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Skin in the Game and Moral Hazard

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Abstract

What determines equilibrium securitization levels, and should they be regulated? To address these questions we develop a model where originators can exert unobservable effort to increase asset quality, subsequently having private information regarding quality when selling ABS to rational investors. In equilibrium, all originators have low/zero retentions if they are financially constrained and/or prices are sufficiently informative. Asymmetric information lowers effort incentives in all equilibria. Effort is promoted by junior retentions, investor sophistication, and informative prices. Optimal regulation promotes effort while accounting for investor-level externalities. It entails either a menu of junior retentions or a single junior retention with size decreasing in price informativeness. Mandated market opacity is only optimal amongst regulations failing to induce originator effort.

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Over the past two decades securitization markets have been an important source of funding for financial and non-financial corporations. As shown in Table 1, mortgage-related and non-mortgage-related asset-backed securities (ABS below) accounted for over 30% of U.S. bond market issuance each year from 1996 to 2011, with the percentage exceeding 50% from 2002 to 2005. As shown in Table 2, non-mortgage-related ABS cover a diverse range of assets outside the housing sector: equipment; auto loans and leases; credit card debt; student loans; and trade receivables. Securitization markets collapsed in 2008, with issuance falling by 44% from 2007 levels. The majority of the decline is accounted for by the virtual disappearance of non-agency mortgage-backed securities. However, it is apparent that weakness extends beyond the housing sector. For example, issuance of credit card and student loan ABS has also fallen significantly in recent years.

Gorton (2010) argues that concern over asymmetric information regarding true asset values accounts for the collapse of ABS markets, and disputes the existence of moral hazard, e.g. the alleged failure of originators to carefully screen borrowers. In contrast, Mishkin (2008) and Stiglitz (2010) argue that low originator retentions created moral hazard. In their behavioral narrative, unwary investors had simply overlooked moral hazard pre-crisis. Indeed, implicit in much discussion surrounding the crisis is the notion that ABS featuring low originator retentions are indicative of market irrationality. Moreover, implicit in the recently-passed Dodd-Frank Act is the view that government-mandated retentions will increase social welfare.

Understanding equilibrium in ABS markets and the formulation of optimal regulation have been hindered by the absence of a comprehensive theoretical framework allowing one to answer some fundamental questions. First, what levels of securitization should one expect to observe in unregulated ABS markets? Clearly, addressing this question is necessary before reaching any conclusion regarding whether observed structures are rational. Second, are there market failures and, if so, can a regulator improve upon unregulated market outcomes? Third, what are the policy options and conditions under which each dominates?

This paper develops a tractable, yet comprehensive, framework to address the positive and normative questions posed above. Although the primary focus is ABS, the economic setting is more general: Ex ante, an agent ("the originator" below) considers exerting costly unobservable effort to increase the probability of producing a high quality asset. This effort decision is made anticipating subsequent issuance of claims backed by the asset to fund a scalable investment with positive NPV.[1] The issuer privately observes the true asset quality (high or low) but investors do not. There are three categories of investors: a speculator; competitive uninformed marketmakers; and rational uninformed investors with hedging motives. The originator can permit (block) speculator information production by choosing *transparency (opacity).*

The model delivers a rich set of predictions regarding how issuers will behave in unregulated ABS markets. We first investigate what securities will be marketed and retained by privately informed issuers. One possible equilibrium is a separating equilibrium in which high types separate from low types by retaining the minimal size junior tranche needed to deter mimicry by low types who fully securitize. In addition to this separating equilibrium, there may exist equilibria in which all originators pool and adopt identical structures. Pooling equilibria exist if both originator types are weakly better off than at the separating equilibrium.

We show that if any pooling equilibrium can be sustained, a pooling equilibrium with full securitization can also be sustained.[2] In this sense, the *originate-to-distribute* business model (OTD below), which features zero issuer retentions, should not be viewed as an anomaly. However, we also show that pooling at full securitization can only be sustained as an equilibrium if prices are sufficiently informative and the originator's project NPV is sufficiently high. Intuitively, a high type will be willing to pool provided informed speculation drives prices sufficiently close to fundamentals. We also show some observed practices are hard to reconcile with notions of rational equilibrium. For example, a deliberate attempt by issuers to preclude speculative information production via opacity is shown to be inconsistent with investor sophistication. A high type should defect from opacity

[1] The fact that securities are written on an asset in place, excluding the new investment, departs from some corporate finance settings and models.

[2] Here we refer only to the continuation equilibrium.

and sophisticated investors should know this.

We next evaluate ex ante effort incentives of originators who anticipate such marketing of securities under asymmetric information. Since effort increases the probability of developing a high quality asset, incentives are increasing in the size of the anticipated wedge between payoffs accruing to owners of high and low quality assets. Critically, asymmetric information at the time of securitization reduces the size of this wedge, lowering effort incentives. In this way, the model shows that the asymmetric information view of Gorton (2010) and the moral hazard view of Mishkin (2008) and Stiglitz (2010) are not competitors. Rather, if there is indeed asymmetric information between originator-distributors and investors at the time of security issuance, then in all possible equilibria, effort incentives are lower than under observable types. In the separating equilibrium incentives are diminished since high types bear signaling costs. In pooling equilibria, incentives are diminished by price noise. In the extreme case of opacity and zero retentions, there is zero effort incentive.

The analysis of unregulated ABS markets reveals two welfare arguments for government-mandated retentions. First, privately optimal retentions can be socially suboptimal since originators do not internalize effects on investor welfare. When the high type credibly signals via junior retentions he benefits directly from his own marketed securities being priced at fundamentals on the issuance date. But he does not internalize the benefit accruing to investors who can now efficiently share risks being symmetrically informed. The second argument favoring regulation is that the payoff differential between high and low types at the (interim) securitization stage may be insufficient to induce originator effort. In order to encourage effort, low types should get low payoffs. But if retentions are not mandated, a low type can always achieve his first-best payoff by admitting he is a low type and proceeding to securitize the entire asset. Government-mandated retentions offer a commitment device against markets implementing such incentive-reducing equilibria. As reflected in the model, equilibria with low effort incentives are especially problematic inasmuch as poor performance of a given originator's asset can trigger reductions in the value of other assets. For example, Campbell, Giglio, and Pathak (2011) and Gerardi et al. (2012) document negative externalities associated with foreclosed and/or distressed real estate.

A socially optimal mandatory retention scheme promotes effort by increasing the spread between payoffs to high and low types at the securitization stage, while accounting for costs imposed on investors as well as originators. There are two regulatory options. In a *separating regulation* issuers must choose from a menu of retentions. The menu is designed so that the chosen retention reveals the issuer's private information. In a *pooling regulation* all issuers must retain the same claim.

In the optimal separating regulation, originators choose from a menu of strictly positive *junior* tranche retentions of differing size. Although menus featuring other retained claims (e.g. fractions of total cash flow) can also induce truthful revelation of private information, junior tranche retentions minimize the cost of underinvestment by originators. In contrast to the separating equilibrium of unregulated markets, the separating regulation forces even the low type to retain a junior claim. This regulation achieves efficient risk-sharing across investors since the originator's chosen retention reveals his private information, thus insulating investors from adverse selection.

In the optimal pooling regulation, issuers are forced to hold identical *junior* tranches. Intuitively, the gap between the interim payoffs of high and low types is maximized if originators hold a junior claim. The size of the mandated retention is lower when price informativeness is high. That is, junior retentions and market discipline are substitutes in terms of effort incentives. Thus, the exact details of the optimal pooling regulation requires taking a view on informational efficiency. The disadvantage of the pooling regulation is that it entails costly speculator effort and distortions in risk-sharing across investors. However, the pooling scheme imposes lower underinvestment costs on originators if prices are sufficiently informative.

Our model is most similar to those of Leland and Pyle (1977) and Myers and Majluf (1984) in that we consider equilibrium security issuance by a privately informed originator. We depart from canonical signaling models in three ways. First, we consider that there is an effort decision to be made before the securitization stage, with costly effort increasing the probability of obtaining a high value asset. Second, at the securitization stage, securities are traded by an endogenously informed speculator. Third, rational uninformed investors with hedging needs also trade securities. The first model element allows us to address how the anticipation of interim-stage asymmetric information affects ex ante effort incentives. The second model element permits assessment of the role of price discipline. The third model element admits a proper analysis of social welfare and the efficiency of risk-sharing in light of potential adverse selection facing uninformed investors.

Dang, Gorton and Holmström (2011) also analyze information production and social welfare, but ignore originator moral hazard. Similar to their analysis, we show opacity combined with full securitization maximizes *interim-stage* social welfare.[3] However, we show opacity is only socially optimal amongst regulatory schemes failing to induce originator effort. Intuitively, opaque markets fail to provide price discipline. Thus, the choice between opacity and transparency must weigh interim-efficient risk-sharing against ex ante moral hazard.

Rajan, Seru and Vig (2010) analyze a setting most similar to ours in that they too consider a bank that can exert unobservable effort prior to entering into securitization contracts. However, they assume each loan is fully securitized with an exogenous probability. In contrast, we first characterize the full set of equilibrium ABS structures and then assess the effect of each on effort incentives. Their model does not allow for informed trading and they do not analyze optimal regulation.

Gorton and Pennacchi (1995), Parlour and Plantin (2008), and Plantin (2011) consider a different agency setting in which contracting occurs before a bank chooses effort. The respective agency problems are different. The pre-contracting effort we consider is akin to screening of loan applicants while the post-contractual effort they consider is akin to monitoring of loan recipients. These papers do not analyze speculative information production or optimal regulation. Plantin (2011) shares one of our predictions: securitization rates should be higher if banks place high value on immediate funding. Hartman-Glaser, Piskorski and Tchistyi (2012) also analyze optimal contracting before unobservable effort. Their optimal dynamic contract features a single positive transfer to the agent made only after a sufficient time with no defaults. Their privately optimal contract is socially optimal and there is no case for regulation.

[3] Pagano and Volpin (2010) also develop a model of tradeoffs associated with primary market opacity.

The role of price informativeness in alleviating moral hazard has been analyzed in other contexts. Holmström and Tirole (1993), Maug (1998), Kahn and Winton (1998), Aghion, Bolton and Tirole (2004) and Faure-Grimaud and Gromb (2004) show price informativeness promotes insider effort. Each of these papers assumes pure noise trading, precluding social welfare analysis. These papers do not analyze socially optimal mandatory retention regulations.

The remainder of the paper is as follows. Section I describes the model. Section II analyzes the final continuation game in which market-makers set prices. Section III analyzes the subgame in which the privately informed originator chooses retentions. Section IV analyzes originator effort incentives. Section V contains an analysis of the sources of welfare losses in unregulated market equilibria, followed by an analysis of socially optimal mandatory retention regulations.

I. The Model

This section describes the production technology, endowments, investor preferences and the timing of events. Figure 1 provides an overview of the time-line.

A. Production Technology, Endowments and Preferences

There is a single storable consumption good and four periods: 1, 2, 3 and 4. Agents consume in periods 3 and 4 and consumption must be non-negative. The originator (denoted O) has one unit of endowment in period 1 which he can use to fund a verifiable investment in an asset generating a verifiable cash flow in period 4. O has no other endowment and is risk neutral with von Neumann-Morgenstern (vNM) utility function $C_3 + C_4$. At the time of the initial investment, O has the option to exert unobservable effort which increases expected cash flow. In particular, by exerting effort O increases the probability of the asset being of high quality from $\underline{\rho}$ to $\overline{\rho}$, where $0 < \underline{\rho} < \overline{\rho} < 1$. A high quality asset generates cash flow H with probability $\overline{q}$ and L with probability $1 - \overline{q}$. A low quality asset generates H with probability $\underline{q}$ and L with probability $1 - \underline{q}$. It is assumed: $0 < \underline{q} < \overline{q} < 1$; $L \in (0, H)$; and $\underline{q}H + (1 - \underline{q})L > 1$. This last assumption implies O always finds it optimal to invest his initial endowment in the asset.

The originator effort cost is denoted c, and this cost is non-pecuniary. We assume the effort cost is less than the expected increase in cash flow that it produces.

$$A1 : 0 < c < (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L).$$

Assumption A1 implies the originator would exert effort if he planned to retain all claims to future cash flow.

At the start of the *interim period* (period 2), Nature draws q. Then O privately observes q, with q being labeled the asset *type* below. Outside investors do not have access to the same information as O at this time and cannot observe q. For example, an originator may have superior granular information regarding local real estate market conditions, permitting a superior forecast of the terminal asset payoff.

At the start of period 3, O gets exclusive access to a scalable linear investment technology providing a private benefit $\beta > 1$. The private benefit is not observable or verifiable and cannot be transferred to other agents. Since the private benefit cannot be sold to other agents, any funding for the new investment must come from marketing some portion of the cash flows coming from the original underlying asset.[4]

There are three categories of investors. First, there is a continuum of deep-pocketed risk neutral market-makers (MM below). Each has a vNM utility function $C_3 + C_4$. Second, there is a risk neutral speculator S with vNM utility function $C_3 + C_4$. Her period 3 endowment is $y_3^s \geq H$, so she has sufficient wealth to buy the entire asset. S is unique in having the requisite skill to learn about asset quality. The possibility of the speculator learning about asset quality depends on whether there is opacity or transparency. Under *opacity* the speculator does not receive any signal. Under *transparency* the speculator can receive an informative signal, but this requires her to incur a fixed non-pecuniary effort cost $e \geq 0$. If the speculator exerts effort, her signal is $s \in \{\underline{s}, \overline{s}\}$ with:

$$\Pr[q = \overline{q} | s = \overline{s}] = \Pr[q = \underline{q} | s = \underline{s}] = \sigma.$$

[4]This setup is equivalent to an alternative setup without new investment but with O being impatient and having vNM utility function $\beta C_3 + C_4$.

The final set of investors is a measure-one continuum of agents who have no information regarding the asset type, labeled *uninformed investors* (UI). The UI are identical ex ante aside from idiosyncratic differences in risk-aversion parameters (θ) discussed below. UI are risk-neutral over period 3 consumption and risk-averse over period 4 consumption.

An extant literature treats uninformed trading as exogenous. Although such noise trading frameworks are a bit simpler, they suffer from two weaknesses in terms of policy analysis. First, noise trading models preclude analysis of total social welfare. Second, by treating uninformed investors as price-insensitive, such models fail to capture deadweight losses arising from portfolio distortions in response to perceived security mispricing. In light of these weaknesses, we depart from the standard noise trading setup. Instead, we model the UI as choosing portfolios optimally given well-defined utility functions described below.

Prior to the trading of securities in period 3 each UI privately learns whether he is *invulnerable* or *vulnerable* to preference and endowment shocks. The utility function of an arbitrary UI, privately observable to them, is:[5]

$$U(C_3, C_4; \theta, \chi) \equiv C_3 + \theta \min\{C_4 - \chi\phi, 0\}.$$

The preference parameters $\theta \in \Theta \equiv [1, \infty)$ and have density f with cumulative distribution function F. The distribution has no atoms and f is strictly positive. The indicator function χ in the utility function is equal to 1 if and only if the UI is vulnerable. The term $\chi\phi$ captures an adverse utility shock hitting vulnerable UI, with $\phi > 0$ representing a higher critical C_4 threshold confronting vulnerable UI. Vulnerable UI face an endowment shock positively correlated with the asset's cash flow.[6] If the cash flow is H, each vulnerable investor's period 4 endowment is equal to their critical consumption threshold ϕ. If the cash flow is L, their period 4 endowment is 0. By construction, the preference and endowment shocks of the vulnerable UI give them a motive to purchase ϕ units of an Arrow security paying 1 if the realized cash flow is L, and they would do so in the absence of

[5] Smooth utility functions could be assumed at the cost of more complex aggregate demands.

[6] The characterization of equilibrium securitization structures and originator effort incentives are unchanged if there is negative correlation between UI endowments and cash flow.

asymmetric information or funding limitations. It is assumed the aggregate period 3 endowment of the UI, denoted y_3^{ui}, exceeds ϕ so vulnerable UI have ample funds to purchase full insurance should they so choose. Finally, the period 4 endowment of the invulnerable UI is ϕ. Since these investors suffer no adverse preference shock, they have no insurance motive and instead desire to transfer resources from period 4 back to period 3.

One may think of the negative endowment shock hitting vulnerable UI in the event of a low cash flow realization as capturing negative externalities arising from distressed or foreclosed properties. For example, Campbell, Giglio, and Pathak (2011) estimate that a foreclosed home causes a 1% decline in neighboring home prices at a distance of 0.05 mile. Gerardi et al. (2012) argue that the principle source of negative externalities is depressed maintenance expenditures by owners of distressed properties. In light of such effects, other agents who are long real estate in the originator's lending market, e.g. other local lenders or property owners, have a motive to hedge against poor performance of an ABS.

The proportion of vulnerable UI is an independent random variable $v \in \{\underline{v}, \overline{v}\}$, with each possible v equiprobable and $\underline{v} < \overline{v}$. Whether an agent is vulnerable or not is not observable or verifiable to others, nor is their realized endowment. This prevents writing insurance contracts directly on individual endowments. Further, the realized v is not observable or verifiable. Thus, securities markets are necessarily incomplete.

B. Securitization Stage

The *Securitization Stage* takes place in period 2. This stage approximates a shelf registration of securities whereby a prospective issuer of a set of securities registers them in advance and is then free to pull securities "off the shelf" over some time interval without further filing requirements. Shelf registrations are commonly used for ABS.[7] Applying a result of Maskin and Tirole (1992) for signaling games in general, Tirole (2006) shows allowing an issuer to first register a set of claims

[7] Some proposals call for mandatory retentions as a requirement for using the shelf registration procedure. See "SEC Proposes Asset-Backed Securities Reform," 12 April 2010, Harvard Law School Forum on Corporate Governance and Financial Regulation.

and then choose "from the menu" can improve their payoff by restricting the set of equilibria.

The Securitization Stage begins with O registering two securitization structures, $(\underline{\Sigma}, \overline{\Sigma})$ with the number of structures equal to the number of possible types.[8] Each structure specifies the amounts (M_L, M_H) that will paid to outside investors in the respective cash flow states should the originator choose to issue it. Investors are assumed to have limited liability, so payments to them must be non-negative.

Next O, selects one of the registered structures to bring to the market, committing to retain the residual cash flow rights. The payoff vector on the retained security is denoted (R_L, R_H). Since the originator has no outside endowment other than the asset, both R_L and R_H must be non-negative. The cash flow rights retained by the originator are assumed to be a legally verifiable contractual commitment, consistent with the mandatory disclosure rules of Regulation AB of the Securities Exchange Act. It is worth noting that the owner of a high quality asset stands to benefit from such a retention commitment as it allows him to credibly signal positive information.

Total state-contingent payoffs on retained and marketed securities are equal to the cash flow generated by the underlying asset:

$$\begin{aligned} R_L + M_L &= L \\ R_H + M_H &= H. \end{aligned}$$

Notice, the preceding payoff identities assume the originator invests all funds raised from investors in the new investment paying him the private benefit β. That is, it is assumed the originator does not place any of the funds raised from investors into risk-free storage. Doing so would simply allow the originator to raise promised payments to investors by one dollar for each additional dollar raised and stored. This would have no effect on any agent's utility since the originator's level of new investment would be unchanged, while outside investors would be no better or worse off relative to storing the funds on their own accounts.

Voluntary disclosure of additional information is also possible at the Securitization Stage. In

[8] That the number of structures should correspond to the number of types is shown by Maskin and Tirole (1992).

particular, the originator has the option to disclose in the prospectus additional information about the underlying asset (transparency) or not (opacity). This additional information can be used by the speculator to acquire a signal of the asset quality.

C. Trading Stage

The *Trading Stage* of the model takes place in period 3. For simplicity, it is assumed all securities trading takes place in this period, just after investors observe their private information. Thus, informational asymmetries across investors are treated as an inherent feature of securities markets.[9] There are two securities markets: a market for risk-free bonds and a market for an Arrow security paying 1 if the realized cash flow is L. These two securities span the only two verifiable states (L and H), and the introduction of markets for redundant securities would have no effect on the equilibrium set.

At the start of the Trading Stage, S chooses whether to pay e to acquire a signal of the asset type. Recall, signal acquisition is only possible if the originator opted for transparency at the Securitization Stage. Next, each UI privately observes whether he is vulnerable to shocks. Next, each agent other than the MM submits his market order.[10] Each MM observes the aggregate buy order and aggregate sell order. The MM then compete à la Bertrand to clear markets. The originator provides the promised supply of payoffs (M_L, M_H) according to the securitization structure but then engages in no further trading. Clandestine sales by the originator at this stage would contradict the retentions disclosed in the Securitization Stage.[11] The payoff pair (M_L, M_H) is sold on the two markets as M_H units of risk-free bonds and $-(M_H - M_L)$ units of the L-state Arrow security. Equivalently, one can think of the MM as pricing the claim to (M_L, M_H) using the equilibrium Arrow security price.

As is standard in the literature on General Equilibrium with Incomplete markets, short-selling

[9] If one were to attempt trading prior to information revelation, all agents would have incentives to accelerate information gathering.

[10] The characterization of equilibrium retentions is unchanged if one instead considers limit orders.

[11] Regulations AB and M of the Securities Exchange Act prohibit originators from clandestine trading.

is possible in both securities markets, but courts will impose an arbitrarily high utility penalty on any agent who fails to deliver promised payments to securities market counterparties, thus ruling out reneging on short sales.[12]

The model is solved by backward induction. As in Maskin and Tirole (1992), the equilibrium concept is pure strategy *perfect Bayesian equilibrium* (PBE).

D. Benchmark: Observable Types

Before characterizing equilibrium under asymmetric information, it is useful to analyze outcomes if the asset type was observable. This benchmark setting is particularly useful in framing our argument that interim-state asymmetric information regarding asset quality can be understood as a root cause of ex ante moral hazard.

If q was observable, O would market all cash flow and receive securitization proceeds equal to the true expected cash flow $qH + (1-q)L$. Full securitization would occur since $\beta > 1$ implies there are gains from trade, and these would be fully exploited under symmetric information. Therefore, if types were observable, the maximum effort cost the originator would be willing to incur is β times the expected increase in cash flow arising from effort:

$$\widehat{c}_{obq} = \beta(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L). \tag{1}$$

Assumption A1 implies that the originator would pay the cost c if types were observable. Since the originator would exert effort with observable types, a failure of the originator to exert effort in the full model can be understood as arising from asymmetric information at the Securitization Stage regarding asset quality.

Consider finally equilibrium risk-bearing with observable types. If q was observable, the speculator would not pay $e > 0$. The MM would set the price of the L-state Arrow security to $1 - q$. At that actuarially fair price, all vulnerable UI would fully insure against negative endowment shocks, buying ϕ units of the L-state Arrow security.

[12] See Dubey, Geanakoplos and Shubik (2005) for GEI with finite penalties to reneging and endogenous default.

II. The Trading Stage

This section determines UI security demand, speculator effort and price setting by the MM. Given that we confine attention to pure strategies, there are two possible information configurations at the start of the Trading Stage: all agents know the asset's type or all agents other than the originator are uninformed regarding the type. We consider these two cases in turn.

A. Asset Type Common Knowledge

Competition between MM ensures risk-free bonds trade at price 1 per unit of face value. Let P denote the price the L-state Arrow security. If the type (q) is known to all agents at the start of the Trading Stage, the MM set $P = 1 - q$. With the type known, the speculator has no incentive to incur effort costs, and any trading by the speculator is of no consequence for any agent's expected utility, including her own.

Since securities markets span the verifiable cash flow states, an uninformed investor's portfolio problem can be framed as a choice of state-contingent period 4 portfolio payoffs, here denoted (x_L, x_H). With common knowledge of type, an optimal UI portfolio solves:

$$\max_{(x_L, x_H)} \quad y_3^{ui} - x_H q - x_L(1-q) + q\theta \min\{C_4^H - \chi\phi, 0\} + (1-q)\theta \min\{C_4^L - \chi\phi, 0\} \tag{2}$$

subject to

$$C_4^L = \phi(1-\chi) + x_L; \quad C_4^H = \phi + x_H; \quad C_4^L \geq 0; \quad C_4^H \geq 0.$$

As shown in the appendix, one finds the following optimal UI portfolios under common knowledge of q. Vulnerable UI purchase ϕ units of the L-state Arrow security while invulnerable UI sell ϕ units of the risk-free bond. The sharing of risks under common knowledge of type is socially efficient ex post, with all vulnerable UI buying from the MM fairly priced insurance against costly consumption shortfalls.

B. Asset Type not Common Knowledge

Consider the remaining case when asset type is not common knowledge at the start of the Trading

Stage. Here the optimal period 4 portfolio for an arbitrary UI solves:

$$\max_{(x_L,x_H)} \quad y_3^{ui} - x_H[1 - E(P|\chi)] - x_L E(P|\chi) \tag{3}$$
$$+[\rho\overline{q} + (1-\rho)\underline{q}]\theta \min\{C_4^H - \chi\phi, 0\} + [1 - (\rho\overline{q} + (1-\rho)\underline{q})]\theta \min\{C_4^L - \chi\phi, 0\}$$

subject to

$$C_4^L = \phi(1-\chi) + x_L; \quad C_4^H = \phi + x_H; \quad C_4^L \geq 0; \quad C_4^H \geq 0.$$

As shown in the appendix, the solution of the preceding program implies the following optimal portfolios. Invulnerable UI sell ϕ units of the risk-free bond. Vulnerable UI buy ϕ units of the L-state Arrow security if $\theta \geq \widehat{\theta}$, where:

$$\widehat{\theta} \equiv \frac{E[P|\chi = 1]}{\rho(1-\overline{q}) + (1-\rho)(1-\underline{q})}. \tag{4}$$

The remaining vulnerable UI do not trade. Under optimal portfolios, vulnerable UI with $\theta \geq \widehat{\theta}$ achieve the critical consumption level $C_4 = \phi$ regardless of the realized asset payoff. In contrast, vulnerable UI with $\theta < \widehat{\theta}$ consume ϕ in state H but only 0 in state L. Intuitively, all vulnerable UI have an incentive to insure against consumption shortfalls by purchasing ϕ units of L-state payoffs. However, if they expect the Arrow security price to exceed its expected payoff ($\widehat{\theta} > 1$), they forego insurance provided their personal loss θ from consumption shortfalls is sufficiently low.

Consider then Trading Stage outcomes if the originator had chosen opacity in the Securitization Stage. In this case, the MM know order flow cannot possibly contain any information regarding the asset type. Consequently, regardless of the observed order flow, the MM set the price of the Arrow security equal to $1 - \rho\overline{q} - (1-\rho)\underline{q}$. It follows from equation (4) that in this case $\widehat{\theta} = 1$. Thus, under opacity risk-sharing is efficient since all vulnerable UI purchase units ϕ of the L-state Arrow security.

Consider next Trading Stage outcomes under transparency, conjecturing the speculator will indeed find it optimal to acquire the noisy signal of the asset type provided e is sufficiently low. Integrating over uninformed investors' optimal demands (x_L^*), the aggregate UI demand for the

L-state Arrow security under transparency is:

$$X_L^{UI} \equiv \int_1^{\infty} x_L^*(\theta) f(\theta) d\theta = v\phi[1 - F(\widehat{\theta}_{tran})] \quad \forall \quad v \in \{\underline{v}, \overline{v}\}. \tag{5}$$

Consider next the speculator's trading strategy in the market for the L-state Arrow security. The speculator cannot make trading gains by shorting, since the MM will justifiably impute any short-selling to the speculator. So she will place buy orders for the L-state Arrow claim when she observes the negative signal $\underline{s}$. In order for the speculator to make positive expected trading gains, she must choose a buy order size such that the MM cannot infer s with probability one. This can only be achieved by choosing an order size for the L-state Arrow claim such that MM cannot distinguish between: speculator buying (based upon signal $\underline{s}$) cum low UI demand ($\underline{v}$) versus speculator not buying (based upon signal $\overline{s}$) and high UI demand ($\overline{v}$). Using the aggregate demand expression from equation (5), we obtain the following condition pinning down the buy order size (X_L^S) that masks the speculator across the states ($\underline{s}, \underline{v}$) and ($\overline{s}, \overline{v}$):

$$X_L^S + \underline{v}\phi[1 - F(\widehat{\theta})] = \overline{v}\phi[1 - F(\widehat{\theta})] \Rightarrow X_L^S = (\overline{v} - \underline{v})\phi[1 - F(\widehat{\theta})]. \tag{6}$$

For brevity, let:

$$\Omega \equiv \phi[1 - F(\widehat{\theta})]. \tag{7}$$

Table 3 depicts potential orders confronting the MM on the equilibrium path. The MM infer $s = \overline{s}$ when the state is ($\overline{s}, \underline{v}$) and $s = \underline{s}$ when the state is ($\underline{s}, \overline{v}$). However, MM cannot infer s in the states ($\overline{s}, \overline{v}$) and ($\underline{s}, \underline{v}$). Using Bayes' rule the MM revise beliefs and set price as follows based upon aggregate demand for the L-state Arrow security (X_L^{AG}):

$$\begin{aligned} P(X_L^{AG}) &= 1 - \overline{q} + (\overline{q} - \underline{q}) \Pr\big[[q = \underline{q} | X_L^{AG}\big] \\ \Pr[q &= \underline{q} | X_L^{AG} = (2\overline{v} - \underline{v})\Omega] = \frac{(1-\rho)\sigma}{\rho + \sigma - 2\sigma\rho} \\ \Pr[q &= \underline{q} | X_L^{AG} = \overline{v}\Omega] = 1 - \rho \\ \Pr[q &= \underline{q} | X_L^{AG} = \underline{v}\Omega] = \frac{1 - \rho - \sigma + \sigma\rho}{1 - \rho - \sigma + 2\sigma\rho}. \end{aligned} \tag{8}$$

Since each UI has measure zero, any order flow configuration off the equilibrium path must arise from a deviation by the speculator. Off the equilibrium path, MM form worst-case beliefs from the speculator's perspective. An aggregate buy (sell) order off the equilibrium path is imputed to her observing $\underline{s}$ ($\overline{s}$). Given such beliefs, no deviation generates a positive gross trading gain for the speculator.

Having pinned down the speculator's optimal signal-contingent trading strategy, we consider next the conditions under which she will pay the effort cost e. If the speculator acquires the signal, her equilibrium expected gross trading gain G as computed from Table 3 is:

$$G = \frac{1}{2}\rho(1-\rho)(\overline{q}-\underline{q})(2\sigma-1)(\overline{v}-\underline{v})\phi[1-F(\widehat{\theta})]. \tag{9}$$

It is readily verified that if the speculator were to instead remain uninformed, her optimal strategy is to abstain from trading.[13]

Returning to Table 3 we find that under transparency vulnerable UI form the following price expectation:

$$\begin{aligned} E[P|\chi &= 1] = \rho(1-\overline{q}) + (1-\rho)(1-\underline{q}) + \rho(1-\rho)(\overline{q}-\underline{q})(2\sigma-1)\left(\frac{\overline{v}-\underline{v}}{\overline{v}+\underline{v}}\right) \\ \Rightarrow \quad & \widehat{\theta}_{tran} = 1 + \frac{\rho(1-\rho)(\overline{q}-\underline{q})(2\sigma-1)\left(\frac{\overline{v}-\underline{v}}{\overline{v}+\underline{v}}\right)}{\rho(1-\overline{q})+(1-\rho)(1-\underline{q})}. \end{aligned} \tag{10}$$

The remainder of the analysis assumes the fixed cost of speculator effort satisfies the following assumption, which implies the speculator exerts effort in the Trading Stage provided the originator chose transparency at the Securitization Stage.

$$A2: e \leq \frac{1}{2}\rho(1-\rho)(\overline{q}-\underline{q})(2\sigma-1)(\overline{v}-\underline{v})\phi\left[1-F\left(1+\frac{\rho(1-\rho)(\overline{q}-\underline{q})(2\sigma-1)\left(\frac{\overline{v}-\underline{v}}{\overline{v}+\underline{v}}\right)}{\rho(1-\overline{q})+(1-\rho)(1-\underline{q})}\right)\right].$$

And it then follows from equation (10) that risk-sharing will be distorted under transparency since a subset of the vulnerable UI fail to insure given that the expected L-state Arrow security price is above its expected payoff.

The following proposition summarizes the continuation equilibrium at the Trading Stage.

[13] Trading based upon a completely uninformative signal generates a loss.

Proposition 1 *[Trading Stage] If the type is common knowledge: the L-state Arrow security price is $P = 1 - q$ and all vulnerable investors insure against shocks. Under opacity: $P = \rho(1 - \overline{q}) + (1 - \rho)(1 - \underline{q})$ and all vulnerable investors insure against shocks. Under transparency: the speculator acquires the costly signal; P is set according to equation (8); and vulnerable investors only insure against shocks if $\theta \geq \widehat{\theta}_{tran}$ as defined in equation (10).*

III. The Securitization Stage

Continuing the backward induction, this section describes the set of continuation equilibria at the Securitization Stage. This subgame begins with Nature drawing the type $q \in \{\underline{q}, \overline{q}\}$, which is then privately observed by the originator. The other players have a common prior ρ for the probability of the type being $\overline{q}$. This ρ-contingent subgame may be of independent interest as it resembles a standard corporate finance signaling game where the equilibrium set is predicated upon investor priors. For simplicity, we borrow terminology from Tirole (2006) when possible.

Recall, at the Securitization Stage the originator performs a shelf-registration of two securitization structures and then chooses one from the menu. A *separating menu* contains two different structures such that each type prefers a different structure. If such a menu is registered, the subsequent choice of structure reveals the type to all agents, so the type becomes common knowledge at the start of the Trading Stage. A *pooling menu* contains only one securitization structure so there is no possibility of the type being revealed by the choice of structure, so the type is not common knowledge at the start of the Trading Stage.[14]

We first characterize the *least-cost separating* (LCS) allocations which maximize the utility of each originator type within the set of separating menus. We conjecture and then verify the high type will not mimic the low type. The LCS allocations allow the low type to fully securitize his asset since this raises his payoff and relaxes the non-mimicry (NM) constraint. The high type's LCS

[14] Another class of pooling menus subsumed in this case is when the menu contains two distinct structures but both types would choose the same structure from it.

retention solves:

$$\max_{(R_L \geq 0, R_H \geq 0)} \quad \overline{q}R_H + (1-\overline{q})R_L + \beta[\overline{q}(H - R_H) + (1-\overline{q})(L - R_L)] \tag{11}$$

subject to the following NM constraint:

$$\beta[\underline{q}H + (1-\underline{q})L] \geq \underline{q}R_H + (1-\underline{q})R_L + \beta[\overline{q}(H - R_H) + (1-\overline{q})(L - R_L)].$$

Solving the above program yields the following lemma.

Lemma 1 *The Least-Cost Separating Allocations entail zero retention by the low type while the high type signals by retaining a junior security with payoffs* $R_L = 0$ *and* $R_H = \beta(\overline{q} - \underline{q})(H - L)/(\beta\overline{q} - \underline{q})$. *The respective continuation utilities for the low and high type are:*

$$\begin{aligned} \underline{U}_{lcs} &= \beta[\underline{q}H + (1-\underline{q})L] \\ \overline{U}_{lcs} &= \beta[\overline{q}H + (1-\overline{q})L] - (\beta - 1)\overline{q}\left[\frac{\beta(\overline{q} - \underline{q})(H - L)}{(\beta\overline{q} - \underline{q})}\right]. \end{aligned} \tag{12}$$

In an LCS allocation, the low type receives his perfect information payoff. The high type receives his perfect information payoff minus foregone NPV due to signaling via retention of a claim paying zero if the realized cash flow is L. Throughout the analysis we refer to such claims as *junior* in that their payoff is equal to that of a junior claim when there is a senior debt claim with face value between L and H. The next lemma is parallel to a general result from Maskin and Tirole (1992), showing that the LCS payoffs constitute a lower bound.

Lemma 2 *The set of equilibrium menus at the Securitization Stage consists of the Least-Cost Separating Allocations and any pooling menus giving each originator type at least his respective Least Cost Separating Allocation payoff.*

In light of the preceding lemma, the PBE in which the LCS allocations are proposed will be denoted as the *Least-Cost Separating Equilibrium* (LCSE). Note, the lemma implies there can be no other separating equilibrium. Thus, we turn next to determination of pooling equilibria. Before doing so, it is worth emphasizing that the lemma shows the equilibrium set consists of pooling structures that Pareto-improve upon the LCSE from the perspective of originators. These structures do not have to be Pareto-improving for all agents in order to be PBE. To the contrary, it is apparent that any pooling cum transparency makes the UI worse off by exposing them to adverse selection in securities trading.

Lemma (2) provides a simple algorithm for assessing whether a pooling structure is in the set of PBE. One must simply compute expected utilities across the two originator types and compare them with the respective LCSE utilities. Originator utility in the event of pooling is equal to β times expected securitization revenues, plus the expected payoff on the retained security, with both expectations computed conditional upon the privately known type. Under opacity, expected securitization revenues are equal across types, i.e. there is no market discipline. Thus, under opacity, the following two inequalities must be satisfied by any pooling equilibrium:

$$\begin{aligned} \underline{U}_{op} &= \beta\left[\rho\left(\overline{q}M_H + (1-\overline{q})M_L\right) + (1-\rho)(\underline{q}M_H + (1-\underline{q})M_L)\right] + \underline{q}R_H + (1-\underline{q})R_L \geq \underline{U}_{lcs} \quad (13) \\ \overline{U}_{op} &= \beta\left[\rho\left(\overline{q}M_H + (1-\overline{q})M_L\right) + (1-\rho)(\underline{q}M_H + (1-\underline{q})M_L)\right] + \overline{q}R_H + (1-\overline{q})R_L \geq \overline{U}_{lcs}. \end{aligned}$$

Under transparency, informed trading drives prices closer to fundamentals and securitization revenues vary across originator types. The following two inequalities must be satisfied by any pooling equilibrium featuring transparency:

$$\begin{aligned} \underline{U}_{tran} &\equiv \beta\left[\underline{z}\left(\overline{q}M_H + (1-\overline{q})M_L\right) + (1-\underline{z})(\underline{q}M_H + (1-\underline{q})M_L)\right] + \underline{q}R_H + (1-\underline{q})R_L \geq \underline{U}_{lcs} \quad (14) \\ \overline{U}_{tran} &\equiv \beta\left[\overline{z}\left(\overline{q}M_H + (1-\overline{q})M_L\right) + (1-\overline{z})(\underline{q}M_H + (1-\underline{q})M_L)\right] + \overline{q}R_H + (1-\overline{q})R_L \geq \overline{U}_{lcs} \end{aligned}$$

where

$$\begin{aligned} \overline{z}(\rho) &\equiv \frac{1}{2}\left[\frac{\rho\sigma^2}{1-\rho-\sigma+2\rho\sigma} + \frac{\rho(1-\sigma)^2}{\rho+\sigma-2\rho\sigma} + \rho\right] \\ \underline{z}(\rho) &\equiv \left(\frac{\rho}{1-\rho}\right)(1-\overline{z}). \end{aligned}$$

The endogenous variable $\overline{z}$ plays a critical role in the model, measuring the informational efficiency of prices. For example, in the hypothetical case where $\overline{z} = 1$, there is no mispricing. In fact, $\overline{z}$ is increasing in σ, with $\overline{z} \in (\rho, (1+\rho)/2]$. Intuitively, if the speculator has a more precise signal, the expected wedge between price and true value is lower.

Exploiting equations (13) and (14), the following proposition characterizes the set of continuation equilibria featuring pooling.

Proposition 2 *The set of pooling perfect Bayesian equilibrium marketed cash flows with opacity (transparency) is the convex set defined by equations 13 (14). In any pooling equilibrium, marketed high state payoffs (M_H) are strictly greater than L. If there is a pooling equilibrium with marketed payoffs (M_L^0, M_H^0), then for all $M_H' \in (M_H^0, H]$ there is a pooling equilibrium with marketed payoffs (M_L^0, M_H'). If there is a pooling equilibrium with partial securitization, there is a pooling equilibrium with full securitization. Under transparency, a necessary and sufficient condition for a pooling equilibrium with full securitization is*

$$\frac{\overline{q}-\underline{q}}{\beta\overline{q}-\underline{q}} \leq \frac{1}{2}\left[\frac{\rho\sigma^2}{1-\rho-\sigma+2\rho\sigma} + \frac{\rho(1-\sigma)^2}{\rho+\sigma-2\rho\sigma} + \rho\right] (\equiv \overline{z}(\rho)).$$

Under opacity, a necessary and sufficient condition for a pooling equilibrium with full securitization is

$$\frac{\overline{q}-\underline{q}}{\beta\overline{q}-\underline{q}} \leq \rho.$$

The intuition for Proposition 2 is as follows. In order for a pooling equilibrium to be supported, both types must be weakly better off than at the LCSE. And the low type is able to fully securitize his asset in the LCSE. In order to improve upon this, M_H must be sufficiently high to ensure the marketed claim is risky, as stated in the second sentence of the proposition. Moreover, the second sentence in the proposition implies total marketed payoffs must increase with cash flow ($M_H > M_L$) in any equilibrium. It is also worth noting that it is possible for originators to pool at structures in which the retained claim is not junior ($R_L > 0$). In fact, it is possible for originators to pool at structures in which the payoff on the retained claim is *decreases* with cash flow ($R_L > R_H$), thus creating a reward for poor performance.

The fourth statement of the proposition demonstrates that uniformly high levels of securitization do not constitute prima facie evidence of market irrationality. To the contrary, a necessary condition for the existence of any pooling equilibrium is the existence of a pooling equilibrium featuring full securitization. The final two statements in the proposition show that price informativeness and funding value are substitutes in supporting pooling equilibria, with the required informational efficiency threshold for pooling ($\overline{z}$) decreasing in β. Thus, pooling can be an equilibrium if and only if informational efficiency is high or originators attach very high value to immediate funding.

It follows from the final two statements of the proposition that if pooling at opacity can be sustained as an equilibrium, then pooling at transparency can also be sustained as an equilibrium. Intuitively, the high type is more willing to pool if prices are closer to fundamentals as is the case under transparency. Finally, pooling at opacity is easier to sustain as a continuation equilibrium at $\overline{\rho}$ than under $\underline{\rho}$. Intuitively, the high type is more willing to pool at opacity if investors have more favorable prior beliefs, a standard result in signaling models.

Further intuition regarding the set of pooling equilibria is provided by Figures 3A and 3B. Using equation (14), each figure plots pairs of marketed cash flows (M_L, M_H) in pooling equilibria that just pin the two originator types to their respective LCSE payoffs. The better-than set is the region above the respective indifference curves.[15] Figure 3A depicts transparency and Figure 3B depicts opacity. To isolate the role of price informativeness, model parameters are held fixed across the two figures. Consider first Figure 3A. With transparency, the low type's indifference curve is above that of the high type. Thus, the low type's indifference curve is the relevant boundary for the set of pooling equilibria. Intuitively, the low type is more reluctant to pool than the high type if prices are close to fundamental value. Consider next Figure 3B. With opacity, the high type's indifference curve is above that of the low type, reflecting his reluctance to pool at opacity given that securities will be priced far from fundamentals. Thus, under opacity the high type's indifference curve is the relevant boundary for the set of pooling equilibria. Comparing across the figures it is apparent that

[15] High type indifference curves always have negative slope while low type indifference curves can have positive or negative slope. These properties follow from signing (K_L, K_H) in the appendix.

the level of securitization sustainable as a pooling equilibrium is influenced by price informativeness.

Post-crisis there has been much debate about whether observed securitization levels and the opacity of structures constitute evidence of investor irrationality. Using the perfect Bayesian equilibrium concept, one cannot argue full securitization and/or opacity are inconsistent with rationality. After all, one implication of Proposition 2 is that full securitization cum opacity can be sustained as a rational market equilibrium if β is sufficiently high. However, it can be argued that the PBE concept constitutes a weak test of rationality inasmuch as it can admit off-equilibrium beliefs that seem unreasonable. The following proposition identifies structures satisfying the Intuitive Criterion, which imposes restrictions on off-equilibrium beliefs.

Proposition 3 *A necessary and sufficient condition for a perfect Bayesian equilibrium to satisfy the Intuitive Criterion is that interim type-contingent utilities for the originator* $(\underline{U}^*, \overline{U}^*)$ *satisfy*

$$(\beta\overline{q} - \underline{q})\overline{U}^* - (\beta - 1)\overline{q}\underline{U}^* \geq \beta(\overline{q} - \underline{q})[\overline{q}H + (1 - \overline{q})L].$$

The Least-Cost Separating Equilibrium satisfies the Intuitive Criterion. Opacity never satisfies the Intuitive Criterion. Pooling with transparency and partial securitization satisfies the Intuitive Criterion if and only if

$$[(\beta - 1)\overline{q}(\overline{z} - \underline{z}) - (1 - \overline{z})(\overline{q} - \underline{q})][M_H - M_L] \geq \beta^{-1}(\beta - 1)(L - M_L).$$

Pooling with transparency and full securitization satisfies the Intuitive Criterion if and only if

$$\frac{\overline{z} - \underline{z}}{1 - \underline{z}} \geq \frac{\overline{q} - \underline{q}}{\beta\overline{q} - \underline{q}}.$$

Proposition 3 shows a PBE only satisfies the Intuitive Criterion if there is a sufficiently large spread between the high and low type interim utilities. Pooling at opacity violates the Intuitive Criterion since all originators get paid the same price for marketed securities. A more "sophisticated" market would infer that only low types prefer opacity. Proposition 3 also shows full securitization can satisfy the Intuitive Criterion. However, comparing inequalities across Proposition 2 and Proposition

3 one sees that in order to satisfy the Intuitive Criterion, pooling at full securitization demands a higher degree of price informativeness.

IV. Originator Effort

As the last step in the backward induction to characterize the equilibrium set, this section considers the originator's effort decision in period 1.

A. Originator Willingness-to-Pay

Let $\widehat{c}$ denote the maximum cost the originator would be willing to incur in order to increase the high type probability from $\underline{\rho}$ to $\overline{\rho}$. For each pair of type-contingent originator utilities $(\underline{U}^*, \overline{U}^*)$ in the set of Securitization Stage continuation equilibria, the *willingness-to-pay* $(\widehat{c})$ is:

$$\widehat{c} = (\overline{\rho} - \underline{\rho})(\overline{U}^* - \underline{U}^*). \tag{15}$$

The preceding equation delivers a simple message: ex ante effort incentives are increasing in the wedge between type-contingent continuation utilities.

Before considering effort incentives under any specific continuation equilibrium, we prove that asymmetric information results diminished effort incentives. In any PBE:

$$\widehat{c} = (\overline{\rho} - \underline{\rho})(\overline{U}^* - \underline{U}^*) \leq (\overline{\rho} - \underline{\rho})[\overline{U}^* - \beta(\underline{q}H + (1-\underline{q})L)] < \beta(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) \equiv \widehat{c}_{obq}. \tag{16}$$

The first inequality in equation (16) follows from the fact that the low type receives at least his symmetric information payoff in any PBE, as shown in Lemma 2. The last inequality follows from the fact that the high type gets less than his symmetric information payoff in any PBE. In the LCSE, the high type underinvests in order to signal positive information. And in any pooling equilibrium the high type's securities are underpriced. We have established the following key result.

Proposition 4 *In all unregulated market equilibria, originator effort incentives are less than under symmetric information regarding types.*

We turn next to a consideration of the effort incentives implied by each possible continuation equilibrium. From equation (15) and Lemma 1 it follows that originator willingness-to-pay in the LCSE is

$$\widehat{c}_{lcs} = [\beta(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L)] \left[\frac{\overline{q} - \underline{q}}{\beta\overline{q} - \underline{q}} \right]. \tag{17}$$

The first square bracketed term in the expression for $\widehat{c}_{lcs}$ is the maximum effort cost the originator would pay under observable types. The second bracketed term is a number less than one. Intuitively, at the LCSE the high type bears the underinvestment cost of signaling while the low type gets his symmetric information payoff. Consequently, there is less incentive to put in effort aimed at becoming a high type.

Consider next effort incentives if the continuation equilibrium entails pooling. Here we must distinguish between pooling cum transparency versus pooling cum opacity. The respective willingness-to-pay expressions are:

$$\begin{aligned} \widehat{c}_{tran} &= (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[R_H - R_L + (M_H - M_L)\beta(\overline{z} - \underline{z})] \qquad (18) \\ \widehat{c}_{op} &= (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[R_H - R_L]. \end{aligned}$$

Notice that under transparency there are two sources of effort incentives: the retained claim and market discipline, with high types expecting a higher price for their marketed security (since Proposition 2 shows $M_H > M_L$ in any pooling equilibrium). In contrast, under opacity the only source of effort incentive is the retained claim. It is apparent from the preceding equation that for the same level of retentions, effort incentives are higher under transparency than opacity. Further, under transparency originator effort incentives are higher for higher assumed values of σ since the wedge between $\overline{z}$ and $\underline{z}$ is increasing in σ.

Equation (18) also shows that under opacity and zero retentions, there is zero effort incentive. Under transparency, effort incentives exist even with zero retentions, with the implied willingness-to-pay equal to:

$$\widehat{c}^{otd}_{tran} \equiv [\beta(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L)][\overline{z} - \underline{z}]. \tag{19}$$

The first square-bracketed term in the expression for $\widehat{c}^{otd}_{tran}$ is the cutoff cost that would obtain under symmetric information regarding asset type. It can be verified that the second bracketed term is number less than one half.

B. Equilibrium Effort

This subsection completes the backward induction to determine the equilibrium set. For the purpose of this analysis, it is useful note that Lemma 2 and Proposition 2 imply the set of Securitization Stage continuation equilibria depends upon investors' prior belief (ρ) regarding the probability of the issuer being a high type. Intuitively, once the Securitization Stage subgame is reached, we have a standard signaling game where the equilibrium set naturally depends upon prior beliefs regarding the distribution of types.

With this in mind, let $\underline{\mathcal{E}}_{SS}$ denote the set of possible Securitization Stage continuation equilibria resulting from $\rho = \underline{\rho}$ and let $\overline{\mathcal{E}}_{SS}$ denote the set of possible continuation equilibria resulting from $\rho = \overline{\rho}$. Each set includes the LCSE and the set of ρ-contingent pooling equilibria described in Proposition 2. Let ξ denote a generic member of either set and $\widehat{c}(\xi)$ denote the corresponding willingness-to-pay using the formulae in the preceding subsection. Next let:

$$\begin{aligned} \underline{\mathcal{E}}^*_{SS} &\equiv \{\xi \in \underline{\mathcal{E}}_{SS} : \widehat{c}(\xi) \leq c\} \\ \overline{\mathcal{E}}^*_{SS} &\equiv \{\xi \in \overline{\mathcal{E}}_{SS} : \widehat{c}(\xi) \geq c\}. \end{aligned}$$

Notice, for each of the sets defined above, the willingness-to-pay is consistent with the posited continuation path, e.g. $\widehat{c}(\xi) \leq c$ if ξ is a continuation equilibrium arising when no effort has been exerted ($\rho = \underline{\rho}$).

Finally, let

$$\begin{aligned} \widehat{c}_{\min} &\equiv \min_{\xi \in \underline{\mathcal{E}}_{SS}} \widehat{c}(\xi) \\ \widehat{c}_{\max} &\equiv \max_{\xi \in \overline{\mathcal{E}}_{SS}} \widehat{c}(\xi). \end{aligned}$$

That is, $\widehat{c}_{\min}$ measures the minimum willingness-to-pay computed over the set of continuation equilibria resulting from $\rho = \underline{\rho}$. Conversely, $\widehat{c}_{\max}$ measures the maximum willingness-to-pay computed over the set of continuation equilibria resulting from $\rho = \overline{\rho}$. Since both sets include the LCSE (Lemma 2), it follows $\widehat{c}_{\min} \leq \widehat{c}_{\max}$.

We have the following proposition.

Proposition 5 *The set of pure strategy perfect Bayesian equilibria for the full game is the non-empty set*

$$(\textit{No-Effort}, \underline{\mathcal{E}}^*_{SS}) \cup (\textit{Effort}, \overline{\mathcal{E}}^*_{SS}).$$

If $c < \widehat{c}_{\min}$, the originator exerts effort in any equilibrium. If $c > \widehat{c}_{\max}$, the originator does not exert effort in any equilibrium. If $c \in [\widehat{c}_{\min}, \widehat{c}_{\max}]$, both effort and no-effort can be equilibrium outcomes.

The first statement of the proposition follows from the fact that it is always possible to construct an equilibrium based on the LCSE as a continuation path. The demonstration of the rest of the proposition is as follows. Under the first inequality, it is impossible to sustain an equilibrium with no-effort since no-effort is inconsistent with any continuation equilibrium that could possibly follow from no-effort. Under the second inequality, it is impossible to sustain an equilibrium with effort, since effort is inconsistent with any continuation equilibrium that could possibly follow from effort. In the remaining case, it is possible to support an equilibrium with effort by positing the continuation equilibrium corresponding to $\widehat{c}_{\max}$ and it is possible to support an equilibrium with no-effort by positing the continuation equilibrium corresponding to $\widehat{c}_{\min}$.

The importance of the preceding proposition is to highlight the possibility of multiple equilibrium effort levels. Of course, since continuation payoffs determine the originator's willingness-to-pay (equation (15)), the possibility of multiple equilibrium effort levels is a natural consequence of the fact that there are potentially multiple Securitization Stage continuation equilibria. To take an example, suppose $\underline{\rho} \geq (\overline{q} - \underline{q})/(\beta\overline{q} - \underline{q})$ and $\beta[\overline{z}(\overline{\rho}) - \underline{z}(\overline{\rho})] \geq 1$. The first inequality implies full securitization combined with either opacity or transparency falls within the set of continuation equilibria. And we have seen that if the continuation equilibrium entails opacity, the originator will not exert effort regardless of the required cost c. In contrast, if the continuation equilibrium entails transparency, the second inequality (combined with Assumption A1) implies the originator will exert effort for each possible c. Therefore, in this example, for each possible c value, no-effort and effort can both be sustained as equilibrium decisions at the origination stage.

The preceding proposition offers two alternative interpretations of the apparent decline in lending standards in the run-up to the credit crisis of 2007-2008, with differing implications for regulation. One interpretation is that no-effort was inevitable in any unregulated market equilibrium. This interpretation corresponds to $c > \widehat{c}_{\max}$. An alternative interpretation is that unregulated markets were simply trapped in an equilibrium with low effort incentives. This interpretation corresponds to $c \in [\widehat{c}_{\min}, \widehat{c}_{\max}]$, with unregulated markets happening to implement an equilibrium with a low $\widehat{c}$. In this case, a sufficient remedy for lender laxity is light-touch regulation selecting an effort-inducing equilibrium from the set of potential unregulated market equilibria, e.g. mandating transparency when opacity was otherwise viable as an equilibrium.

The prior analysis also suggests a potentially critical role for investor sophistication in alleviating originator moral hazard by way of eliminating Securitization Stage continuation equilibria generating low effort incentives. For example, the Intuitive Criterion precludes pooling at full securitization cum opacity, an outcome that destroys effort incentives. More generally, from Proposition 3 it follows the Intuitive Criterion demands that the gap between type-contingent interim utilities be sufficiently large, which is precisely what is needed to promote originator effort ex ante, as shown in equation (15).

V. Social Welfare and Optimal Mandatory Retentions

Up to this point attention has been confined to a positive analysis of potential equilibria in unregulated markets. This section addresses three normative questions. First, what are the market failures and sources of welfare losses in the various unregulated market equilibria? Second, can mandatory retentions increase social welfare? And finally, which form of mandatory retention scheme maximizes social welfare? Anticipating, the alternative policy options will create winners and losers so Pareto improvements are not generally available. For example, opacity or policies that induce issuers to reveal their private information benefit uninformed investors as they are insulated from adverse selection. At the same time, such policies make the speculator worse off by preventing her from making trading gains. Below we evaluate alternatives taking the perspective of a utilitarian social planner placing equal weight on the utility of each agent. Social welfare is then the sum of expected utilities, accounting for all private benefits and externalities.

A. Welfare in Unregulated Markets

This subsection considers the welfare losses implicit in the various unregulated market equilibria. To understand the source of welfare losses, it is useful to recall outcomes if the asset type was observable. As discussed above, with observable q, the originator would find it optimal to exert effort given that the expected output increase exceeds effort costs (Assumption A1). At the Securitization Stage the entire asset would be marketed since the originator's investment has positive NPV. And it was shown in Section II that with known q each vulnerable UI would fully insure against consumption shortfalls by purchasing ϕ units of the L-state Arrow security at an actuarially fair price of $1-q$. Invulnerable UI would borrow ϕ in period 3 against their future endowment windfall in order to shift consumption forward as desired. Finally, the speculator would not exert costly effort to acquire information and would simply consume his endowment. The implied social welfare with observable types is equal to the sum of the expected utilities of the originator, uninformed investor and speculator:

$$\begin{aligned} W_{obq} &= \beta[(\overline{\rho}(1-\overline{q})+(1-\overline{\rho})(1-\underline{q}))L+(\overline{\rho}\overline{q}+(1-\overline{\rho})\underline{q})H]-c \\ &\quad +y_3^{ui}-\frac{1}{2}(\overline{\nu}+\underline{\nu})[\overline{\rho}(1-\overline{q})+(1-\overline{\rho})(1-\underline{q})]\phi+\left[1-\frac{\overline{\nu}+\underline{\nu}}{2}\right]\phi+y_3^s. \end{aligned} \tag{20}$$

Consider first the welfare gap if the unregulated market equilibrium entails pooling at opacity cum full securitization of the underlying asset ("OTD"). Such an equilibrium has a number of benefits in terms of social welfare. The speculator does not exert costly effort. And with symmetric ignorance, efficient risk-sharing is achieved, with each vulnerable UI buying fairly priced insurance against consumption shortfalls (Proposition 1). Finally, with full securitization, there are no under-investment costs. In fact, the only social cost of such an equilibrium is that it provides zero effort incentive ($\widehat{c} = 0$), as shown in Section IV. So here the welfare gap is equal to the net social value of originator effort. Using the social welfare formulae in the appendix, this social value of originator effort is equal to:

$$W_{obq} - W_{op}^{otd} = (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q}) \left[\beta(H - L) + \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi \right] - c. \tag{21}$$

The first term in the square brackets in the preceding equation is the expected increase in the asset's cash flow resulting from originator effort, which is scaled up by his funding value β. The second term in square brackets is the expected increase in the endowment of uninformed investors resulting from originator effort. Recall, a low realized cash flow results in an endowment loss of ϕ units for each vulnerable UI, with the aggregate measure of the vulnerable UI being an equiprobable random variable $\nu \in \{\underline{\nu}, \overline{\nu}\}$. Essentially, the second term captures the social value of reductions in externalities arising from distressed or foreclosed properties. The failure of lenders to account for such externalities at the time of loan origination is a first market failure.

As shown below, the net social value of originator effort is actually a key welfare loss associated with any unregulated market equilibrium failing to induce effort. And at this point it is worth addressing the following question: Why does an unregulated securitization market admit equilibria failing to induce originator effort? Essentially, the unregulated market admits as equilibria securitization structures achieving a sufficiently high payoff to originators *post-effort*, as shown in Lemma 2. For example, as shown in Proposition 2, if β is very high originators may pool at OTD cum opacity. And such an outcome actually maximizes interim-stage social welfare. However, such an anticipated outcome results in zero ex ante effort incentive. Tension between interim-efficiency and moral hazard is common to many agency settings (see e.g. Fudenberg and Tirole (1990)). Anticipating, the tension between ex ante and interim efficiency provides one potential rationale for government intervention. Regulation can commit issuers not to implement some structures, even some with a high level of interim-efficiency (e.g. opaque OTD), with the goal of restoring effort incentives.

Consider next the welfare gap if the unregulated market equilibrium entails pooling at opacity and partial securitization. In this case, the social welfare gap is increased by an amount equal to the foregone project NPV due to originator retentions. However, the net social value of originator effort is potentially recaptured since the retained claim increases effort incentives provided $R_H > R_L$, as shown in equation (18). We have the following welfare gap.

$$
\begin{aligned}
W_{obq} - W_{op} &= (\beta - 1)\left[(\rho_{op}(1-\overline{q}) + (1-\rho_{op})(1-\underline{q}))R_L + (\rho_{op}\overline{q} + (1-\rho_{op})\underline{q})R_H\right] \quad (22)\\
&+ \frac{\overline{\rho} - \rho_{op}}{\overline{\rho} - \underline{\rho}}\left[(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})\left(\beta(H-L) + \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi\right) - c\right].
\end{aligned}
$$

Consider next the welfare gap if the unregulated market equilibrium entails pooling at transparency. In this case, there are four sources of welfare losses. First, there is a welfare loss equal to the foregone NPV from investment due to originator retentions. Second, the net social value of originator effort is lost if $\widehat{c}_{tran} < c$. Third, under transparency the speculator exerts costly effort gathering information. Fourth, as shown in Proposition 1, the existence of an informed speculator distorts risk-sharing in that a subset of vulnerable UI forego insurance against consumption shortfalls, fearing adverse selection. As shown in Lemma 2, in their own decisionmaking, originators do not account for the negative externality associated with pooling, a more subtle market failure. The implied total welfare loss under a transparent pooling equilibrium is:

$$
\begin{aligned}
W_{obq} - W_{tran} &= (\beta - 1)\left[(\rho_{tran}(1-\overline{q}) + (1-\rho_{tran})(1-\underline{q}))R_L + (\rho_{tran}\overline{q} + (1-\rho_{tran})\underline{q})R_H\right] \quad (23)\\
&+ \frac{\overline{\rho} - \rho_{tran}}{\overline{\rho} - \underline{\rho}}\left[(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})\left(\beta(H-L) + \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi\right) - c\right]\\
&+ e + \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi\left[\int_1^{\widehat{\theta}}(\theta - 1)f(\theta)d\theta\right][\rho_{tran}(1-\overline{q}) + (1-\rho_{tran})(1-\underline{q})].
\end{aligned}
$$

Consider finally the welfare gap if the LCSE is the unregulated market equilibrium. The LCSE has a number of benefits. In the LCSE the private information of the originator is credibly signaled at the Securitization Stage so there is common knowledge of the asset type at the Trading Stage. As shown in Proposition 1, it follows that the speculator does not exert effort. And with the type revealed, each vulnerable UI purchases a fairly priced Arrow security to insure against consumption shortfalls, so that risk-sharing is efficient. Thus, there are only two sources of welfare loss in the

LCSE. First, high type retentions result in foregone project NPV. Second, the net social value of originator effort is lost if $\widehat{c}_{lcs} < c$. We have the following welfare gap in the LCSE:

$$\begin{aligned} W_{obq} - W_{lcs} &= (\beta - 1)\rho_{lcs}\overline{q}\left[\frac{\beta(\overline{q} - \underline{q})(H - L)}{\beta\overline{q} - \underline{q}}\right] \\ &\quad + \frac{\overline{\rho} - \rho_{lcs}}{\overline{\rho} - \underline{\rho}}\left[(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})\left(\beta(H - L) + \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi\right) - c\right]. \end{aligned} \tag{24}$$

The next two subsections consider socially optimal mandatory retention schemes that serve to induce speculator effort. In contrast, the following proposition singles out the optimal regulation inducing no-effort.

Proposition 6 *Mandating opacity and zero originator retentions is is socially optimal amongst regulations failing to induce originator effort.*

The preceding proposition shows that an optimal regulation need not mandate retentions or more transparent disclosure. To the contrary, if the regulator is content to tolerate originator moral hazard and forego the net social value of originator effort (equation (21)), then the government should actually mandate zero retentions, with the goal of maximizing originator funding. And if effort incentives are not a concern, there is no need for market discipline, so opacity is optimal. Proposition 6 is consistent with the arguments in Dang, Gorton and Holmström (2011) regarding the benefits of opacity. Opacity conserves speculator effort costs and promotes efficient risk-sharing. With this in mind, it follows that a high degree of investor sophistication is not necessarily beneficial in terms of social welfare. In particular, if investor beliefs are "sophisticated" in the sense of satisfying the Intuitive Criterion, then pooling at opacity cannot be sustained as an unregulated market equilibrium (Proposition 3).

B. Motivating Effort via Separating Regulations

From Proposition 6 it follows that inducing effort is a necessary condition for some regulation other than mandatory opaque OTD to be socially optimal. Therefore, the remainder of the analysis is devoted to determining socially optimal methods for inducing originator effort. This subsection determines the optimal mandatory retention scheme amongst those inducing originators to exert effort, as well as compelling them to credibly reveal the true asset type to investors. From a social perspective, all schemes meeting these two objectives result in the same expected utility for the speculator, who consumes her endowment, and the UI, who fully insure against negative shocks. Therefore, the socially optimal separating regulation maximizes the expected utility of the originator subject to appropriate incentive constraints.

We begin by noting that if effort is incentive compatible (IC below) in the LCSE, there is no socially preferable separating scheme. Consider then the socially optimal separating regulation when the IC constraint is violated at the LCSE ($c > \widehat{c}_{lcs}$). Let $(\underline{M}_L, \underline{M}_H)$ and $(\overline{M}_L, \overline{M}_H)$ denote the cash flows to be marketed by low and high types, respectively. The planner's problem is to maximize the expected utility of the originator subject to IC, non-mimicry by the low type (with the high type's non-mimicry constraint being slack), and limited liability for the originator. We solve the following relaxed program which ignores some limited liability constraints and then verify the neglected constraints are slack:

$$\begin{aligned}
& \max_{\underline{M}_L,\underline{M}_H,\overline{M}_L,\overline{M}_H} \overline{\rho}\left\{\overline{q}(H-\overline{M}_H)+(1-\overline{q})(L-\overline{M}_L)+\beta[\overline{q}\overline{M}_H+(1-\overline{q})\overline{M}_L]\right\} \qquad (25)\\
& +(1-\overline{\rho})\{\underline{q}(H-\underline{M}_H)+(1-\underline{q})(L-\underline{M}_L)+\beta[\underline{q}\underline{M}_H+(1-\underline{q})\underline{M}_L]\}\\
& s.t.\\
IC \ :\ & \overline{q}(H-\overline{M}_H)+(1-\overline{q})(L-\overline{M}_L)+\beta[\overline{q}\overline{M}_H+(1-\overline{q})\overline{M}_L]-\frac{c}{\overline{\rho}-\underline{\rho}}=\\
& \underline{q}(H-\underline{M}_H)+(1-\underline{q})(L-\underline{M}_L)+\beta[\underline{q}\underline{M}_H+(1-\underline{q})\underline{M}_L]\\
NM \ :\ & \underline{q}(H-\underline{M}_H)+(1-\underline{q})(L-\underline{M}_L)+\beta[\underline{q}\underline{M}_H+(1-\underline{q})\underline{M}_L]\geq\\
& \underline{q}(H-\overline{M}_H)+(1-\underline{q})(L-\overline{M}_L)+\beta[\overline{q}\overline{M}_H+(1-\overline{q})\overline{M}_L]\\
LL \ :\ & \overline{M}_L\leq L, \quad \underline{M}_L\leq L
\end{aligned}$$

NM must bind in the relaxed program otherwise the objective function could be increased by raising $\overline{M}_H$ by an infinitesimal amount while still meeting all constraints. Substituting the binding NM constraint into the objective function and IC constraint allows one to rewrite the relaxed program as:

$$\max_{\overline{M}_L,\overline{M}_H} \rho\left\{\overline{q}(H-\overline{M}_H)+(1-\overline{q})(L-\overline{M}_L)+\beta[\overline{q}\overline{M}_H+(1-\overline{q})\overline{M}_L]\right\} \tag{26}$$

$$+(1-\rho)\{\underline{q}(H-\overline{M}_H)+(1-\underline{q})(L-\overline{M}_L)+\beta[\overline{q}\overline{M}_H+(1-\overline{q})\overline{M}_L]\}$$

$$s.t.$$

$$IC' \quad : \quad \overline{M}_H = H - L + \overline{M}_L - \frac{c}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}.$$

$$LL \quad : \quad \overline{M}_L \leq L.$$

Substituting the right side of IC$'$ into the objective function we find it is increasing in $\overline{M}_L$ from which it follows the socially optimal separating contract entails:

$$(\overline{M}^*_L, \overline{M}^*_H) = \left(L, H - \frac{c}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}\right) = \left(L, L + \frac{(\beta-1)\underline{q}(H-L)}{\beta\overline{q}-\underline{q}} - \frac{c-\widehat{c}_{lcs}}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}\right). \tag{27}$$

Next, we substitute $(\overline{M}^*_L, \overline{M}^*_H)$ into the NM constraint to compute the low type's utility under the socially optimal separating contract:

$$\underline{U}_{sep} = \beta[\underline{q}H + (1-\underline{q})L] - \frac{(\beta\overline{q}-\underline{q})(c-\widehat{c}_{lcs})}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}. \tag{28}$$

Any pair $(\underline{M}_L, \underline{M}_H)$ giving the low type the correct utility level suffices. For example, set:

$$(\underline{M}^*_L, \underline{M}^*_H) = \left(L, H - \frac{(\beta\overline{q}-\underline{q})(c-\widehat{c}_{lcs})}{(\beta-1)\underline{q}(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}\right). \tag{29}$$

We have established the following proposition.

Proposition 7 *The socially optimal separating regulation for inducing originator effort calls for both types to retain junior claims paying zero in state L. In state H, the retained claims of the high and low types have respective payoffs:*

$$\overline{R}^{sep}_H = \frac{\beta(\overline{q}-\underline{q})(H-L)}{\beta\overline{q}-\underline{q}} + \frac{(c-\widehat{c}_{lcs})^+}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}$$

$$\underline{R}^{sep}_H = \left[\frac{(\beta\overline{q}-\underline{q})}{(\beta-1)\underline{q}(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}\right](c-\widehat{c}_{lcs})^+.$$

The separating regulation described in Proposition 7 accomplishes two distinct tasks: provision of ex ante effort incentives by increasing the wedge between high and low type Securitization Stage continuation utilities *and* revelation of the originator's private information. This last effect is socially valuable since it eliminates the speculator's incentive to pay costs to acquire information and also serves to insulate uninformed investors from adverse selection, facilitating efficient risk-sharing.

The proposition shows that in order to restore effort incentives the high type is forced to hold a larger junior tranche than in the LCSE. Examination of the low type contract reveals a stark contrast between the LCSE and the socially optimal separating regulation inducing effort. In the LCSE, a low type fully securitizes his asset and achieves his symmetric information payoff. In contrast, the optimal regulation mandates that the low type must also retain a junior claim, albeit of smaller size than that of the high type. Such a mandated retention increases the wedge between high and low type continuation payoffs, restoring effort incentives.

It is apparent that in terms of continuation utilities both originator types are worse off than at the LCSE. Lemma 2 shows an unregulated market would never implement such an outcome since it is interim-inefficient from the perspective of originators. The role of the government regulation here is to serve as a commitment device to implement interim-inefficient equilibria in order to restore ex ante effort incentives. Finally, the optimality of forcing the originator to hold a junior claim in the context of the separating regulation is a consequence of the fact that in the present setting a standard single-crossing condition is satisfied, with high types placing a higher relative valuation on high state payoffs. This fact makes the retention of a junior claim a less costly signaling device. That is, other retained claims might suffice to separate types and restore effort incentives, but they would generate larger underinvestment costs. This signaling argument is distinct from the traditional moral hazard argument that calls for risk-neutral agents, such as our originator, to be residual claimants (see e.g. Innes (1990)).

C. Motivating Effort via Pooling Regulations

Consider next the socially optimal means of inducing originator effort using some form of pooling regulation such that all originators are forced to retain the same claim. A pooling regulation can be used in combination with either mandated transparency or opacity.

Consider first the optimal pooling regulation combined with mandated transparency. The socially optimal regulation maximizes the weighted average of originator utilities subject to the appropriate IC constraint, since the expected utility of all other agents is the same across all transparent pooling regulations. The social planner's program is:

$$\max_{M_L \le L, M_H \le H} \quad \overline{\rho}\,\overline{U} + (1-\overline{\rho})\underline{U} = L + (H-L)[\overline{\rho q} + (1-\overline{\rho})\underline{q}] + (\beta - 1)[M_L + (M_H - M_L)(\overline{\rho q} + (1-\overline{\rho})\underline{q})]$$

$$\text{subject to}$$

$$IC \quad : \quad \overline{U} - \underline{U} = (\overline{q} - \underline{q})[(H-L) - (M_H - M_L)(1 - \beta(\overline{z} - \underline{z}))] \ge \frac{c}{\overline{\rho} - \underline{\rho}}.$$

If the IC constraint is slack then the solution to the above program is full securitization. Consider then the remaining case in which the IC constraint binds ($c > \widehat{c}^{otd}_{tran}$). Substituting the IC constraint into the objective function it follows that the optimal pooling contract cum transparency calls for the originator to market the following bundle of cash flows:

$$\begin{aligned} M_L^{**} &= L \\ M_H^{**} &= L + \frac{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H-L) - c}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[1 - \beta(\overline{z} - \underline{z})]} = H - \frac{(H-L)(c - \widehat{c}^{otd}_{tran})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H-L) - \widehat{c}_{otd}}. \end{aligned} \tag{30}$$

Consider next the optimal pooling regulation when combined with mandated opacity. Again, the socially optimal regulation maximizes the weighted average of originator utilities. The social planner's program is:

$$\max_{M_L \le L, M_H \le H} \quad \overline{\rho}\,\overline{U} + (1-\overline{\rho})\underline{U} = L + (H-L)[\overline{\rho q} + (1-\overline{\rho})\underline{q}] + (\beta - 1)[M_L + (M_H - M_L)(\overline{\rho q} + (1-\overline{\rho})\underline{q})]$$

$$\text{subject to}$$

$$IC \quad : \quad \overline{U} - \underline{U} = (\overline{q} - \underline{q})[(H-L) - (M_H - M_L)] \ge \frac{c}{\overline{\rho} - \underline{\rho}}.$$

Here the IC constraint must bind since otherwise the optimum would entail full securitization, but this would necessarily violate the IC constraint. Substituting the IC constraint into the objective function it follows that the optimal pooling regulation cum opacity calls for the originator to market the following bundle of cash flows:

$$\begin{aligned} M_L^{***} &= L \\ M_H^{***} &= H - \frac{c}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}. \end{aligned} \tag{31}$$

We have established the following proposition.

Proposition 8 *Socially optimal pooling regulations for inducing effort call for originators to retain junior claims paying zero in state L. If the regulation mandates transparency, the retained claim has state H payoff equal to:*

$$R_H^{tpool} = \frac{(H-L)(c-\widehat{c}_{tran}^{otd})^+}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})(H-L)-\widehat{c}_{tran}^{otd}}.$$

If the regulation mandates opacity, the retained claim has state H payoff equal to:

$$R_H^{opool} = \frac{c}{(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})}.$$

Proposition 8 shows that if the regulatory intent is for originators to pool at a common structure, the socially optimal means of providing effort incentives is for the originator to retain a junior claim such that $R_L = 0$. Intuitively, reductions in R_L serve to relax the respective IC constraints as well as increasing the level of originator fundraising. The proposition also shows that originators must be forced to hold larger junior claims if the regulation mandates opacity. After all, under opacity market discipline is absent at the time of securitization, so all effort incentives must come from the retained claim. Finally, it is readily verified that R_H^{tpool} decreases with the informational efficiency of markets, as measured by $\overline{z}-\underline{z}$. Intuitively, under the pooling regulation, originator retentions and market discipline are substitute mechanisms for providing effort incentives. Thus, the optimal pooling regulation cum transparency requires making a judgement about informational efficiency.

D. Welfare Comparisons Across Regulations

Having characterized the optimal regulations within each category in the preceding two subsections, we can now determine the optimal effort-inducing regulation. Appendix B contains the social welfare equations. For brevity, this section compares social welfare losses across the alternatives.

Consider first a comparison of social welfare under the separating regulation versus the opaque pooling regulation. Both regulatory schemes have the benefit of conserving speculator effort costs and achieving first-best risk-sharing. In the separating regulation, symmetric information across investors is restored by inducing issuers to credibly signal their type. Under the opaque pooling regulation, investors have symmetric ignorance. Under both schemes the only deadweight welfare loss is expected underinvestment by originators. Here it is readily verified that expected underinvestment costs are higher under the opaque pooling regulation since $\underline{R}_H^{sep} < \overline{R}_H^{sep} = R_H^{opool}$. Essentially, the opaque pooling regulation imposes the same high level of retentions that the separating regulation reserves for the high type, with low types being permitted to retain smaller claims. We have:

$$(\beta - 1)\left[\overline{\rho q}\overline{R}_H^{sep} + (1-\overline{\rho})\underline{q}\underline{R}_H^{sep}\right] < (\beta-1)[\overline{\rho q} + (1-\overline{\rho})\underline{q}]R_H^{opool} \Rightarrow W_{sep}^* > W_{opool}^*. \quad (32)$$

It follows from the preceding argument that the optimal effort-inducing regulation is either the separating regulation or a pooling regulation with mandatory transparency. Qualitatively, the two regulations differ along the following lines. The separating scheme conserves speculator effort costs and achieves first-best risk-sharing. Again, this is due to the fact that the separating scheme restores symmetric information across investors by compelling originators to credibly signal positive information via higher retentions. In contrast, no such signal is sent under the transparent pooling scheme. To the contrary, transparency allows the speculator to exert costly effort in order to gain an informational advantage over other investors. Risk-sharing is then distorted as a subset of uninformed investors fail to insure against endowment shocks fearing adverse selection (Proposition 1). Finally, as shown in Proposition 7, the separating scheme necessarily generates underinvestment costs since $\overline{R}_H^{sep} > \underline{R}_H^{sep} \geq 0$. In contrast, as shown in Proposition 8, the transparent pooling regulation only generates underinvestment costs if $\widehat{c}_{tran}^{otd} < c$. The separating scheme yields higher social welfare if:

$$(\beta-1)\left[\overline{\rho q}\overline{R}_H^{sep} - (1-\overline{\rho})\underline{q}\underline{R}_H^{sep}\right] \leq \begin{array}{c} (\beta-1)[\overline{\rho q} + (1-\overline{\rho})\underline{q}]R_H^{tpool} + e + \\ \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi[\overline{\rho}(1-\overline{q}) + (1-\overline{\rho})(1-\underline{q})]\left[\int_1^{\widehat{\theta}}(\theta-1)f(\theta)d\theta\right] \end{array}. \quad (33)$$

The first term on either side of the preceding inequality measures expected underinvestment costs under the two regulatory schemes. The rest of the terms capture effort costs and welfare losses from foregone insurance under the transparent pooling regulation. Since the transparent pooling regulation results in speculator effort costs and distorted risk-sharing, it is clearly dominated if it also creates higher underinvestment costs. Here it is worth noting that R_H^{tpool} converges to $\overline{R}_H^{sep}$ as σ approaches one-half. Since $\underline{R}_H^{sep} < \overline{R}_H^{sep}$ it follows that a sufficient condition for the separating regulation to be superior is for σ to be sufficiently low. Conversely, the pooling regulation imposes no underinvestment costs at all if $\widehat{c}_{tran}^{otd} \geq c$ and may be superior accounting for underinvestment costs. Of course, this will be the case only if prices are sufficiently informative. Therefore, determination of the optimal regulation for inducing effort requires taking a view on the informational efficiency of markets. If it is low, the separating regulation is preferred. It it is high, then the pooling regulation has the potential to yield higher social welfare.

Once the optimal effort-inducing regulation has been determined, its respective social welfare loss should be compared with the social value of originator effort in equation (21). If it is smaller, then the optimal regulation induces effort. Otherwise, it is optimal to forego effort incentives and instead mandate opacity and full securitization (Proposition 6).

Conclusions

This paper revisits a canonical problem in corporate finance, security issuance and retention when the issuer has private information. The model departs from prior literature in three ways. First, we address how the anticipated issuance-stage equilibrium affects ex ante effort incentives. Second, we analyze how the prospect of informed trading alters equilibrium retentions and effort incentives. Finally, we consider how informed trading effects the efficiency of risk-sharing when rational uninformed investors shift portfolios in response to adverse selection. The primary focus is on ABS markets, where moral hazard and adverse selection problems appear acute, but the setup considered approximates many other real-world settings. For example, owner-managers of private firms choose effort anticipating a subsequent sale of securities under asymmetric information. Mature conglomerates expend resources to improve the quality of business units prior to carve-outs.

We consider first potential equilibria in unregulated markets. One possible equilibrium is a separating equilibrium in which high types separate from low types by retaining the minimum junior tranche needed deter mimicry by low types who fully securitize. In addition, pooling equilibria exist if both originator types are weakly better off than at the separating equilibrium. We show that if any pooling equilibrium can be sustained, a pooling equilibrium with full securitization can also be sustained. In this sense, full securitization should not be viewed as an anomaly. Unobservability of types at the securitization stage reduces effort incentives in all unregulated market equilibria. This is because asymmetric information at the time of security issuance reduces the payoff differential between owners of high and low quality assets. Transparency and sophisticated investor beliefs were shown to increase originator effort incentives. Finally, there can be multiple self-fulfilling levels of originator effort in unregulated markets.

Privately optimal retentions can be socially suboptimal since originators do not internalize effects on investor welfare. In particular, when the high type credibly signals via large junior retentions he benefits directly from his own marketed securities being priced at fundamentals at the time of issuance. But he does not internalize the benefit accruing to investors who can now efficiently share risks being symmetrically informed. Further, the anticipation of asymmetric information at the time of securitization reduces originator effort incentives. We show mandated retentions can raise social welfare by increasing effort incentives in an efficient way, accounting for investor-level externalities.

The first policy implication to emerge from the model is that originators should be required to hold junior tranches. The underlying logic for this prescription depends on the nature of the regulation. In a pooling regulation, retention of a junior claim increases the spread between payoffs accruing to high and low types. In a separating regulation, retention of a junior claim allows issuers to signal with minimal reduction in their investment. Second, in contrast to standard signaling results, it is optimal to impose mandatory retentions on even the low type, since this increases effort incentives efficiently. Third, in the optimal pooling regulation, the size of the mandated junior retention is decreasing in informational efficiency. Fourth, a necessary condition for the pooling regulation to dominate is sufficient informational efficiency. Fifth, the separating (pooling) regulation generally maximizes welfare if efficient risk-sharing (originator investment) is the dominant concern. Finally, if the net social value of originator effort is low, then it is optimal to forego effort incentives altogether and instead maximize investment and the efficiency of risk-sharing. This is achieved by mandating opacity and zero retentions.

The model delivers a broader message. It is commonly argued that the decline in lending standards prior to the subprime crisis of 2007/8 was inevitable given the preceding shift from relationship banking to the OTD business model. And in fact, existing theoretical models of the ABS market support the notion that lender laxity is a necessary consequence of OTD. After all, so the argument goes, an originator has no incentive to screen if he is going to sell all claims on cash flow at an unconditional price reflecting only the average ABS quality. And indeed, in existing ABS models prices are uninformative precisely because traders are assumed to be incapable of generating information about asset quality. In reality, traders can generate useful information and securities prices can be informative. Viewed from this perspective, the problem of lender laxity must be understood as a failure of the price mechanism. Moreover, for those believing in the importance of market discipline, praise of and calls for increased opacity seem exactly the wrong policy response to the subprime crisis unless one is willing to accept lender laxity as a fact of life.

The model presented gives a stylized overview of the agency problems and policy tradeoffs in ABS markets. However, it surely fails to capture some features of specific ABS markets. Given the size of each of the respective ABS markets, it would be useful for future models to take a more granular perspective in order to better capture the institutional details, risk characteristics, and agency problems inherent in the different ABS classes. Next-generation models should also pursue a richer specification of underlying stochastic processes and better capture dynamics.

Appendix A: Proofs

Uninformed Investor Portfolios

Consider first portfolio choice under common knowledge of type. Each vulnerable UI solves the following program:

$$\max_{(x_L \geq 0, x_H \geq -\phi)} \quad y_3^{ui} - x_H q - x_L(1-q) + q\theta \min\{x_H, 0\} + (1-q)\theta \min\{x_L - \phi, 0\}.$$

Utility is increasing in x_L for all $x_L \in (0, \phi)$ and is decreasing in x_L for all $x_L \geq \phi$. Utility is decreasing in x_H for all $x_H \geq 0$ and increasing in x_H for all $x_H \in (-\phi, 0)$. Consider next portfolio choice for each invulnerable UI. They solve the following program:

$$\max_{(x_L \geq -\phi, x_H \geq -\phi)} \quad y_3^{ui} - x_H q - x_L(1-q) + q\theta \min\{\phi + x_H, 0\} + (1-q)\theta \min\{\phi + x_L, 0\}.$$

For an invulnerable UI utility is decreasing in x_L and x_H on the relevant interval so their optimal portfolio payoff is $(-\phi, -\phi)$.

Consider next UI portfolio choice when the type is not common knowledge. A vulnerable UI solves the following program:

$$\max_{(x_L \geq 0, x_H \geq -\phi)} \quad y_3^{ui} - x_H[1 - E(P|\chi = 1)] - x_L E(P|\chi = 1)$$
$$+[\rho\overline{q} + (1-\rho)\underline{q}]\theta \min\{x_H, 0\} + [1 - (\rho\overline{q} + (1-\rho)\underline{q})]\theta \min\{x_L - \phi, 0\}.$$

We conjecture (and verify):

$$E(P|\chi = 1) \geq 1 - [\rho\overline{q} + (1-\rho)\underline{q}].$$

Under the stated conjecture, utility is increasing in x_L for all $x_L \in (0, \phi)$ iff $\theta \geq \widehat{\theta}$, and is otherwise decreasing. Utility is decreasing in x_L for all $x_L \geq \phi$. Utility is decreasing in x_H for all $x_H \geq 0$ and increasing in x_H for all $x_H \in (-\phi, 0)$.

The optimal portfolio for an invulnerable UI solves:

$$\max_{(x_L \geq -\phi, x_H \geq -\phi)} \quad y_3^{ui} - x_H[1 - E(P|\chi = 0)] - x_L E(P|\chi = 0)$$
$$+[\rho\overline{q} + (1-\rho)\underline{q}]\theta \min\{\phi + x_H, 0\} + [1 - (\rho\overline{q} + (1-\rho)\underline{q})]\theta \min\{\phi + x_L, 0\}.$$

For an invulnerable UI utility is decreasing in x_L and x_H on the relevant interval so their optimal portfolio payoff is $(-\phi, -\phi)$.■

Lemma 1: LCS Allocations

The program can be written as

$$\max_{(M_L, M_H)} \quad \overline{q}(H - M_H) + (1 - \overline{q})(L - M_L) + \beta[\overline{q}M_H + (1 - \overline{q})M_L]$$

subject to

$$\begin{aligned} \beta[\underline{q}H + (1 - \underline{q})L] &\geq \underline{q}(H - M_H) + (1 - \underline{q})(L - M_L) + \beta[\overline{q}M_H + (1 - \overline{q})M_L] \\ M_L &\leq L; \quad M_H \leq H. \end{aligned}$$

We solve a relaxed program ignoring the last constraint and then verify the neglected constraint is slack. In this relaxed program the nonmimicry constraint must bind since otherwise the objective function could be increased by raising M_H by an infinitesimal amount. From the binding nonmimicry constraint M_H can be expressed as:

$$M_H(M_L) = M_L + \frac{(\beta - 1)[\underline{q}H + (1 - \underline{q})L - M_L]}{\beta\overline{q} - \underline{q}}.$$

Substituting $M_H(M_L)$ into the objective function and ignoring constants, the relaxed program can now be expressed as:

$$\max_{M_L \leq L} \quad \overline{q}M_H(M_L) + (1 - \overline{q})M_L.$$

This objective function is strictly increasing in M_L, implying optimality of $M_L = L$. Substituting this value into $M_H(M_L)$ and verifying the neglected constraint is slack, it follows an LCS allocation entails:

$$(M_L, M_H) = \left(L, L + \frac{(\beta - 1)\underline{q}(H - L)}{\beta\overline{q} - \underline{q}}\right).■$$

Lemma 2: Set of Equilibrium Payoffs

Each type can guarantee himself at least his LCS payoff (in any sequential equilibrium) by proposing the LCS retention scheme. It follows that no other separating contract is in the equilibrium set since such a contract would lower at least one type's payoff. Further, it follows a necessary condition for a pooling menu to be in the equilibrium set is that both types are weakly better off than at the LCS. We next establish sufficiency. To this end, consider any conjectured equilibrium in which both types receive at least their LCS payoff. Deviations to a separating contract cannot be profitable for either type since no separating contract improves upon the LCS payoffs. Consider next deviations to a pooling menu. We need only identify and stipulate off-equilibrium beliefs sufficient to deter deviation.

Consider first deviations with total marketed cash flows such that $M_H \geq M_L$. Such deviations are assumed to be imputed to the low type. The low type payoff to such a deviation is:

$$\underline{q}(H - M_H) + (1 - \underline{q})(L - M_L) + \beta[\underline{q}M_H + (1 - \underline{q})M_L] \leq \underline{U}_{lcs}.$$

And the high type payoff to deviating is:

$$\begin{aligned} & \overline{q}(H - M_H) + (1 - \overline{q})(L - M_L) + \beta[\underline{q}M_H + (1 - \underline{q})M_L] \\ \leq \;& \overline{q}(H - M_H) + \beta[\underline{q}M_H + (1 - \underline{q})L] < \overline{U}_{lcs}. \end{aligned}$$

Consider finally a deviation to a pooling contract with $M_H < M_L$. Such deviations are assumed to be imputed to the high type. The high type payoff to deviating is then:

$$\begin{aligned} & \overline{q}(H - M_H) + (1 - \overline{q})(L - M_L) + \beta[\overline{q}M_H + (1 - \overline{q})M_L] \\ = \;& \overline{q}H + (1 - \overline{q})L + (\beta - 1)[\overline{q}M_H + (1 - \overline{q})M_L] \\ \leq \;& \overline{q}H + (1 - \overline{q})L + (\beta - 1)L < \overline{U}_{lcs}. \end{aligned}$$

And the payoff to the low type from such a deviation is:

$$\begin{aligned} & \underline{q}(H - M_H) + (1 - \underline{q})(L - M_L) + \beta[\overline{q}M_H + (1 - \overline{q})M_L] \\ = \;& \underline{q}H + (1 - \underline{q})L + (\beta\overline{q} - \underline{q})M_H + [\beta(1 - \overline{q}) - (1 - \underline{q})]M_L \\ < \;& \underline{q}H + (1 - \underline{q})L + (\beta\overline{q} - \underline{q})M_L + [\beta(1 - \overline{q}) - (1 - \underline{q})]M_L \\ = \;& \underline{q}H + (1 - \underline{q})L + (\beta - 1)M_L \leq \underline{U}_{lcs}. \blacksquare \end{aligned}$$

Proposition 2: Characterization of Pooling Equilibria

For brevity, we express the constraints on pooling equilibria as follows.

$$\begin{aligned} \underline{U}_{pool} &\equiv K_L(\underline{q},\underline{z})M_L + K_H(\underline{q},\underline{z})M_H + \underline{q}H + (1-\underline{q})L \geq \underline{U}_{lcs} \\ \overline{U}_{pool} &\equiv K_L(\overline{q},\overline{z})M_L + K_H(\overline{q},\overline{z})M_H + \overline{q}H + (1-\overline{q})L \geq \overline{U}_{lcs} \\ K_L(q,z) &\equiv \beta[z(1-\overline{q}) + (1-z)(1-\underline{q})] - (1-q) \\ K_H(q,z) &\equiv \beta[z\overline{q} + (1-z)\underline{q}] - q. \end{aligned} \tag{34}$$

The case of opacity is subsumed in the prior equations by setting $\overline{z} = \underline{z} = \rho$.

We begin by proving a few useful lemmas.

Lemma. $M_H > M_L$ in any pooling equilibrium.

Proof: Suppose to the contrary there exists a pair of marketed payoffs (M_L^0, M_H^0) in the equilibrium set such that $M_H^0 \leq M_L^0$. The low type's pooling payoff would be

$$\begin{aligned} & K_L(\underline{q},\underline{z})M_L^0 + K_H(\underline{q},\underline{z})M_H^0 + \underline{q}H + (1-\underline{q})L \\ \leq\ & K_L(\underline{q},\underline{z})M_L^0 + K_H(\underline{q},\underline{z})M_L^0 + \underline{q}H + (1-\underline{q})L \\ =\ & (\beta-1)M_L^0 + \underline{q}H + (1-\underline{q})L < \underline{U}_{lcs} \end{aligned}$$

with the second inequality following from $K_H(\underline{q},\underline{z}) > 0$ and the last line following from $K_L + K_H = \beta - 1$. This is a contradiction.▲

Lemma. If there is a pooling equilibrium, then $K_H(\overline{q},\overline{z}) > 0$.

Proof: Suppose to the contrary there exists a pair of marketed payoffs (M_L^0, M_H^0) in the equilibrium set while $K_H(\overline{q},\overline{z}) \leq 0$. Since $M_H > M_L$ in any pooling equilibrium we then know the high type's equilibrium payoff is:

$$\begin{aligned} & K_L(\overline{q},\overline{z})M_L^0 + K_H(\overline{q},\overline{z})M_H^0 + \overline{q}H + (1-\overline{q})L \\ \leq\ & K_L(\overline{q},\overline{z})M_L^0 + K_H(\overline{q},\overline{z})M_L^0 + \overline{q}H + (1-\overline{q})L \\ =\ & (\beta-1)M_L^0 + \overline{q}H + (1-\overline{q})L \leq (\beta-1)L + \overline{q}H + (1-\overline{q})L < \overline{U}_{lcs}. \end{aligned}$$

This is a contradiction.▲

Lemma. $M_H > L$ *in any pooling equilibrium.*

Proof: Suppose to the contrary there exists a pair of marketed payoffs (M_L^0, M_H^0) in the equilibrium set while $M_H^0 < L$. Since $K_L(\overline{q},\overline{z}) > 0$ and $K_H(\overline{q},\overline{z}) > 0$ (preceding lemma) we know

$$\begin{aligned} & K_L(\overline{q},\overline{z})M_L^0 + K_H(\overline{q},\overline{z})M_H^0 + \overline{q}H + (1-\overline{q})L \\ < \; & K_L(\overline{q},\overline{z})L + K_H(\overline{q},\overline{z})L + \overline{q}H + (1-\overline{q})L \\ = \; & (\beta - 1)L + \overline{q}H + (1-\overline{q})L < \overline{U}_{lcs}. \end{aligned}$$

This is a contradiction.▲

The third statement in the proposition follows from the fact that $K_H > 0$ for both types if there is a pooling equilibrium. To prove the fourth statement in the proposition, assume there is a pooling equilibrium at the marketed pair (M_L^0, M_H^0). Since $K_L(\overline{q},\overline{z}) > 0$ and $K_H(\overline{q},\overline{z}) > 0$, we know the high type's payoff at full securitization is

$$\begin{aligned} & K_L(\overline{q},\overline{z})L + K_H(\overline{q},\overline{z})H + \overline{q}H + (1-\overline{q})L \\ \geq \; & K_L(\overline{q},\overline{z})M_L^0 + K_H(\overline{q},\overline{z})M_L^0 + \overline{q}H + (1-\overline{q})L \geq \overline{U}_{lcs} \end{aligned}$$

And the low type is always better off when pooling at full securitization than under his LCS allocation since

$$K_L(\underline{q},\underline{z})L + K_H(\underline{q},\underline{z})H + \underline{q}H + (1-\underline{q})L > \beta[\underline{q}H + (1-\underline{q})L] = \underline{U}_{lcs}.$$

Finally, to establish the existence of a pooling equilibrium at full securitization we need only check the condition under which the high type is better off than at the LCS (since the low type is necessarily better off). We have:

$$\begin{aligned} & K_L(\overline{q},\overline{z})L + K_H(\overline{q},\overline{z})H + \overline{q}H + (1-\overline{q})L \\ \geq \; & \beta[\overline{q}H + (1-\overline{q})L] - (\beta-1)\overline{q}\left[\frac{\beta(\overline{q}-\underline{q})(H-L)}{(\beta\overline{q}-\underline{q})}\right] \\ & \Updownarrow \\ \overline{z} \geq \; & (\overline{q}-\underline{q})/(\beta\overline{q}-\underline{q}). \blacksquare \end{aligned}$$

Proposition 3: The Intuitive Criterion

We begin by recalling that with two types (t, t'), a PBE fails to satisfy the Intuitive Criterion if there exists: an unsent menu proposal m'; a type t' who is strictly better off than at the posited PBE by proposing m' for all best responses with beliefs focused on t'; and a type t who is strictly better at the posited PBE than at m' for all best responses for all beliefs in response to m'.

With this definition in mind a few lemmas are immediate. First, a PBE will never be pruned via a low type deviation (imputed to him) since the associated payoff is weakly less than his LCS payoff. Second, no separating menu can prune the PBE set since any separating contract yields either type weakly less than his LCS payoff. Third, any pruning high type pooling contract deviation must feature $M_H > L$ since a deviation to $M_H \leq L$ imputed to him yields strictly less than his LCS payoff. Thus, without loss of generality in pruning the set of PBE attention can be confined to high type deviations to pooling contracts entailing $M_H > L \geq M_L$. The following lemma further narrows the set of relevant deviations.

Lemma: If a deviation to (M_L^0, M_H^0) prunes a PBE, so too does a deviation to (L, M_H^1) where $M_H^1 \equiv M_H^0 - (L - M_L^0)(1 - \overline{q})/\overline{q}$.

Proof: By construction the high type achieves the same payoff deviating to (L, M_H^1) as opposed to (M_L^0, M_H^0). Further, since the high type gains from both deviations it must be that $M_H^1 > L$ and $M_H^0 > L \geq M_L^0$. Thus, for either deviation the most favorable belief is that it is being made by the high type. Given such beliefs the low type must have been worse off deviating to (M_L^0, M_H^0). Relative to that deviation payoff, the low type is even worse off deviating to (L, M_H^1) with the change in utility (for beliefs focused on the high type) computed via

$$\begin{aligned} U &= \underline{q}(H - M_H) + (1 - \underline{q})(L - M_L) + \beta[\overline{q}M_H + (1 - \overline{q})M_L] \\ &\Rightarrow \Delta U = (\beta\overline{q} - q)\Delta M_H + [\beta(1 - \overline{q}) - (1 - \underline{q})]\Delta M_L \\ &\Rightarrow \Delta U = -[(\beta\overline{q} - q)(1 - \overline{q})/\overline{q} + (\beta(1 - \overline{q}) - (1 - \underline{q}))](L - M_L^0) < 0.\blacktriangle \end{aligned}$$

Lemma: A necessary and sufficient condition for a perfect Bayesian equilibrium to satisfy the

Intuitive Criterion is that the associated type-contingent interim utilities ($\underline{U}^*$,$\overline{U}^*$) *satisfy*

$$\beta(\overline{q}-\underline{q})[\overline{q}H+(1-\underline{q})L] \leq (\beta\overline{q}-\underline{q})\overline{U}^* - (\beta-1)\overline{q}\underline{U}^*.$$

Proof: From the preceding lemma, a necessary and sufficient condition to prune a PBE is to find an M_H such that

$$\begin{aligned} \underline{q}(H-M_H)+\beta[\overline{q}M_H+(1-\overline{q})L] &< \underline{U}^* \\ \overline{q}(H-M_H)+\beta[\overline{q}M_H+(1-\overline{q})L] &> \overline{U}^* \end{aligned}$$

The first inequality immediately above implies an upper bound $M_H^{up} < H$ and the second implies a lower bound $M_H^{low} > L$. Thus, there exists a feasible pruning deviation iff $M_H^{up} > M_H^{low}$. The inequality stated in the lemma is necessary and sufficient to ensure $M_H^{low} \geq M_H^{up}$ so that no pruning deviation exists.▲

The LCSE utilities satisfy the necessary and sufficient condition stated in the preceding lemma. We turn now to proving a final lemma.

Lemma: A PBE survives the Intuitive Criterion if and only if

$$\beta\left[(\beta-1)\overline{q}(\overline{z}-\underline{z})-(1-\overline{z})(\overline{q}-\underline{q})\right](M_H-M_L) \geq (\beta-1)(L-M_L).$$

Proof: Let $\overline{REV}$ and $\underline{REV}$ denote the expected revenues of high and low types, respectively. We established above the following necessary and sufficient condition to satisfy the Intuitive Criterion:

$$
\begin{aligned}
(\beta\overline{q}-\underline{q})\overline{U}-(\beta-1)\overline{q}\underline{U} &\geq \beta(\overline{q}-\underline{q})\left[\overline{q}H+(1-\overline{q})L\right] \\
&\Updownarrow \\
(\beta\overline{q}-\underline{q})\beta\overline{REV}-(\beta-1)\overline{q}\beta\underline{REV} &\geq (\beta-1)(\overline{q}-\underline{q})L+(\overline{q}-\underline{q})\left[\beta\overline{q}M_H+(1-\beta\overline{q})M_L\right] \\
&\Updownarrow \\
\beta\left[(\beta\overline{q}-\underline{q})(\overline{z}-\underline{z})-(1-\underline{z})(\overline{q}-\underline{q})\right](M_H-M_L) &\geq (\beta-1)(L-M_L) \\
&\Updownarrow \\
\beta\left[(\beta-1)\overline{q}+(\overline{q}-\underline{q}))(\overline{z}-\underline{z})-(1-\underline{z})(\overline{q}-\underline{q})\right](M_H-M_L) &\geq (\beta-1)(L-M_L) \\
&\Updownarrow \\
\beta\left[(\beta-1)\overline{q}(\overline{z}-\underline{z})-(1-\overline{z})(\overline{q}-\underline{q})\right](M_H-M_L) &\geq (\beta-1)(L-M_L)\,.\blacktriangle
\end{aligned}
$$

The full securitization condition follows immediately from the preceding lemma. And finally, no opaque structuring ($\overline{z}=\underline{z}$) satisfies the condition stated in the lemma.■

Appendix B: Social Welfare

This appendix presents expressions for total social welfare under both unregulated and regulated market equilibria.

$$
\begin{aligned}
W_{op}^{otd} &= \beta[(\underline{\rho}(1-\overline{q}) + (1-\underline{\rho})(1-\underline{q}))L + (\underline{\rho}\overline{q} + (1-\underline{\rho})\underline{q})H] \\
&\quad + y_3^s + y_3^{ui} - \frac{1}{2}(\overline{\nu}+\underline{\nu})\phi[\underline{\rho}(1-\overline{q}) + (1-\underline{\rho})(1-\underline{q})] + \left[1 - \frac{\overline{\nu}+\underline{\nu}}{2}\right]\phi.
\end{aligned} \tag{35}
$$

$$
\begin{aligned}
W_{op} &= (\rho_{op}(1-\overline{q}) + (1-\rho_{op})(1-\underline{q}))R_L + (\rho_{op}\overline{q} + (1-\rho_{op})\underline{q})R_H \\
&\quad + \beta[(\rho_{op}(1-\overline{q}) + (1-\rho_{op})(1-\underline{q}))M_L + (\rho_{op}\overline{q} + (1-\rho_{op})\underline{q})M_H] - \frac{(\rho_{op}-\underline{\rho})c}{\overline{\rho}-\underline{\rho}} \\
&\quad + y_3^s + y_3^{ui} - \frac{1}{2}(\overline{\nu}+\underline{\nu})\phi[\rho_{op}(1-\overline{q}) + (1-\rho_{op})(1-\underline{q})] + \left[1 - \frac{\overline{\nu}+\underline{\nu}}{2}\right]\phi.
\end{aligned} \tag{36}
$$

$$
\begin{aligned}
W_{tran} &= (\rho_{tran}(1-\overline{q}) + (1-\rho_{tran})(1-\underline{q}))R_L + (\rho_{tran}\overline{q} + (1-\rho_{tran})\underline{q})R_H \\
&\quad + \beta[(\rho_{tran}(1-\overline{q}) + (1-\rho_{tran})(1-\underline{q}))M_L + (\rho_{tran}\overline{q} + (1-\rho_{tran})\underline{q})M_H] - \frac{(\rho_{tran}-\underline{\rho})c}{\overline{\rho}-\underline{\rho}} \\
&\quad + y_3^{ui} - \frac{1}{2}(\overline{\nu}+\underline{\nu})\phi\left[1 + \int_1^{\widehat{\theta}}(\theta-1)f(\theta)d\theta\right][\rho_{tran}(1-\overline{q}) + (1-\rho_{tran})(1-\underline{q})] \\
&\quad + \left[1 - \frac{\overline{\nu}+\underline{\nu}}{2}\right]\phi + +y_3^s - e.
\end{aligned} \tag{37}
$$

$$
\begin{aligned}
W_{lcs} &= \beta[(\rho_{lcs}(1-\overline{q}) + (1-\rho_{lcs})(1-\underline{q}))L + (\rho_{lcs}\overline{q} + (1-\rho_{lcs})\underline{q})H] - (\beta-1)\rho_{lcs}\overline{q}R_H \\
&\quad - \frac{(\rho_{lcs}-\underline{\rho})c}{\overline{\rho}-\underline{\rho}} + y_3^s + y_3^{ui} - \frac{1}{2}(\overline{\nu}+\underline{\nu})\phi[\rho_{lcs}(1-\overline{q}) + (1-\rho_{lcs})(1-\underline{q})] + \left[1 - \frac{\overline{\nu}+\underline{\nu}}{2}\right]\phi.
\end{aligned} \tag{38}
$$

$$
\begin{aligned}
W_{sep}^{*} &= \beta[L + (H-L)(\overline{\rho q} + (1-\overline{\rho})\underline{q})] - c + y_3^s + \\
&\quad y_3^{ui} - \frac{1}{2}(\overline{\nu}+\underline{\nu})\phi[\overline{\rho}(1-\overline{q}) + (1-\overline{\rho})(1-\underline{q})] + \left[1 - \frac{\overline{\nu}+\underline{\nu}}{2}\right]\phi \\
&\quad -(\beta-1)\left[\overline{\rho q}\overline{R}_H^{sep} - (1-\overline{\rho})\underline{q}\underline{R}_H^{sep}\right].
\end{aligned} \tag{39}
$$

$$
\begin{aligned}
W^*_{tpool} &= \beta[L + (H-L)(\overline{\rho q} + (1-\overline{\rho})\underline{q})] - c + y^s_3 - e \\
&+ y^{ui}_3 - \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi \left[1 + \int_1^{\widehat{\theta}} (\theta - 1) f(\theta) d\theta\right] [\overline{\rho}(1-\overline{q}) + (1-\overline{\rho})(1-\underline{q})] \\
&+ \left[1 - \frac{\overline{\nu} + \underline{\nu}}{2}\right] \phi - (\beta - 1)[\overline{\rho q} + (1-\overline{\rho})\underline{q}] R^{tpool}_H.
\end{aligned} \tag{40}
$$

$$
\begin{aligned}
W^*_{opool} &= \beta[L + (H-L)(\overline{\rho q} + (1-\overline{\rho})\underline{q})] - c + y^s_3 \\
&+ y^{ui}_3 - \frac{1}{2}(\overline{\nu} + \underline{\nu})\phi[\overline{\rho}(1-\overline{q}) + (1-\overline{\rho})(1-\underline{q})] + \left[1 - \frac{\overline{\nu} + \underline{\nu}}{2}\right] \phi \\
&- (\beta - 1)[\overline{\rho q} + (1-\overline{\rho})\underline{q}] R^{opool}_H.
\end{aligned} \tag{41}
$$

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Table 3: Aggregate Demand Outcomes

Type	Signal	% Uninformed Vulnerable	Informed Demand	Uninformed Demand	Aggregate Demand	Probability
$\overline{q}$	$\overline{s}$	$\overline{v}$	0	$\overline{v}\Omega$	$\overline{v}\Omega$	$\frac{\rho\sigma}{2}$
$\overline{q}$	$\overline{s}$	$\underline{v}$	0	$\underline{v}\Omega$	$\underline{v}\Omega$	$\frac{\rho\sigma}{2}$
$\overline{q}$	$\underline{s}$	$\overline{v}$	$(\overline{v}-\underline{v})\Omega$	$\overline{v}\Omega$	$(2\overline{v}-\underline{v})\Omega$	$\frac{\rho(1-\sigma)}{2}$
$\overline{q}$	$\underline{s}$	$\underline{v}$	$(\overline{v}-\underline{v})\Omega$	$\underline{v}\Omega$	$\overline{v}\Omega$	$\frac{\rho(1-\sigma)}{2}$
$\underline{q}$	$\underline{s}$	$\overline{v}$	$(\overline{v}-\underline{v})\Omega$	$\overline{v}\Omega$	$(2\overline{v}-\underline{v})\Omega$	$\frac{(1-\rho)\sigma}{2}$
$\underline{q}$	$\underline{s}$	$\underline{v}$	$(\overline{v}-\underline{v})\Omega$	$\underline{v}\Omega$	$\overline{v}\Omega$	$\frac{(1-\rho)\sigma}{2}$
$\underline{q}$	$\overline{s}$	$\overline{v}$	0	$\overline{v}\Omega$	$\overline{v}\Omega$	$\frac{(1-\rho)(1-\sigma)}{2}$
$\underline{q}$	$\overline{s}$	$\underline{v}$	0	$\underline{v}\Omega$	$\underline{v}\Omega$	$\frac{(1-\rho)(1-\sigma)}{2}$