L(1 - \sigma)^2}{2}, \tag{12}$$

which is less than or equal to the terminating workout payoff of $P^L(1 - \sigma)$. As a result, the outside debtholder will request a continuation payment of $\mathscr{C}^L = P^L(1 - \sigma) - \mathscr{E}^L$. The borrower will agree to this request since he is willing to pay up to $\mathscr{C} = P(1 - \sigma) - \mathscr{E}$, where

$$\mathscr{E} = \frac{L(1 + \iota) + P(1 - \sigma)^2}{2}. \tag{13}$$

Thus, given that loan extension is a feasible renegotiation outcome, the time-zero outside debt value remains at D^L. As with the termination workout case, this occurs because the lemons discount has already been internalized into (outside) debt value. When the debt is sold whole, the outsider is therefore indifferent between terminating workout and loan extension. There is no overall efficiency loss given these outcomes, since liquidation costs are avoided and because the borrower receives the informationally related bargaining surplus. However, the inside debtholder would have clearly done better than the outsider due to endowment of better asset value information.

Governance and Design

We will now examine the impact of governance structure on security value and optimal senior/subordinated security design. Our first step is to address who—the senior or the junior securityholder—should be designated as controlling the liquidation/renegotiation policy decision given borrower default. Governance structure is established at the time of security issuance in order to maximize ex post payoffs from loan liquidation or renegotiation. Then, once governance structure is set, we determine how the security should be designed to maximize total security value at issuance while also meeting the capital constraint.

Working backward in time, first assume borrower default at time 1 and consider the payoffs to placing the junior securityholder in control. This securityholder is informed as to asset value, which means that she can obtain a total time 1 payoff of up to $P(1 - \sigma)$ given a terminating workout outcome. Conversely, she can secure a continuation payment of up to $\mathscr{C}$ from loan extension, where the resulting time 1 expected payoff is also $P(1 - \sigma)$. Because of her first loss position, she is motivated to maximize these relative payoffs. Furthermore, the junior securityholder will clearly never prefer liquidation over workout or extension when liquidation costs are positive.

Thus, the total security payoff is equivalent given either a terminating workout or a loan extension outcome. However, due to differences in the relative allocation of the payoff, the individual securityholders may prefer one outcome over another. Extension will be strongly preferred by the junior securityholder if her expected payoff from extending plus the continuation payment exceeds her payoff from a terminating workout; i.e., if

$$\frac{L(1-\alpha)(1+i_J)+L(1-\alpha)i_J}{2}+\mathscr{C}>P(1-\sigma)-L\alpha, \tag{14}$$

where it is assumed that the face interest rate paid to the senior security is zero and that the continuation payment, $\mathscr{C}$, is nonverifiable to outsiders.[11]

[11] Thus the subordinated securityholder is able to pocket the surplus gained from renegotiation. If $\mathscr{C}$ were verifiable, structural rules could be written to ensure that the senior security received some of the surplus. However, verifiability would introduce additional strategic complexity into the bargaining game. Moreover, given the insider's superior asset value information, she could formally agree to some low continuation payment amount while simultaneously entering into an informal side agreement with the borrower to extract the remaining surplus.

The following lemma answers the workout versus loan extension preference question in the case of junior securityholder control.

LEMMA 6 (Liquidation versus renegotiation incentives, junior securityholder control). *Assume a senior/subordinated security structure with arbitrary credit support level,* $1 - \alpha$. *For simplicity, also assume the senior and junior securities were priced at security issuance such that* $L\alpha + L(1 - \alpha) i_J = L\iota$, *i.e., that par value pricing holds regardless of* α. *Given borrower default at time* 1 *and junior securityholder control, the junior securityholder will always prefer to extend the loan term at low subordination levels; i.e., whenever*

$$1 - \alpha < 1 + \iota - \frac{P^L(1 - \sigma)^2}{L}.$$

Otherwise, at higher levels of subordination, she is indifferent between the terminating workout or the loan extension outcome.

The intuition for this result follows from the incentive of the junior securityholder to increase the variance of her state contingent payoffs. Given a low subordination level, the junior security payoff function is locally convex whereas the senior security payoff function is locally concave. Loan extension introduces additional volatility into the payoff structure, which results in an ex post transfer of wealth from the senior securityholder to the junior securityholder. Alternatively, if subordination levels are set high enough, senior security payoffs are monotonic and hence immune to wealth transfer effects. This results in the junior securityholder being indifferent between workout and loan extension.

Given junior securityholder control and a low level of subordination, security pricing effects at issuance prove to be interesting. Because of loan extension incentives, default loss sensitivity is reintroduced into senior security valuation. This will impact total security value, since the senior security will sell at a discount to its fundamental value when its payoffs are sensitive to borrower payment outcomes. Payoff sensitivity at the senior security level therefore suggests an interdependence between up-front security design and governance structure, where security design may be used to mitigate ex post opportunism by the junior securityholder.

Prior to establishing ‘‘extension compatible’’ security design, we will briefly analyze an alternative governance structure in which the uninformed senior securityholder controls the liquidation versus renegotiation policy decision. Because of the increasing variance effect of loan extension, we would expect to observe at least a weak preference for loan termination at time 1 by the senior securityholder. The following lemma confirms this intuition.

LEMMA 7 (Liquidation versus renegotiation incentives, senior securityholder control). *Assume control by the uninformed senior securityholder as well as time-zero par-value security pricing as described in Lemma 6. Then, the senior securityholder will always weakly prefer terminating workout. At certain higher subordination levels, costly liquidation is also a feasible outcome.*

Given any feasible liquidation/renegotiation policy outcome, recognize that total security value under senior securityholder control will also be less than the fundamental security value, D. When subordination levels are low, terminating workout is strictly preferred. Because the senior securityholder is uninformed as to true asset value, he will accept a termination payoff that is less than could be obtained given full information. This information effect produces a negative payoff externality to the junior securityholder, since she is in the first-loss position given borrower default. At higher subordination levels, the senior securityholder may be indifferent between terminating workout, liquidation, and/or loan extension. In particular, the senior securityholder may rationally choose to liquidate given borrower default. This outcome is feasible because the senior securityholder is well protected against default loss and hence has no incentive to internalize the deadweight costs of liquidation. Thus, negative payoff externalities associated with senior control may be due to incentive as well as information effects.

We have now established that the junior securityholder will never liquidate inefficiently and will secure larger expected payoffs from debt renegotiation than the senior securityholder. However, assuming junior securityholder control and given that a senior security is to be sold externally to satisfy the capital constraint, additional structure is required to guarantee that total security value will be maximized ex ante. To provide this additional structure, we focus on two security design alternatives that are particularly easy to implement and monitor: (i) explicitly restrict extension from occurring and set the credit support level according to that determined in Proposition 1, or (ii) do not restrict extension, and reset credit support levels to ensure "extension compatibility."

Given a credit support level as defined in Proposition 1, complete restriction of extension clearly eliminates introducing information sensitivity into senior security payoffs. As an alternative to loan extension restriction, the security can be redesigned. This involves increasing the subordination level such that the senior security remains riskless even when extension occurs. Because the worst case realization from extending is a default state outcome at time 2, the following relationship must hold for extension compatibility (EC)

$$P^L(1-\sigma)^2 = L\alpha + L(1-\alpha)i_J^{\mathrm{EC}}, \tag{15}$$

where α and i_J^{EC} are to be determined. Note that this relationship differs from the analogous no-extension subordination relationship seen in Eq. (3) only by the period-2 default state payoff replacing the period-1 default state payoff on the left-hand side of the equality.

The following proposition states the combined optimal governance structure/security design outcome.

PROPOSITION 3 (Governance and extension compatible subordination level). *Security value is maximized by granting the junior securityholder control, subject to the following additional structure. Security value can always be maximized by restricting loan extension from occurring and setting* $1 - \alpha$ *equal to the level determined in Proposition* 1. *If the capital constraint is such that* $D - L\alpha^{\mathrm{EC}} \leq D^C$, *where*

$$1 - \alpha^{\mathrm{EC}} = 1 + \iota - \frac{P^L(1-\sigma)^2}{L},$$

then total (*internal*) *security value of D can be realized by allowing a one period extension given borrower default at time* 1 *and by setting a subordination level of* $1 - \alpha^{\mathrm{EC}}$ *as defined above.*

Observe that the extension-compatible credit support level, $1 - \alpha^{\mathrm{EC}}$, is higher than the credit support level obtained in Proposition 1. A higher credit support level is required to neutralize the junior securityholder's incentive to exploit the senior securityholder ex post. Assuming a nonbinding capital constraint, the junior securityholder is indifferent between accepting a restriction on extension or agreeing to the higher credit support level. Conversely, if the capital constraint is newly binding at the higher credit support level, restrictions to extension will be accepted to maximize total security value.

Results from this section generate several empirically testable implications. First and foremost, our model suggests that it is the junior securityholder who retains control with respect to addressing borrower financial distress in a senior/subordinated asset-backed security structure. In addition, to reduce conflicts of interest between security classes, restrictions to loan extension are predicted to be observed. The degree to which loan extension is restricted should be positively related to the severity of the issuer's capital constraint. When extension is not completely restricted, a positive relationship between security subordination level and the amount of loan extension flexibility should be observed.

V. CONCLUSION AND SUMMARY OF EMPIRICAL IMPLICATIONS

This paper has analyzed the design and governance of risky asset-backed securities. Assuming liquidation motives and asymmetrically informed market participants, we show that lemons-related liquidation costs can be internalized through retention of the risky security. Security subordination levels must be adjusted, however, to account for adverse selection risk. Because they are packaging strategies that lower the probability of extreme state value outcomes, pool diversification and loan bundling can be used to partially mitigate lemons pricing effects. Security design is also shown to depend on security governance structure. Junior securityholders—who possess superior asset value information and strong incentives to maximize bargaining payoffs—will optimally control the debt renegotiation process given borrower default. However, loan extension incentives lead to even higher levels of subordination or to explicit restriction of loan extension occurrence.

As a final point of discussion, it is useful to summarize some of the more important empirical implications of the model.

1. Supply-driven motivations for liquidation together with private asset value information suggest a prominent role for the issuance of senior/subordinated asset-backed securities. To internalize lemons-related liquidation costs, there are clear incentives for the issuer to retain the subordinated security. This incentive grows as the information asymmetry increases (i.e., as asset quality decreases). However, as a loan pool seasons and asset quality is revealed over time, low-rated securities are predicted to become more liquid (in the sense that they are externally valued nearer their fundamental value). Thus, liquidity is predicted to be positively related with credit rating at the time of security issuance, but differences in liquidity by initial rating category should decline over time.

2. Subordination levels are set higher than fundamental debt values would dictate. A negative relationship between asset quality and subordination level, as well as between the degree of pool diversification and subordination level, are predicted. In order to increase proceeds from senior security issuance, incentives to issue a well-diversified pool (as well as to cross-collateralize pooled loans) may increase as asset quality decreases.

3. On average and over time, security performance should exceed outside expectations. This suggests an upward migration on average with respect to credit rating. The speed at which the rating upgrades occur should, on average, be negatively related with the perceived initial quality of the asset pool.

4. Junior securityholders are predicted to exert strong control in the renegotiation process with financially distressed borrowers. In the absence of restrictions to the contrary, junior securityholders will tend to extend loan terms when default occurs. Because senior securityholders generally prefer immediate payoff to extension, conflicts of interest are predicted to exist between senior and junior securityholders with respect to addressing borrower default. This suggests that provisions may be written to restrict extension from occurring when junior securityholders control the renegotiation process. When extension is allowed, subordination levels are predicted to increase, all else equal. A positive relationship between subordination level and the degree of flexibility granted to the junior securityholder with respect to extension is predicted.

Thus, our simple model of asset-backed security design produces a relatively rich set of empirical predictions. As compared to other papers in the security design area, our approach—and therefore the empirical predictions of the model—is unique with respect to addressing variance reduction benefits of pool diversification/loan bundling as well as with respect to addressing the interaction of security governance and security design. Perhaps most significantly, we provide a counterexample to the usual senior debt/renegotiation control argument found in the corporate finance literature. In the context of the senior/subordinated asset-backed security, our results point out the importance of information and incentives when determining control over ex post liquidation/renegotiation policy decisions.

APPENDIX

Proof of Lemma 1 (*Single-asset security credit support*). Straightforward.

Proof of Proposition 1 (*Optimal liquidation strategy, single-asset security*).

Case I. $D - L\alpha_S \leq D^C$. In this Case it is clear that a senior security can be issued at its fundamental value, which also satisfies the capital constraint. This dominates whole loan sale.

Case II. $D - L\alpha_S > D^C$. In this Case issuing a senior security does not satisfy the capital constraint. Consequently, consider issuing a proportion of the junior security externally, where π denotes a proportionality parameter, $0 < \pi \leq 1$. To satisfy the capital constraint exactly, the issuer will retain a proportion of the junior security such that $(D - L\alpha_S)(1 - \pi) = D^C$, which implies that $\pi = (D - L\alpha_S - D^C)/(D - L\alpha_s)$. Thus, a senior security with value $L\alpha_S$ is issued externally (at no discount to its fundamental value), a junior security with value $(D^L - L\alpha_S)\pi$ is issued externally (at a discount to its fundamental value), and a junior security with value $(D - L\alpha_S)(1 - \pi)$ is retained internally (at its fundamental value). Total security value in this case is $D(1 - \pi) + D^L\pi$. This value exceeds the value of D^L resulting from a simple lemons-discounted whole loan sale.

Proof of Lemma 2 (*Valuing 2-asset discrete contingent claims*). Relationship (i) follows from the definition of expected return given the discrete-time dynamics associated with asset 1, from the assumption of risk neutrality, and from the fact that the riskless rate of interest, r, is normalized to equal zero. By denoting the current asset value by P_i, the random asset value one period hence by $\tilde{P}_i$ and the random return one period hence to asset i by $\tilde{R}_i$, the expected return for asset 1 is

$$E[\tilde{R}_1] = E\left[\frac{\tilde{P}_1 - P_1}{P_1}\right] = \frac{(p_1 + p_2)P_1(1 + \sigma) + (p_3 + p_4)P_1(1 - \sigma) - P_1}{P_1},$$

which becomes $p_1 + p_2 - p_3 - p_4 = 0$. Note that the ordering of probabilities in the expected return equation follow from the fact that p_1 and p_2 represent probabilities of an up state for asset 1 while p_3 and p_4 represent probabilities of a down state. A similar procedure with asset 2 results in relationship (ii) in which $p_1 - p_2 + p_3 - p_4 = 0$. Next, to obtain (iii), we wish to establish the covariance relationship between assets 1 and 2. First, some algebra verifies that $E[\tilde{R}_1^2] = E[\tilde{R}_2^2] = \sigma^2$, which means that $\mathrm{Var}[\tilde{R}_1] = \mathrm{Var}[\tilde{R}_2] = \sigma^2$ as well. Now define

$$\rho = \frac{\mathrm{Cov}[\tilde{R}_1, \tilde{R}_2]}{\sqrt{\mathrm{Var}[\tilde{R}_1]}\sqrt{\mathrm{Var}[\tilde{R}_2]}}.$$

Simple algebra and substitution results in $E[\tilde{R}_1\tilde{R}_2] = \rho\sigma^2$, which we will refer to as Eq. (#). An alternative expression for $E[\tilde{R}_1\tilde{R}_2]$ can also be developed, in which

$$E[\tilde{R}_1\tilde{R}_2] = E\left[\left(\frac{\tilde{P}_1 - P_1}{P_1}\right)\left(\frac{\tilde{P}_2 - P_2}{P_2}\right)\right].$$

Substitution and simplification of this expression results in $E[\tilde{R}_1\tilde{R}_2] = \sigma^2[p_1 - p_2 - p_3 + p_4]$, which can now be equated with (#). Doing this results in relationship (iii) as seen in the proposition. Relationships (i) through (iii), combined with the fact that the probabilities must sum to 1, can be simultaneously solved to produce explicit expressions for p_1 through p_4.

Proof of Lemma 3 (*Incentive to bundle loans*).

Case I. $D/2 \leq D^C < D$. In this Case, it is possible to sell just one of the loans and satisfy the capital constraint. To show that a single loan sale strategy dominates a bundling strategy, we must show that $((D + D^L)/2) > D_B^L - \Delta$. Using the definitions of these terms, this amounts to showing that

$$\frac{2L(1+\iota) + (P + P^L)}{4} > \left(\frac{3-\rho}{4}\right) L(1+\iota) + \left(\frac{1+\rho}{4}\right) P^L(1-\sigma) - \left(\frac{1-\rho}{4}\right)[L(1+\iota) - P(1-\sigma)],$$

which, after some algebra, is indeed true whenever $P > P^L$.

Case II. $D^C < D/2$. In this Case the capital constraint is binding, so that both loans must be sold. Consequently, net proceeds from unbundled whole loan sale are D^L. As an alternative, consider the net proceeds from bundling the loans together through a cross-default clause. The net improvement to portfolio value (given an external sale perspective) from bundling the loans is Δ^L, as defined in Eq. (8). The cost of bundling is the compensation that must be paid to the borrower for bundling together previously unbundled loans. This cost is Δ, as defined in Eq. (6). Thus, relative to D^L, the net benefit to loan bundling is $\Delta^L - \Delta = p_3(P - P^L)(1 - \sigma) > 0$. Therefore, the insider is better off to bundle the loans together when whole loan sale is contemplated. The net external proceeds from a bundled loan sale are $D_B^L - \Delta$.

Proof of Lemma 4 (*Multiple asset/cross-default credit support*). Solve Eqs. (10) and (11) simultaneously for α_B and $i_{J,B}$. It is straightforward to show that $1 - \alpha_B < 1 - \alpha_S$.

Proof of Lemma 5 (*Strong dominance of securitization alternative*). We wish to show that portfolio value to the issuer from securitization exceeds portfolio value from whole loan sale. To do this, there are three cases to consider.

Case I. $D^C < D/2$. From Lemma 3, whole loan sale requires that both loans must be liquidated and that this will occur at a discount to fundamental value. From Proposition 1, it is clear that, if the loans are bundled together (to form one loan), securitization payoffs will exceed whole loan sale payoffs since at least some of the lemons-related marketing costs can be internalized by retaining the junior security.

Case II. $D/2 \leq D^C < D$ and $D - L\alpha_B \leq D^C$. In this Case it is feasible to sell one loan to satisfy the capital constraint. However, because $D - L\alpha_B \leq D^C$, issuance of a senior security satisfies the capital constraint with no lemons marketing costs. Consequently, the value associated with securitization exceeds the value associated with liquidating one whole loan.

Case III. $D/2 \le D^C < D$ and $D - L\alpha_B > D^C$. In this Case, issuing a senior security does not satisfy the capital constraint. Hence, we must show that total proceeds from issuing a riskless senior as well as a risky junior security exceed the proceeds from liquidating one whole loan. Consider the contra-positive, i.e., that whole loan sale dominates securitization. This implies that $((D + D^L)/2) > D(1 - \pi_B) + D_B^L\pi_B$, where

$$\pi_B = \frac{D - L\alpha_B - D^C}{D - L\alpha_B}.$$

In order for this inequality to hold it is apparent that $\pi_B > 1/2$, since $D^L < D_B^L$. $\pi_B > 1/2$ implies that $D - L\alpha_B > 2D^C$. However, by assumption, $D \le 2D^C$. Given that $D \le 2D^C$, it cannot be the case that $D - L\alpha_B > 2D^C$ as well (given that α_B is positive, which it always is). Therefore, we have a contradiction, and securitization dominates whole loan sale.

Proof of Proposition 2 (*Optimal liquidation strategy, multiple asset/cross-collateralized security*). Lemmas 3 and 5 generate the conclusion that a security with cross-defaulted loans is at least as valuable as any other feasible liquidation strategy. To show that the two cases found in the proposition hold, just follow the basic logic seen in the proof of Proposition 1. We must also show that several additional assertions made in the proposition are true. First, $D - L\alpha_B < D - L\alpha_S$ follows directly from Lemma 4. Next, straightforward algebra verifies that $\pi_B < \pi$. Third, to show that $(1 - \pi_B)D + \pi_B D_B^L > (1 - \pi)D + \pi D^L$, it must be that $\pi_B(D - D_B^L) < \pi(D - D^L)$. This is clearly true, since $\pi_B < \pi$ and $D_B^L > D^L$.

Proof of Lemma 6 (*Liquidation versus renegotiation incentives, junior securityholder control*). First, we previously assumed that $P^L(1 - \sigma^2) \ge L(1 + \iota)$. This implies that $P^L \ge P(1 - \sigma)$ which, in turn, implies that the payoff to the junior securityholder given a down state after extension is $L(1 - \alpha)i_J$ (given that $P^L(1 - \sigma)^2 > \iota L$). Given this fact, extension will be preferred if

$$\frac{L(1 - \alpha)(1 + 2i_J)}{2} + \mathscr{C} > P(1 - \sigma) - L\alpha.$$

Using the par value pricing relationship stated in the lemma, the above inequality holds if $1 - \alpha < 1 + \iota - (P^L(1 - \sigma)^2)/L$. When $1 - \alpha \ge 1 + \iota - (P^L(1 - \sigma)^2)/L$, it is straightforward to show that the payoffs from workout and extension are equal to one another.

Proof of Lemma 7 (*Liquidation versus renegotiation incentives, senior securityholder control*). We will first show that terminating workout is weakly preferred to loan extension over all α (Cases I and II). Then we will show that terminating workout is weakly preferred to immediate liquidation over all α (Cases III and IV).

Case I. $1 - \alpha \leq 1 + \iota - ((P^L(1-\sigma)^2 + \mathscr{C}^L)/L)$ (Extension alternative, low subordination level). In this Case the payoff to the senior securityholder from a terminating workout is $P^L(1-\sigma) - L\iota$ if $1 - \alpha < 1 + \iota - ((P^L(1-\sigma))/L)$ and is $L\alpha$ if $1 + \iota - ((P^L(1-\sigma))/L) \leq 1 - \alpha \leq 1 + \iota - ((P^L(1-\sigma)^2 + \mathscr{C}^L)/L)$. When subordination levels are lower than those determined from Proposition 1, there is not enough (perceived) payoff from workout to result in a full payoff to the senior security. In either subcase, the payoff to the senior securityholder from loan extension is

$$\frac{L\alpha - (\mathscr{C}^L - L\iota) + P^L(1-\sigma)^2 - L\iota}{2} + \mathscr{C}^L - L\iota.$$

The explanation of this payoff is as follows. Given his information set, the senior securityholder will request and receive a continuation payment from the borrower of $\mathscr{C}^L$. However, interest of $L(1-\alpha)i_J = L\iota$ must be paid to the junior security at time 1 to continue. But, because the senior security receives a known amount of $\mathscr{C}^L - L\iota$ from extending, this amount must be subtracted from the face security value of $L\alpha$. Thus the payoff from a good state realization at time 2 is $L\alpha - (\mathscr{C}^L - L\iota)$. Alternatively, the payoff from a bad state payoff at time 2 is simply $P^L(1-\sigma)^2 - L\iota$ (which is always less than $L\alpha - (\mathscr{C}^L - L\iota)$ whenever $1 - \alpha \leq 1 + \iota - ((P^L(1-\sigma)^2 + \mathscr{C}^L)/L)$. Therefore, terminating workout will be preferred to loan extension whenever

$$\min\{P^L(1-\sigma) - L\iota, L\alpha\} > \frac{L\alpha - (\mathscr{C}^L - L\iota) + P^L(1-\sigma)^2 - L\iota}{2} + \mathscr{C}^L - L\iota.$$

Straightforward algebra and use of the par valuation relationship stated in the body of Lemma 6 verifies that this strict inequality holds.

Case II. $1 - \alpha > 1 + \iota - ((P^L(1-\sigma)^2 + \mathscr{C}^L)/L)$ (Extension alternative, high subordination level). In this Case the payoff to the senior security given a terminating workout is $L\alpha$. The payoff to extension is

$$\frac{L\alpha - (\mathscr{C}^L - L\iota) + \min\{P^L(1-\sigma)^2 - L\iota, L\alpha - (\mathscr{C}^L - L\iota)\}}{2} + \mathscr{C}^L - L\iota,$$

which can be easily shown to be always less than or equal to the payoff from workout.

Case III. $1 - \alpha < 1 + \iota - ((P^L(1 - \sigma) - K)/L)$ (Liquidation alternative, low subordination level). In this Case, the senior security payoff from liquidating is $P^L(1 - \sigma) - L\iota - K$, which is less than the payoff that could be obtained from working out. Consequently, terminating workout dominates liquidation.

Case IV. $1 - \alpha \geq 1 + \iota - ((P^L(1 - \sigma) - K)/L)$ (Liquidation alternative, high subordination level). In this case the payoff to the senior security is $L\alpha$ regardless of whether immediate liquidation or terminating workout occurs. Hence the senior securityholder is indifferent between the two outcomes.

In sum, terminating workout is always weakly preferred to extension or immediate liquidation. However, when subordination levels are high, the senior securityholder may be indifferent between workout or these two alternatives.

Proof of Proposition 3 (*Governance and extension compatible subordination level*). From Proposition 1, when there is no extension we can do no better than setting credit support equal to $1 - \alpha_S$. To obtain the extension compatible credit support level result, use Eq. (15) and the par value junior security relationship seen in Eq. (4) to solve for α^{EC} and i_J^{EC}. Given that the capital constraint is satisfied, it is clear that total security value equals D.

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