Skin in the Game and Moral Hazard[*]

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April 2012

Abstract

Are observed ABS structures irrational? And should skin in the game be regulated? To address these questions we develop a noisy rational expectations model where originators can exert effort to increase the probability of high asset quality type and then exploit interim private information regarding type in choosing retentions and tranching. With sufficient price informativeness full securitization can be consistent with rational equilibrium, although opacity requires naive investors. In favor of regulation, we show asymmetric information reduces the payoff differential between types, discouraging effort. Further, originators do not internalize benefits of signaling via retentions in facilitating efficient risk-sharing across investors. Effort can be induced by mandating high junior tranche retentions, punishing low types. In an optimal "separating regulation" inducing effort, originators choose from a menu of junior tranche retention sizes. In an optimal "pooling regulation" inducing effort, all originators retain a single junior claim, with size inversely related to price informativeness. The separating (pooling) regulation generally maximizes welfare if efficient risk-sharing (originator investment) is the dominant concern. Mandated opacity is optimal amongst mechanisms providing zero effort incentive.

JEL Codes: G32, G28.

In the wake of the recent credit crisis, empirical researchers have sifted through the wreckage to locate root causes of sharp declines in the value of various classes of asset-backed securities (ABS). Securitization and the originate-to-distribute (OTD below) business model, which features zero originator retentions, have figured prominently in the list of causal factors. For example, there is now a compelling body of empirical evidence establishing a negative relationship between securitization rates and ABS performance (see e.g. Mian and Sufi (2009), Keys et al. (2010) and Keys, Seru and Vig (2011)).

Implicit in much of the discussion surrounding the ABS-linked financial crisis is the notion that observed ABS structures were reliant upon agents being irrational or naïve. Further, implicit in recent legislation in the United States is the view that government intervention in ABS markets will increase social welfare. In particular, the Dodd-Frank Act, recently codified as Section 15G of the Securities Exchange Act, charges six federal agencies (the Federal Reserve, Treasury, FDIC, SEC, FHA, and HUD) with setting mandatory retention standards for ABS securitizers. Unfortunately, understanding the root causes of the crisis and the formulation of optimal regulation of ABS is hindered by the absence of a coherent theoretical framework allowing one to answer some fundamental questions. First, what types of structures should one expect to see in an unregulated ABS market? Second, are there market failures and, if so, can a regulator possibly improve upon unregulated market outcomes? Third, how do mandated retentions affect determinants of social welfare such as effort incentives, investment levels and risk-sharing? Finally, given the trade-offs what are the policy options and conditions under which each dominates?

This paper develops a tractable mechanism and security design framework to address the questions posed above. Although the primary focus is ABS markets, the economic setting is pervasive: *An agent ("originator" below) is considering exerting costly hidden effort ex ante, anticipating subsequent marketing of claims to investors who will not know the asset's true type while the agent will know its type.* Securitization proceeds fund a scalable investment with positive NPV. Ex post, ABS are purchased in competitive markets by an endogenously informed speculator and rational unin-

Electronic copy available at: http://ssrn.com/abstract=1911922

formed investors with hedging motives. We make three key departures from the canonical private information setting considered by Myers and Majluf (1984). First, we follow DeMarzo and Duffie (1999) in considering optimal securities written on assets-in-place. Second, we allow speculator orders to drive prices closer to fundamentals in noisy rational expectations equilibria. Finally, and most importantly, there is an ex ante stage in which the originator can increase the probability of "becoming a high type" by exerting unobservable costly effort. Although other papers analyze aspects of equilibria with private information, we present an encompassing treatment of the private information problem in securities markets, show when this interim problem can be a root cause of ex ante moral hazard, and evaluate social welfare implications.

We first describe potential equilibria in unregulated ABS markets. This positive analysis is useful in developing empirical implications, and also sheds light on the debate regarding whether observed pre-crisis ABS structures evidence irrationality. Moreover, the positive analysis will be useful in identifying potential market failures in order to perform normative analysis. One possible equilibrium in unregulated markets is a least-cost separating equilibrium (LCSE) in which the low type securitizes the entire asset while the high type signals by retaining the minimal junior tranche needed to deter mimicry.[1]

In addition to the LCSE, there can be equilibria in which originators pool by adopting identical securitization structures, provided both high and low type originators are weakly better off than at the LCSE.[2] We show that if price informativeness is sufficiently high, pooling at full securitization can be a fully rational equilibrium outcome. Intuitively, a high type will be willing to pool provided informed speculation drives prices sufficiently close to fundamentals. In contrast, opacity is shown to be inconsistent with sophisticated investor beliefs. Intuitively, a high type should defect from opacity *and* investors should know this. In the event of pooling, security design is shown to increase informational efficiency since catering to hedging clienteles promotes uninformed trade and speculator effort. Finally, we there can be multiple self-fulfilling levels of originator effort in pooling

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[1] Leland and Pyle (1977) first noted the signal value of retentions.

[2] This is an application of a result of Maskin and Tirole (1992).

equilibria. This latter point illustrates a role for light-touch regulation which simply selects the socially preferred unregulated equilibrium.

Our positive analysis of unregulated ABS markets reveals two welfare arguments for moving away from unregulated equilibria and mandating retentions. First, privately optimal retentions can be socially suboptimal since originators do not internalize the benefit of improved investor risk-sharing resulting from signaling/separation. Specifically, signaling conveys the private information of originators and thus eliminates the motive of speculators to acquire costly information as well as eliminating uninformed investor concerns about adverse selection. In contrast, in the event of pooling by originators, costly speculative information acquisition occurs and uninformed investors distort their portfolios to reduce their expected trading losses. The second argument favoring regulation is that the equilibrium payoff to ex ante effort in unregulated markets may be insufficient to induce effort. Curbing moral hazard requires punishing originators who produce low value assets. But if retentions are not mandated, a low type can always achieve his first-best payoff, if not more, by admitting he is a low type and proceeding to securitize the entire asset.

The formal basis for the preceding two arguments favoring regulation is as follows. The equilibrium set at the interim securitization stage consists of all structures Pareto dominating the LCSE from the perspective of originators. The first problem with such unregulated equilibria from a social welfare perspective is that Pareto optimality is only evaluated from the originator perspective. Thus, investor-level benefits of signaling are ignored. Second, a low type always receives at least his first-best interim payoff, in opposition to the punishment needed to encourage effort ex ante.

A socially optimal mandatory retention scheme promotes effort by increasing the spread between interim payoffs to high and low types, while accounting for costs imposed on investors as well as originators. There are two kinds of skin-in-the-game regulatory schemes featuring differing benefits and costs: *separating schemes* inducing originators to reveal the true asset type and *pooling schemes* that do not.

In an optimal separating scheme, originators are forced to choose from a menu of strictly posi-

tive junior tranche retentions. As in the LCSE of unregulated markets, ex post efficient risk-sharing across investors is achieved by a separating regulatory scheme. However, unlike the LCSE, the low type retains a stake in order to increase the spread between type-contingent interim payoffs. Significantly, unregulated markets cannot implement this outcome since it is interim Pareto dominated by the LCSE from the perspective of originators.

The optimal pooling regulation relies upon informed speculation to strengthen price discipline, with originators also being forced to hold a single junior tranche size. Intuitively, the gap between the interim payoffs of high and low types is maximized if originators receive zero as a final period cash payoff if the total asset payoff is low. The size of the mandated retention is lower, and potentially zero, when price informativeness is high. Thus, the optimal pooling regulation requires taking a view on informational efficiency. The disadvantage of the pooling regulatory scheme 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.

The model delivers a rich set of policy prescriptions. First, originators should be forced to hold junior tranches. Second, when discretion is granted to originators, it should be over the size of the junior tranche, as distinct from proposals granting originators discretion over which tranches to hold. Third, in contrast to standard signaling results, optimal separating mechanisms impose underinvestment costs on even the lowest type in order to motivate effort. Fourth, the choice between separating versus pooling regimes generally trades off improved risk-sharing in the former against higher originator investment in the latter. Finally, regulation should vary according to the informational efficiency of the specific ABS market. If informational efficiency is high, it can be optimal to require originators to hold a small junior claim, relying on prices for discipline. If regulators view a market as having low informational efficiency, originators should be forced to choose from a granular menu of junior tranche retention sizes in a separating mechanism.

In addition to the papers discussed above, our paper is also closely related to work by Gorton and Pennacchi (1995), Parlour and Plantin (2008), and Rajan, Seru and Vig (2010) who analyze the

link between securitization and effort incentives. There are a number of important differences. First, these papers do not analyze the social welfare arguments for and against mandatory retentions. Second, they do not analyze optimal security design from either a public or private perspective. Third, these papers abstract from the effect of ABS on risk-sharing by investors. Finally, these papers rule out the possibility of informed speculation. Importantly, we show the possibility of informed speculation radically changes the set of unregulated market equilibria and is also a necessary ingredient for optimal pooling regulation.

With its focus on the social welfare implications of ABS, our paper is also related to that of Dang, Gorton and Holmström (2010). Consistent with their analysis, we find opacity combined with full securitization yields the highest interim social welfare.[3] However, we show this structure is only optimal if one confines attention to schemes that fail to provide any effort incentive to originators. Intuitively, an opaque market is one in which prices fail to provide any discipline. Thus, the choice between opacity and transparency must weigh interim-efficient risk-sharing against ex ante moral hazard.

DeMarzo and Duffie (1999) analyze optimal security design by a principal in advance of his acquiring private information, with debt being an optimal security to minimize price impact of his future selling. There is no moral hazard in their model. Boot and Thakor (1993) analyze security design in a pure hidden information setting with no originator effort. They show tranching can stimulate speculator effort, but focus on a different lever. In their model, tranching relaxes speculator wealth constraints as they trade against pure noise traders. Fulghieri and Lukin (2001) also analyze the role of security design in a setting with pure noise traders.

In Gorton and Pennacchi (1990), uninformed investors carve out riskless debt furnishing themselves with safe storage. Hennessy and Chemla (2011) show a privately informed bank may not issue a safe claim in such a setting, relying on uninformed trade in risky debt to promote informed trading. Both papers abstract from effort. Further, the theory of security design presented here differs fundamentally in that uninformed investors only buy the riskiest marketed tranche in order

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

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to hedge endowments. Effectively, we argue ABS issuers may try to increase asset span, as in Allen and Gale (1988), but now with the motive of stimulating uninformed trade with speculators. Hanson and Sunderam (2010) also analyze the link between security design and information acquisition. In their model, debt has low informational-sensitivity during good times and speculators do not acquire information. The ABS market freezes in bad times since investors did not invest in slow-moving information systems during booms. Originator effort incentives are not analyzed.[4]

The role of price informativeness in alleviating moral hazard has been analyzed in other contexts. Holmström and Tirole (1993) present a model in which the equity float affects information acquisition, price informativeness, and managerial risk premia. Maug (1998), Aghion, Bolton and Tirole (2004) and Faure-Grimaud and Gromb (2004) show price informativeness promotes insider effort. Only Aghion, Bolton and Tirole analyze security design. Each of these papers assumes pure noise trading, precluding the use of tranching to increase uninformed demand and the gains to informed speculation. Social welfare analysis is impossible in such noise trader models, and there is no analysis of socially optimal mandatory retention schemes.

The remainder of the paper is as follows. Section I describes the game and timing. Section II analyzes the final continuation game in which market-makers set prices. Section III analyzes the penultimate continuation game in which the privately informed originator chooses retentions and security design. Section IV analyzes originator effort incentives. Section V analyzes social welfare and socially optimal mandatory retention schemes.

I. The Game

This section describes the timing of events in the various stages of the game. The equilibrium concept is *perfect Bayesian equilibrium* (PBE) as defined in Maskin and Tirole (1992).

A. Technology and Agent Preferences

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[4]In Shleifer and Vishny (2010), securitization increases if exogenous prices exceed fundamentals.

There are four periods 1, 2, 3 and 4. There is a single storable good and consumption occurs in periods 3 and 4. The originator enters the model with 1 unit of endowment that he can store or invest in order to develop the asset underlying the ABS. He derives utility from consumption equal to $C_3 + C_4$. In period 1, Originator decides whether to exert an unobservable non-scalable effort having a non-pecuniary cost $c > 0$. The effort increases the probability of generating a high quality asset from $\underline{\rho}$ to $\overline{\rho}$ where $0 < \underline{\rho} < \overline{\rho} < 1$. A high quality asset delivers H with probability $\overline{q}$ and L with probability $1 - \overline{q}$. A low quality asset delivers H with probability $\underline{q}$ and L with probability $1 - \underline{q}$. The cash flow generated by the underlying asset accrues in period 4. It is assumed: $0 < \underline{q} < \overline{q} < 1$; $L \in (0, H)$; and $\underline{q}H + (1 - \underline{q})L > 1$ implying the originator always finds it optimal to develop the underlying asset.

It is assumed the effort cost c is sufficiently low such that in the absence of any financial market imperfection effort would be incentive compatible:

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

By the *interim period* (period 2) the originator has developed the asset and has privately observed its true quality q (its *type,* below). In contrast, outside investors do not have access to the same information as the originator and cannot observe asset quality. We let ρ denote outside investors' uninformed assessment of the probability of the type being $\overline{q}$ at the start of period 2.

In the ABS context, this effort and information environment can be motivated as follows. Suppose there are three possible scenarios for the market value of underlying loan collateral (e.g. home price): price can rise, fall, or remain flat. Reliable borrowers will only default if prices fall while unreliable borrowers will only repay if prices rise. ABS composed of unscreened loans will be of high quality only if prices rise, whereas an ABS composed of screened loans will be of high quality even if prices remain flat. In this way, ex ante screening to assess borrower characteristics increases the probability of an ABS being of high quality. Moreover, interim private information regarding underlying collateral price allows the originator to know the asset type while outside investors do not.

In period 3 the originator gains exclusive access to a scalable investment with an expected payoff of $\beta > 1$ units accruing in period 4 per unit invested in period 3. Other agents receive endowments and consume in periods 3 and 4. They can safely store their period 3 endowment in order to carry resources to period 4, or they can buy securities sold by the originator. Limitations on the verifiability of endowments leads to endogenously incomplete markets.[5] In particular, the endowments of the other agents are not verifiable by courts. Consequently, other agents cannot issue securities, borrow or short-sell.[6] The only verifiable quantity is the realized period 4 payoff (*the state*, below) of the underlying asset developed by the originator. Courts cannot verify the payoff on the originator's second investment. Thus, the originator must sell claims on the first asset in order to increase the scale of the new investment.

There is a continuum of *uninformed investors* (UI) of measure one who have an insurance motive for purchasing securities delivering consumption in period 4. The UI are sufficiently wealthy in aggregate to buy the entire asset since each has a period 3 endowment $y_3^{ui} \geq H$. As in Kyle (1985) and subsequent noisy rational expectations models, UI face imperfectly correlated shocks that confound market-makers. To make welfare analysis possible, we model UI preferences explicitly and their trading decisions endogenously. The period 4 endowment of an arbitrary UI is either ζ or $\zeta - \phi$, where $\zeta > \phi > 0$. Just prior to securities trading during period 3, each UI privately observes a signal regarding his own period 4 endowment. In particular, a fraction $v \in \{\underline{v}, \overline{v}\}$ of UI discover they are vulnerable to a negative endowment shock. Each UI knows whether or not he is personally vulnerable, but no agent in the economy observes the realized v. Each realization of v is equally likely. An invulnerable UI knows his period 4 endowment will be ζ for sure. In contrast, vulnerable UI face endowment shocks negatively correlated with the asset payoff, creating a hedging demand. Conditional upon being vulnerable, if the underlying asset delivers L the investor's period 4 endowment will be ζ and if the underlying delivers H his period 4 endowment will be $\zeta - \phi$. For example, one may think of ϕ as a negative shock hitting prospective homebuyers if defaults are low.

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[5] This follows Allen and Gale (1988), for example.

[6] As in Maug (1998), results do not change if the speculator can short.

UI are risk-neutral over period 3 consumption and risk-averse over period 4 consumption, with ζ being a critical threshold for final period consumption. They are indexed by the intensity of their risk-aversion as captured by a preference parameter θ. The utility function of a UI of type θ is:

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

The preference parameters have support $\Theta \equiv [1, \infty)$ and density f with cumulative density F. This distribution has no atoms and f is strictly positive. The kinked preferences described above follow Dow (1998). However, other continuously differentiable utility functions could be assumed at the cost of more complex aggregate demand functions.

There is a speculator S with utility $C_3 + C_4$. In period 3 she is endowed $y_3^s \geq H$ units of the numeraire, so she can afford to buy the entire asset. Her period 4 endowment is zero. Under *transparency* the speculator can analyze the asset and get a noisy signal of its quality, but must incur some costs in order to do so. Under *opacity* the speculator cannot analyze the asset and gets a completely uninformative signal of asset quality.

The speculator is unique in that she can exert costly effort to get an informative signal if there is transparency. Letting $s \in \{\underline{s}, \overline{s}\}$ denote the signal and q the true asset quality, S chooses $\sigma \equiv \Pr(s = q)$ from the feasible set $[1/2, 1]$. Her non-pecuniary effort cost function e is twice continuously differentiable, strictly increasing, and strictly convex with

$$\lim_{\sigma \downarrow \frac{1}{2}} e(\sigma) = \lim_{\sigma \downarrow \frac{1}{2}} e'(\sigma) = 0$$
$$\lim_{\sigma \uparrow 1} e'(\sigma) = \infty.$$

Starting from an uninformed prior belief ρ, if S exerts effort the signal becomes informative since a positive signal causes her to correctly revise upwards her estimate of the true type being $\overline{q}$, with

$$\sigma > \frac{1}{2} \Rightarrow \Pr[q = \overline{q} | s = \overline{s}] = \frac{\Pr[q = \overline{q} \cap s = \overline{s}]}{\Pr[s = \overline{s}]} = \frac{\rho\sigma}{\rho\sigma + (1 - \rho)(1 - \sigma)} > \rho. \tag{1}$$

The final set of agents in the economy is a continuum of market-makers (MM below) of measure one. Their period 3 aggregate endowment exceeds H, so they can afford to buy the entire asset.

Each has utility $C_3 + C_4$.

B. The Securitization Stage

The *Securitization Stage* takes place in period 2. This stage begins with Originator registering a *menu* containing two securitization structures, $\{\underline{\Sigma}, \overline{\Sigma}\}$ that he will choose from subsequently. Each structure on the registered menu stipulates payoffs to all claimholders as a function of the asset payoff in period 4. Since investor endowments are not verifiable, contractual payments to investors in period 4 must be non-negative. Further, since only the asset payoff is verifiable, total contractual payments to investors in each state (L or H) cannot exceed the asset payoff.[7] Finally at this stage, the originator can choose to give investors access to potentially useful information that will require skill and effort to process (transparency) or can refuse to give investors such access (opacity).

Abstractly, the menu is a direct revelation mechanism in which the originator reports his type and then implements the corresponding securitization, e.g. type $\underline{q}$ implements $\underline{\Sigma}$. From the revelation principle for Bayesian games we may confine attention to direct revelation mechanisms inducing truth-telling. In reality, one may think of this menu mechanism as akin to a shelf-registration.

C. The Trading Stage

In period 3, play passes to a *Trading Stage*.[8] At this stage, prices are set competitively by the MM. The originator agrees not to trade in this market so that his net exposure to the asset is known by all parties based on the structure Σ he chose in period 2.

At the start of the Trading Stage, Speculator chooses σ at cost $e(\sigma)$, with $\sigma = 1/2$ if the originator chose opacity during the Securitization Stage. Next S privately observes her signal. Next, each UI privately observes whether he is personally vulnerable to a negative endowment shock. Next, the UI and S simultaneously submit non-negative market orders. MM then set prices competitively based on observed aggregate demands in all markets, with no market segmentation. MM clear markets, buying securities not purchased by UI or S.

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[7] If the originator had other verifiable assets he would sell them directly or equivalently use them as an enhancement to the ABS.

[8] This game is similar to that presented in Maug (1998), but we have endogenous security design and UI demand.

Since Originator is the only agent capable of issuing claims delivering goods in period 4, MM cannot be called upon to take short positions. To this end, we impose a second technical assumption.

$$A2 : \phi \leq \frac{H - L - c/(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})}{2} \Rightarrow c \leq (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[H - L - 2\phi].$$

The role of Assumption 2 is as follows. The aggregate demand of UI is weakly increasing in ϕ. To avoid the possibility of aggregate demand exceeding supply for any security, the endowment shock must be sufficiently small. Assumption 2 also implies that originator effort is socially beneficial, even after accounting for potential losses incurred by UI when the realized asset payoff is H.

Figure 1 provides a review of the time-line.

II. The Trading Stage

This section determines UI demand, speculator effort, and how the market-makers (MM) set security prices. Securities marketed by the originator are indexed by $j \in \{1, ..., J\}$. The contractual state-contingent payoff for security j is denoted (A_{jL}, A_{jH}). Safe storage is indexed by $j = 0$. Safe storage has a price of 1 and delivers 1 in period 4.

A. Trading and Pricing

We first analyze the security demands of uninformed investors. Consider an arbitrary UI with utility parameter θ. If he is invulnerable to a negative endowment shock, he optimally buys no security. If vulnerable, he can store his endowment and/or place orders for securities marketed by the originator. Let x_j denote the order placed for security j. The optimal portfolio solves the following program:

$$\max_{\{x_j\}_{j=0}^J} \quad y_3^{ui} - \sum_{j=0}^J x_j E[P_j | \text{Vulnerable}] - [\rho \overline{q} + (1 - \rho)\underline{q}]\theta \left[\phi - \sum_{j=0}^J x_j A_{jH} \right] \quad (2)$$

$$s.t.$$

$$\phi \geq \sum_{j=0}^J x_j A_{jH}$$

$$x_j \geq 0.$$

The first two terms in the objective function above determine expected C_3. The final term in the objective function is the expected loss incurred if C_4 is less than the critical level ζ. The first constraint in the program reflects that overinsuring, and achieving $C_4 > \zeta$ with probability one, is suboptimal. The second set of constraints reflects the impossibility of shorting.

Solving the above program and aggregating the individual UI demands yields the following lemma.

Lemma 1 *If the originator only markets decreasing securities, uninformed demand will be confined to safe storage. If the originator markets any strictly increasing security, uninformed demand will be confined to the security with the lowest ratio of low state payoff to high state payoff ("Security 1"). Then for either realized aggregate endowment shock $v \in \{\underline{v}, \overline{v}\}$, aggregate uninformed demand for Security 1 will be vX where*

$$
\begin{aligned}
X &\equiv \frac{\phi}{A_{1H}}[1 - F(\widehat{\theta})] \\
\widehat{\theta} &\equiv \frac{E[P_1 | Vulnerable]}{[\rho\overline{q} + (1 - \rho)\underline{q}]A_{1H}}.
\end{aligned}
$$

The intuition for Lemma 1 is as follows. Vulnerable UI will insure against potential negative endowment shocks if, and only if, their disutility (θ) from consumption shortfalls is sufficiently high. Those choosing to insure will only invest in the security with the lowest ratio of low to high state payoff since this is the cheapest hedge.

The trading strategy of the speculator (and pricing policy of the MM) depends upon whether she has private information regarding the asset type. There are three possibilities at the Trading Stage: all agents know the type, all agents other than Originator are completely uninformed regarding the type, or the speculator has an informative private signal regarding the type. If the type is known to all agents at the start of the trading stage the MM set prices

$$
P_j = qA_{jH} + (1 - q)A_{jL} \quad \forall \quad j. \tag{3}
$$

where $q \in \{\underline{q}, \overline{q}\}$ is the true probability of the high state. Since all securities are priced at fundamental value in this case, the expected trading gain of the speculator is zero and it is assumed without loss of generality she does not trade.

If instead the speculator is uninformed (e.g. due to opacity), the MM know order flow cannot contain any information regarding the true type. Thus, if the prior belief is ρ, the MM set prices

$$P_j = \rho[\overline{q}A_{jH} + (1 - \overline{q})A_{jL}] + (1 - \rho)[\underline{q}A_{jH} + (1 - \underline{q})A_{jL}] \quad \forall \quad j. \tag{4}$$

In this case expected trading gains of the speculator are also zero and it is assumed without loss of generality she does not trade.

Suppose finally the speculator has an informative private signal ($\sigma > 1/2$). As shown in Lemma 1, she cannot trade profitably if the originator has only issued decreasing securities since UI demand would be zero for any risky security and orders would be revealing. If instead any increasing securities have been marketed by the originator, the speculator can make gains trading in Security 1 where she can hide behind the noisy UI demand. Since she cannot short, her optimal strategy is to place a buy order for Security 1 if, and only if, she receives the positive signal $\overline{s}$. In order to confound the MM, the size of her buy order must be $(\overline{v} - \underline{v})X$. With this order size, when aggregate demand is $\overline{v}X$, the MM are unsure whether this resulted from a large aggregate UI demand cum negative speculator signal or small aggregate UI demand cum positive speculator signal. Table 1 lists the possible aggregate demands for Security 1 (D_1) in this case.

In Table 1, order flow fully reveals the speculator's signal as positive when aggregate demand is $(2\overline{v} - \underline{v})X$. And order flow fully reveals the speculator's signal as negative when aggregate demand is $\underline{v}X$. The MM are confounded when observing demand $\overline{v}X$. Using Bayes' rule the MM revise beliefs as follows

$$
\begin{aligned}
\Pr(q &= \overline{q}|D_1 = (2\overline{v} - \underline{v})X) = \frac{\rho\sigma}{1 - \rho - \sigma + 2\rho\sigma} \tag{5}\\
\Pr(q &= \overline{q}|D_1 = \overline{v}X) = \rho\\
\Pr(q &= \overline{q}|D_1 = \underline{v}X) = \frac{\rho(1 - \sigma)}{\rho + \sigma - 2\rho\sigma}.
\end{aligned}
$$

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Based upon these beliefs, the MM set prices

$$P_j(D_1) = \Pr(q = \overline{q}|D_1)[\overline{q}A_{jH} + (1 - \overline{q})A_{jL}] + \Pr(q = \underline{q}|D_1)[\underline{q}A_{jH} + (1 - \underline{q})A_{jL}] \quad \forall \quad j. \quad (6)$$

The continuation equilibrium depicted in Table 1 can be supported by having market-makers form the worst possible beliefs from the perspective of a privately informed speculator in response to any order flow off the equilibrium path. For example, market-makers clearing markets for increasing securities believe $s = \overline{s}$ and those clearing markets for decreasing securities believe $s = \underline{s}$.

B. Speculator Effort

Continuing the backward induction we observe the speculator will not find it optimal to exert effort to acquire an informative signal if: the type is already known by all agents, the structure is opaque, or the originator has not marketed any increasing securities. Consider then the remaining case in which the type is not known, the structure is transparent, and the originator has marketed at least one increasing security.

From Table 1, the speculator's expected gross trading gain is:

$$G = \frac{(\overline{v} - \underline{v})X}{2}\left[\begin{array}{c} \rho\sigma\{[\overline{q}A_{1H} + (1 - \overline{q})A_{1L} - P_1((2\overline{v} - \underline{v})X)] + [\overline{q}A_{1H} + (1 - \overline{q})A_{1L} - P_1(\overline{v}X)]\}+ \\ (1 - \rho)(1 - \sigma)\{[\underline{q}A_{1H} + (1 - \underline{q})A_{1L} - P_1((2\overline{v} - \underline{v})X)] + [\underline{q}A_{1H} + (1 - \underline{q})A_{1L} - P_1(\overline{v}X)]\} \end{array}\right].$$

(7)

All speculator gains arise from the non-revealing aggregate order flow $\overline{v}X$. The trading gain expression simplifies to

$$G(\sigma) = \frac{1}{2}(\overline{v} - \underline{v})X\rho(1 - \rho)(2\sigma - 1)(\overline{q} - \underline{q})(A_{1H} - A_{1L}). \quad (8)$$

The first-order condition for the optimal signal precision is $G_\sigma = e_\sigma$. Letting Ψ denote the inverse function of e_σ, incentive compatible signal precision is

$$\sigma_{ic} = \Psi[\rho(1 - \rho)(\overline{q} - \underline{q})(A_{1H} - A_{1L})(\overline{v} - \underline{v})X]. \quad (9)$$

Equation (9) shows the incentive compatible signal precision for the speculator is increasing in the endogenous demand factor X. Figure 2 illustrates this effect.

Returning to the demand factor X, Lemma 1 shows UI demand hinges upon the conditional expectation of price. From Table 1 the expected price computed by UI vulnerable to negative endowment shocks is

$$
\begin{aligned}
E[P_1|\text{Vulnerable}] &= \rho[\overline{q}A_{1H} + (1 - \overline{q})A_{1L}] + (1 - \rho)[\underline{q}A_{1H} + (1 - \underline{q})A_{1L}] \\
&\quad + \rho(1 - \rho)(2\sigma - 1)(\overline{q} - \underline{q})(A_{1H} - A_{1L})\left(\frac{\overline{v} - \underline{v}}{\overline{v} + \underline{v}}\right).
\end{aligned}
\tag{10}
$$

The preceding equation shows UI face adverse selection when submitting buy orders, since the security is overpriced relative to fundamental value. Note, adverse selection is zero if $\sigma = 1/2$ and increasing in σ. From Lemma 1, it follows the minimum value of θ such that a vulnerable UI places a buy order is the following increasing function of σ

$$
\begin{aligned}
\widehat{\theta}(\sigma) &= 1 + \frac{\rho(1 - \rho)(2\sigma - 1)(\overline{q} - \underline{q})(\overline{v} - \underline{v})/(\overline{v} + \underline{v})}{\rho\overline{q} + (1 - \rho)\underline{q}} \\
&\quad + \frac{A_{1L}}{A_{1H}}\left[\frac{1 - \rho(1 - \rho)(2\sigma - 1)(\overline{q} - \underline{q})(\overline{v} - \underline{v})/(\overline{v} + \underline{v})}{\rho\overline{q} + (1 - \rho)\underline{q}} - 1\right].
\end{aligned}
\tag{11}
$$

As illustrated in Figure 2, the preceding equation shows aggregate UI demand is decreasing in σ reflecting the fact that adverse selection facing the UI becomes more severe as the speculator's signal precision increases. Figure 2 also illustrates the determination of equilibrium of σ which is at the intersection of the curves.

Substituting the UI demand expression into the speculator's first-order condition, we know an equilibrium σ, denoted σ^{eq}, solves

$$
\sigma^{eq} = \Psi\left[\rho(1 - \rho)(\overline{q} - \underline{q})(\overline{v} - \underline{v})\phi\left(1 - \frac{A_{1L}}{A_{1H}}\right)\left(1 - F\left(\widehat{\theta}(\sigma^{eq})\right)\right)\right].
\tag{12}
$$

The appendix shows equation (12) has a unique solution $\sigma^{eq} \in (1/2, 1)$ that is decreasing in the ratio A_{1L}/A_{1H}. Thus, maximum speculator effort is induced by including in the bundle of marketed securities an Arrow security paying only in the high state. Intuitively, it can be seen from Lemma 1 that such a security attracts the maximum volume of uninformed hedging demand by lowering

the demand cutoff shown in equation (11). The increase in uninformed trading volume allows the speculator to place larger buy orders and raises the marginal gain to increased signal precision.

The following lemma summarizes the analysis above of the incentive compatible signal precision.

Lemma 2 *The speculator acquires an informative signal if, and only if, the type is not yet known, the structure is transparent, and the originator has marketed at least one increasing security. The equilibrium signal precision is the unique solution to equation (12) and is decreasing in the ratio of low to high state payoffs on Security 1.*

The real-world significance of Lemma 2 is as follows. The much maligned "slicing and dicing" commonly observed in securitizations can serve an important role. By catering to the idiosyncratic demands of various investor clienteles, here the vulnerable hedgers, uninformed demand is stimulated. In turn, increases in uninformed demand stimulate speculator effort which drives prices closer to fundamentals.

III. The Securitization Stage

At the start of the Securitization Stage the originator has private knowledge of the true type $q \in \{\underline{q}, \overline{q}\}$. The other players have a common prior ρ regarding the probability of the asset being type $\overline{q}$. In this setting, the privately informed originator registers a menu $\{\underline{\Sigma}, \overline{\Sigma}\}$ containing two optional securitization structures and then chooses from the menu. A *separating menu* contains two different securitization structures such that each type prefers a different structure. If such a menu is registered, the choice from the menu reveals the type. A *pooling menu* contains only one securitization structure ($\underline{\Sigma} = \overline{\Sigma}$) so there is no possibility of the type being revealed by the choice from the menu.[9]

Let R_i denote the state i payoff on the security retained by the originator and let M_i denote the total state i payoff on all securities marketed by the originator (e.g. $R_L + M_L = L$). We

---

[9]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.

first characterize the *least-cost separating* (LCS) allocations for the two originator types. The LCS allocations maximize the utility of each originator type within the set of separating menus. We conjecture and then verify the high type will not want to mimic the low type given the respective LCS allocations. The LCS allocation allows the low type to fully securitize his asset since this raises his payoff and relaxes the constraint that he not mimic (NM, below) the high type. The high type's LCS retention solves the following program:

$$\max_{(R_L, R_H)} \quad \overline{q}R_H + (1 - \overline{q})R_L + \beta[\overline{q}(H - R_H) + (1 - \overline{q})(L - R_L)] \tag{13}$$

subject to the NM constraint and two-sided limited liability constraints:

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

$$R_L \leq L; \quad R_H \leq H; \quad R_L \geq 0; \quad R_H \geq 0.$$

Solving the above program yields the following lemma.

Lemma 3 *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 interim type-contingent originator utilities are:*

$$\begin{aligned}
\underline{U}_{lcs} &= \beta[\underline{q}H + (1 - \underline{q})L] \tag{14} \\
\overline{U}_{lcs} &= \beta[\overline{q}H + (1 - \overline{q})L] - (\beta - 1)\overline{q}\left[\frac{\beta(\overline{q} - \underline{q})(H - L)}{(\beta\overline{q} - \underline{q})}\right].
\end{aligned}$$

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 junior claim. The next lemma is parallel to a general result from Maskin and Tirole (1992).

Lemma 4 *The set of equilibrium menu offers includes the least-cost separating allocations and any pooling menus giving each originator type at least his respective Least Cost Separating payoff.*

In light of the preceding lemma, a PBE in which the two types propose the LCS allocations will be denoted as a *least-cost separating equilibrium* (LCSE). We turn next to determining precisely

18

which pooling structures are in the set of PBE. Using Table 1, expected securitization revenues in the event of pooling is

$$
\begin{aligned}
E[REVENUE] &= z[\overline{q}M_H + (1-\overline{q})M_L] + [1-z][\underline{q}M_H + (1-\underline{q})M_L] \qquad (15) \\
q &= \overline{q} \Rightarrow z = \overline{z}(\sigma) \equiv \frac{1}{2}\left[\frac{\rho\sigma^2}{1-\rho-\sigma+2\rho\sigma} + \frac{\rho(1-\sigma)^2}{\rho+\sigma-2\rho\sigma} + \rho\right] \\
q &= \underline{q} \Rightarrow z = \underline{z}(\sigma) \equiv \left(\frac{\rho}{1-\rho}\right)[1 - \overline{z}(\sigma,\rho)].
\end{aligned}
$$

The variable $\overline{z}$ measures the informational efficiency of prices. For example, all securities are priced at fundamental value in the hypothetical case where $\overline{z} = 1$. In fact, the appendix shows $\overline{z}$ is increasing in σ, with $\overline{z}(1/2) = \rho$ and $\overline{z}(1) = (1+\rho)/2$. Intuitively, higher speculator signal precision drives prices closer to fundamentals.

Originator utility in the event of pooling is equal to the value of any retained claim plus β times his expected revenues from equation (15). From the respective pooling payoffs and Lemma 4 it follows that a pooling menu featuring marketed payoffs (M_L, M_H) will be in the equilibrium set if and only if:

$$
\begin{aligned}
\underline{U}_{pool} &\equiv K_L(\underline{q},\underline{z})M_L + K_H(\underline{q},\underline{z})M_H + \underline{q}H + (1-\underline{q})L \geq \underline{U}_{lcs} \qquad (16) \\
\overline{U}_{pool} &\equiv K_L(\overline{q},\overline{z})M_L + K_H(\overline{q},\overline{z})M_H + \overline{q}H + (1-\overline{q})L \geq \overline{U}_{lcs} \\
K_L(q,z) &\equiv \beta[z(1-\overline{q}) + (1-z)(1-\underline{q})] - (1-q) \\
K_H(q,z) &\equiv \beta[z\overline{q} + (1-z)\underline{q}] - q.
\end{aligned}
$$

From equation (16) we obtain the following characterization of the set of pooling equilibria.

Proposition 1 *In any pooling equilibrium, total marketed security payoffs in the high state must be strictly greater than L. If there exists a pooling equilibrium with speculator effort σ and partial securitization, there exists a pooling equilibrium with effort σ and full securitization. A necessary and sufficient condition for a pooling equilibrium with full asset securitization is*

$$
\overline{z}(\sigma^{eq}) \geq (\overline{q} - \underline{q})/(\beta\overline{q} - \underline{q}) \Leftrightarrow \sigma^{eq} \geq \overline{z}^{-1}[(\overline{q} - \underline{q})/(\beta\overline{q} - \underline{q})].
$$

The intuition for Proposition 1 is as follows. In order for a pooling equilibrium to exist, both types must be weakly better off than at the LCS allocations. The low type is necessarily better off if pooling occurs at full securitization since he gains from overvaluation of the fully marketed asset. However, even with pooling he will be worse off if retentions are sufficiently high. This explains why securitized cash flows must be sufficiently large in any pooling equilibrium.

The second statement of the proposition plays a useful technical role in showing that if pooling at full securitization cannot be supported for a given σ, then pooling at partial securitization cannot be supported at that σ. Moreover, this illustrates that full securitization of assets should not be viewed as necessarily inconsistent with equilibrium in rational securities markets. The last statement of the proposition shows that what is critical is not the level of securitization but the degree of price informativeness. Further, the required informational efficiency threshold ($\overline{z}$) is decreasing in β. Thus, pooling can be an equilibrium if informational efficiency is high or funding value (β) is high.

The last inequality in the proposition implies that if a pooling equilibrium can be sustained with full securitization and some level of speculator effort, then pooling can be sustained with full securitization and higher levels of speculator effort. For example, if pooling at full securitization cum opacity can be sustained as an equilibrium, then pooling at full securitization cum transparency can also be sustained as an equilibrium. Intuitively, the low type always prefers pooling at full securitization to his LCS payoff so the critical test is whether the high type is better off–a test more readily passed with higher speculator effort.

Further intuition regarding the set of possible pooling equilibria is provided by Figures 3A and 3B. In each figure we consider either a transparent or opaque structuring and plot the pairs of marketed cash flows (M_L, M_H) pinning each type to his LCS payoff based upon equation (16). The slopes of the indifference curves are equal to $-K_L/K_H$. It is readily verified $K_H(\underline{q}, \underline{z}) > 0$ while the sign of $K_L(\underline{q}, \underline{z})$ is ambiguous. Conversely, $K_L(\overline{q}, \overline{z}) > 0$ while the appendix shows $K_H(\overline{q}, \overline{z}) \geq 0$ in any pooling equilibrium. Thus, the relevant high type indifference curves are always downward sloping while the low type indifference curves can be upward or downward sloping. Finally, for both

types the better-than set is north of the respective indifference curve (since K_H is positive).

The potential equilibrium securitization levels depends critically on whether there is transparency or opacity. To see this, consider first Figure 3A. Here the set of pooling equilibria corresponds to pairs (M_L, M_H) to the northeast of the highest indifference curve. With opacity, the high type's indifference curve is above that of the low type, reflecting his reluctance to pool at an opaque structuring given that marketed securities will be priced far from fundamental value ($\overline{z} = \underline{z} = \rho$). Thus with opacity, the high type's indifference curve is the relevant constraint on the feasibility of various pooling equilibria. Conversely, we see in Figure 3A that with transparency the low type's indifference curve is above that for the high type and so the low type's indifference curve is the relevant boundary for the feasibility of pooling equilibria. Intuitively, the low type is more reluctant to pool if prices are closer fundamental value.

Figure 3B plots the remaining case where the low type's indifference curve is upward sloping. Here again with opacity the high type's indifference curve is above that for the low type so the high type indifference curve is the relevant boundary for the feasibility of pooling equilibria. With transparency the indifference curves cross. Here, as M_L is increased the low type becomes less willing to pool. Intuitively, the low type may prefer lower values of M_L since he knows from his private information that the market undervalues claims on his asset in low states. Consequently, the low type indifference curve becomes the relevant equilibrium boundary for sufficiently high M_L.

The set of PBE may be defined formally as follows. For each $M_L \geq 0$, equation (16) defines the minimum high state marketed cash flow improving upon respective LCS payoffs:

$$
\begin{aligned}
\underline{M}_H^{\min}(M_L) &\equiv \frac{\underline{U}_{lcs} - K_L(\underline{q}, \underline{z})M_L - \underline{q}H - (1 - \underline{q})L}{K_H(\underline{q}, \underline{z})} \\
\overline{M}_H^{\min}(M_L) &\equiv \frac{\overline{U}_{lcs} - K_L(\overline{q}, \overline{z})M_L - \overline{q}H - (1 - \overline{q})L}{K_H(\overline{q}, \overline{z})}.
\end{aligned}
$$

With these definitions in-hand, the set of PBE is just the intersection of the available cash and the better-than sets, as stated in the following proposition.

Proposition 2 *For each σ^{eq}, the set of pooling perfect Bayesian equilibrium marketed cash flows is*

the convex set[10]

$$\bigcup_{M_L \in [0,L]} [\underline{M}_H^{\min}(M_L), \infty] \cap [\overline{M}_H^{\min}(M_L), \infty] \cap [L, H].$$

In the wake of the financial crisis there has been much debate about whether opacity and full securitization constituted evidence in favor of the hypothesis of limited investor rationality. Conveniently, equilibrium refinements allow us to think about limited rationality in a structured way. Using the perfect Bayesian equilibrium concept, one cannot argue full securitization and/or opacity are necessarily inconsistent with rationality. After all, Proposition 1 shows full securitization cum opacity can be sustained as a rational market equilibrium if β is sufficiently high.

However, the PBE concept imposes a rather soft test for market rationality inasmuch as it may admit off-equilibrium beliefs that seem unreasonable. For example, pooling at opacity can be maintained as a PBE by imputing to the low type an off-equilibrium deviation to a transparent structure. With this motivation, the following proposition identifies structures satisfying the Intuitive Criterion of Cho and Kreps (1987).

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

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

The least-cost separating allocation satisfies the Intuitive Criterion. Opacity never satisfies the Intuitive Criterion. A pooling structure with 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 at full securitization satisfies the Intuitive Criterion if and only if

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

---

[10]Convexity follows trivially from linearity of the utility functions given fixed σ.

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. Intuitively, the high type will be tempted to deviate from any PBE entailing opacity since he can do better by offering to retain a junior claim while utilizing a transparent structuring. At the same time, the low type favors opacity. Consequently, a more sophisticated market should infer that only low types would propose an opaque structure. Proposition 3 also shows full asset securitization can satisfy the Intuitive Criterion. However, comparing the final inequalities in Proposition 1 and Proposition 3 one sees that in order to satisfy the Intuitive Criterion, pooling at full securitization demands a relatively high degree of price informativeness.

Before concluding discussion of interim-stage outcomes, we make the following remark.

Remark 1 *Interim first-best social welfare is achieved if originators pool at full securitization cum opacity with the asset split into safe debt with face value L and a junior residual equity tranche.*

The remark above illustrates that opacity has benefits since it facilitates efficient risk sharing and deters costly speculative information production. Also, with this remark in mind it is worth recalling that the higher degree of investor sophistication implicit in the Intuitive Criterion would be socially costly at the interim stage since it precludes pooling at the socially preferred continuation outcome.[11] In other words, ignorance is bliss at the interim stage, and somewhat naïve investor beliefs are needed to maintain such ignorance as a continuation equilibrium.

IV. Originator Effort

As a last step in the backward induction this section considers the originator's effort decision in period 1. To that end let $\widehat{c}$ denote the maximum cost the originator would be willing to incur to

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[11] A similar argument applies in canonical signaling models, e.g. Spence (1973).

increase the high type probability from $\underline{\rho}$ to $\overline{\rho}$. Given interim utilities $(\underline{U}^*, \overline{U}^*)$, the *willingness-to-pay* $(\widehat{c})$ is equal to the expected utility gain arising from the increase in ρ

$$\widehat{c} = (\overline{\rho} - \underline{\rho})(\overline{U}^* - \underline{U}^*). \tag{17}$$

The preceding equation delivers a simple message: ex ante effort incentives hinge upon the continuation equilibrium at the securitization stage, with larger wedges between interim type-contingent utilities increasing ex ante effort incentives. It follows from Lemma 3 that originator willingness-to-pay arising from implementation of an LCS allocation is

$$\widehat{c}_{lcs} = [(\overline{\rho} - \underline{\rho})\beta(\overline{q} - \underline{q})(H - L)]\left[\frac{\overline{q} - \underline{q}}{\beta\overline{q} - \underline{q}}\right]. \tag{18}$$

The first square bracketed term in the expression for $\widehat{c}_{lcs}$ is the cutoff cost that would obtain under symmetric information regarding asset type. The second bracketed term is a number less than one. Thus, at the LCS allocation asymmetric information at the securitization stage diminishes the originator's effort incentive. Intuitively, at the LCS allocation the high type bears the underinvestment cost of signaling while the low type gets his first-best payoff. So there is less incentive to put in effort aimed at becoming a high type.

Consider next effort incentives if the equilibrium entails pooling at the securitization stage. It follows from equation (16) that originator willingness-to-pay in the event of pooling is

$$\begin{aligned}
\widehat{c}_{pool} &\equiv (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[H - L - (M_H - M_L)(1 - \beta(\overline{z} - \underline{z}))] \tag{19} \\
&= (\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[R_H - R_L + (M_H - M_L)\beta(\overline{z} - \underline{z})]
\end{aligned}$$

From Proposition 1 we know $M_H > L \geq M_L$ in any pooling equilibrium. Therefore, if $\beta(\overline{z} - \underline{z}) \geq 1$ due to extremely high β values, the originator is always willing to incur the effort cost given that effort is profitable in a first-best economy (Assumption 1). For the remainder of the analysis we confine attention to the interesting case where β does not take on extremely high values and $\beta(\overline{z} - \underline{z}) < 1$. In this case effort is not assured. However, equation (19) shows that in pooling equilibria effort incentives can be generated by retentions and/or market discipline $(\overline{z} > \underline{z})$.

Equation (19) shows that originator retentions are not necessary to generate effort incentives. For example, even the much maligned OTD business model with zero retentions can generate strong incentives with sufficient information production by the market. However, effort incentives under the OTD business model are necessarily less than symmetric information incentives since the willingness-to-pay under OTD is

$$\widehat{c}_{otd} \equiv [(\overline{\rho} - \underline{\rho})\beta(\overline{q} - \underline{q})(H - L)](\overline{z} - \underline{z}). \tag{20}$$

The first square bracketed term in the expression for $\widehat{c}_{otd}$ is the cutoff cost that would obtain under symmetric information regarding asset type. The second bracketed term is a number less than one reflecting price informational inefficiency. In this way the model shows that a corollary of the Grossman-Stiglitz paradox is that the OTD business model necessarily produces less effort incentive than under symmetric information. Finally, equation (20) shows OTD cum opacity destroys originator effort incentives ($\overline{z} = \underline{z} \Rightarrow \widehat{c} = 0$).

The following lemma, which follows from performing comparative statics on equation (19), describes pooling contracts that maximize and minimize originator effort incentives.

Lemma 5 *Amongst pooling equilibria featuring marketed cash flows (M_L, M_H), originator effort incentives are increasing in speculator effort (σ) and thus higher under transparency than opacity. There is zero effort incentive if originators pool at full securitization cum opacity. Amongst equilibrium pooling structures inducing signal precision σ, effort incentives are maximal if the originator holds the largest possible junior equity tranche resulting from marketed payments*

$$(M_L, M_H) = (L, \max\{\underline{M}_H^{\min}(L), \overline{M}_H^{\min}(L)\}).$$

Amongst equilibrium pooling structures inducing signal precision σ, minimal originator effort incentives are generated by marketing $M_H = H$ and the minimum M_L in the equilibrium set.

Lemma 5 has the following economic intuition. The criteria for a PBE is that each type receive at least as much as their LCS payoff at the interim stage. However, ex ante effort incentives are increasing in the wedge between interim-stage type-contingent utilities. Thus, effort incentives are

stronger under contracts that confer a relative advantage to the high type at the interim stage. In the event of pooling, transparency confers a relative advantage to the high type, as does the marketing of a senior claim.

Importantly, this analysis reveals a potentially critical role for investor sophistication. In particular, in the preceding section it was shown that ignorance is bliss in terms of interim social welfare. Moreover, it was shown that such ignorance is inconsistent with investors having sophisticated beliefs satisfying the Intuitive Criterion. However, investor sophistication is valuable in promoting ex ante 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 utilities be sufficiently large, which is precisely what is needed to promote ex ante effort. In fact, Proposition 3 implies the originator's willingness-to-pay in any equilibrium surviving the Intuitive Criterion satisfies

$$\widehat{c}_{intuitive} \geq \frac{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[\beta(\overline{q}H + (1 - \overline{q})L) - \underline{U}^*]}{\beta\overline{q} - \underline{q}} > \frac{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})^2 \beta(H - L)(1 - \rho)}{\beta\overline{q} - \underline{q}}. \qquad (21)$$

Consider finally what effort can be sustained in equilibrium. Suppose first all agents conjecture the LCSE will be played as the continuation equilibrium starting at the Securitization Stage. Then the originator will exert effort if and only if $c \leq \widehat{c}_{lcs}$. Suppose next all agents conjecture pooling will occur at the Securitization Stage. Intriguingly, it is possible that both effort and no-effort can be equilibrium outcomes even when attention is confined to pooling equilibria. The reasoning is as follows. If the originator exerts effort then the uninformed prior is $\rho = \overline{\rho}$ and if he does not the prior is $\rho = \underline{\rho}$. Critically, the set of interim continuation equilibria and originator utilities depend on the uninformed prior.[12] This is because updated market-maker beliefs (equation (5)), the uninformed demand cutoff (equation (11)), and speculator effort (equation (9)) all depend upon the uninformed prior ρ.

For example, Figure 4 depicts indifference curves under both effort ($\rho = \overline{\rho}$) and no-effort ($\rho = \underline{\rho}$). In both cases, the high type's indifference curve is the relevant boundary for the set of pooling PBE.

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[12] In contrast, the LCSE does not depend on priors.

A shift to no-effort makes the high type less willing to pool since he faces more severe underpricing. This fact is captured by the upward shift in the high type indifference curve. A necessary and sufficient condition for there to exist a pooling equilibrium cum originator effort is that c be weakly less than the originator's willingness to pay under the effort maximizing pooling contract described in Lemma 5. For example, in Figure 4 this contract features the marketing of $(M_L, M_H) = (1, 1.89)$. Conversely, a necessary and sufficient condition for there to exist a pooling equilibrium sans originator effort is that c be greater than the originator's willingness to pay under the effort minimizing pooling contract described in Lemma 5. For example, in Figure 4 this contract features the marketing of $(M_L, M_H) = (0.35, 2)$. Thus, a possible interpretation of the source of the apparent collapse in lending standards during the run up to the credit crisis is that the market was simply trapped in the low-effort equilibrium.

V. Welfare and Socially Optimal Mandatory Retentions

Up to now attention has been confined to a positive analysis of potential equilibria in unregulated markets. This section addresses three normative questions. First, what are the welfare tradeoffs entailed in the various unregulated equilibria? Second, can mandatory skin-in-the-game increase welfare? And finally, which form of mandatory retention scheme maximizes social welfare?

A. Welfare in Unregulated Markets

We consider a social planner placing equal weight on each agent. The welfare of market-makers is ignored in the calculations since their expected utility is always just equal to their exogenous endowments. Finally, when calculating social welfare under the various regimes we assume the Arrow security preferred by the UI is amongst the portfolio of marketed claims. Otherwise there would be additional deadweight losses stemming from UI portfolio distortions.

Consider first social welfare under opacity. With opacity the speculator does not exert effort and all claims are priced according to equation (4). From Lemma 1 it follows that all vulnerable

UI fully insure $(\widehat{\theta} = 1)$ against negative endowment shocks. Social welfare under a generic pooling equilibrium cum opacity is thus equal to the expected originator utility plus the expected UI endowment plus the speculator endowment. The implied social welfare is

$$
\begin{aligned}
W_{op} = {} & (\rho_{op}(1 - \overline{q}) + (1 - \rho_{op})(1 - \underline{q}))(L - M_L) + (\rho_{op}\overline{q} + (1 - \rho_{op})\underline{q})(H - M_H) \quad (22) \\
& + \beta[(\rho_{op}(1 - \overline{q}) + (1 - \rho_{op})(1 - \underline{q}))M_L + (\rho_{op}\overline{q} + (1 - \rho_{op})\underline{q})M_H] - \frac{(\rho_{op} - \underline{\rho})c}{\overline{\rho} - \underline{\rho}} \\
& + y_3^s + y_3^{ui} - \frac{(\overline{\nu} + \underline{\nu})\phi}{2}[\rho_{op}\overline{q} + (1 - \rho_{op})\underline{q}].
\end{aligned}
$$

Amongst opaque pooling equilibria inducing no originator effort, social welfare is highest if the originator holds zero retentions. Evaluating equation (22) at zero retentions and no-effort one obtains social welfare

$$
\begin{aligned}
W_{otdo} = {} & \beta[(\underline{\rho}(1 - \overline{q}) + (1 - \underline{\rho})(1 - \underline{q}))L + (\underline{\rho}\overline{q} + (1 - \underline{\rho})\underline{q})H] \quad (23) \\
& + y_3^s + y_3^{ui} - \frac{(\overline{\nu} + \underline{\nu})\phi}{2}[\underline{\rho}\overline{q} + (1 - \underline{\rho})\underline{q}].
\end{aligned}
$$

Social welfare under a pooling equilibrium cum transparency is

$$
\begin{aligned}
W_{tran} = {} & (\rho_{tran}(1 - \overline{q}) + (1 - \rho_{tran})(1 - \underline{q}))(L - M_L) + (\rho_{tran}\overline{q} + (1 - \rho_{tran})\underline{q})(H - M_H) \quad (24) \\
& + \beta[(\rho_{tran}(1 - \overline{q}) + (1 - \rho_{tran})(1 - \underline{q}))M_L + (\rho_{tran}\overline{q} + (1 - \rho_{tran})\underline{q})M_H] - \frac{(\rho_{tran} - \underline{\rho})c}{\overline{\rho} - \underline{\rho}} \\
& + y_3^s - e(\sigma^{eq}) + y_3^{ui} - \frac{(\overline{\nu} + \underline{\nu})\phi}{2}[\rho_{tran}\overline{q} + (1 - \rho_{tran})\underline{q}]\left[1 + \int_1^{\widehat{\theta}}(\theta - 1)f(\theta)d\theta\right] \\
\widehat{\theta} \equiv {} & 1 + \frac{\rho(1 - \rho)(2\sigma - 1)(\overline{q} - \underline{q})(\overline{v} - \underline{v})/(\overline{v} + \underline{v})}{\rho\overline{q} + (1 - \rho)\underline{q}}.
\end{aligned}
$$

One can best understand the social welfare benefits and costs of transparency relative to opacity by comparing equation (24) with equation (22). First, it can be verified that the ex ante expected utility of the originator under transparency is identical in form to that under opacity if one assumes the same values for (ρ, M_L, M_H). Intuitively, in such a case the only effect of transparency is to transfer value from the low type to the high type since the latter benefits from prices being closer to fundamentals. However, transparency generates two deadweight losses from a social perspective,

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as shown by comparing across the respective third lines. First, the speculator incurs effort costs. Second, the presence of an informed speculator results in adverse selection and foregone risk-sharing opportunities since vulnerable UI with disutility parameters in $[1, \widehat{\theta}]$ fail to buy insurance against negative endowment shocks.

Comparing welfare across equations (22) and (24) it might be tempting to conclude that for any marketed pair (M_L, M_H) opacity dominates transparency. After all, all the terms seem to cancel except for the two deadweight losses from transparency just discussed. However, the similar terms in the two equations only cancel if the originator's effort decision is the same. But inspection of equation (19) reveals that effort incentives are higher under transparency.

To place opacity and transparency on a level playing field, consider the following thought experiment. Assume a marketed pair (L, M_H) such that the originator is just willing to exert effort provided the market is transparent. At this same marketed pair, the originator would not be willing to exert effort if the market was opaque. From equation (19) it follows the originator would be willing to exert effort under opacity if the high-state marketed cash flows were lowered to:

$$\widetilde{M}_H = M_H - \beta(\overline{z} - \underline{z})(M_H - L).$$

Consequently, transparency would here be socially preferable if the costs of incremental underinvestment, arising from the need for higher retentions under opacity, exceeds the costs of speculator effort and distorted risk sharing under transparency, or:

$$(\beta - 1)[\overline{\rho q} + (1 - \overline{\rho})\underline{q}]\beta(\overline{z} - \underline{z})(M_H - L) \geq e(\sigma^{eq}) + \frac{(\overline{\nu} + \underline{\nu})\phi}{2}[\overline{\rho q} + (1 - \overline{\rho})\underline{q}] \int_1^{\widehat{\theta}} (\theta - 1)f(\theta)d\theta. \quad (25)$$

Consider finally social welfare in the LCSE. Here the speculator consumes his endowment achieving utility y_3^s. The vulnerable UI are insulated from adverse selection since the private information of the originator has been signaled. Each vulnerable UI purchases a fairly priced Arrow claim paying ϕ if the realized cash flow is H allowing them to avoid the cost θ of a consumption shortfall in the final period. Adding these terms to the ex ante utility of the originator, accounting for underinvestment

by the high type, we find:

$$
\begin{aligned}
W_{lcs} &= \beta[(\rho_{lcs}(1-\overline{q}) + (1-\rho_{lcs})(1-\underline{q}))L + (\rho_{lcs}\overline{q} + (1-\rho_{lcs})\underline{q})H] &(26)\\
&\quad -(\beta-1)\rho_{lcs}\overline{q}\left[\frac{\beta(\overline{q}-\underline{q})(H-L)}{\beta\overline{q}-\underline{q}}\right] - \frac{(\rho_{lcs}-\underline{\rho})c}{\overline{\rho}-\underline{\rho}}\\
&\quad +y_3^s + y_3^{ui} - [\rho_{lcs}\overline{q} + (1-\rho_{lcs})\underline{q}]\frac{(\overline{\nu}+\underline{\nu})\phi}{2}.
\end{aligned}
$$

The case of full securitization cum opacity places the tradeoffs of the LCSE in sharpest relief. From equations (23) and (26) we have:

$$
W_{otdo} - W_{lcs} = (\beta-1)\rho_{lcs}\overline{q}\left[\frac{\beta(\overline{q}-\underline{q})(H-L)}{\beta\overline{q}-\underline{q}}\right] - \frac{\rho_{lcs}-\underline{\rho}}{\overline{\rho}-\underline{\rho}}\left[(\overline{\rho}-\underline{\rho})(\overline{q}-\underline{q})\left(\beta(H-L) - \frac{(\overline{\nu}+\underline{\nu})\phi}{2}\right) - c\right].
$$

$$(27)$$

As shown above, the benefit of opaque equilibrium with full securitization is that there is no reduction in expected originator investment, a benefit captured by the first term. However, the cost of the opaque scheme is that it destroys effort incentives, as captured by the second term.

Notice that the only cost to the opaque OTD structure in terms of total social welfare is that it fails to provide any incentive for originator effort. This implies the following general result.

Proposition 4 *Originate-to-distribute cum opacity is socially optimal amongst schemes failing to create any effort incentive for originators.*

Proposition 4 is consistent with the arguments in Dang, Gorton and Holmström (2010) regarding the benefits of opacity. However, it also illustrates that opacity is optimal within a relatively narrow set. From Proposition 4 it follows that inducing effort is a *necessary* condition for some configuration other than opacity to be socially optimal. Therefore, the remainder of the analysis is devoted to finding socially optimal methods for inducing originator effort.

B. Motivating Effort via Separating Mechanisms

Consider first the optimal mandatory retention scheme aimed at inducing effort and interim type revelation. From a social perspective, all such schemes yield the same expected utility for the speculator, who consumes her endowment, and the UI provided a suitable Arrow claim is carved out

of marketed securities. So we can focus on separating mechanisms maximizing the expected utility of the originator.

We begin by noting that if effort is incentive compatible (IC below) in the LCS allocation, there is no socially preferable separating scheme. Thus, we need only determine the socially optimal separating mechanism when the IC constraint is violated at the LCS allocation ($c > \widehat{c}_{lcs}$). To this end, let $(\underline{M}_L, \underline{M}_H)$ and $(\overline{M}_L, \overline{M}_H)$ denote the bundles of cash flows to be marketed by low and high types, respectively. The planner's problem is to maximize expected originator utility subject to IC, self-selection by the low type (with the high type's self-selection constraint being slack), and two-sided limited liability.

We solve the following relaxed program which ignores some limited liability constraints and then verify the neglected constraints are slack:

$$\max_{\underline{M}_L, \underline{M}_H, \overline{M}_L, \overline{M}_H} \overline{\rho}\left\{\overline{q}(H - \overline{M}_H) + (1 - \overline{q})(L - \overline{M}_L) + \beta[\overline{q}\overline{M}_H + (1 - \overline{q})\overline{M}_L]\right\} \quad (28)$$
$$+(1 - \overline{\rho})\{\underline{q}(H - \underline{M}_H) + (1 - \underline{q})(L - \underline{M}_L) + \beta[\underline{q}\underline{M}_H + (1 - \underline{q})\underline{M}_L]\}$$

$$s.t.$$

$$IC \;\; : \;\; \overline{q}(H - \overline{M}_H) + (1 - \overline{q})(L - \overline{M}_L) + \beta[\overline{q}\overline{M}_H + (1 - \overline{q})\overline{M}_L] - \frac{c}{\overline{\rho} - \underline{\rho}} =$$
$$\underline{q}(H - \underline{M}_H) + (1 - \underline{q})(L - \underline{M}_L) + \beta[\underline{q}\underline{M}_H + (1 - \underline{q})\underline{M}_L]$$

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

$$LL \;\; : \;\; \overline{M}_L \leq L, \quad \underline{M}_L \leq L$$

We first observe that 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. Next, we substitute the binding NM into both the objective function and IC constraint to rewrite

the relaxed program as:

$$\max_{\overline{M}_L, \overline{M}_H} \rho \left\{ \overline{q}(H - \overline{M}_H) + (1 - \overline{q})(L - \overline{M}_L) + \beta[\overline{q}\overline{M}_H + (1 - \overline{q})\overline{M}_L] \right\} \tag{29}$$
$$+ (1 - \rho)\{\underline{q}(H - \overline{M}_H) + (1 - \underline{q})(L - \overline{M}_L) + \beta[\overline{q}\overline{M}_H + (1 - \overline{q})\overline{M}_L]\}$$

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 new objective function we find it is increasing in $\overline{M}_L$ from which it follows the socially optimal separating contract entails:

$$(\overline{M}_L^*, \overline{M}_H^*) = \left(L, H - \frac{c}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})} \right) = \left(L, L + \frac{(\beta - 1)\underline{q}(H - L)}{\beta\overline{q} - \underline{q}} - \frac{c - \widehat{c}_{lcs}}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})} \right). \tag{30}$$

The optimality of forcing the originator to take a junior position, with $\overline{M}_L^* = L$, is a consequence of the standard single-crossing condition in adverse selection settings, as distinct from the traditional moral hazard argument that calls for agents to be residual claimants (see e.g. Innes (1990)).

Inspection of equation (30) reveals that in order to curb ex ante moral hazard the high type is forced to hold a larger junior tranche than in the LCSE. 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:

$$\underline{U}_{sep} = \beta[\underline{q}H + (1 - \underline{q})L] - \frac{(\beta\overline{q} - \underline{q})(c - \widehat{c}_{lcs})}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})}. \tag{31}$$

Here we see a stark contrast between the LCSE and the socially optimal separating mechanism inducing effort. In the LCSE, a low type achieves his first-best utility level, since doing so relaxes the nonmimicry constraint. The separating mechanism calls for interim-inefficient punishments of the low type to induce effort.

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

$$(\underline{M}_L^*, \underline{M}_H^*) = \left(L, H - \frac{(\beta\overline{q} - \underline{q})(c - \widehat{c}_{lcs})}{(\beta - 1)\underline{q}(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})} \right). \tag{32}$$

We have established the following proposition:

Proposition 5 *The socially optimal separating mechanism for inducing originator effort calls for both types to sell safe senior claims with face L. The high and low types should market junior claims with respective face values:*

$$\left[\frac{(\beta - 1)\underline{q}}{\beta \overline{q} - \underline{q}} \right] (H - L) - \frac{(c - \widehat{c}_{lcs})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})}$$

and

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

The originator retains the residual junior tranche.

The separating mechanism described above is designed to accomplish three distinct tasks: increasing asset span via the creation of Arrow claims; provision of ex ante effort incentives by increasing the wedge between high and low-type interim payoffs; and revelation of the originator's private information. This last effect is socially valuable since it eliminates the need for speculators to acquire information and insulates uninformed investors from adverse selection, facilitating efficient risk-sharing.

Consider now social welfare under the effort-inducing separating contract described in Proposition 5:

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

The social gain to OTD cum opacity over the effort-inducing separating contract is:

$$
\begin{aligned}
W_{otdo} - W_{sep} &= \overline{\rho}\overline{q}(\beta - 1) \left[\frac{\beta(\overline{q} - \underline{q})(H - L)}{\beta \overline{q} - \underline{q}} \right] \\
&\quad + (c - \widehat{c}_{lcs})^+ \left[\frac{\overline{\rho}\overline{q}(\beta - 1) + (1 - \overline{\rho})(\beta \overline{q} - \underline{q})}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})} \right] \\
&\quad - \left[(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q}) \left(\beta(H - L) - \frac{(\overline{\nu} + \underline{\nu})\phi}{2} \right) - c \right].
\end{aligned}
$$

Above we see that opacity has costs and benefits relative to the separating mechanism. The separating mechanism induces effort, which has positive social value (last term in square brackets), but also imposes underinvestment costs as originators retain positive tranches regardless of their interim type. Thus, regulators must decide whether the social benefit of effort exceeds the underinvestment costs required to induce that effort.

C. Motivating Effort via Pooling Mechanisms

Suppose instead the social planner would like to induce effort using a pooling mechanism. To characterize the optimal pooling mechanism, we note that for arbitrary fixed σ, a socially optimal contract maximizes the weighted average of originator utilities, here subject to the appropriate IC constraint. Intuitively, the sum of speculator and UI utilities is decreasing in σ, so the dual problem for the planner is to maximize expected originator utility for fixed σ.

The program is:

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

$$s.t.$$

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

$$LL \;\; : \;\; M_L \in [0, L] \text{ and } M_H \in [0, H].$$

If the IC constraint were slack then the solution to the above program would entail full securitization (and this would only be possible under transparency). Consider then the remaining case in which the IC binds due to $c > \widehat{c}_{otd}$ from equation (20). Substituting the IC constraint into the objective function it follows immediately that the optimal pooling contract allows the originator to market the following bundle of cash flows:

$$M_L^{**} \;\; = \;\; L \tag{33}$$

$$M_H^{**} \;\; = \;\; L + \frac{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) - c}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})[1 - \beta(Z - z)]} = H - (H - L)\frac{(c - \widehat{c}_{otd})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) - \widehat{c}_{otd}}.$$

If the planner wants to induce pooling, he mandates that all originators maintain the same skin-in-the-game, holding only the junior tranche. Intuitively, increases in M_L allow both types to

invest more and simultaneously relaxes the IC constraint. However, increases in M_H tighten the IC constraint, and must be limited to ensure effort incentives. Also, we see that mandatory retentions and information production by the speculator are substitutes. In particular, $\widehat{c}_{otd}$ is increasing in σ. Thus, the originator should be allowed to market more of the asset (increase M_H) for higher levels of σ.

We have established the following proposition:

Proposition 6 *The socially optimal pooling mechanism for inducing effort calls for originators to sell a senior claim with face L and a junior claim with face value:*

$$(H - L)\left[1 - \frac{(c - \widehat{c}_{otd})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) - \widehat{c}_{otd}}\right].$$

The originator retains the residual junior tranche.

We are now in position to compare the merits of using the separating scheme as opposed to the pooling scheme for inducing effort. The socially optimal pooling scheme now reflects mandatory retentions, with implied social welfare:

$$
\begin{aligned}
W_{pool} &= \beta[L + (H - L)(\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q})] - c + y_3^s - e(\sigma^{eq}) + y_3^{ui} \\
&\quad -[\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q}]\frac{(\overline{\nu} + \underline{\nu})\phi}{2}\left[1 + \int_1^{\widehat{\theta}} (\theta - 1)f(\theta)d\theta\right] \\
&\quad -(\beta - 1)[\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q}](H - L)\frac{(c - \widehat{c}_{otd})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) - \widehat{c}_{otd}}.
\end{aligned}
$$

The implied welfare differential between the pooling and separating regulatory regimes is:

$$
\begin{aligned}
W_{pool} - W_{sep} &= (\beta - 1)\overline{\rho}\overline{q}\left[\frac{\beta(\overline{q} - \underline{q})(H - L)}{\beta\overline{q} - \underline{q}}\right] + (c - \widehat{c}_{lcs})^+\left[\frac{\overline{\rho}\overline{q}(\beta - 1) + (1 - \overline{\rho})(\beta\overline{q} - \underline{q})}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})}\right] \\
&\quad -(\beta - 1)[\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q}](H - L)\frac{(c - \widehat{c}_{otd})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) - \widehat{c}_{otd}} \\
&\quad -e(\sigma^{eq}) - \frac{(\overline{\nu} + \underline{\nu})\phi}{2}[\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q}]\left[\int_1^{\widehat{\theta}} (\theta - 1)f(\theta)d\theta\right].
\end{aligned}
\tag{34}
$$

The final two terms in the equation above represent the key cost of inducing effort via pooling contracts: socially costly effort by speculators and socially inefficient risk sharing arising from UI

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portfolio distortions in the presence of informed speculators. The first three terms in the equation represent the difference in underinvestment costs between the two regulatory regimes. This sum is strictly positive when the informational efficiency of markets is high, so that $c - \widehat{c}_{otd}$ is small.

However, it is not necessarily the case that the separating regime entails higher underinvestment costs. For example, suppose $c = \widehat{c}_{lcs}$ so that the IC constraint is just slack at the LCSE. At the same time suppose the market is inherently informationally inefficient with $\widehat{c}_{otd}$ close to zero. In such cases, the pooling contract converges to the high type's separating contract, so that the pooling contract imposes gratuitous underinvestment costs on the low type, implying the separating contract dominates on all counts, including originator investment levels. More generally, the pooling regime is preferred from an investment perspective when the informational efficiency of markets is high, so that little/no underinvestment is needed to provide effort incentives.

Finally, we can evaluate the merits of opacity relative to the effort-inducing pooling scheme:

$$
\begin{aligned}
W_{otdo} - W_{pool} \quad = \quad & e(\sigma^{eq}) + \frac{(\overline{\nu} + \underline{\nu})\phi}{2}[\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q}] \left[\int_1^{\widehat{\theta}} (\theta - 1) f(\theta) d\theta \right] \\
& + (\beta - 1)[\overline{\rho}\overline{q} + (1 - \overline{\rho})\underline{q}](H - L) \frac{(c - \widehat{c}_{otd})^+}{(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q})(H - L) - \widehat{c}_{otd}} \\
& - \left[(\overline{\rho} - \underline{\rho})(\overline{q} - \underline{q}) \left(\beta(H - L) - \frac{(\overline{\nu} + \underline{\nu})\phi}{2} \right) - c \right].
\end{aligned}
\tag{35}
$$

As shown above, there are three welfare costs to the pooling scheme: speculator effort costs, distorted risk-sharing across investors, and underinvestment stemming from mandated retentions. However, these costs must be weighed against the positive social benefits of ex ante effort, as captured by the final term.

Conclusions

This paper develops a tractable framework for analyzing social welfare in both regulated and unregulated ABS markets, accounting for ex ante moral hazard, interim asymmetric information

between the originator and investors, and ex post asymmetric information between investors. This framework allows us to perform a positive analysis of the types of securitization structures consistent with rational markets and financial contracting. This analysis is important in light of recent arguments claiming that observed structures are evidence of irrationality.

We show that in unregulated markets the OTD business model can be an equilibrium outcome. However, opacity is inconsistent with sophisticated investor beliefs satisfying the Intuitive Criterion. Sophisticated investor beliefs and speculator effort were shown to promote originator effort by strengthening price discipline. Here security design is shown to play a part inasmuch as catering to hedging clienteles promotes uninformed trade and speculator effort. Finally, there can be multiple equilibrium levels of originator effort in unregulated markets.

This framework also allows us to perform a normative analysis of the social welfare implications of alternative securitization structures. We show that originators operating in unregulated markets fail to internalize the costs they impose on investors as they change ABS structures. Further, interim adverse selection reduces ex ante effort incentives as type-contingent payoffs are compressed due to low types always receiving at least their first-best payoff. Thus, mandated retentions have the potential to increase welfare by increasing effort incentives in an efficient way, accounting for investor welfare.

The first important policy implication to emerge from the model is that originators should be required to hold the most junior tranche, with the underlying logic for this policy depending on the nature of the mechanism. In a pooling mechanism, marketing more of the low-state payoff increases the spread between the interim payoffs of high and low types. In a separating mechanism, a natural single-crossing condition implies it is most efficient to use the size of the junior tranche as the basis for sorting.

Second, in the separating mechanism originators should only have discretion regarding the size of the junior tranche retention. This is distinct from existing proposals to grant originators broad discretion over the form of skin-in-the-game. For example, our analysis indicates that it would be

socially inefficient to grant originators the option of retaining a fraction of each tranche. Third, in contrast to standard signaling results, which call for low types to receive their first best allocations, our analysis shows it is optimal to impose costs on even the low type, since this serves to increase the spread between interim payoffs across types.

Fourth, the case for government intervention is weakest in informationally efficient markets. And further, in any pooling mechanism, the size of the socially optimal junior tranche retention is smaller the more informationally efficient the market. For example, this implies that securitized assets with high documentation levels should carry smaller retention requirements than assets with low levels of documentation. Conversely, in informationally inefficient or inherently opaque markets, separating mechanisms are socially preferable. Thus, implementation of optimal regulation requires taking a view on informational efficiency.

It should also be stressed that our analysis shows that it may be both necessary and optimal to impose caps on retentions as well as floors. For example, we showed that if markets are informationally inefficient, pooling equilibria impose higher underinvestment costs on both types than the optimal separating mechanism, and the separating mechanism dominates. However, absent the imposition of a cap on retentions, originators may end up playing the inefficient pooling equilibrium.

Our 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 are consistent with the notion that lender laxity is a necessary consequence of OTD. For example, see Gorton and Pennacchi (1995), Parlour and Plantin (2008), and Rajan, Seru and Vig (2010). 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 a price reflecting unconditional expected quality–the so-called pooling price. And indeed, in these models prices are equal to the pooling price precisely because traders are assumed to be incapable of generating information about loan quality. In reality, traders can generate useful information and securities prices can be informative. Viewed from the perspective of our model, the

problem of lender laxity must be understood as a failure of the price system. Moreover, for those believing in the criticality of price discipline in a market economy, praise of and calls for increased opacity seem exactly the wrong policy response unless one is willing to accept lender laxity as a fact of life.

Appendix

Lemma 1: Optimal Investor Portfolio

The Lagrangian for this linear program is:

$$\mathbf{L} = y_3^{ui} - \sum_{j=0}^{J} x_j E[P_j|\text{Vulnerable}] - [\rho\overline{q} + (1-\rho)\underline{q}]\theta \left[\phi - \sum_{j=0}^{J} x_j A_{jH} \right] \qquad (36)$$

$$+ \mu \left[\phi - \sum_{j=0}^{J} x_j A_{jH} \right] + \sum_{j=0}^{J} \lambda_j x_j.$$

The optimal portfolio and associated multipliers satisfy:

$$
\begin{aligned}
0 &= [\rho\overline{q} + (1-\rho)\underline{q}]\theta A_{jH} - E[P_j|\text{Vulnerable}] - \mu^* A_{jH} + \lambda_j^* \quad \forall \quad j \\
0 &\leq \left[\phi - \sum_{j=0}^{J} x_j^* A_{jH} \right] \mu^* \\
0 &\leq \lambda_j^* x_j^* \quad \forall \quad j \\
0 &\leq \lambda_j^* \quad \forall \quad j.
\end{aligned}
$$

Since the objective function and constraints are linear, $\mu^* = 0$ implies demand is zero for all securities, implying $\lambda_j^* > 0$ for all securities. This holds iff:

$$\max_j \frac{A_{jH}}{E[P_j|\text{Vulnerable}]} < \frac{1}{\theta[\rho\overline{q} + (1-\rho)\underline{q}]}.$$

Suppose next $\mu^* > 0$. Then:

$$\frac{A_{jH}}{E[P_j|\text{Vulnerable}]} \leq \frac{1}{\theta[\rho\overline{q} + (1-\rho)\underline{q}]} \Rightarrow \lambda_j^* > 0 \Leftrightarrow x_j^* = 0.$$

and

$$\lambda_j^* = 0 \Rightarrow \frac{A_{jH}}{E[P_j|\text{Vulnerable}]} = \frac{1}{[\rho\overline{q} + (1-\rho)\underline{q}]\theta - \mu^*} > \frac{1}{\theta[\rho\overline{q} + (1-\rho)\underline{q}]}.$$

Thus, those UI making nonzero investments place all funds into the security with the highest ratio of high state payoff to expected price. Iff $A_{jH} \leq A_{jL}$ for all $j \geq 1$, any investment is in safe storage.

If $A_{jH} > A_{jL}$ for some $j \geq 1$, safe storage is dominated and attention can be confined to $j \geq 1$ such that $A_{jH} > 0$. Further, MM will set the price for all securities using some weighting, call it ω, on the high state. Security j ranks highest on the above ratio test iff

$$\frac{A_{jH}}{\omega A_{jH} + (1-\omega)A_{jL}} \geq \frac{A_{kH}}{\omega A_{kH} + (1-\omega)A_{kL}} \Leftrightarrow \frac{A_{jL}}{A_{jH}} \leq \frac{A_{kL}}{A_{kH}}.$$

And since $\mu^* > 0$, the complementary slackness condition implies $x_j^* = \phi/A_{jH}$.

Finally, returning to those who do not invest in any security, it must be that

$$\max_j \frac{A_{jH}}{\omega A_{jH} + (1-\omega)A_{jL}} \quad < \quad \frac{1}{\theta[\rho\overline{q} + (1-\rho)\underline{q}]}$$

$$\Updownarrow$$

$$\frac{\omega + (1-\omega)\min_j(A_{jL}/A_{jH})}{[\rho\overline{q} + (1-\rho)\underline{q}]} \quad \equiv \quad \widehat{\theta} > \theta.\blacksquare$$

Lemma 2: Equilibrium Speculator Signal Precision

Define, for this lemma, the function Ω with domain $[1/2, 1]$ as follows

$$\Omega(\sigma) \equiv \Psi\left[\rho(1-\rho)(\overline{q}-\underline{q})(\overline{v}-\underline{v})\phi\left(1 - \frac{A_L}{A_H}\right)\left(1 - F\left(\widehat{\theta}(\sigma)\right)\right)\right].$$

The function Ω is continuous and strictly decreasing with $\Omega(1/2) > 1/2$. It follows there exists a unique solution to the equation $\Omega(\sigma) = \sigma$ in $(1/2, 1)$. For comparative statics, applying the implicit function theorem to the equilibrium condition for σ yields

$$\frac{d\sigma}{d\frac{A_L}{A_H}} = \frac{-\Psi'(\cdot)\rho(1-\rho)(\overline{q}-\underline{q})(\overline{v}-\underline{v})\phi\left(1 - F\left(\widehat{\theta}\right)\right)}{1 + \Psi'(\cdot)\rho(1-\rho)(\overline{q}-\underline{q})(\overline{v}-\underline{v})\phi\left(1 - \frac{A_L}{A_H}\right)f\left(\widehat{\theta}\right)\frac{\partial\widehat{\theta}}{\partial\sigma}} < 0.\blacksquare$$

Lemma 3: LCS Allocations

The program can be rewritten as

$$\max_{(M_L, M_H)} \quad \overline{q}(H - M_H) + (1-\overline{q})(L - M_L) + \beta[\overline{q}M_H + (1-\overline{q})M_L] \tag{37}$$

subject to

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

$$M_L \leq L; \quad M_H \leq H; \quad M_L \geq 0; \quad M_H \geq 0.$$

We solve a relaxed program ignoring the last three constraints and then verify the neglected constraints are 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:

$$M_H(M_L) = M_L + \frac{(\beta - 1)[\underline{q}H + (1-\underline{q})L - M_L]}{\beta\overline{q} - \underline{q}}. \tag{38}$$

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

$$\max_{M_L \leq L} \quad \overline{q}M_H(M_L) + (1-\overline{q})M_L. \tag{39}$$

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 constraints are slack, it follows an LCS allocation entails:

$$
\begin{aligned}
(M_L, M_H) &= \left(L, L + \frac{(\beta - 1)\underline{q}(H - L)}{\beta\overline{q} - \underline{q}}\right) \tag{40} \\
&\Rightarrow (R_L, R_H) = \left(0, \frac{\beta(\overline{q} - \underline{q})(H - L)}{\beta\overline{q} - \underline{q}}\right). \blacksquare
\end{aligned}
$$

Lemma 4: 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 now establish sufficiency. In particular, 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:

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

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:

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

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

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

Proposition 1: Characterization of Pooling Equilibria

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

$$K_L(\underline{q}, \underline{z})M_L^0 + K_H(\underline{q}, \underline{z})M_H^0 + \underline{q}H + (1 - \underline{q})L$$

$$\leq \quad K_L(\underline{q}, \underline{z})M_L^0 + K_H(\underline{q}, \underline{z})M_L^0 + \underline{q}H + (1 - \underline{q})L$$

$$= \quad (\beta - 1)M_L^0 + \underline{q}H + (1 - \underline{q})L < \underline{U}_{lcs}$$

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. $K_H(\overline{q}, \overline{z}) > 0$ 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 $K_H(\overline{q}, \overline{z}) < 0$. Since $M_H > M_L$ in any pooling equilibrium we then know the high type's equilibrium payoff is:

$$K_L(\overline{q}, \overline{z})M_L^0 + K_H(\overline{q}, \overline{z})M_H^0 + \overline{q}H + (1 - \overline{q})L$$

$$< \quad K_L(\overline{q}, \overline{z})M_L^0 + K_H(\overline{q}, \overline{z})M_L^0 + \overline{q}H + (1 - \overline{q})L$$

$$= \quad (\beta - 1)M_L^0 + \overline{q}H + (1 - \overline{q})L \leq (\beta - 1)L + \overline{q}H + (1 - \overline{q})L < \overline{U}_{lcs}.$$

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 $M_H < L$. Since both $K_L(\overline{q}, \overline{z}) > 0$ can be verified and $K_H(\overline{q}, \overline{z}) > 0$ from the preceding lemma we know

$$K_L(\overline{q}, \overline{z})M_L^0 + K_H(\overline{q}, \overline{z})M_H^0 + \overline{q}H + (1 - \overline{q})L$$

$$< \quad K_L(\overline{q}, \overline{z})L + K_H(\overline{q}, \overline{z})L + \overline{q}H + (1 - \overline{q})L$$

$$= \quad (\beta - 1)L + \overline{q}H + (1 - \overline{q})L < \overline{U}_{lcs}.$$

This is a contradiction.▲

To prove the second 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

$$K_L(\overline{q}, \overline{z})L + K_H(\overline{q}, \overline{z})H + \overline{q}H + (1 - \overline{q})L$$

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

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:

$$K_L(\overline{q}, \overline{z})L + K_H(\overline{q}, \overline{z})H + \overline{q}H + (1 - \overline{q})L$$

$$\geq \quad \beta[\overline{q}H + (1 - \overline{q})L] - (\beta - 1)\overline{q}\left[\frac{\beta(\overline{q} - \underline{q})(H - L)}{(\beta\overline{q} - \underline{q})}\right]$$

$$\Updownarrow$$

$$\overline{z} \quad \geq \quad (\overline{q} - \underline{q})/(\beta\overline{q} - \underline{q}).\blacksquare$$

Lemma 3: The Intuitive Criterion

We begin by recalling that for the case here 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

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

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 $M_H^{\max} < H$ and the second implies a lower bound $M_H^{\min} > L$. Thus, there exists a feasible pruning deviation iff $M_H^{\max} > M_H^{\min}$. The inequality stated in the lemma is necessary and sufficient to ensure $M_H^{\min} \geq M_H^{\max}$ 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 have established as a necessary and sufficient condition

$$(\beta\overline{q} - \underline{q})\overline{U} - (\beta - 1)\overline{q}\underline{U} \geq \beta(\overline{q} - \underline{q})\left[\overline{q}H + (1 - \overline{q})L\right]$$

$$\Updownarrow$$

$$(\beta\overline{q} - \underline{q})\beta\overline{REV} - (\beta - 1)\overline{q}\beta\underline{REV} \geq (\beta - 1)(\overline{q} - \underline{q})L + (\overline{q} - \underline{q})\left[\beta\overline{q}M_H + (1 - \beta\overline{q})M\right.$$

$$\Updownarrow$$

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

$$\Updownarrow$$

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

$$\Updownarrow$$

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

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 preceding lemma.■

Proof of $\overline{z}$ Increasing in σ

From the definition of $\overline{z}$ we have:

$$\frac{2\overline{z}}{\rho} = 1 + \frac{\sigma^2}{(1-a)} + \frac{(1-\sigma)^2}{a}$$

$$a(\sigma) \equiv \rho + \sigma - 2\sigma\rho.$$

Differentiating we obtain:

$$\frac{2\overline{z}'(\sigma)}{\rho} = \frac{2(1-a)\sigma + (1-2\rho)\sigma^2}{(1-a)^2} - \frac{2a(1-\sigma) + (1-2\rho)(1-\sigma)^2}{a^2}$$

$$= \frac{[2(1-a) + (1-2\rho)\sigma]\sigma a^2 - (1-a)^2(1-\sigma)[2a + (1-2\rho)(1-\sigma)]}{(1-a)^2 a^2}$$

This is strictly positive if and only if.

$$[2(1-a) + \sigma(1-2\rho)]\sigma a^2 > (1-a)^2(1-\sigma)[2a + (1-2\rho) - \sigma(1-2\rho)]$$

$$\Updownarrow$$

$$[(1-a) + (1-\rho)]\sigma a^2 > (1-a)^2(1-\sigma)[a + (1-\rho)]$$

$$\Updownarrow$$

$$(1-\rho)\sigma a^2 > (1-a)\left[(1-\sigma)(1-a)a + (1-\sigma)(1-\rho)(1-a) - \sigma a^2\right]$$

$$\Updownarrow$$

$$(1-\rho)\sigma a^2 > (1-a)[a(1-a) - a\sigma + (1-\sigma)(1-\rho)(1-a)]$$

$$\Updownarrow$$

$$[(1-\rho)a + 1 - a]\sigma a > (1-a)^2[a + (1-\sigma)(1-\rho)]$$

$$\Updownarrow$$

$$[1 - \rho a]\,\sigma a \;>\; (1-a)^2(1-\rho\sigma)$$

$$\Updownarrow$$

$$\sigma a - \sigma\rho a^2 \;>\; (1-a)^2 - \rho\sigma(1-a)^2$$

$$\Updownarrow$$

$$\rho\sigma\left[(1-a)^2 - a^2\right] + \sigma a \;>\; (1-a)^2$$

$$\Updownarrow$$

$$\rho\sigma + \sigma a(1-2\rho) \;>\; (1-a)^2$$

$$\Updownarrow$$

$$a^2 + \rho(\sigma - a) \;>\; (1-a)^2$$

$$\Updownarrow$$

$$\rho^2(2\sigma - 1) + 2\left[\sigma - \rho(2\sigma - 1)\right] \;>\; 1$$

$$\Updownarrow$$

$$(\rho - 1)^2(2\sigma - 1) - (2\sigma - 1) + 2\sigma \;>\; 1$$

$$\Updownarrow$$

$$(\rho - 1)^2(2\sigma - 1) \;>\; 0.\blacksquare$$

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Table 1: Aggregate Demand Outcomes

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

Figure 1: Timeline

S chooses σ at cost e(σ)

S observes signal

O observes true q

UI vulnerable/not

O hidden
effort at cost
c or not

O registers menu

Market orders submitted

O chooses from menu

MM set prices

Payoffs

Period 1   Period 2   Period 3   Period 4

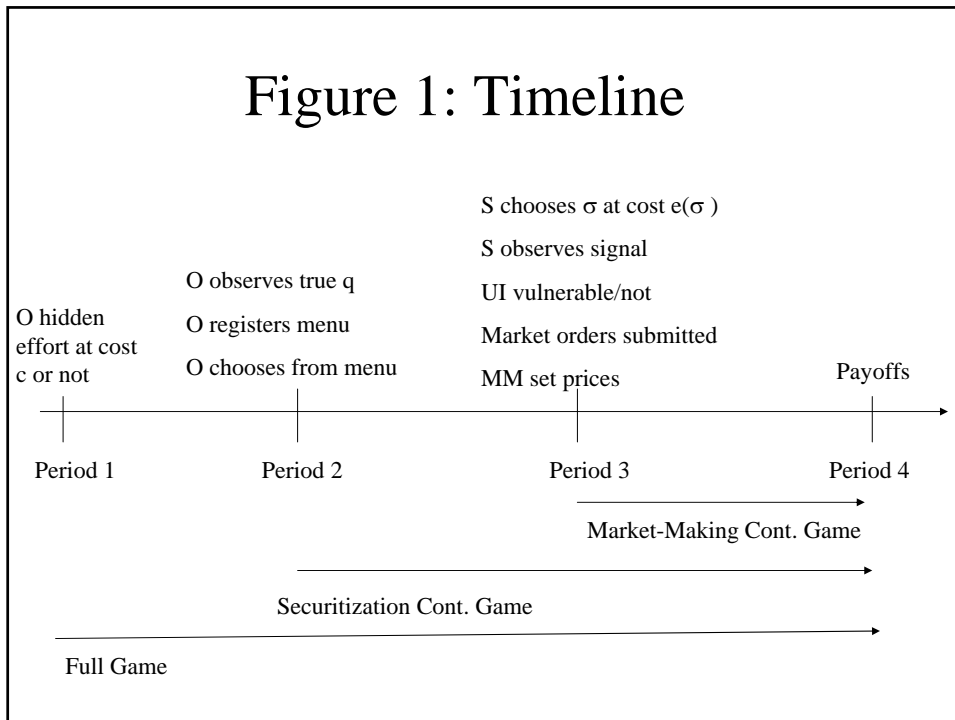Market-Making Cont. Game

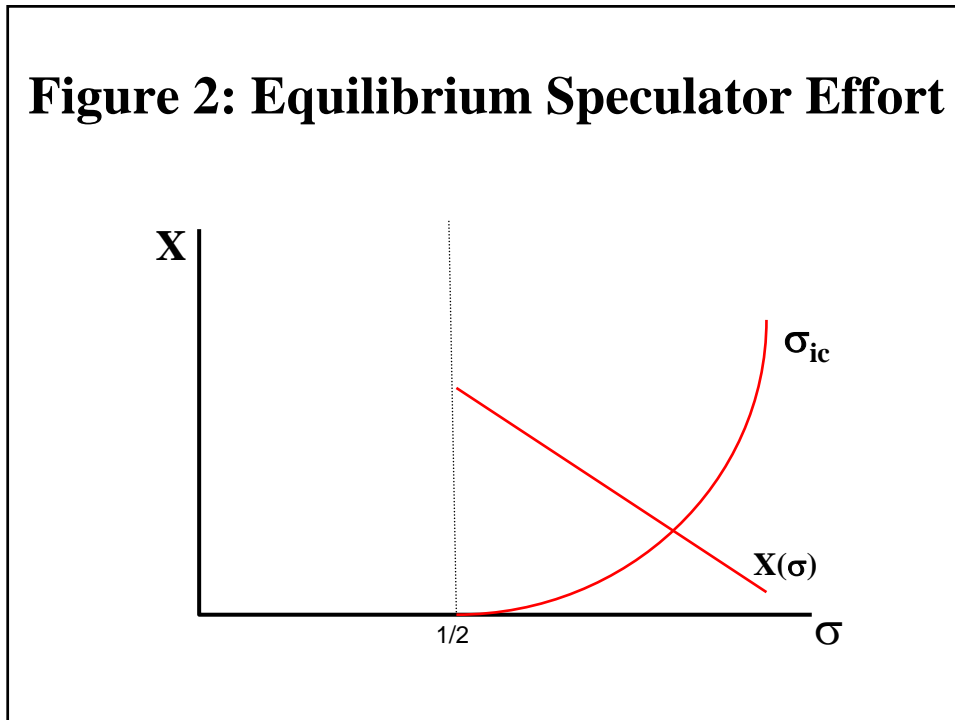Securitization Cont. Game

Full Game

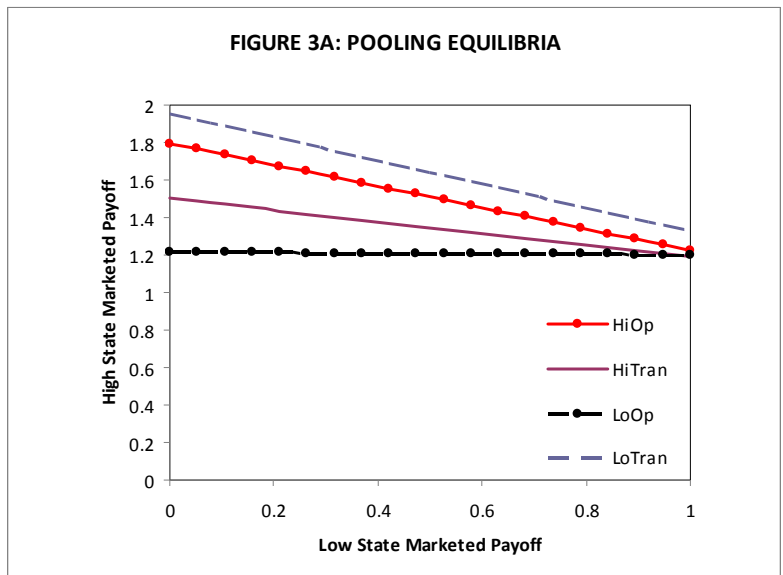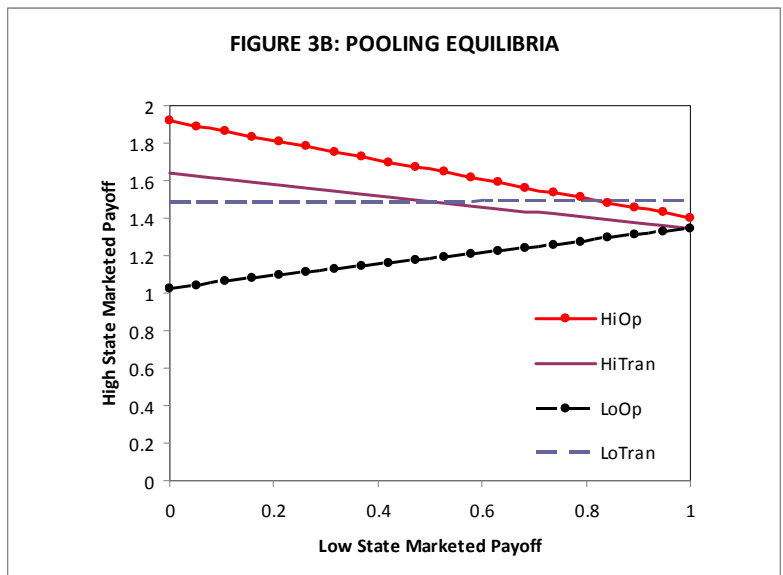# Figure 2: Equilibrium Speculator Effort

FIGURE 3A: POOLING EQUILIBRIA

FIGURE 3B: POOLING EQUILIBRIA

Figure 4: Equilibrium Verification