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Abstract

We study the problem of a seller (e.g. a bank) who is privately informed about the quality of her asset and needs to raise funds from uninformed buyers (e.g. investors) by issuing securities backed by her asset cash flows. In our setting, buyers post menus of contracts to screen the seller, but the seller cannot commit to trade with only one buyer, i.e., markets are *non-exclusive*. Non-exclusive markets behave very differently from exclusive ones: (i) separating contracts are never part of equilibrium; (ii) mispricing of claims is always larger than in exclusive markets; (iii) there is always a semi-pooling equilibrium where all sellers issue the same debt contract priced at *average*-valuation, and sellers of *low*-quality assets issue remaining cash flows at *low*-valuation; (iv) market liquidity can be higher or lower than in exclusive markets, but (v) the average quality of originated assets is always lower. Our model's predictions are consistent with empirical evidence on issuance and pricing of mortgage-backed securities, and we use the theory to evaluate recent reforms aimed at enhancing transparency and exclusivity in markets.

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1 Introduction

The question of how markets function in the presence of information asymmetries has been central in economics and finance since the seminal work of Akerlof (1970), who showed that information asymmetries between sellers and buyers can give rise to equilibrium multiplicity and market failures. In the study of asset markets, a large literature followed to explore the role of security design – the ability of sellers to optimally design and issue securities backed by asset cash flows – in ameliorating such information frictions. From it, we learned that by retaining exposure to an asset's cash flows a seller may be able to credibly convey to buyers information about her asset quality (e.g. Leland and Pyle (1977); DeMarzo and Duffie (1999)); and that standard debt emerges as the optimal security design since it minimizes the distortions due to adverse selection (e.g. Gorton and Pennacchi (1990); Nachman and Noe (1994); DeMarzo and Duffie (1999); Biais and Mariotti (2005); DeMarzo (2005); Daley et al. (2020b)). This literature, however, has mostly focused on exclusive contracting, i.e., environments where the buyer of claims can ensure that the seller does not engage in trade with other buyers.[1] In many settings of interest, however, exclusivity may be difficult to enforce.

Exclusivity effectively requires that the seller is able to commit to trade with only one buyer, even if gains from trade arise with other buyers; or, alternatively, that the buyers are able to observe and contract upon the entire set of the seller's trades. In the context of modern financial markets, however, these requirements are unlikely to be fulfilled: there is little information about agents' trades, and the complexity of certain financial products makes it difficult for potential buyers to understand a seller's overall asset positions and resulting risk-exposures.[2] This has been of particular concern to policymakers in the US and Europe, who are in the process of implementing policies aimed at enhancing exclusivity in financial markets.

Motivated by these observations, we revisit the classic problem of a seller who is privately informed about the quality of her asset and raises funds from uninformed buyers by issuing securities backed by her asset cash flows. We consider a screening game, where buyers post menus of contracts (securities and prices) to be accepted by the seller, but where the seller cannot commit to trade with only one buyer, i.e., markets are *non-exclusive*. We use our framework to study the implications of non-exclusivity for equilibrium allocations, as characterized by issued securities and their prices, which we show are consistent with recent empirical evidence from markets for mortgage-backed securities. We then investigate the theory's normative implications and relate our findings to proposed policies and reforms in the aftermath of the global financial crisis.

[1]Biais and Mariotti (2005) consider a non-exclusive market setting but where quantities of a pre-designed security are traded.

[2]This was first observed and analyzed by Jaynes (1978) in the context of insurance markets.

Our setup is as follows. There is a risk-neutral seller endowed with an asset that pays random cash flow, X, in the future; and, there is a large number of competitive, risk-neutral, deep-pocket buyers. Gains from trade arise because the seller is more impatient than the buyers. The seller, however, is privately informed about the quality of her asset, which could be *high*- or *low*-quality, and where higher cash flows are more likely to be obtained from a *high*-quality asset. Buyers compete by posting menus of bilateral contracts, where each contract is a security-price pair (F, p), where F maps cash flow X to a payment $F(X)$ to be received by the buyer in the future. The seller can accept contracts from multiple buyers but is subject to limited liability, i.e., all issued securities must be fully backed by asset cash flows. For technical reasons, in order to ensure that an equilibrium always exists, we allow each buyer to withdraw his menu at small cost after observing the initial menu offers.[3] Our equilibrium notion is perfect Bayesian.

Our setting features two frictions: the seller is privately informed about her asset quality and the securities market is non-exclusive. As a preliminary step, we consider two benchmark settings in which we shut down each of these frictions in turn. First, we study the full information benchmark in which the asset quality is public information but markets are non-exclusive. Here, we show that the first-best allocations are attained, as all asset cash flows are transferred from the seller to the buyers, i.e., equity is the optimal security design and it is priced at its full information expected value. By implication, our findings will be due to the interaction of asymmetric information with non-exclusivity.

Second, we study an *exclusive* markets benchmark in which the seller is restricted to trade with at most one buyer.[4] We show that an equilibrium exists, is unique, and can be separating or feature some cross-subsidization depending on the buyers' prior belief that the seller has a *high*-quality asset, i.e., that she is a *high*-type. When the belief is below a threshold, the equilibrium is separating: the *high*-type seller issues a debt security priced at *high*-valuation and retains the remaining cash flows, whereas the *low*-type seller issues equity priced at *low*-valuation. In contrast, when the belief is above the threshold, the *high*-type seller continues to issue a debt security, but with higher face value and priced below *high*-valuation, whereas the *low*-type seller continues to issue equity but priced above *low*-valuation.[5]

We then turn to our main setup and show that, in the presence of asymmetric information, non-exclusive markets behave very differently from exclusive ones: (i) separating contracts are never part of equilibrium; (ii) mispricing of claims is larger than in exclusive markets; (iii) there is always a semi-pooling equilibrium in the sense that some, but not all, traded contracts are

[3]This approach is in the spirit of the seminal papers by Wilson (1977) and Miyazaki (1977), and the more recent work by Netzer and Scheuer (2014) and Mimra and Wambach (2019).

[4]This restriction effectively captures the seller's ability to commit not to trade with other buyers.

[5]Buyers' ability to withdraw loss-making menus allows us to support this cross-subsidizing equilibrium, as "cream-skimming" deviations are rendered unprofitable.

accepted by both seller types; (iv) market liquidity (i.e., realized gains trade) can be higher or lower than in exclusive markets, but (v) the average quality of originated assets (which is endogenized in an extension) is always lower.

In non-exclusive markets, there is *always* cross-subsidization from the *high*- to the *low*-type seller. Furthermore, such cross-subsidization, and the resulting mispricing of claims, is always larger than in exclusive markets. One might intuitively think that, as cash flow retention is more costly for the *low*- than for the *high*-type, it should be possible for buyers to separate the *high*-type seller by offering her a contract that requires enough cash flow retention for it to be unattractive for the *low*-type. When markets are non-exclusive, however, retention of cash flows cannot be enforced: there is always a profitable deviation for a buyer to offer to buy the retention implied by the contract of the *high*-type seller, allowing the *low*-type to accept the contract meant for the *high*-type without having to retain the remaining cash flows. Standard debt then emerges as the optimal security design for the *high*-type seller, as it minimizes the mispricing she faces due to adverse selection.

Moreover, there is always an equilibrium where both seller types issue the same debt security (senior tranche). Moreover, while the *high*-type optimally chooses to retain (i.e., not sell) her remaining cash flows (junior tranche), the *low*-type sells them to a distinct buyer. We refer to this as the *star equilibrium*, and we show that it is unique among all candidate equilibria in which the seller can issue any set of cash flows at (or above) *low*-valuation. In it, the senior tranche is *mispriced*, in the sense that its price reflects the average rather than the true asset quality; whereas the junior tranche is priced at its true, *low*-valuation.

The *star equilibrium* is supported by the presence of *latent* contracts, i.e., contracts that are posted by some buyers but not traded in equilibrium, which price all feasible securities at *low*-valuation. The role of such contracts is to allow the *low*-type seller to exploit all gains from trade with buyers, on and off equilibrium path. Intuitively, consider a "cream-skimming" deviation that attracts the *high*-type from her equilibrium contract. Then, the menu containing the senior tranche that was originally issued by both seller types must be withdrawn, as it would now be loss-making. But then, the *low*-type would also find it optimal to accept the deviating contract together with a collection of latent contracts from other buyers, rendering the deviation unprofitable.[6]

Our theory's predictions are consistent with evidence from markets where exclusivity is difficult to enforce. First, we provide a new rationale for the practice of tranching underlying cash flows that are sold separately in markets. Indeed, within the context of markets for commercial mortgage-backed securities (CMBS), where tranching is common practice, Ashcraft, Gooriah,

[6]The role of latent contracts in supporting equilibria in non-exclusive markets was first analyzed in Arnott and Stiglitz (1991) and Attar et al. (2011) in environments with moral hazard and adverse selection, respectively.

and Kermani (2019) argue that complex products like collateralized debt obligations (CDOs) enabled informed parties in the securitization pipeline to reduce their cash flow retention in a way not observable to other market participants, suggesting that exclusivity is hard to enforce. Second, and in sharp contrast to conventional models, our theory predicts that the amount of cash flows retained by a seller *should not* predict differential pricing in the market for her senior tranches, but that it *should* predict differential quality of these tranches. This is consistent with findings in Ashcraft et al. (2019) that, in the CMBS market, initially retained cash flows sold into CDOs in the twelve months following a transaction are not correlated with the prices of the more senior tranches, though they do predict a higher probability of default of these tranches.

After the 2008-09 financial crisis, a number of reforms were discussed in the US, which would either directly or indirectly enhance exclusivity in contracting. For instance, the Dodd-Frank Act explicitly prohibits the sellers of asset-backed securities to engage in trades that have any material conflicts of interest with the investors of trades completed within the previous year.[7] A natural obstacle to the enforcement of such rules is the complexity of balance sheets of financial institutions and the opacity of markets in which they can trade. To address this, a number of complementary rules were implemented, primarily consisting of more stringent information disclosure requirements combined with the relocation of trading of certain securities from opaque over-the-counter markets to more transparent platforms. Our framework provides a natural laboratory within which one can evaluate the effects of such interventions.

First, we show that when the distribution of asset qualities in the market is exogenous (as in our baseline setting) non-exclusive markets increase welfare vis-à-vis exclusive markets if and only if they generate higher market liquidity (i.e., more trade), which only occurs when the average asset quality is sufficiently high. This finding contrasts with the by-now conventional "ignorance is bliss" view of Dang, Gorton, and Holmström (2010) and Dang, Gorton, Holmström, and Ordonez (2017), according to which market liquidity and efficiency are maximized through complexity of assets and opacity of issuers' balance sheets. Our model instead provides a more nuanced view: to the extent that complexity/opacity inhibits exclusive contracting, its effects on liquidity and efficiency will depend on the average quality of assets in the market.

Second, in some applications (e.g. loan origination), both the liquidity of markets and the manner by which claims are priced may impact efficiency by distorting investment incentives. To address this, we consider a simple extension where we allow the seller (who is now also the asset

[7]Statement at Open Meeting: Asset-Backed Securities Disclosure and Registration, by Commissioner Kara M. Stein on Aug. 27, 2014 states that "Section 621 prohibits an underwriter, placement agent, initial purchaser, sponsor, or any affiliate or subsidiary of any such entity, of an asset-backed security from engaging in any transaction that would involve or result in any material conflict of interest with respect to any investor in a transaction arising out of such activity for a period of one year after the date of the first closing of the sale of the asset-backed security."

originator) to exert costly, unobservable effort to increase the likelihood of having a *high*-quality asset. Here, we uncover a robust result: the average quality of originated assets is *always* lower with non-exclusive markets than with exclusive markets, even when they implement higher retention levels. This is due to the fact that non-exclusive markets always feature a greater mispricing of claims than exclusive markets. Taking the above results together, we conclude that non-exclusive markets increase welfare vis-à-vis exclusive markets whenever the potential (though not guaranteed) gains from increased market liquidity more than compensate for the (guaranteed) fall in asset quality. Thus, our results suggest that complexity/opacity is desirable only when efficiency gains are mostly driven by reallocation of assets in markets *and* originators need not be too incentivized to produce *high*-quality assets.

Our paper naturally relates to the literature that studies non-exclusive competition in markets plagued with adverse selection (e.g. Pauly (1974); Jaynes (1978); Riley (1979); Hellwig (1988); Bisin and Gottardi (1999, 2003); Santos and Scheinkman (2001b); Ales and Maziero (2009, 2016); Attar et al. (2011, 2014); Kurlat (2016); Stiglitz et al. (2020).[8] We contribute to this literature by studying the implication of non-exclusivity for the optimal design and pricing of asset-backed securities. Within this literature, the paper that is closest to ours is Attar et al. (2011), who study non-exclusive competition in the market for lemons. In their model the seller can only accept securities of the form $F(X) = q \cdot X$ for some $q \in [0, 1]$, so there is no room to study the role of security design. There are two important differences in terms of results from Attar et al. (2011). First, due to optimal security design, we do not obtain Akerlof-like outcomes: there is always a non-trivial debt security that the *high*-type trades at average valuation and there is never a market collapse. Second, in our setting, the equilibrium demand for securities must generally be non-linear, in the sense that buyers must stand ready to buy one set of securities at *average*-valuation and another set at *low*-valuation, as in Jaynes (1978) and Stiglitz et al. (2020). This feature yields novel predictions regarding issuance and pricing of asset-backed securities which are in line with empirical evidence.

While the literature on security design that we mentioned above has mostly focused on exclusive contracting, there are some exemptions. Biais and Mariotti (2005) study the problem of a seller who designs a security ex-ante, before learning private information, and then ex-post trades quantities of that security in non-exclusive markets. They show that when markets are competitive, debt is the optimal security design that allows for pooling of all types. In contrast, in our setting, the securities are designed ex-post, and thus the seller is able to trade different securities with different buyers. More closely related to our paper, Li (2019) studies the optimal design of securities that are traded by informed parties in a competitive

[8] A rich survey of the literature that explores the issue of non-existence of equilibrium in competitive insurance markets can be found in Mimra and Wambach (2014).

and segmented search market. In her setting, a seller can access multiple markets but the buyers in one market cannot observe the trades in other markets. Thus, while segmentation allows for non-exclusive contracting, which induces the seller to tranche her asset cash flows, separation is still possible, as the seller of a given security can sort into markets with different degrees of market tightness/liquidity.

Finally, on the normative front, we contribute to a growing literature that studies the costs and benefits of transparency in financial markets plagued with adverse selection (e.g. Chemla and Hennessy (2014); Asriyan, Fuchs, and Green (2017, 2019a); Daley, Green, and Vanasco (2020a)). This literature primarily focuses on how transparency affects the agents' ability to obtain additional information about the seller's asset quality (e.g. by observing signals). In contrast, we focus on the implications of transparency through its effects on exclusivity; that is, through the ability of an agent to observe *and* contract upon the set of trades that his counterparty enters into with others.

Our paper is organized as follows. In Section 2, we present the setup of our model, and we establish two useful benchmarks against which we compare our results. In Section 3, we characterize the equilibrium of our model. We consider the model's normative implications, which we relate to policy discussions, in Section 4; and its positive predictions, which we relate to empirical facts, in Section 5. All proof are relegated to the Appendix.

2 The Model

There are two dates, indexed by $t \in \{1, 2\}$. There is an asset seller (e.g. bank) and a large number N of "deep pocket" buyers (e.g. investors). The seller's preferences are:

$$U^S = c_1^S + \delta \cdot c_2^S, \tag{1}$$

where $\delta \in (0, 1)$ and c_t^S is the cash flow she receives in period t. A buyer's preferences are:

$$U^B = c_1^B + c_2^B, \tag{2}$$

where c_t^B is the cash flow he receives in period t. Thus, gains from trade between the seller and the buyers arise due to heterogeneity in discount factors.[9]

[9] The assumption that the seller is more impatient than the buyers is a common modeling device to rationalize gains from trade (e.g. DeMarzo and Duffie (1999); Biais and Mariotti (2005); DeMarzo (2005); Daley et al. (2020a,b)). In practice, there are many reasons why an asset owner might want to raise funds by selling asset cash flows. For example, a bank that is financially constrained and has new profitable investment opportunities may benefit from selling a fraction of its loans to finance these new opportunities. Alternatively, asset securitization may allow loan originators to share-risks with market investors.

The seller is endowed with an asset that delivers a random cash flow X in period $t = 2$. The asset can be of *high*- or *low*-quality, denoted by $\theta \in \{H, L\}$, and its cash flow is distributed according to cdf G_θ. We assume that G_θ has an associated pdf g_θ with full support on the interval $[0, \bar{X}]$ for some $\bar{X} > 0$. The pdfs are in turn related by the monotone likelihood ratio property (MLRP); that is, $\frac{g_H(x)}{g_L(x)}$ is increasing in x. In the spirit of Akerlof (1970), asymmetric information arises because the seller knows the quality θ of her asset, whereas the buyers are uninformed and have a prior belief $\mu_0 = \mathbb{P}(\theta = H) \in (0, 1)$.

To realize gains from trade, the seller raises funds at $t = 1$ by issuing securities fully backed by her asset cash flows to buyers. Formally, a security is a function $F : [0, \bar{X}] \to \mathbb{R}$ and its payoff is denoted by $F(x)$ when the realized cash flow is $X = x$. Let $\mathcal{F}$ be the collection of securities issued by the seller, then we say that this collection is *feasible* if:

- (Limited Liability - LL) $\sum_{F \in \mathcal{F}} F(x) \leq x$ and $F(x) \geq 0$ for all $F \in \mathcal{F}$.
- (Weak Monotonicity - WM) $F(x)$ and $x - \sum_{F \in \mathcal{F}} F(x)$ are weakly increasing in x.

We denote the set of all feasible (collections of) securities by Φ. Conditions (LL) and (WM) are generalizations of the limited liability and the monotonicity constraints often used in the asset-backed security design literature (e.g. Nachman and Noe (1994); DeMarzo and Duffie (1999); Biais and Mariotti (2005)) to a setting with multiple securities, and their role is to ensure tractability. We interpret these feasibility conditions as technological.

The securities market is non-exclusive in the sense that trade between the seller and the buyers is bilateral, and a buyer cannot exclude the seller from trading with other buyers. Formally, we study the following three-stage screening game:

- Stage 1: buyers simultaneously post menus of contracts, where a menu $\mathcal{M}$ posted by a buyer is a (potentially infinite) set of contracts or security-price pairs (F, p).
- Stage 2: buyers observe all posted menus and simultaneously decide whether to remain in the market or to become inactive by withdrawing their menus at infinitesimal cost $\kappa > 0$.
- Stage 3: seller observes all active menus and accepts at most one contract from each menu, subject to the accepted collection of securities being feasible.[10]

Contracts are executed at the end of the game. Namely, if the seller has accepted contract (F, p) from a buyer at $t = 1$, then the buyer makes a transfer p to the seller at $t = 1$ and in exchange receives $F(x)$ at $t = 2$ when the realized cash flow is $X = x$.

[10] That the seller accepts at most one contract from each menu is without loss of generality.

The following remarks are in order. First, our modeling approach of allowing buyers to withdraw menus is in the spirit of Wilson (1977) and Miyazaki (1977), and it simply ensures existence of equilibrium (see Section 3 for a detailed discussion).[11] Second, our (LL) condition, by restricting the seller to issue an asset-backed security, helps us isolate the mechanism arising due to asymmetric information from other mechanisms that may also be at play in non-exclusive settings, e.g. dilution.[12] For the interested reader, we provide a microfoundation that rationalizes our feasibility conditions in a non-exclusive market setting in Appendix C.

Payoffs. At Stage 3, the θ-type seller decides which contracts to accept from the active menus. Let $\mathcal{C}$ denote the set of contracts chosen by the seller, where we set $\mathcal{C} = \{(0,0)\}$ if the seller chooses not to trade. Then, her payoff at Stage 3 is:

$$u_\theta \equiv \sum_{(F,p)\in\mathcal{C}} p + \delta \cdot \mathbb{E}_\theta \left[X - F(X)\right], \tag{3}$$

where $\mathbb{E}_\theta[\cdot]$ is the expectations operator conditional on the seller's type θ.

At Stage 2, after observing all menus $\cup_j \mathcal{M}^j$ posted at Stage 1, buyer i decides whether to withdraw his menu $\mathcal{M}^i$. Let $\mu_2^i(F,p)$ denote buyer i's belief at Stage 2 that the seller is an H-type if she were to accept contract $(F,p) \in \mathcal{M}^i$. Buyer i's expected payoff at Stage 2 is:

$$(1-w^i) \cdot \sum_{(F,p)\in\mathcal{M}^i} \mathbb{P}\left(\text{seller accepts } (F,p) | \cup_j \mathcal{M}^j\right) \cdot \Big(-p + \mathbb{E}_{\mu_2^i}[F(X)]\Big) - w^i \cdot \kappa, \tag{4}$$

where $w^i \in \{0,1\}$, $w^i = 1$ if and only if buyer i withdraws, and $\mathbb{E}_\mu[F(X)] \equiv \mu(F,p) \cdot \mathbb{E}_H[F(X)] + (1-\mu(F,p)) \cdot \mathbb{E}_L[F(X)]$ for any $(F,p) \in \mathcal{M}^i$ accepted with positive probability by the seller.

At Stage 1, buyer i decides which contracts to post in his menu. By inspection of the payoff in (4), it is immediate that buyer i will never post a menu that he expects to withdraw at Stage 2, since he can always ensure a payoff of zero by posting only the trivial contract $(0,0)$. Let $\mu_1^i(F,p)$ denote buyer i's belief at Stage 1 that the seller is an H-type if she were to accept contract $(F,p) \in \mathcal{M}^i$. Buyer i's payoff at Stage 1 is:

$$\sum_{(F,p)\in\mathcal{M}^i} \mathbb{P}\left(\text{seller accepts } (F,p)\right) \cdot \Big(-p + \mathbb{E}_{\mu_1^i}[F(X)]\Big). \tag{5}$$

[11] That there is a small cost of menu withdrawal acts as a refinement of equilibrium, as in Netzer and Scheuer (2014). Such withdrawal cost can be interpreted directly as communication/administrative cost or indirectly as the loss of reputation associated with withdrawal of contracts posted in a marketplace.

[12] A large literature has focused on the problem of dilution in financial markets, which arises when a firm is able to dilute existing claims by issuing new claims on the same set of cash flows (e.g. Parlour and Rajan (2001); Santos and Scheinkman (2001a,b); DeMarzo and He (2016); Admati, DeMarzo, Hellwig, and Pfleiderer (2018); Donaldson, Gromb, and Piacentino (2019)). Instead, we focus on asset sales by supposing that the transfer of asset cash flows in spot markets can be easily verified.

We study pure strategy perfect Bayesian Nash equilibria (PBE) of the above screening game, which has the following implications. First, the seller's acceptance strategy must be optimal, given the menus that remain active after Stage 2 (*Seller Optimality*). Second, a buyer's menu chosen at Stage 1 and his decision to withdraw at Stage 2 must be optimal given his belief at each stage (*Buyer Optimality*). Finally, a buyer's belief at Stages 1 and 2 about the seller's type who is likely to accept a contract from his menu must be consistent with other buyers' posting and withdrawal strategies, the seller's acceptance strategy and Bayes' rule (*Belief Consistency*).

Our environment features two frictions: (i) the seller is privately informed about θ, and (ii) the securities market is non-exclusive. Before proceeding to the equilibrium analysis, we consider two benchmarks in which we shut down each of these frictions in turn.

2.1 Benchmark without Asymmetric Information

We first consider the allocations that would be attained in a setting without asymmetric information; that is, if the seller's asset quality, θ, were observable to the buyers.

Proposition 1 *Suppose that buyers observe asset quality θ before posting their menus. Then, the aggregate cash flows issued by the θ-type seller are $F_\theta(X) = X$, which are priced at their full information valuation $p_\theta = \mathbb{E}_\theta[X]$.*

In the absence of asymmetric information, first-best allocations are attained, as all gains from trade between the seller and the buyers are realized. Moreover, due to competition, the seller's cash flows are priced at their expected value, conditional on the true quality of the seller's asset. As we can see, in this setting, the fact that the securities market is non-exclusive has no bite. Therefore, all our novel findings will be due to the interaction of non-exclusivity with asymmetric information.

2.2 Benchmark with Exclusive Markets

We next consider the allocations that would be attained in a setting where the securities market is exclusive; that is, if the seller were restricted to accept contracts from *at most one* menu.

Consider the following optimization program, which will be useful in characterizing equilibria of this benchmark:

$$\max_{\{(F_\theta,p_\theta)\}_\theta;\ F_\theta\in\Phi} \quad p_H + \delta \cdot \mathbb{E}_H[X - F_H] \tag{P1}$$

subject to the following constraints:

$$p_L + \delta \cdot \mathbb{E}_L[X - F_L] \geq p_H + \delta \cdot \mathbb{E}_L[X - F_H], \tag{6}$$

$$p_H + \delta \cdot \mathbb{E}_H[X - F_H] \geq p_L + \delta \cdot \mathbb{E}_H[X - F_L], \tag{7}$$

$$\mu_0 \cdot (\mathbb{E}_H[F_H] - p_H) + (1-\mu_0) \cdot (\mathbb{E}_L[F_L] - p_L) \geq 0, \tag{8}$$

$$p_L \geq \mathbb{E}_L[F_L]. \tag{9}$$

Program P1 maximizes the H-type's payoff subject to: the seller's incentive compatibility constraints (6) and (7), which implicitly assume that when allocation (F, p) is accepted, the remaining cash flows $X - F_\theta(X)$ must be retained (i.e., not transferred to buyers); the buyers' participation constraint (8), which states that buyers do not make losses in expectation; and the constraint (9), which states that the L-type receives at least her full information payoff.

The following lemma characterizes the solution to program P1.

Lemma 1 *The unique solution to P1 is as follows. There exists $\widetilde{\mu} \in (0, 1)$ such that:*

1. *If $\mu_0 \leq \widetilde{\mu}$, the solution features perfect separation: there exists $d^S \in (0, \bar{X})$ such that:*
   - *(i) $F_H(X) = \min\{d^S, X\}$ and $p_H = \mathbb{E}_H[\min\{d^S, X\}]$;*
   - *(ii) $F_L(X) = X$ and $p_L = \mathbb{E}_L[X]$.*
2. *If $\mu_0 > \widetilde{\mu}$, the solution features cross-subsidization: there exists $d^C \in (d^S, \bar{X}]$ such that:*
   - *(i) $F_H(X) = \min\{d^C, X\}$ and $p_H = E_{\mu_0}[F_H] + (1-\mu_0)(1-\delta) E_L[X - F_H] < \mathbb{E}_H[F_H]$;*
   - *(ii) $F_L(X) = X$ and $p_L = E_{\mu_0}[F_H] + [(1-\mu_0)(1-\delta) + \delta] E_L[X - F_H] > \mathbb{E}_L[X]$.*

The first part of Lemma 1 states that when the buyers' prior belief is low the solution to P1 is separating; i.e., constraint (9) binds. The seller's type is screened through two distinct contracts: (F_H, p_H), which offers to buy less cash flows, but at *high*-valuation; and (F_L, p_L), which offers to buy all cash flows, but at *low*-valuation. Because cash flow retention is more costly for the L-type seller, the security F_H is designed so that the L-type is indifferent between issuing all of her cash flows at *low*-valuation or mimicking the H-type by accepting contract (F_H, p_H). Consistent with this, debt is the optimal security design, as it relaxes the incentive

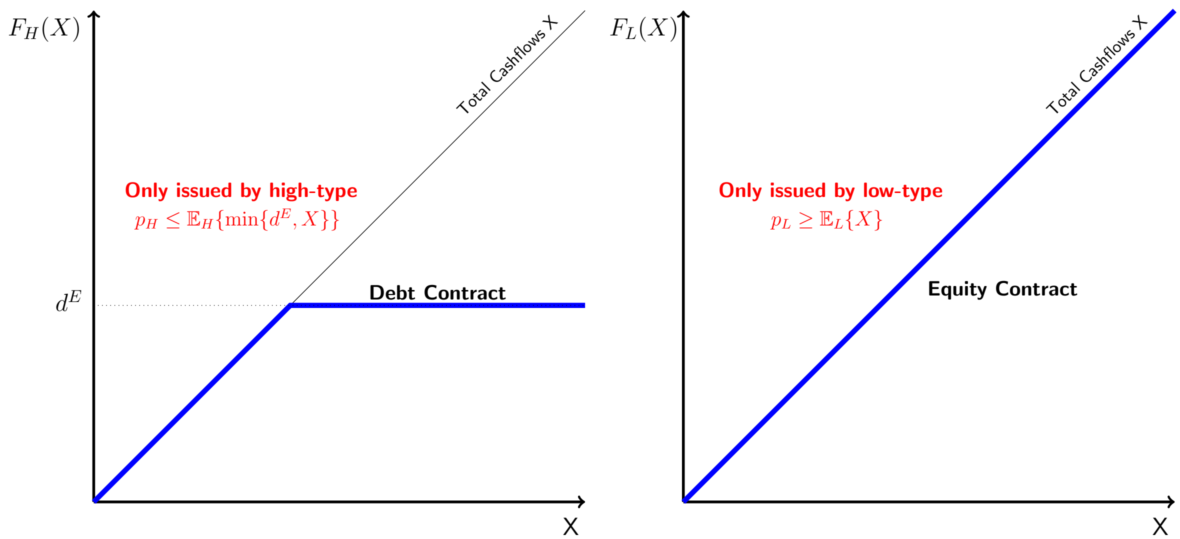

Figure 1: **Security Design in Exclusive Markets.** The left-panel depicts the security issued by the H-type seller (where $d^E \equiv \max\{d^S, d^C\}$), which is priced at or below *high*-valuation; whereas the right-panel depicts the security issued by the L-type seller, which is priced at or above *low*-valuation.

compatibility constraint of the L-type relative to other feasible securities. In particular, d^S is pinned down by requiring that the incentive compatibility constraint of the L-type binds.[13]

The second part of Lemma 1 states that when the buyers' prior belief is high the solution features cross-subsidization from the H- to the L-type seller; i.e., constraint (9) is slack. In this scenario, the H-type is better off by selling more cash flows, as $d^C > d^S$, even though this comes at the cost of receiving less than *high*-valuation for them. Debt continues to be the optimal security design, as it now minimizes the subsidy that the H-type has to give to the L-type by being the feasible security for which the difference in valuations between the types is the smallest. Furthermore, d^C is exactly chosen to optimally trade off the marginal benefit for the H-type of selling more cash flows with the marginal cost of subsidizing the L-type.

Proposition 2 (Equilibrium in Exclusive Markets) *Suppose that the seller can accept contracts from at most one menu. Then, an equilibrium always exists and it is unique.*[14] *In it, the H-type seller accepts contract (F_H, p_H), while the L-type seller accepts contract (F_L, p_L), which are given by the solution to program P1 in Lemma 1.*

The proof of Proposition 2 consists of, first, showing that any equilibrium allocation must solve program P1. As markets are exclusive, any cash flow that is not transferred to the buyer

[13] We provide the expressions defining d^S and d^C in the Appendix; see equations (20) and (21) respectively.

[14] Since there are many buyers who compete, a given buyer's equilibrium menu is not pinned down. We say that the equilibrium is unique when the allocation of the transfer at $t = 1$ and of the asset cash flows at $t = 2$ between each seller type and the buyers is uniquely pinned down.

must be retained by the seller, as stated by the incentive compatibility constraints (6)-(7).[15] With this, we show that if equilibrium allocations are such that one of the constraints in P1 is violated or if the H-type's payoff is not maximized, there is a profitable deviation for a buyer. Second, we show that the solution to program P1 can be supported as a PBE, i.e., there are no profitable deviations for the buyers nor for the seller. We depict the contracts traded in equilibrium in Figure 1.

It is worth noting that when the buyers' prior belief is low, i.e., $\mu_0 \leq \widetilde{\mu}$, the unique equilibrium is separating and its allocations coincide with those of the least-costly separating equilibrium (LCSE) typically studied in signaling games (DeMarzo, 2005; Daley et al., 2020b). On the other hand, when the buyers' prior belief is high, i.e., $\mu_0 > \widetilde{\mu}$, the unique equilibrium features some cross-subsidization from the H-to the L-type. In contrast to Rothschild and Stiglitz (1978), existence of a cross-subsidizing equilibrium in our setting is ensured by buyers' ability to withdraw loss-making menus, as was first pointed out by Wilson (1977) and Miyazaki (1977) in the context of insurance markets.

3 Equilibrium

We are now ready to characterize equilibria of our model, where the seller is able to accept contracts from multiple menus.

Consider the following optimization program, which will be useful in characterizing equilibria in non-exclusive markets:

$$\max_{\{(F_\theta,p_\theta)\}_\theta \text{ s.t. } F_\theta\in\Phi} \quad p_H + \delta \cdot \mathbb{E}_H[X - F_H] \tag{P2}$$

subject to the following constraints:

$$p_L + \mathbb{E}_L[X - F_L] \geq p_H + \mathbb{E}_L[X - F_H], \tag{10}$$

$$p_H + \delta \cdot \mathbb{E}_H[X - F_H] \geq p_L + \delta \cdot \mathbb{E}_H[X - F_L], \tag{11}$$

$$\mu_0 \cdot (\mathbb{E}_H[F_H] - p_H) + (1 - \mu_0) \cdot (\mathbb{E}_L[F_L] - p_L) \geq 0, \tag{12}$$

$$p_L \geq \mathbb{E}_L[F_L]. \tag{13}$$

Program P2 maximizes the H-type's payoff subject to the same constraints as in program P1 except for the L-type's incentive compatibility constraint (10). Now, if the L-type were to mimic

[15] We highlight this, as understanding what is the appropriate incentive compatibility constraint will prove to be essential in the study of non-exclusive markets.

the H-type seller, she would also be able to issue her remaining cash flows at *low*-valuation rather than have to retain them.

The following lemma characterizes the solution to program P2.

Lemma 2 *The unique solution to P2 is as follows. There exists $d^{NE} \in (0, \bar{X}]$ such that*

(i) $F_H(X) = \min\{d^{NE}, X\}$ *and* $p_H = \mathbb{E}_{\mu_0}[F_H(X)]$*;*

(ii) $F_L(X) = X$ *and* $p_L = \mathbb{E}_{\mu_0}[F_H(X)] + \mathbb{E}_L[X - F_H(X)]$.

By comparing Lemma 2 with Lemma 1, it follows that when the L-type is able to sell her remaining cash flows at *low*-valuation, the solution is never separating, i.e., there is always cross-subsidization from the H- to the L-type seller. Furthermore, the cross-subsidy is such that the H-type seller receives the average valuation for all the cash flows that she issues. The optimal security issued by the H-type is debt, as it is the design that maximizes the H-type's payoff by minimizing the subsidy given to the L-type among all feasible securities.

The allocations that solve P2 can be conveniently implemented through a set of non-cross-subsidizing contracts, i.e., contracts that earn zero expected profits for the buyer:

(i) A *senior tranche*, $F_S(X) = \min\{d^{NE}, X\}$, priced at average valuation, $p_S = \mathbb{E}_{\mu_0}[F_S(X)]$, and accepted by all seller types.

(ii) A *junior tranche*, $F_J(X) = \max\{X - d^{NE}, 0\}$, priced at *low*-valuation, $p_J = \mathbb{E}_L[F_J(X)]$, and accepted only by the L-type seller.

In the remainder of the paper, we use $\mathcal{C}^* \equiv \{(F_S, p_S), (F_J, p_J)\}$ to represent the set of contracts whose resulting allocations solve P2.[16]

Proposition 3 (Equilibrium in Non-Exclusive Markets) *Suppose that the seller can accept contracts from multiple menus. Then, there exists an equilibrium in which all seller types accept contract (F_S, p_S), and in addition the L-type seller accepts contract (F_J, p_J).*

Proposition 3 states that there always exists an equilibrium in which both seller types issue the same, non-trivial, debt security. In addition to accepting the same contract as the H-type, the L-type seller issues her remaining cash flows $F_J(X) = X - F_S(X)$ at *low*-valuation to a distinct buyer, in order to further exploit gains from trade. We refer to this equilibrium as the *star equilibrium*, and we depict the contracts traded in it in Figure 2.

[16]Focusing on $\mathcal{C}^*$ is without loss of generality, since the solution to program P2 is unique in terms of allocations between each seller type and the buyers.

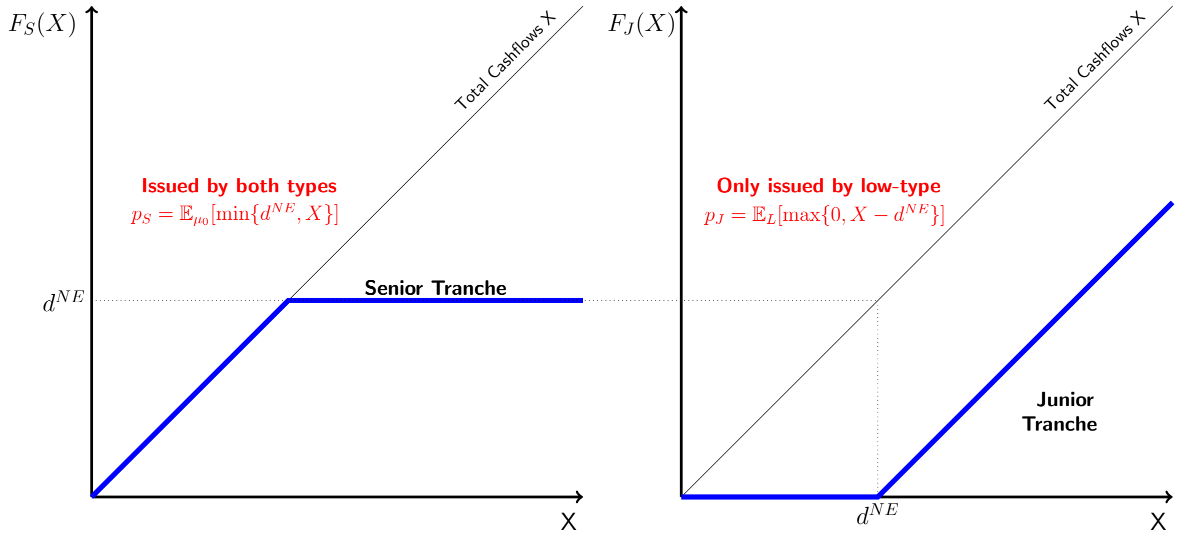

Figure 2: **Security Design in Non-Exclusive Markets.** The left-panel depicts the security issued by both seller types, which is priced at average valuation; whereas the right-panel depicts the security issued by the L-type seller only, which is priced at *low*-valuation.

The *star equilibrium* is supported by the presence of *latent contracts*, which are contracts that are offered, though not accepted, on equilibrium path and whose only role is to deter deviations by buyers at Stage 1. In what follows, we sketch the proof of Proposition 3 and show how the presence of latent contracts combined with the ability of buyers to withdraw menus at Stage 2 ensure equilibrium existence.

Consider the following candidate equilibrium strategies. At Stage 1, buyers 1 and 2 offer to purchase the senior tranche at average valuation, $\{(F_S, p_S)\}$, buyers 3 and 4 offer to purchase any claim at *low*-valuation $\{F, E_L[F]\}_{F\in\Phi}$, and the remaining buyers offer the trivial contract, $\{(0, 0)\}$. At Stage 2, there are no menu withdrawals. At Stage 3, the H-type accepts contract (F_S, p_S) from buyer 1 whereas the L-type accepts (F_S, p_S) from buyer 1 and (F_J, p_J) from buyer 3. Note that buyers 3 and 4, in addition to contract (F_J, p_J), are posting latent contracts, allowing the L-type to issue any feasible claim at *low*-valuation following a deviation.

By construction, there are no profitable deviations for any seller at Stage 3. Moreover, since in equilibrium buyers break-even and menu withdrawal is costly, there are no profitable deviations at Stage 2 either. Thus, to establish that the above strategies constitute a PBE, it suffices to rule out deviations by buyers at Stage 1.

First, consider a deviation that attracts both types from the (F_S, p_S) contract. As $\mathcal{C}^*$ maximizes the H-type's payoff subject to the incentive compatibility constraints that incorporate the presence of latent contracts and buyers not making losses (see program P2), any such deviation must be loss-making. Second, any deviation to attract the L-type alone would need to price her cash flows above *low*-valuation and must also be loss-making. Finally, consider a deviation that attracts only the H-type from contract (F_S, p_S) to some contract $(\widetilde{F}, \widetilde{p})$. As the L-type seller would still issue (F_S, p_S), buyers 1 and 2 would withdraw their menus at Stage 2, as those would now be loss-making. But then, the deviating buyer must be attracting also the L-type seller, a contradiction (e.g. the L-type can pick up contract $(\tilde{F}, \tilde{p})$, in addition to latent contract $(X - \tilde{F}(X), E_L[X - \tilde{F}(X)])$ from the buyers 3 or 4).

A natural next question is whether the *star equilibrium* is unique. To this end, in the Appendix, we show that any equilibrium in non-exclusive markets must satisfy the following properties: buyers break-even and all gains from trade between the L-type and the buyers are realized (see Lemma B.1). Hence, an equilibrium is fully characterized by the cash flows the H-type transfers to the buyers and how the buyers price them. We next show that these allocations are indeed uniquely pinned down under the additional requirement that the seller be able to issue any feasible security at (or above) *low*-valuation.

Proposition 4 *The* star equilibrium *is unique among all candidate equilibria in which the seller is able to issue any feasible security F at some price $p(F) \geq E_L[F]$.*

This result follows from the observation that, when the seller is able to issue any feasible security at (or above) *low*-valuation, then any equilibrium allocation must solve program P2, which has a unique solution $\mathcal{C}^*$ (see Lemma 2). The reason is that the incentive compatibility constraint in program P2 already takes into account that, following a deviation to mimic the H-type, the L-type seller can find a latent contract to sell her remaining cash flows at *low*-valuation rather than having to retain them. The availability of such contracts aims to capture an intuitive idea that, when markets are non-exclusive, the L-type should be able to exploit all gains from trade with the buyers, both on and off-equilibrium path. An immediate implication of Proposition 4 is that for another equilibrium to exist, buyers must be able to coordinate *not* to post a set of latent contracts that price securities at (or above) *low*-valuation. We conjecture that such equilibria do not exist, though we could not formally rule them out.[17] Moreover, equilibria that rely on such coordination seem implausible to us when thinking about real-world asset markets.

Lastly, we show that the *star equilibrium* allocations provide a lower bound on the welfare and on the extent of cross-subsidization in non-exclusive markets.

Proposition 5 *The seller's payoffs $\{u^*_\theta\}_\theta$ in the* star equilibrium *provide a lower bound on the payoffs of each seller type in any equilibrium with non-exclusive markets.*

[17] Our conjecture is that, in any other candidate equilibrium, there is a profitable deviation for a buyer that involves him posting some of the missing latent contracts and, possibly, another contract that attracts the H-type after some candidate equilibrium menus are withdrawn as a result of the deviation.

A corollary to Proposition 5 is that, in contrast to exclusive markets, non-exclusive markets must always feature cross-subsidization as $u_L^* > E_L[X]$, i.e., separation is not possible. Intuitively, any candidate equilibrium where the L-type gets her full information payoff (or anything below u_L^*) can be destroyed by a deviation where a buyer offers the L-type to sell her remaining cash flows after mimicking the issuance of the H-type. The result that non-exclusivity makes cross-subsidization a necessary feature of equilibrium is also present in Attar et al. (2011), who study the sale of divisible goods, i.e., equity contracts, in a setting related to ours. However, as noted in Attar et al. (2014), cross-subsidizing allocations may be difficult to support as PBE in the presence of non-linearities (e.g. preferences, technology). Although non-linearities are also present in our setting due to optimal security design, as we have shown, equilibrium existence is ensured by the presence of the withdrawal stage. In this sense, our equilibrium notion is close in spirit to the Miyazaki-Wilson-Spence equilibrium (Wilson, 1977; Miyazaki, 1977; Spence, 1978), where buyers are able to withdraw offers upon observing the offers available in the market.

4 Costs and Benefits of Non-Exclusivity

As we already discussed in the introduction, after the 2008-09 financial crisis, a number of exclusivity and transparency-enhancing financial market reforms were discussed in the US and Europe, which would either directly or indirectly enhance exclusivity in contracting. Despite of these efforts of policymakers and regulators, there is surprisingly little theoretical work on the policy implications of non-exclusivity in markets with asymmetric information. Motivated by this, in this section we consider the normative implications of our theory by studying the potential costs and benefits of non-exclusivity. First, we study the welfare properties of our baseline model, where the distribution of asset qualities is exogenous. Second, we consider a simple extension of the model that endogenizes asset quality.

4.1 Non-Exclusivity and Market Liquidity

We begin by introducing the notion of efficiency/welfare in our setting. Since buyers break-even in any equilibrium, efficiency is determined by the ex-ante expected payoff to the seller:

$$W(\mu_0) \equiv \mu_0 \cdot u_H(\mu_0) + (1 - \mu_0) \cdot u_L(\mu_0). \tag{14}$$

where $u_\theta(\mu_0)$ denotes the equilibrium payoff of a θ-type seller when the buyers' prior belief that the seller is H-type is μ_0.[18] In what follows, we will sometimes use superscripts to indicate the

[18] We are using the fact that the average quality of assets and the buyers' prior belief are the same.

outcomes in the first-best (FB), exclusive (E) or non-exclusive (NE) market settings. Unless specified otherwise, by an equilibrium in non-exclusive markets we refer to the *star equilibrium*.

In the presence of asymmetric information, equilibrium allocations may be distorted away from first-best for two reasons. First, due to retention of cash flows by the H-type seller, some gains from trade remain unrealized. We say that the market is more *liquid* when more gains from trade between the seller and the buyers are realized, i.e., when cash flow retention is lower. Second, because the prices of claims need not reflect true underlying asset quality θ, the H-type seller may effectively subsidize the L-type seller. When this occurs, we say that there is *mispricing*. To illustrate the effects of these distortions, the equilibrium payoff of a θ-type seller can be expressed as follows:

$$u_L(\mu_0) = \underbrace{\mathbb{E}_L[X]}_{=u_L^{FB}} \quad + \quad \underbrace{\Delta(\mu_0)}_{\text{Mispricing Subsidy}} \quad , \tag{15}$$

$$u_H(\mu_0) = \underbrace{\mathbb{E}_H[X]}_{=u_H^{FB}} - \underbrace{(1-\delta) \cdot \mathbb{E}_H[X - F_H(X)]}_{\text{Cost of Retention}} - \underbrace{\frac{1-\mu_0}{\mu_0} \cdot \Delta(\mu_0)}_{\text{Mispricing Tax}} . \tag{16}$$

where F_H denotes the cash flows issued by the H-type seller in equilibrium.

Since the mispricing of claims generates a transfer from the H-type to the L-type seller, equilibrium welfare is distorted away from first-best only due to inefficient cash flow retention:

$$W(\mu_0) = \underbrace{\mu_0 \cdot \mathbb{E}_H[X] + (1-\mu_0) \cdot \mathbb{E}_L[X]}_{=W^{FB}(\mu_0)} - \underbrace{\mu_0 \cdot (1-\delta) \cdot \mathbb{E}_H[X - F_H(X)]}_{\text{Expected Cost of Retention}} . \tag{17}$$

Thus, when asset quality is exogenous, a more liquid market is also more efficient. Hence, non-exclusive markets are more efficient than exclusive markets whenever they implement higher liquidity, i.e., when $d^{NE} > d^E$. The next proposition shows when this is the case.

Proposition 6 *There exist $0 < \underline{\mu} < \bar{\mu} < 1$, such that welfare in exclusive markets is greater than in non-exclusive markets for $\mu_0 < \underline{\mu}$, lower for $\mu_0 \in (\underline{\mu}, \bar{\mu})$, and equal for $\mu_0 \geq \bar{\mu}$.*

Figure 3 depicts the debt levels d^E and d^{NE} in exclusive and non-exclusive markets respectively as a function of μ_0. And, recall that there is a one-to-one mapping between these debt-levels and welfare. Consider the region $\mu_0 \leq \widetilde{\mu}$, where $\widetilde{\mu}$ is specified in Lemma 1. Here, d^E is pinned down by the L-type's incentive compatibility constraint (6) and, thus, it is independent of μ_0. Instead, d^{NE} starts below d^E, is continuously increasing in μ_0, and crosses d^E at some $\underline{\mu} < \widetilde{\mu}$. Consider next the region $\mu_0 > \widetilde{\mu}$. Here, d^E is also continuously increasing in μ_0, since the H-type is willing to cross-subsidize the L-type even in exclusive markets; however,

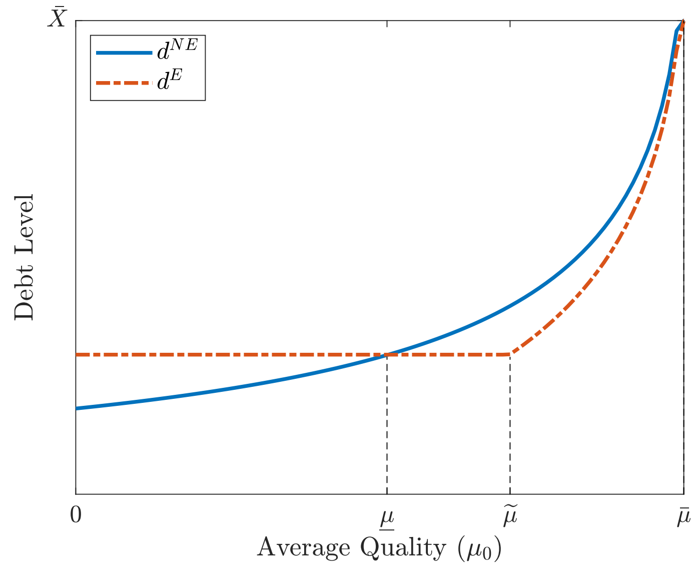

Figure 3: **Which market structure is more efficient for an exogenously given average quality μ_0?** The figure depicts the debt levels $d^E \equiv \max\{d^S, d^C\}$ and d^{NE} that arise with exclusive markets and in the star equilibrium with non-exclusive markets, as a function of μ_0.

we show that d^{NE} is always greater than d^E. Lastly, after μ_0 increases above some $\bar{\mu}$, the seller issues equity in both markets structures and, thus, the welfares coincide.[19]

These findings contrast with the by-now conventional 'ignorance is bliss' view of Dang et al. (2010) and Dang et al. (2017), according to which market liquidity and efficiency are maximized through complexity of assets and opacity of issuers' balance sheets. Our results instead suggest that to the extent that complexity/opacity inhibits exclusive contracting, it can actually reduce market liquidity and efficiency whenever the underlying asset quality is low.

4.2 Non-Exclusivity and Origination Incentives

In the previous section, we showed that non-exclusive markets may either increase or decrease market liquidity, and therefore efficiency, depending on the average quality of assets. However, due to larger cross-subsidization, non-exclusive markets always induce a larger mispricing of claims than exclusive markets. In our baseline setting, such mispricing was irrelevant for efficiency, as the distribution of asset quality was exogenous. In many applications, however, such mispricing may impact efficiency by distorting agent's decisions, e.g. distorting investment decisions. To address this, we now explore how non-exclusivity, through its effects on market liquidity and the pricing of claims, affects incentives to originate high quality assets.

[19]Note that, since the *star equilibrium* allocations provide a lower bound on welfare in non-exclusive markets (see Proposition 5), it follows that welfare in any equilibrium with non-exclusive markets must be greater than with exclusive markets when $\mu_0 \in (\underline{\mu}, \bar{\mu})$.

We consider a simple extension of our baseline setting, where we now allow the seller (who is now also an asset originator) to exert costly, unobservable effort $C(q)$ to ensure that her asset is of high quality with probability $q \in [0,1]$. For interior solution, we suppose that $C(0) = C'(0) = 0$, $C'(q) > 0$ and $C''(q) > 0$ for $q \in (0,1)$, and $\lim_{q\to 1} C'(q) = \infty$.[20] Given the buyers' prior belief μ_0, efficiency is given by the ex-ante payoff of the seller, now given by:

$$W(\mu_0) = \max_q \; q \cdot u_H(\mu_0) + (1-q) \cdot u_L(\mu_0) - C(q), \tag{18}$$

where $u_\theta(\mu_0)$ denotes the payoff of a θ-type seller in the equilibrium of the *trading stage* as defined in Section 2, for given belief μ_0. The solution q^* to problem (18) exists, is unique, and satisfies:

$$C'(q^*) = \underbrace{\mathbb{E}_H[X] - \mathbb{E}_L[X] - (1-\delta) \cdot \mathbb{E}_H[X - F_H(X)] - \frac{\Delta(\mu_0)}{\mu_0}}_{=u_H(\mu_0) - u_L(\mu_0)}. \tag{19}$$

An equilibrium of the entire game now in addition requires that (i) given the seller's payoffs $\{u_\theta(\mu_0)\}_\theta$ at the trading stage, her effort choice is optimal, i.e., solves (19); and (ii) the buyers' prior belief is consistent with the seller's optimal effort choice, i.e. $\mu_0 = q^*$. It is straightforward to show that an equilibrium exists both in exclusive and non-exclusive markets.

From equation (19), we see that both market liquidity (as captured by the cash flows sold by the H-type at the *trading stage*, F_H, which varies with μ_0) and the extent to which the claims are mispriced (as captured by $\Delta(\mu_0)$) are relevant for determining the originator's effort incentives. Moreover, even though market liquidity may be higher or lower in non-exclusive markets (see Proposition 5), the mispricing of claims is always larger in non-exclusive markets, which, as we show next, is crucial for understanding origination incentives.

Proposition 7 *The average quality of originated assets in non-exclusive markets is lower than in exclusive markets:* $0 < \mu_0^{NE} < \mu_0^{E} < \mu_0^{FB} < 1$.

Proposition 7 establishes a very strong result: non-exclusive markets always implement lower equilibrium asset quality than exclusive markets. The reason behind it is intuitive, and it is driven by fundamental differences between exclusive and non-exclusive markets. Recall that the originator's incentive to exert effort increases with the payoff gap between seller types, $u_H(\mu_0) - u_L(\mu_0)$ (see equation (19)). The proof then consists of showing that this gap is always smaller in non-exclusive markets.[21]

[20] This formulation is standard and has been employed in several papers that study the effect of secondary market liquidity on origination incentives (e.g. Chemla and Hennessy (2014); Vanasco (2017); Caramp (2017);

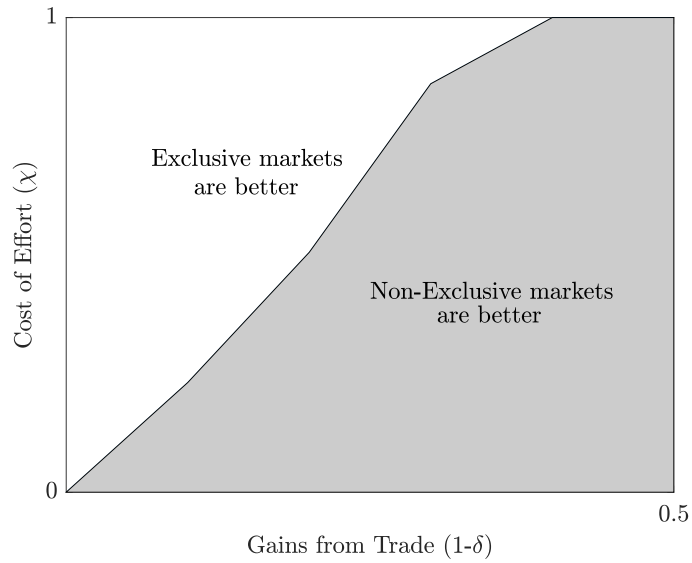

Figure 4: **Which market structure is more efficient when average quality is endogenous?** The unshaded region depicts parameter values for which welfare in the equilibrium with exclusive markets is greater than welfare in the *star equilibrium*. The shaded region depicts parameter values for which welfare in the *star equilibrium* is greater than welfare in the equilibrium with exclusive markets.

By combining the results of Propositions 6 and 7, we conclude that non-exclusive markets can only be more efficient if the potential (though not guaranteed) gains from increased market liquidity more than compensate for the (guaranteed) fall in asset quality. Figure 4 illustrates that this happens when the gains from trade (as captured by $1-\delta$) are large relative to the cost of exerting effort (as captured by χ), where we use a simple parameterization, $C(q) = \chi \cdot \frac{q^2}{1-q}$. It is important to highlight that when asset quality is endogenous, there is never an equilibrium in which all seller types sell a full claim to their cash flows: there is always retention in equilibrium.

These findings thus suggest that complexity/opacity is desirable only in environments where efficiency gains are mostly driven by reallocation of assets in markets *and* at the same time the originators need not be too incentivized to produce high-quality assets.

5 Empirical Implications

Our model has important implications for markets in which exclusivity is difficult to enforce. This is likely to be the case in markets where sellers' (e.g. firms', banks') risk exposures or trades are either not observable or hard to understand by other market participants (e.g. investors, regulators, courts). Understanding the implications of non-exclusivity is particularly relevant

Neuhann (2017); Daley, Green, and Vanasco (2020a); Fukui (2018); Asriyan, Fuchs, and Green (2019b)).

[21] We note that this result holds for any equilibrium in non-exclusive markets.

for the study of modern financial markets, where the increasing complexity of assets and balance sheets of financial intermediaries combined with the opacity of markets where these assets are traded makes it virtually impossible for outsiders to ensure that a seller retains a particular risk-exposure. In what follows, we present the novel empirical implications of our model and relate them to empirical evidence in the market for mortgage-backed securities. When doing so, we focus on the *star* equilibrium in non-exclusive markets.

Prediction 1. As exclusivity becomes harder to enforce, the practice of splitting asset cash flows into different tranches that are sold separately in markets is more likely to occur.

Indeed, in recent decades, the expansion of securitization and of the practice of tranching loan cash flows coincided with an increase in the complexity of financial intermediaries' balance sheets, whose risk-exposures became harder to understand and contract upon. As argued in a recent paper by Ashcraft et al. (2019), the complexity of collateralized debt obligations (CDOs) "enabled informed parties in the commercial mortgage-backed securitization pipeline to reduce their skin-in-the-game [retention] in a way not observable to other market participants."

Prediction 2. In non-exclusive markets, the amount of cash flows retained **should not** *predict differential pricing of securities in the market for senior tranches.*

This prediction follows from Proposition 3, which states that the senior tranche, issued by all seller types in equilibrium is priced at average valuation. As a result, whether the seller retains (H-type) or sells (L-type) her junior tranche does not affect its pricing. This result is consistent with findings in Ashcraft et al. (2019), who study cash flow retention and its relation to security performance in the conduit segment of the commercial mortgage-backed securities market.[22] They find that the fraction of initially retained cash flows sold into CDOs in the twelve months following a transaction, i.e., not observed at the time of the transaction, is not correlated with the prices of the more senior tranche.

Prediction 3. In non-exclusive markets, the amount of cash flows retained **should** *predict differential quality of the senior tranches.*

This prediction also follows from Proposition 3, which states that while the H-type seller only issues a senior tranche, and thus retains a junior tranche, the L-type seller issues both

[22] They study the retention of B-piece investors, who are buyers that perform due-diligence and re-underwrite all of the loans in a given pool, indicating there is no asymmetric information between the actual seller and the B-piece investors. Importantly, even though the size of the B-piece is disclosed to other (uninformed) buyers, how much the B-piece buyer actually retains over time is not transparent to these buyers. See Ashcraft et al. (2019) for a more detailed description of the environment and empirical strategy.

tranches to distinct buyers, and thus does not retain cash flows in equilibrium. This result is consistent with evidence in Ashcraft et al. (2019), who find that a higher fraction of initial cash flow retention sold into CDOs predicts a higher probability of default of the more senior tranches, even after controlling for all information available at issuance. To the best of our knowledge, the predictions 2 and 3 combined are not consistent with other models of security design where cash flow retention operates as a signal/screening device.

Prediction 4. As exclusivity becomes harder to enforce, the quality of originated assets declines.

This prediction is effectively a re-statement of Proposition 7. Though we are not aware of a formal test of this prediction, it is broadly consistent with the well-known stylized fact that the US credit boom of the early 2000s, fueled by securitization and financial engineering of complex assets traded in opaque markets, has been associated with falling lending standards and a decline in the quality of originated assets (e.g. Mian and Sufi (2009); Keys et al. (2010); DellAriccia et al. (2012)). This is commonly attributed to the observed decline in the originators' cash flow retention (i.e., less skin-in-the-game) that the securitization process had apparently enabled (Parlour and Plantin (2008); Chemla and Hennessy (2014); Vanasco (2017)). As we showed in Section 4, however, the manner by which secondary markets price claims is also an essential determinant of the originators' incentives, above and beyond overall cash flow retention.

6 Concluding Remarks

We revisit the classic problem of a seller who is privately informed about the quality of her asset and needs to raise funds from uninformed buyers by issuing securities backed by her asset cash flows. We depart from the traditional literature by positing that the securities market is non-exclusive; that is, the seller cannot commit to trade with only one buyer. We show that non-exclusive markets behave very differently from exclusive ones in the presence of information asymmetries: (i) separating contracts are never part of equilibrium; (ii) mispricing of claims is always larger than in exclusive markets; (iii) there is always a semi-pooling equilibrium where a senior debt security is issued by both seller types; (iv) market liquidity can be higher or lower than in exclusive markets, but (v) the average quality of originated assets is always lower. Our model's predictions are consistent with empirical evidence on issuance and pricing of mortgage-backed securities, and we use the theory to evaluate some recent reforms aimed at enhancing transparency and exclusivity in financial markets.

References

Admati, A. R., P. M. DeMarzo, M. F. Hellwig, and P. Pfleiderer (2018): "The leverage ratchet effect," *The Journal of Finance*, 73, 145–198.

Akerlof, G. (1970): "The Market for Lemons: Quality Uncertainty and the Market Mechanism," *Quaterly Journal for Economics*, 84.

Ales, L. and P. Maziero (2009): "Non-Exclusive Dynamic Contracts," *Competition, and the Limits of Insurance, kworking paper.*

——— (2016): "Non-exclusive dynamic contracts, competition, and the limits of insurance," *Journal of Economic Theory*, 166, 362–395.

Arnott, R. and J. E. Stiglitz (1991): "Moral hazard and nonmarket institutions: Dysfunctional crowding out of peer monitoring?" *The American Economic Review*, 179–190.

Ashcraft, A. B., K. Gooriah, and A. Kermani (2019): "Does skin-in-the-game affect security performance?" *Journal of Financial Economics.*

Asriyan, V., W. Fuchs, and B. Green (2017): "Information spillovers in asset markets with correlated values," *American Economic Review*, 107, 2007–40.

——— (2019a): "Aggregation and design of information in asset markets with adverse selection," *Available at SSRN 2959043.*

——— (2019b): "Liquidity sentiments," *American Economic Review*, 109, 3813–48.

Attar, A., T. Mariotti, and F. Salanié (2011): "Nonexclusive competition in the market for lemons," *Econometrica*, 79, 1869–1918.

——— (2014): "Nonexclusive competition under adverse selection," *Theoretical Economics*, 9, 1–40.

Axelson, U. (2007): "Security design with investor private information," *The journal of finance*, 62, 2587–2632.

Biais, B. and T. Mariotti (2005): "Strategic liquidity supply and security design," *Review of Economic Studies*, 72, 615–649.

Bisin, A. and P. Gottardi (1999): "Competitive equilibria with asymmetric information," *Journal of Economic Theory*, 87, 1–48.

——— (2003): "Competitive markets for non-exclusive contracts with adverse selection: The role of entry fees," *Review of Economic Dynamics*, 6, 313–338.

Caramp, N. (2017): "Sowing the seeds of financial crises: Endogenous asset creation and adverse selection," *Available at SSRN 3009977.*

Chemla, G. and C. Hennessy (2014): "Skin in the game and moral hazard," *Journal of Finance.*

Daley, B., B. Green, and V. Vanasco (2020a): "Securitization, ratings, and credit supply," *The Journal of Finance*, 75, 1037–1082.

Daley, B., B. S. Green, and V. Vanasco (2020b): "Security design with ratings," *Available at SSRN 2940791*.

Dang, T. V., G. Gorton, and B. Holmström (2010): "Financial Crises and the Optimality of Debt for Liquidity," *Working Paper*.

Dang, T. V., G. Gorton, B. Holmström, and G. Ordonez (2017): "Banks as secret keepers," *American Economic Review*, 107, 1005–29.

DellAriccia, G., D. Igan, and L. U. Laeven (2012): "Credit booms and lending standards: Evidence from the subprime mortgage market," *Journal of Money, Credit and Banking*, 44, 367–384.

DeMarzo, P. and Z. He (2016): "Leverage dynamics without commitment," Tech. rep., National Bureau of Economic Research.

DeMarzo, P. M. (2005): "The pooling and tranching of securities: A model of informed intermediation," *Review of Financial Studies*, 18, 1–35.

DeMarzo, P. M. and D. Duffie (1999): "A Liquidity-Based Model of Security Design," *Econometrica*, 67, 65–99.

Donaldson, J. R., D. Gromb, and G. Piacentino (2019): "The paradox of pledgeability," *Journal of Financial Economics*.

Fukui, M. (2018): "Asset quality cycles," *Journal of Monetary Economics*, 95, 97–108.

Gorton, G. and G. Pennacchi (1990): "Financial intermediaries and liquidity creation," *The Journal of Finance*, 45, 49–71.

Hellwig, M. F. (1988): "A note on the specification of interfirm communication in insurance markets with adverse selection," *Journal of Economic Theory*, 46, 154–163.

Jaynes, G. D. (1978): "Equilibria in monopolistically competitive insurance markets," *Journal of Economic Theory*, 19, 394–422.

Keys, B. J., T. Mukherjee, A. Seru, and V. Vikrant (2010): "Did securitization lead to lax screening? Evidence from Subprime Loans," *Quarterly Journal of Economics*.

Kurlat, P. (2016): "Asset markets with heterogeneous information," *Econometrica*, 84, 33–85.

Leland, H. E. and D. H. Pyle (1977): "Informational asymmetries, financial structure, and financial intermediation," *Journal of Finance*, 32, 371–387.

Li, Q. (2019): "Securitization and Liquidity Creation in Markets with Adverse Selection," *Available at SSRN 2932441*.

Mian, A. and A. Sufi (2009): "The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis," *The Quarterly Journal of Economics*, 124, 1449–1496.

Mimra, W. and A. Wambach (2014): "New developments in the theory of adverse selection in competitive insurance," *The Geneva Risk and Insurance Review*, 39, 136–152.

——— (2019): "Contract withdrawals and equilibrium in competitive markets with adverse selection," *Economic Theory*, 67, 875–907.

Miyazaki, H. (1977): "The rat race and internal labor markets," *The Bell Journal of Economics*, 394–418.

Nachman, D. and T. Noe (1994): "Optimal Design of Securities under Asymmetric Information," *Review of Financial Studies*, 7, 1–44.

Netzer, N. and F. Scheuer (2014): "A game theoretic foundation of competitive equilibria with adverse selection," *International Economic Review*, 55, 399–422.

Neuhann, D. (2017): "Macroeconomic effects of secondary market trading," *Available at SSRN 3095730*.

Parlour, C. A. and G. Plantin (2008): "Loan sales and relationship banking," *The Journal of Finance*, 63, 1291–1314.

Parlour, C. A. and U. Rajan (2001): "Competition in loan contracts," *American Economic Review*, 91, 1311–1328.

Pauly, M. V. (1974): "Overinsurance and Public Provision of Insurance: the Roles of Moral Hazard and Adverse Selection," *Quarterly Journal of Economics*, 88, 44–62.

Riley, J. G. (1979): "Informational Equilibrium," *Econometrica*, 47, 331–359.

Rothschild, M. and J. Stiglitz (1978): "Equilibrium in competitive insurance markets: An essay on the economics of imperfect information," in *Uncertainty in economics*, Elsevier, 257–280.

Santos, T. and J. A. Scheinkman (2001a): "Competition among exchanges," *The Quarterly Journal of Economics*, 116, 1027–1061.

——— (2001b): "Financial intermediation without exclusivity," *American Economic Review*, 91, 436–439.

Spence, M. (1978): "Product differentiation and performance in insurance markets," *Journal of Public Economics*, 10, 427–447.

Stiglitz, J. E., J. Yun, and A. Kosenko (2020): "Bilateral Information Disclosure in Adverse Selection Markets with Nonexclusive Competition," Tech. rep., National Bureau of Economic Research.

Vanasco, V. (2017): "The downside of asset screening for market liquidity," *The Journal of Finance*, 72, 1937–1982.

Wilson, C. (1977): "A model of insurance markets with incomplete information," *Journal of*

Economic theory, 16, 167–207.

A Proofs

Proof of Proposition 1. The proof is straightforward. ■

Proof of Lemma 1. We prove this result by establishing a set of intermediate lemmas. We begin by guessing that the incentive compatibility constraint (7) in program P1 is slack at the optimum and, thus, dropping it from the program. We then verify that this is indeed the case.

The first lemma shows that the L-type transfers all of her cash flows to the buyers.

Lemma A.1 $F_L(x) = x \; \forall x$.

Proof. Suppose to the contrary that the solution to P1 consists of allocations $\{(F_\theta, p_\theta)\}$ with $F_L(x) < x$ for some $x \in \left[0, \bar{X}\right]$. Consider next the allocations $\{(F'_\theta, p'_\theta)\}$ where: (i) $F'_H(x) = F_H(x) \; \forall x$ and $p'_H = p_H + \frac{1-\mu_0}{\mu_0} \cdot \varepsilon$; and (ii) $F'_L(x) = x \; \forall x$ and $p'_L = p_L + E_L[X - F_L(X)] - \varepsilon$. For $\varepsilon > 0$ sufficiently small, with the new allocations $\{(F'_\theta, p'_\theta)\}$, the constraints (6), (8), and (9) are satisfied, but the objective of the program has increased, a contradiction. ■

The second lemma shows that at the optimum the incentive compatibility constraint of the L-type, given by (6), and the buyers' participation constraint, given by (8), bind.

Lemma A.2 *The constraints* (6) *and* (8) *are satisfied with equality.*

Proof. Suppose not. If the constraint (8) were slack, then the objective of the program could be increased by raising p_H and p_L by a small amount $\varepsilon > 0$, which leaves the constraints (6) and (9) satisfied, a contradiction.

If instead the constraint (6) were slack, then there are two possibilities. If also the constraint (9) is slack, then decreasing p_L by ε and increasing p_H by $\frac{1-\mu_0}{\mu_0} \cdot \varepsilon$ increases the objective while, for $\varepsilon > 0$ sufficiently small, still satisfying the constraints (6), (8) and (9), a contradiction. On the other hand, if the constraint (9) binds and thus $p_L = E_L[X]$, it must be that $F_H(x) < x$ for some x; otherwise, since the constraint (8) binds, the constraint (6) would have to be violated. But then, replacing allocation (F_H, p_H) with (F'_H, p'_H), where $F'_H(x) = \min\{F_H(x) + \epsilon, x\} \; \forall x$ and $p'_H = E_H[F'_H(x)]$ and $\epsilon > 0$ is small, increases the objective of the program while still satisfying the constraints (6), (8) and (9), a contradiction. ■

The third lemma shows that the H-type issues a non-trivial debt security.

Lemma A.3 $F_H(x) = \min\{d, x\} \; \forall x$ *and some* $d \in (0, \bar{X}]$.

Proof. Suppose to the contrary that F_H is not a debt security, and let d' be such that $\mathbb{E}_H[F_H(X)] = \mathbb{E}_H[\min\{d', X\}]$. Since $F_H(\cdot)$ is monotonic, there exists $\widehat{x} \in [0, \bar{X}]$ such that $F_H(x) > d'$ if and only if $x > \widehat{x}$. By MLRP, it must then be that $\mathbb{E}_L[X - F_H(X)] > \mathbb{E}_L[X - \min\{d', X\}]$, since both securities have the same *high*-valuation:

$$\mathbb{E}_L[F_H(X) - \min\{d', X\}] = \mathbb{E}_H\left[(F_H(X) - \min\{d', X\}) \cdot \frac{g_L(X)}{g_H(X)}\right]$$
$$< \mathbb{E}_H[F_H(X) - \min\{d', X\}] \cdot \frac{g_L(\widehat{x})}{g_H(\widehat{x})} = 0.$$

Thus, whereas the H-type is indifferent between (F_H, p_H) and (F', p_H) with $F'(X) = \min\{d', X\}$, the L-type strictly prefers her allocation (X, p_L) to (F', p_H). Next, consider changing the allocation of the H-type to (F'', p'') with $F''(X) = \min\{d'', X\}$, $p'' = \mathbb{E}_H[F''(X)]$, and $d'' > d'$. If d'' is close to d', then the L-type still prefers to accept (X, p_L) to (F'', p''), and the H-type strictly prefers (F'', p'') to (F_H, p_H). Hence, such a change increases the objective of the program while leaving the constraints (6), (8) and (9) satisfied, a contradiction. ■

Next, we determine the optimal debt level. Define $d^C : [0,1] \to \left[0, \bar{X}\right]$ as follows:

$$d^C(\mu_0) = \arg \max_{d \in \left[0, \bar{X}\right]} E_{\mu_0}\left[\min\{d, X\}\right] - (1-\mu_0)(1-\delta) E_L\left[\min\{d, X\}\right] - \delta \cdot E_H[\min\{d, X\}]. \quad (20)$$

From Lemmas A.1-A.3, this is the debt level that solves program P1 when constraint (9) is slack. Define $d^S \in (0, \bar{X})$ as follows:

$$(1-\delta) \cdot E_L[X] = E_H\left[\min\left\{d^S, X\right\}\right] - \delta \cdot E_L\left[\min\left\{d^S, X\right\}\right]. \quad (21)$$

From Lemmas A.1-A.3, this is the debt level that solves program P1 when constraint (9) binds.

The derivative of the expression on the right-hand side of equation (20) w.r.t. d is:

$$H(d, \mu_0) = (\mu_0 - \delta) \cdot (1 - G_H(d)) + (1-\mu_0) \cdot \delta \cdot (1 - G_L(d)), \quad (22)$$

which satisfies the following properties:

(i) $H(\cdot, \cdot)$ is continuous in both arguments; $H(0,0) = H(\bar{X}, \cdot) = 0$; for $\mu_0 > 0$, $H(\cdot, \mu_0) > 0$ and it is decreasing initially.

(ii) for $\mu_0 > 0$, $H(\cdot, \mu_0)$ crosses zero at an interior d, at most once, and iff $\mu_0 < \delta \cdot \lim_{x \to \bar{X}} \frac{\frac{g_H(x)}{g_L(x)} - 1}{\frac{g_H(x)}{g_L(x)} - \delta} \equiv \bar{\mu}$.

(iii) since $H_2(\cdot, \cdot) > 0$, this interior value of d is continuously increasing in μ_0 for $\mu_0 < \bar{\mu}$, i.e., it goes to zero as $\mu_0 \downarrow 0$ and to $\bar{X}$ as $\mu_0 \uparrow \bar{\mu}$.

It follows that the solution $d^C(\mu_0)$ is unique for any μ_0, and that $d^C(0) = 0$, $d^C(\cdot)$ is continuous and increasing on $[0, \bar{\mu}]$ and $d^C(\cdot) = \bar{X}$ for $\mu_0 \geq \bar{\mu}$. On the other hand, d^S is also unique and satisfies $d^S \in (0, \bar{X})$ for any μ_0. It is then straightforward to show that the constraint (9) is slack if and only if $d^C(\mu_0) > d^S$, which is equivalent to μ_0 being greater than some $\widetilde{\mu} \in (0, \bar{\mu})$. Once the optimal debt level is found, the expressions for the prices $\{p_\theta\}$ follow directly from Lemmas A.1-A.3 and the fact that the constraint (9) is slack if and only if $\mu_0 > \widetilde{\mu}$.

Finally, the result stated in the proposition follows from Lemmas A.1-A.3 together with the following verification that the constraint (7) is always slack. The latter holds if:

$$p_H + \delta \cdot E_H\left[X - \min\left\{d^E, X\right\}\right] \geq p_L = p_H + \delta \cdot E_L\left[X - \min\left\{d^E, X\right\}\right],$$

which holds if and only if:

$$E_H\left[X - \min\left\{d^E, X\right\}\right] \geq E_L\left[X - \min\left\{d^E, X\right\}\right].$$

The last inequality follows from MLRP, as $x - \min\left\{d^E, x\right\}$ is monotonically increasing in x. ■

Proof of Proposition 2. We first show that any equilibrium must consist of allocations that solve program P1. To this end, consider an equilibrium with allocations $\{(F_\theta, p_\theta)\}$; that is, the θ-type transfers cash flows $F_\theta(x)$ to the buyers at $t = 2$ when $X = x$, and the buyers transfer p_θ to the seller at $t = 1$.

In any equilibrium, each buyer must make zero expected profits. Suppose to the contrary that the buyers' aggregate profits are positive. Suppose now that buyer i who were earning less than half of the aggregate profits were to deviate and add the contracts $\{(F_\theta, p_\theta + \varepsilon)\}$ to his menu. Clearly, the seller would pick these contracts instead of the equilibrium allocation $\{(F_\theta, p_\theta)\}$, independently of whether the other buyers withdraw their menus or not. Moreover, for ε small enough, such a deviation is profitable as buyer i effectively captures all of the aggregate expected profits, a contradiction.

It is clear that the assumption that equilibrium allocations satisfy the incentive compatibility constraints (6) and (7) is without loss of generality.

It must also be that in any equilibrium $p_L \geq E_L[X]$. Suppose to the contrary that $p_L < E_L[X]$, and consider a buyer who were to deviate and add the following contract to his menu: (F', p') with $F'(X) = X$ and $p' = E_L[X] - \varepsilon$. For ε small, the low-type prefers this contract to his equilibrium allocation and, thus, would pick it up. Moreover, this contract makes strictly positive profits even if it is also picked up by the H-type. Thus, independently of whether other buyers withdraw their menus or not, such a deviation is profitable; a contradiction.

Lastly, the equilibrium allocations must also maximize H-type's payoff. Suppose to the contrary, and let $\left\{\left(F_\theta^{P1}, p_\theta^{P1}\right)\right\}$ denote the unique solution to program P1, which note cannot be offered in the candidate equilibrium. Suppose that the candidate allocations are picked up from buyers i (and possibly j), and consider a deviation by buyer $k \neq i, j$ to post a menu that consists of the contracts $\left\{\left(F_\theta^{P1}, p_\theta^{P1} - \varepsilon\right)\right\}$. For $\varepsilon > 0$ small enough, such a deviation attracts the H-type seller to contract $\left(F_H^{P1}, p_H^{P1} - \varepsilon\right)$, and the deviation is profitable whether or not the L-type is attracted to the contract $\left(F_L^{P1}, p_L^{P1} - \varepsilon\right)$, a contradiction.

We next show that an equilibrium exists when the cost of withdrawal κ is small enough. That equilibrium allocations are unique (in terms of allocations between each seller type and the buyers) will follow from the uniqueness of the solution to P1.

Consider the following candidate equilibrium strategies. At Stage 1, buyers 1 and 2 offer the contracts $\left\{\left(F_\theta^{P1}, p_\theta^{P1}\right)\right\}$, whereas the remaining buyers post the trivial contract. At Stage 2, there are no menu withdrawals. At Stage 3, the H-type accepts contract (F_H, p_H) and the L-type accepts contract (F_L, p_L) from buyer 3 (or both from buyer 4).

By construction, there are no deviations for the seller at Stage 3. Also, since in the candidate equilibrium buyers break even, there are also no deviations at Stage 3 as $\kappa > 0$. We are therefore left to rule out deviations at Stage 1. There are three types of deviations to consider.

(i) Consider a deviation that attracts only the L-type. Such a deviation clearly cannot be profitable as it would need to offer the L-type a price $p_L > E_L[X]$.

(ii) Consider a deviation that attracts both types. Let $\{(F_\theta, p_\theta)\}$ denote the allocations of the seller when she accepts a contract from the deviating menu. For it to be profitable, $\{(F_\theta, p_\theta)\}$ must satisfy the constraints of P1. Additionally, in order to attract the H-type, the deviating buyer would need to offer her a higher payoff than the solution to P1, which is not possible.

(iii) Consider a deviation that attracts only the H-type. There are two cases to consider. Case (1). Suppose that $\mu_0 \leq \widetilde{\mu}$, so that the solution to P1 is separating, i.e., $p_L^{P1} = E_L\{X\}$. A deviation that attracts only the H-type to some contract $\{(F_H, p_H)\}$ would have to satisfy the constraints:

$$p_H + \delta \cdot E_H\{X - F_H\} \geq E_L\{X\},$$
$$E_L\{X\} \geq p_H + \delta E_L\{X - F_H\},$$
$$p_H \leq E_H\{F_H\},$$

as, after the deviation, the equilibrium menus do not make losses and are therefore not withdrawn at Stage 2. But note that these are exactly the constraints in program P1. Therefore, it is impossible that such a deviation yields the H-type a higher payoff than the equilibrium allocation, a contradiction.

Case (2). Suppose that $\mu_0 > \widetilde{\mu}$, so that at the solution to P1 involves cross-subsidization, i.e., $p_L^{P1} > E_L\{X\}$. Consider a deviation by a buyer to attract the H-type to an allocation (F_H, p_H). If κ is small enough (i.e., $\kappa < (1-\mu_0) \cdot \left(p_L^{P1} - E_L\{X\}\right)$), buyers 1 and 2 will withdraw their menus at Stage 2 as these are now loss-making. But then, the L-type must also be picking a non-trivial contract from the deviating menu, a contradiction. ■

Proof of Lemma 2. We prove this result by establishing a set of intermediate lemmas. We begin by guessing that the incentive compatibility constraint (11) in program P2 is slack at the optimum and, thus, dropping it from the program. We then verify that this is indeed the case.

The first lemma shows that it is without loss to assume that the L-type transfers all of her cash flows to the buyers.

Lemma A.4 *It is without loss of generality to set* $F_L(x) = x \ \forall x$.

Proof. Suppose that at a solution to program (P2), (F_L, p_L) is such that $F_L(x) < x$ for some x. Consider changing the L-type's allocation to (F', p') with $F'(x) = x$ for all x and $p' = p_L + E_L[X - F_L(X)]$. Observe that the H-type's payoff is unaffected, and the remaining constraints are still satisfied. ■

The second lemma shows that at the optimum the incentive compatibility constraint of the L-type, given by (10), and the buyers' participation constraint, given by (12), bind. However, constraint (13) is slack.

Lemma A.5 *The constraints* (10) *and* (12) *are satisfied with equality, whereas the constraint* (13) *is slack.*

Proof. Suppose not. If the constraint (12) were slack, then the objective of the program could be increased by raising p_H and p_L by a small amount $\varepsilon > 0$, which leaves the constraints (10) and (13) satisfied, a contradiction.

If instead the constraint (10) were slack, then there are two possibilities. If also the constraint (13) is slack, then decreasing p_L by ε and increasing p_H by $\frac{1-\mu_0}{\mu_0} \cdot \varepsilon$ increases the objective while, for $\varepsilon > 0$ sufficiently small, still satisfying the constraints (10), (12) and (13), a contradiction. On the other hand, if the constraint (13) binds and thus $p_L = E_L[X]$, it must be that $F_H(x) = 0$ for all x; otherwise, since the constraint (12) binds, the constraint (10) would have to be violated. But then, the constraint (10) is satisfied with equality as both sides are equal to $E_L[X]$, a contradiction.

Finally, suppose that the constraint (13) is satisfied with equality. From the constraints (10) and (12), it must be that $p_H = E_H[F_H]$ and therefore $F_H(x) = 0$ for all x, which yields an expected payoff $\delta \cdot E_H[X]$ to the H-type. But then, it is straightforward to show that the allocations proposed in the statement of Lemma 2 both raise the objective of the program and satisfy the constraints (10)-(13), a contradiction. ■

The third lemma shows that the H-type issues a non-trivial debt security.

Lemma A.6 *$F_H(x) = \min\{d, x\}$ $\forall x$ and some $d \in (0, \bar{X}]$.*

Proof. Suppose to the contrary that F_H is not a debt security, and let d' be such that $\mathbb{E}_H[F_H(X)] = \mathbb{E}_H[\min\{d', X\}]$. Since $F_H(\cdot)$ is monotonic, there exists $\widehat{x} \in [0, \bar{X}]$ such that $F_H(x) > d'$ if and only if $x > \widehat{x}$. By MLRP, it must then be that $\mathbb{E}_L[X - F_H(X)] > \mathbb{E}_L[X - \min\{d', X\}]$, since both securities have the same *high*-valuation:

$$\begin{aligned}\mathbb{E}_L[F_H(X) - \min\{d', X\}] &= \mathbb{E}_H\left[(F_H(X) - \min\{d', X\}) \cdot \frac{g_L(X)}{g_H(X)}\right] \\ &< \mathbb{E}_H[F_H(X) - \min\{d', X\}] \cdot \frac{g_L(\widehat{x})}{g_H(\widehat{x})} = 0.\end{aligned}$$

Thus, whereas the H-type is indifferent between (F_H, p_H) and (F', p_H) with $F'(X) = \min\{d', X\}$, the L-type strictly prefers her allocation (X, p_L) to (F', p_H). Next, consider changing the allocation of the H-type to (F'', p'') with $F''(X) = \min\{d'', X\}$, $p'' = \mathbb{E}_H[F''(X)]$, and $d'' > d'$. If d'' is close to d', then the L-type still prefers to accept (X, p_L) to (F'', p''), and the H-type strictly prefers (F'', p'') to (F_H, p_H). Hence, such a change increases the objective of the program while leaving the constraints (6), (8) and (9) satisfied, a contradiction. ■

Next, we determine the optimal debt level. Define $d^{NE} : [0, 1] \to \left[0, \bar{X}\right]$ as follows:

$$d^{NE}(\mu_0) = \arg \max_{d \in \left[0, \bar{X}\right]} E_{\mu_0}[\min\{d, X\}] - \delta \cdot E_H[\min\{d, X\}]. \tag{23}$$

From Lemmas A.4-A.6, this is the debt level that solves program P2. The derivative of the expression on the right-hand side of equation (23) w.r.t. d is:

$$\widehat{H}(d, \mu_0) = (\mu_0 - \delta) \cdot (1 - G_H(d)) + (1 - \mu_0) \cdot (1 - G_L(d)). \tag{24}$$

Note the similarity between equations (24) and (22), where the only difference is that the last term does not have a δ multiplying it. Therefore, by arguments similar to those in the proof of Lemma 1, it follows that $d^{NE}(\mu_0)$ is continuously increasing in μ_0 until it reaches $\bar{X}$ at $\widehat{\mu} = \lim_{x \to \bar{X}} \frac{\delta \cdot \frac{g_H(x)}{g_L(x)} - 1}{\frac{g_H(x)}{g_L(x)} - 1}$, which note is strictly greater than $\bar{\mu}$, which was defined in the proof of Lemma 1. Moreover, by inspection of equation (24), $d^{NE}(\mu_0) > d^C(\mu_0)$ for any $\mu_0 < \bar{\mu}$.

Finally, the result stated in the proposition follows from Lemmas A.4-A.6 together with the following verification that the constraint (11) is always slack. The latter holds if:

$$p_H + \delta \cdot E_H\left[X - \min\left\{d^{NE}, X\right\}\right] \geq p_L = p_H + E_L\left[X - \min\left\{d^{NE}, X\right\}\right],$$

which holds if and only if:

$$\delta \cdot E_H \left[X - \min\left\{d^{NE}, X\right\}\right] \geq E_L \left[X - \min\left\{d^{NE}, X\right\}\right].$$

But the last inequality follows by the observation that, if it were violated, then it would be possible to increase the payoff to the H-type by simply increasing the debt level above d^{NE}, contradicting the optimality of the security $F_H(X) = \min\{d^{NE}, X\}$. ■

Proof of Proposition 3. Consider the following candidate equilibrium strategies. At Stage 1, buyers 1 and 2 post contract (F_S, p_S), buyers 3 and 4 offer to purchase any feasible security at *low*-valuation $\{F, E_L[F]\}_{F\in\Phi}$, while the remaining buyers offer the trivial contract, $\{(0,0)\}$. At Stage 2, there are no menu withdrawals. At Stage 3, the H-type accepts contract (F_S, p_S) from buyer 1 whereas the L-type accepts (F_S, p_S) from buyer 1 and (F_J, p_J) from buyer 3.

By construction, there are no profitable deviations for the seller at Stage 3. Also, since in the candidate equilibrium buyers break even, there are also no deviations at Stage 3 as $\kappa > 0$. We are therefore left to rule out deviations at Stage 1.

(i) Consider a deviation that attracts only the L-type. Such a deviation clearly cannot be profitable as it would need to price L-type's cash flows above *low*-valuation.

(ii) Consider a deviation that attracts only the H-type, so that she no longer accepts contract (F_S, p_S). Then the menu of any buyer who posted contract (F_S, p_S) at Stage 1 would only attract the L-type and make losses equal to $(1 - \mu_0) \cdot (E_{\mu_0}[F_S] - E_L[F_S])$; thus, if κ is small, such a menu would be withdrawn at Stage 2. But then, the deviating buyer would also attract the L-type, who would be strictly better off by picking up a contract from the deviating menu and selling the remaining cash flows by accepting a latent contract from other buyers.

(iii) Consider a deviation that attracts both types, so that they no longer accept contract (F_S, p_S). Note that the allocations of such a deviation must satisfy the constraints (10), (11) and (13) of program P2, since the L-type has access to the menus of buyers 3 or 4, which would not be withdrawn at Stage 2. But then, such a deviation cannot at the same time attract the H-type and be profitable for the buyers.

(iv) Lastly, consider a deviation that attracts the H-type, so that she still continues to accept contract (F_S, p_S). Such a deviation cannot only attract the H-type, since the L-type could obtain a higher payoff by simply mimicking the H-type and issuing any residual cash flows using latent contracts. Thus, suppose that the deviation attracts both types, and let $\{(F_\theta, p_\theta)\}$ be the contracts of the deviating buyer. But then again such contracts must satisfy the constraints (10), (11) and (13) of program P2, which therefore cannot attract the H-type and be profitable at the same time. ■

Proof of Proposition 4. Let $F_\theta(x)$ denote the aggregate cash flows that the θ-type seller transfers to buyers in state $X = x$; and let p_θ denote the aggregate transfer that she receives from the buyers. By Lemma B.1, we have that $F_L(x) = x$ for all x and:

$$\mu_0 \cdot (E_H F_H - p_H) + (1 - \mu_0) \cdot (E_L X - p_L) = 0. \tag{25}$$

Thus, to demonstrate that the allocations between each seller type and the buyers are unique, it suffices to show that $F_H = F_S$ and $p_H = p_S$. To this end, observe that the fact that the

L-type is able to issue any feasible security at weakly above *low*-valuation implies that:

$$\begin{aligned} & p_L \geq p_H + E_L[X - F_H] \\ & \iff \\ & p_H \leq E_{\mu_0}[F_H], \end{aligned}$$

where we used equation (25). But then, it must be that:

$$\begin{aligned} u_H &= p_H + \delta \cdot E_H[X - F_H] \\ &\leq E_{\mu_0} F_H + \delta \cdot E_H[X - F_H] \\ &\leq u_H^*, \end{aligned}$$

where the last inequality holds since $F_S = \arg\max_{F \in \Phi} E_{\mu_0} F + \delta \cdot E_H[X - F]$. But then, it must be that $u_H < u_H^*$ if either $p_H \neq p_S$ or $F_H \neq F_S$. But, since $u_H \geq u_H^*$ in any equilibrium (see Lemma B.2), it follows that $F_H = F_S$ and $p_H = p_S$. ■

Proof of Proposition 5. This result follows from Lemmas B.2 and B.3. ■

Proof of Proposition 6. Under both exclusive and non-exclusive market structures, the buyers break even. So the entire trading surplus accrues to the seller.

Given buyers prior belief μ_0, when markets are non-exclusive, the expected trading surplus (i.e., the expected welfare of the seller) is given by:

$$W^{NE}(\mu_0) \equiv \mathbb{E}_{\mu_0}[X] - \mu_0 \cdot (1 - \delta) \cdot \mathbb{E}_H[X - \min\left\{d^{NE}(\mu_0), X\right\}], \tag{26}$$

whereas the expected trading surplus with exclusive markets is given by:

$$W^{E}(\mu_0) \equiv \mathbb{E}_{\mu_0}[X] - \mu_0 \cdot (1 - \delta) \cdot \mathbb{E}_H[X - \min\left\{\max\{d^S, d^C(\mu_0)\}, X\right\}]. \tag{27}$$

Hence, we have that:

$$W^{NE}(\mu_0) - W^{E}(\mu_0) = \mu_0 \cdot (1 - \delta) \cdot \mathbb{E}_H[\min\{d^{NE}(\mu_0), X\} - \min\left\{\max\{d^S, d^C(\mu_0)\}, X\right\}]. \tag{28}$$

The result then follows from the following three observations:

(i) $d^{NE}(\mu_0) < d^S$ for μ_0 sufficiently small. This is because by revealed preference in non-exclusive markets the H-type is willing to issue the security $\min\{d^{NE}(0), X\}$ at low valuation. However, in exclusive markets, the H-type strictly prefers not to issue any additional cash flows (i.e., more than $d^E = d^S$) at low valuation (otherwise, in equilibrium she would had done so), i.e., $d^S > d^{NE}(0)$. By continuity of $d^{NE}(\cdot)$ (see proof of Proposition 3), this must also be the case for μ_0 small enough.

(ii) $d^{NE}(\mu_0)$ is continuously increasing and crosses d^S at some $\underline{\mu} < \widetilde{\mu}$, i.e., when $d^E = d^S$. See the proof of of Lemma 2.

(iii) $d^{NE}(\mu_0) > d^C(\mu_0)$ for all $\mu_0 < \bar{\mu}$, where $\bar{\mu}$ is such that $d^{NE}(\mu_0) = \bar{X}$. See the proof of Lemma 2. ■

Proof of Proposition 7. Recall that the L-type's payoff u_L^{NE} in non-exclusive markets is bounded below by her payoff u_L^* in the *star equilibrium* (Proposition 5), which is strictly greater than her payoff u_L^E in exclusive markets as long as $\mu_0 < \bar{\mu}$ (the only possibility when the asset quality is endogenous). It is therefore sufficient to show that the H-type's payoff u_H^{NE} in non-exclusive markets is weakly lower than her payoff u_H^E in exclusive markets, and thus $u_H^E - u_L^E > u_H^{NE} - u_L^{NE}$. But, the latter follows from the observation that, whereas u_H^E is the maximum of program P1, any equilibrium allocation in non-exclusive markets must satisfy the constraints (6) and (8) with $F_L(x) = x$ for all x (Lemma B.1) and $p_L \geq u_L^*$; that is, the L-type's participation constraint (9) is tightened. ■

B Complementary Lemmas

Lemma B.1 *In any equilibrium, each buyer earns zero expected profits, and the L-type seller transfers all of her cash flows to the buyers.*

Proof. Let $F_\theta(x)$ denote the aggregate cash flows that the θ-type seller transfers to buyers in state $X = x$; and let p_θ denote the aggregate transfer that she receives from the buyers.

Suppose to the contrary that the buyers' aggregate profits are positive (not that a buyer cannot earn negative profits, as she can always earn zero by posting only the trivial contract). Suppose now that buyer i who were earning less than half of the aggregate profits were to deviate and add the contracts $\{(F_\theta, p_\theta + \varepsilon)\}$ to his menu. Clearly, the seller would pick these contracts instead of her equilibrium allocation $\{(F_\theta, p_\theta)\}$, independently of whether the other buyers withdraw their menus or not. Moreover, for ε small enough, such a deviation is profitable as buyer i effectively captures all of the aggregate expected profits, a contradiction.

Suppose to the contrary that there exists an equilibrium in which $F_L(x) < x$ for some x. Consider a deviation by a buyer to add to his menu the contracts $(F_H, p_H + \varepsilon)$ and (F, p) with $F(x) = x$ for all x and $p = p_L + E_L[X - F_L(X)] - \frac{\mu_0}{1-\mu_0} \cdot 2 \cdot \varepsilon$. For ε small, the deviation attracts both types: the L-type to (F, p) and the H-type to either $(F_H, p_H + \varepsilon)$ or (F, p). But, the deviation is clearly profitable in either case, a contradiction. ■

Lemma B.2 *In any equilibrium, the H-type's payoff, u_H, is bounded below by her payoff in the* star equilibrium*, u_H^*.*

Proof. Suppose to the contrary that there is an equilibrium in which u_H is strictly below u_H^*. By Lemma B.1, buyers must break even in this equilibrium. But then, consider a deviation for a buyer to replace all his contracts with the contract $(F_S, p_S - \varepsilon)$. For ε small enough, this contract would attract the H-type (independently of whether other buyers withdraw at Stage 2) and possibly the L-type. As a result the deviation would be profitable, a contradiction. ■

Lemma B.3 *In any equilibrium, the L-type's payoff, u_L, is bounded below by her payoff in the* star equilibrium*, u_L^*.*

Proof. Suppose to the contrary that there is an equilibrium in which u_L is strictly below u_L^*.

Consider a deviation by a buyer to withdraw his equilibrium menu and instead post essentially the full set of latent contracts, i.e., $\{(F, E_L[F] - \varepsilon\}$ for some $\varepsilon > 0$ small. If any of these contracts attract the seller (of any type), the deviation is clearly profitable. Thus, assume that the seller is not attracted to the menu of the deviating buyer.

Let (F_θ, p_θ) denote the allocation of the θ-type seller after the deviation, i.e., the aggregate cash flows she transfers to buyers at $t = 2$ and the aggregate transfer she receives from buyers at $t = 1$. Moreover, note that these allocations must have been available in equilibrium and, thus, the L-type's payoff after the deviation cannot exceed u_L^*, i.e.,

$$p_L + \delta \cdot E_L[X - F_L] < u_L^*.$$

If (F_θ, p_θ) was the equilibrium allocation, then for ε small enough it must also be that

$$p_H + \delta \cdot E_H[X - F_H] < u_H^*,$$

because the allocation $\{(F_\theta, p_\theta)\}$ must satisfy all of the constraints of program P2 (as all latent contracts are now available to the seller) and because the L-type's payoff is strictly below u_L^*. Conversely, if (F_θ, p_θ) is not the equilibrium allocation (e.g. some buyer withdraws his menu after the deviation), then it must be that the H-type's payoff is below u_H^*, i.e., $p_H + \delta \cdot E_H[X - F_H] < u_H^*$, as these allocations were available to the seller in equilibrium. But then, it is straightforward to show that the buyer could add the contracts $(\min\{d, X\}, E_{\mu_0}[\min\{d, X\}] - \varepsilon)$ and $(X, E_{\mu_0}[\min\{d, X\}] + E_L[X - \min\{d, X\}] - \varepsilon)$ to his deviating menu, which for some $d \in (0, d^{NE}]$ and $\varepsilon > 0$ small attracts the H-type to the former and the L-type to the latter contract, rendering the deviation profitable. ■

C Feasibility conditions in anonymous markets

A central friction that we consider throughout our analysis is that of market non-exclusivity. A way to view non-exclusivity is that it captures a form of market anonymity or opacity, whereby agents cannot observe (and therefore contract upon) all the trades that their counterparties enter into. The reader may wonder, however, whether the feasibility conditions (LL) and (WM), which we have exogenously imposed on the seller's strategy, are consistent with that view of the world. In what follows, we describe such an environment, which has two key features.

Limited commitment. Suppose that neither the seller nor the buyers have the commitment to deliver goods to their contracting counterparties at $t = 2$, i.e., upon learning X, an agent can always default and walk away with all the goods he or she has. This immediately implies that any credible contract between the seller and a buyer must take the form of a spot trade at $t = 1$, consisting of a transfer of assets in exchange for a payment (price).

Financial innovation. We have assumed that the seller is endowed with an asset at $t = 1$ that delivers risky cash flows X at $t = 2$. Suppose that, due to financial innovation, the seller is able to split the asset's cash flows into separate assets that can be individually traded in spot markets. In particular, the seller has one unit of each of the following so-called basis assets, indexed by $a \in [0, \bar{X}]$, with payoffs:

$$a(x) = \begin{cases} 0 & \text{if } x < a \\ 1 & \text{if } x \geq a \end{cases}. \tag{29}$$

Thus, $X = \int_0^{\bar{X}} a(X) \cdot da$.

In this context, security design simply means that the seller can choose which bundle of assets to sell to the buyers in the spot market: $F(X) = \int_0^{\bar{X}} g_F(a) \cdot a(X) \cdot da$ where $g_F(\cdot) \in [0, 1]$ determines the amount of each basis asset sold in the bundle.[23] Observe that the feasibility conditions hold naturally in this setting:

- (LL) If the seller transfers a bundle of basis assets to a buyer, she cannot transfer the cash flows of these assets to another buyer since she no longer has them.
- (WM) If the seller sells a collection of securities $\mathcal{F} = \{F\}$ to the buyers, then by construction $x - \sum_{F \in \mathcal{F}} F(x)$ and, for each F, $F(x)$ are weakly increasing in x.

Finally, non-exclusivity is equivalent to a notion of market anonymity or opacity: each buyer observes the bundle of basis assets that the seller transfers to him, but she cannot observe the assets or prices at which the seller trades with other buyers.

[23] See also Axelson (2007) for such a representation of monotone securities.