Review of Economic Studies (2009) **76**, 395–412
0034-6527/09/00140395$02.00

Learning by Holding and Liquidity

GUILLAUME PLANTIN
London Business School

First version received September 2004*; final version accepted January* 2008 (*Eds.*)

A number of assets do not trade publicly but are sold to a restricted group of investors who subsequently receive private information from the issuers. Thus, the holders of such privately placed assets learn more quickly about their assets than other agents. This paper studies the pricing implications of this "learning by holding". In an economy in which investors are price takers and risk-neutral, and absent any insider trading or other transaction costs, we show that risky assets command an excess expected return over safe assets in the presence of learning by holding. This is reminiscent of the "credit spread puzzle"—the large spread between BBB-rated and AAA-rated corporate bonds that is not explained by historical defaults, risk aversion, or trading frictions. The intuition is that the seller of a risky bond needs to offer a "coordination premium" that helps potential buyers overcome their fear of future illiquidity. Absent this premium, this fear could become self-justified in the presence of learning by holding because a future lemons problem deters current market participation, and this in turn vindicates the fear of a future lemons problem.

1. INTRODUCTION

A number of securities, such as securitized pools of loans, are not traded publicly but are sold to institutional investors who from then on receive from the issuer information that is not publicly available. Thus, investors in such privately placed securities buy a bundle comprised of not only a claim to future cash flows but also a flow of future privileged information about these cash flows. This paper studies the liquidity of such securities. More precisely, the paper examines the pricing implications of "learning by holding", which is the fact that the holders of an asset learn more quickly about it than other investors.

The paper develops a model in which an issuer seeks to sell long-term securities to competitive potential investors who value liquidity because they incur private liquidity shocks. If the investors have the ability to re-trade with each other to meet their future liquidity needs and if their private liquidity shocks are diversifiable, then the securities should be perfectly liquid. Diversifiable liquidity risks are not priced because investors acknowledge that all the gains from trade between agents with different future liquidity needs will be realized. Thus, they do not require compensation for buying long-term cash flows absent aggregate liquidity risk. The additional feature that the securities will distribute proprietary information to their holders in the future suffices to give rise to self-fulfilling illiquidity in this set-up. Because of this learning by holding, a small participation in the primary market may subsequently create a lemons problem. Reciprocally, the fear of a future lemons problem deters participation in the primary market. Thus, current and future illiquidity reinforce each other, so much so that the fear of future illiquidity is self-justified and can lead to a current liquidity dry-up even with an arbitrarily large pool of potential investors.

Adapting global games techniques to this set-up, I derive a unique issuance price in which idiosyncratic liquidity risk is partially priced. Because of coordination risk, sufficiently risky securities are offered at a discount over safer securities. This "coordination premium" fosters coordination by making potential investors more optimistic about market thickness. Investors believe that other investors believe that the deal is attractive, and so on at higher orders, and all investors are therefore confident that they participate in a thick, liquid market.

In sum, I develop a model in which investors are risk-neutral and price takers, and in which there are neither transaction costs nor trade between heterogeneously informed agents. Yet, I predict that sufficiently risky securities command a higher expected return than less risky securities and that this excess return is a highly non-linear function of risk. This result offers a theoretical explanation for the so-called "credit spread puzzle"—the fact that there is a large differential spread between corporate bonds with fairly similar credit risks. For instance, Amato and Remolona (2003) reported that over the 1997–2003 period, investors required an excess spread of more than 100 basis points for holding a 5-year bond with an expected credit loss of 20 basis points (a BBB-rated bond) over holding a 5-year bond with an expected credit loss around 1 basis point (AAA-rated or AA-rated bonds). As detailed in the body of the paper, most studies conclude that this spread cannot be explained by credit risk, risk aversion, taxes, or other transaction costs. In light of this "puzzle", I show that learning by holding suffices in theory to generate an excess expected return on risky bonds over safer bonds *absent any of the aforementioned frictions*.

Learning by holding is particularly relevant for privately placed debt. A private placement is a private sale of securities to a selected group of sophisticated investors without general investor solicitation. Not only privately held firms but also public corporations have wide recourse to private placements.[1] Also, investment banks commonly place their structured products such as collateralized debt obligations (CDOs) privately. Lenders in private placements are institutional investors who typically review their portfolio on a quarterly basis, using non-public information provided by the issuers.[2] In securities law, private investors are therefore considered to be insiders and prohibited from using this non-public information to trade public securities. That private investors almost by definition "learn by holding" is not merely a theoretical risk. This is evident in the growing concern among practitioners that hedge funds might misuse the non-public information they glean from small stakes in private placements made by public firms.[3] Also, evidence provided in Acharya and Johnson (2007) suggests that the assumption that financing relationships generate inside information may even apply to companies with publicly traded stock. They find that insider trading in the credit derivatives market around credit events is more pronounced for such companies when, *ceteris paribus*, they have a larger number of banking relationships.

Interestingly, the broad intuition that the fear of future adverse selection generates thick market externalities crops up in the practitioners' literature. In their popular textbook on CDOs, Lucas, Goodman and Fabozzi (2006) explain the fact that secondary markets for CDOs are relatively illiquid with what they refer to as their "safety in numbers theory". As they put it:

> Some primary CDO buyers will not consider the secondary market because they feel safer buying into the initial distribution of a CDO, when a number of other investors are also making the same decision. Other primary-only investors feel uneasy about buying something another investor is selling.

In addition, Lucas *et al.* claim that better dissemination of information by CDO arrangers is a crucial factor in the improvement in CDOs' liquidity.

Many observers argue that opacity and lack of public information about market participation were responsible for the sudden and dramatic evaporation of liquidity in securitization markets in August 2007. For instance, *The Economist* wrote in its edition of 20 September, 2007:

1. In a comprehensive set of 13,000 debt and equity issues by public U.S. corporations during the 1995–2003 period studied by Gomes and Phillips (2005), more than half of the transactions are private.

2. In the case of CDOs, this proprietary information would typically feature detailed information about the pool of borrowers, for instance about the evolution of the number of delinquencies.

3. See, for example "The New Insider Trading? Concerns Mount that Private Information Furnished to Lenders is Seeping into Trading", *Investment Dealers' Digest*, 13 June, 2005, or "More Heat on Hedge Funds", *Business Week*, 6 February, 2006.

> What should banks and regulators do about all this? In the short run, the focus will be on transparency. Investors need to know who is holding what . . . .

As discussed in more detail in Section 5.3, my theory of illiquidity also implies that committing to release public information about CDO market thickness is an appropriate response to such liquidity dry-ups.

To the best of our knowledge, this paper is the first to study the liquidity implications of this learning by holding assumption. That the liquidity of financial assets can be self-fulfilling may stem from a number of other frictions. For instance, in Allen and Gale (1994) and Pagano (1989), the prices at which trades are executed are more sensitive to quantities if participation in the stock market is limited. This potential sensitivity deters investors from participating in the stock market for hedging purposes. In the presence of exogenous costs of participating in the market, low participation and a high price impact reinforce each other, leading to multiple—liquid or illiquid—equilibria. In a set-up with insider trading, Dow (2004) establishes that hedging activity may have multiple equilibrium levels. A key distinction between these contributions and this paper—besides, of course, the difference in the frictions—is that I develop a set-up in which the risk of coordination failure, despite being priced, almost never materializes, precisely because the seller gives up a coordination premium to avoid it.

2. MODEL

2.1. *Outline*

In an economy with three dates $t = 0$, 1, and 2, there are two classes of agents: an issuer and n investors, where $n \geq 2$. Investors value liquidity: each investor maximizes a utility function with stochastic time preference. At $t = 0$, the utility of an investor is:

$$U(c_0, c_1, c_2) = E(c_0 + c_1 + (1 - \widetilde{\delta})c_2),$$

where $\widetilde{\delta}$ is a binary random variable whose realization at date 1 is:

$$\tilde{\delta} = \begin{cases} \delta \in (0, 1) & \text{with probability } q, \\ 0 & \text{with probability } 1 - q. \end{cases}$$

At $t = 1$, each investor learns *privately* whether she discounts date 2 consumption or not. We refer to investors who discount future consumption as "impatient" or "distressed".

The issuer aims to maximize the expected proceeds from the issuance of n identical bonds backed by an asset that generates consumption at $t = 2$. The date 2 pay-off of the asset is:

$$\begin{cases} n & \text{with probability } 1 - d, \\ 0 & \text{with probability } \quad d, \end{cases}$$

where $d \in (0, 1)$. The collateral's pay-off and investors' liquidity shocks are independent random variables.

At $t = 0$, the issuer posts a bond price p. Investors simultaneously decide to accept or decline the offer. Also, to satisfy investors' demand for liquidity, the issuer makes a market at date 1. Investors who want to off-load bonds at $t = 1$ entrust them to the issuer, who makes take-it-or-leave-it offers to the other investors. The issuer acts in the best interests of the sellers and offers the highest possible price. Equivalently, she maximizes dollar trading volume in the secondary market. Frictions such as search and bargaining are therefore not a source of illiquidity in this environment.[4] In fact, absent any other friction, the bonds would be liquid in this set-up,

4. See Duffie, Garleanu and Pedersen (2005) for a model of such frictions in over-the-counter markets.

in the sense that the date 0 posted price p would reflect only aggregate liquidity risk:

$$p = (1 - q^n \delta)(1 - d).$$

When contemplating investing in the bond at $t = 0$, investors would anticipate that the bond can be sold at a price equal to $(1 - d)$ at $t = 1$, unless all investors are hit by a liquidity shock.

The additional crucial feature of the model, which gives rise to thick market externalities, is the assumption of learning by holding. It is assumed that holding the bond between dates 0 and 1 enables investors to acquire private information about the quality of the collateral. For simplicity, an investor knows the date 2 asset's pay-off at date 1 if she bought the bond at date 0. In the following, an investor is referred to as an insider if she buys the bond at date 0, and as an outsider if she does not.

The timing of the game may be summarized as follows:

- At $t = 0$, investors decide whether to accept or decline the offer to pay p for a bond.
- Between $t = 0$ and $t = 1$, insiders learn the date 2 pay-off.
- At $t = 1$, investors privately learn their type. The secondary market takes place.
- At $t = 2$, bonds pay off.

2.2. *Self-fulfilling liquidity*

In the presence of learning by holding, impatient insiders and patient outsiders may fail to realize gains from trade in the secondary market. Outsiders cannot disentangle private value motives to trade (liquidity shocks) from common value motives (credit events). Accordingly, patient outsiders who are being offered a bond charge a lemons discount. Distressed insiders may therefore prefer to carry their bonds. Thus, the secondary market may be illiquid, or break down as in Akerlof (1970). At $t = 0$, this inefficiency is anticipated by potential investors. Their reservation price is all the lower because they expect a small number of insiders, and this may generate multiple equilibria. In other words, if investors in the primary market fear an illiquid secondary market, the issuance is not successful, thereby vindicating investors' concern about an illiquid secondary market. The mere fear of future illiquidity suffices to give rise to current and future illiquidity. In this section, I formalize this intuition by describing the equilibria played by investors after the issuer has posted a given price p.

Let $k \in \{0; n - 1\}$. I first compute the expected return from holding one bond for an investor who expects that k fellow investors will invest in bonds. This return depends on the liquidity of the date 1 secondary market. At $t = 1$:

- An insider who is not distressed and knows that the bond will not default has the highest possible date 1 valuation of the bond and is not willing to sell it at less than 1.
- An insider who knows that the bond will default has the lowest valuation and is willing to sell it at any non-negative price.
- An impatient insider who knows that the bond will not default is willing to sell it at any price strictly larger than $1 - \delta$.

Thus, in the secondary market, the issuer will sell a bond for 1 to the insiders who have not tendered their bonds at $t = 1$, if any. If all insiders have tendered their bonds, it means that either they are aware of a forthcoming credit event or they are all hit by a liquidity shock. In either case, there are no possible gains from trade among them. If they are all hit by a liquidity shock, they could benefit from transferring their bonds to a patient outsider, if any. A patient outsider who receives an offer to purchase bonds works out that it means that all the insiders have tendered their bonds, either because of a credit event or because they are all distressed. Thus, the reservation price of an outsider is:

$$\frac{q^{k+1}(1-d)}{q^{k+1}(1-d)+d} = 1 - \frac{d}{q^{k+1}+d(1-q^{k+1})}. \tag{1}$$

As a result, the market between insiders and outsiders is a lemons market if

$$1 - \frac{d}{q^{k+1}+d(1-q^{k+1})} < 1-\delta,$$

or

$$d > \frac{\delta q^{k+1}}{1-\delta+\delta q^{k+1}}. \tag{2}$$

If equation (2) is not satisfied, the secondary market is liquid. It is a pooling market, and all Pareto improving trades between patient and impatient investors take place. Insiders who receive an aggregate liquidity shock at $t = 1$ are penalized because in the eyes of the outsiders, they may just be trying to get rid of a "lemon" at $t = 1$. These transfers across future investors' types cancel out in the $t = 0$ reservation price because the $t = 1$ price (1) charged by outsiders reflects the *ex ante* probabilities of each type. To see this, note that insiders can sell a lemon with probability d, and in this case, pocket

$$\frac{q^{k+1}(1-d)}{q^{k+1}(1-d)+d}$$

per bond. If they are all distressed but hold non-defaulting bonds, they lose

$$1 - \frac{q^{k+1}(1-d)}{q^{k+1}(1-d)+d}$$

per bond. This occurs with probability $q^{k+1}(1-d)$. The *ex ante* profit or loss from trading with outsiders at this pooling price (1) is therefore:

$$d\frac{q^{k+1}(1-d)}{q^{k+1}(1-d)+d} - q^{k+1}(1-d)\left(1 - \frac{q^{k+1}(1-d)}{q^{k+1}(1-d)+d}\right) = 0.$$

The only risk that potential investors price *ex ante* is aggregate risk. Their reservation price for a bond is:

$$(1-q^n\delta)(1-d).$$

Conversely, if equation (2) is satisfied, potential investors price not only aggregate risk but also the risk that all patient agents are outsiders, in which case, liquidity dries up in the secondary market. Thus, if an investor expects that k fellow investors will invest in bonds, his or her reservation price for the bond at date 0 is:

$$\underbrace{(1-q^n\delta)}_{\text{(i)}}(1-d) - \underbrace{q^{k+1}(1-d)}_{\text{(ii)}}\underbrace{(1-q^{n-k-1})}_{\text{(iii)}}\delta = (1-q^{k+1}\delta)(1-d). \tag{3}$$

(i) is the discount for aggregate liquidity risk; (ii) is the probability that the bond does not default and that all insiders are distressed; and (iii) is the probability that at least one outsider is not distressed.

In sum, if equation (2) is satisfied, bonds end up carried by distressed investors if and only if all insiders are distressed, hence the formula (3). Lemma 1 follows directly from these observations.

Lemma 1. *For $k \in \{0; n-1\}$, let*

$$d_k = \frac{\delta q^{k+1}}{1-\delta+\delta q^{k+1}},$$

$$p_k = (1-q^{k+1}\delta)(1-d).$$

$\{d_k\}_{k\in\{0;n-1\}}$ *and* $\{p_k\}_{k\in\{0;n-1\}}$ *are, respectively, decreasing and increasing series. If she believes that k other investors invest in the bonds, an investor has a date* 0 *reservation bond price equal to*

$$\begin{cases} p_k & \text{if } d > d_k, \\ p_{n-1} & \text{if } d \leq d_k. \end{cases}$$

Lemma 1 has some simple implications for the equilibria of the investment game conditional on a posted price p. First, if $p > p_{n-1}$, then investors find not investing in bonds to be a dominant strategy. At such a price, the bond generates a negative excess return regardless of the liquidity in the secondary market. Conversely, if $p < p_0$, then investing in bonds is a dominant strategy. The bond generates a positive excess return regardless of the extent of participation. If $p \in [p_0, p_{n-1}]$, then all the investors investing in bonds is a possible equilibrium. If $p \in [p_0, p_{n-1}]$ and $d > d_0$, no investor investing in bonds is another possible equilibrium, and it is easy to check that there are no other pure strategy equilibria. The following proposition collects this result.

Proposition 1. *If $d > d_0$ and $p \in [(1-q\delta)(1-d), (1-q^n\delta)(1-d)]$, there are two pure strategy equilibria, in which all or no investors invest.*

Proposition 1 captures liquidity as a self-fulfilling phenomenon. If investors expect the market to be liquid, then it is liquid in the sense that the issuer can price the asset according to standard asset pricing theory. That is, she can take only aggregate liquidity risk into account. Conversely, if investors have a self-justified concern about liquidity, then the issuer must price idiosyncratic liquidity risk.

As such, the model cannot deliver accurate predictions for the pricing of liquidity risk. For $d > d_0$ and a bond price within the range $[(1-q\delta)(1-d), (1-q^n\delta)(1-d)]$, the expected proceeds from the issuance are not defined because it is impossible to assign a probability distribution over investors' beliefs about liquidity. It is also of course impossible to solve for a price that maximizes expected proceeds. Liquidity risk can stand anywhere between a first-order and an n-th-order concern. In the balance of the paper, I apply global games techniques to this set-up to resolve this indeterminacy and predict a unique liquidity premium.

3. THE COORDINATION PREMIUM

Following Morris and Shin (1998), a strand of applied literature has used the theory of global games introduced by Carlsson and van Damme (1993) to pin down a unique rationalizable outcome in the presence of strategic complementarities. The theory of global games readily applies to games of *global* strategic complementarities, namely games for which players' actions are strategic complements for all values of the parameters. This restriction to global strategic complementarities turns out to be an important constraint in applied models that depart from the reduced-form coordination games typically assumed in global games theory. In such applications, strategic complementarities often coexist with congestion effects and are therefore not global. This has been an important limitation in financial economics in particular. For instance, in the model of bank run of Goldstein and Pauzner (2005) or in the model of financial market crash by Morris and Shin (2004), strategic complementarities fail for all values of the parameters. In both the models, if many other agents have liquidated their position, so that the bank is already bankrupt or that traders have already hit their risk limits, then liquidations are strategic *substitutes*, regardless of the fundamental value of the asset. The global game argument does not operate in this case, and Goldstein and Pauzner (2005) and Morris and Shin (2004) restrict to monotone strategies[5] or impose strong distributional assumptions to pin down unique outcomes.

Our set-up is also a case in which strategic complementarities are not global. To see this, note that the probability that all insiders are distressed is smaller when they are more numerous. This reduction in the risk that all insiders become distressed has ambiguous net implications. The positive implication is clearly that it is less likely that insiders will have to trade with outsiders. A negative implication, however, is that trading with outsiders is more costly whenever it occurs. This is because when they are being offered the bond, outsiders put more weight on this offer being made because of a credit event rather than an aggregate liquidity shock if there are more insiders. Which effect dominates depends on the values of the parameters. For instance, if

$$d_{k+1} < d < d_k$$

for some $k \in \{0; n-2\}$, then investing if $k+1$ fellow investors invest is less appealing than in the case in which there are only k other insiders. The $(k+1)$-th investor creates overall a negative externality for the others. This is because the secondary market breaks down in her presence, whereas this market is liquid if there are only k insiders. Thus, k investors buying a bond is an asymmetric equilibrium if

$$p_{n-1} > p > p_{k+1}.$$

An important property of our set-up is that, unlike in Goldstein and Pauzner (2005) and Morris and Shin (2004), the set of parameters for which decisions to buy the bond are not strategic complements is only $[d_{n-1}, d_0]$, a strict, bounded subset of all possible fundamentals d. We now show that in this situation in "which strategic complementarity fails only for a bounded subset of fundamentals", global games techniques partially apply, and they are all the more efficient because agents have diffuse *posterior* beliefs about the fundamental parameter.

I modify the baseline model as follows. I assume that the probability of default of the bond is a decreasing function $d(x)$ of a real state variable x. My key assumption is that only extreme realizations of the state variable x are informative about the probability of default. An interpretation of this condition is that when potential investors conduct due diligence, they only perform a coarse screening. For instance, Carey, Prowse, Rea and Udell (1993) report that private lenders typically make initial commitments that are merely based on the memo supplied by the arranger and that they withdraw from their initial commitments only when they come across a major misrepresentation of the borrower's circumstances.

Formally, there exists $\theta > 0$ and a measurable function $D(\cdot)$ such that the probability of default of the bond is:

$$d(x) = D((x-\theta)1_{\{x \geq \theta\}} + (x+\theta)1_{\{x \leq -\theta\}}),$$

where $D(\cdot)$ is decreasing, $D(0) = d \in (d_0, 1)$, and $\lim_{x \to +\infty} D(x) = 1 - \lim_{x \to -\infty} D(x) = 0$. Figure 1 depicts a typical function $d(\cdot)$.

5. In such strategies, the probability that an agent liquidates her position is assumed to be a monotonic function of her signal about the value of the asset.

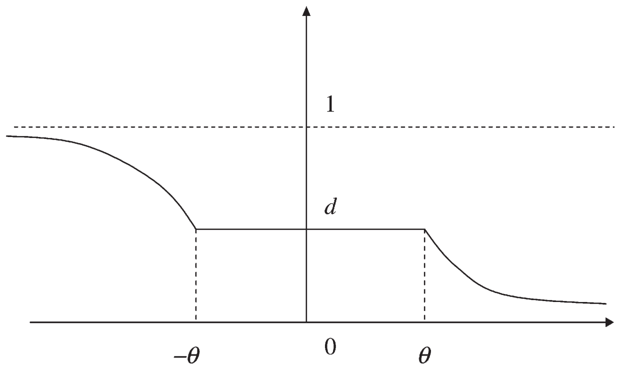

FIGURE 1
The function $d(\cdot)$

The state variable $\widetilde{x}$ is realized at date 1 only. The issuer and investors share the common *prior* that the distribution of $\widetilde{x}$ admits the probability density function:

$$\frac{1}{\sigma} f\left(\frac{x}{\sigma}\right),$$

where $\sigma > 0$. At date 0, after the price p has been posted and before making an investment decision, each investor $i \in \{1, n\}$ privately observes a signal s_i such that

$$s_i = x + y_i.$$

The c.d.f. and p.d.f. of $\widetilde{y}_i$ are continuous functions $G(\cdot)$ and $g(\cdot)$, respectively. Random variables $(\widetilde{x}, (\widetilde{y}_i)_{1 \leq i \leq n})$ are independent.

I assume that $f(\cdot)$ has sufficiently fat tails in the sense that $\log f$ is uniformly continuous over $\mathbb{R}$. This restriction is mild in the sense that the restriction of f to any arbitrarily large compact can be any continuous density. Power or exponential tails satisfy this condition, but Gaussian tails do not.

I also impose two restrictions on $g(\cdot)$ that play no role in our main result but ease its exposition. We assume that $g(-x) = g(x)$. This simplifies the expression of the equilibrium price p^* below, which does not depend on the distribution $g(\cdot)$ in this case. I also assume that $g(\cdot)$ has bounded support U, which shortens the proofs.

I focus on situations in which $\frac{\theta}{\sigma}$ is large, in which case, realizations of $\widetilde{x}$ carry very little information about the probability of default unless extreme. In other words, the focus is on situations that are arbitrarily close to the baseline model in the sense that the probability of default is equal to d in most states of nature, but in which a "grain of doubt" about other investors' beliefs suffices to change the rationalizable outcomes of the investment game.

I let

$$\Gamma = d^{-1}([d_{n-1}, d_0]).$$

In words, Γ is the set of realizations of $\widetilde{x}$ for which the game is not one of strategic complementarities. This set is bounded because $d(\cdot)$ is monotonic and $\lim_{+\infty} d(\cdot) = 1 - \lim_{-\infty} d = 0$. An important parameter of the model is:

$$\gamma = \sup_{x} \{G(x + \lambda(\Gamma)) - G(x)\},$$

where λ is the Lebesgue measure. Notice that γ is small if $\lambda(\Gamma)$ is small and $G(\cdot)$ uniformly continuous, or if $g(\cdot)$ is sufficiently diffuse.

Let

$$p^* = \left(1 - \frac{q}{n}\frac{1-q^n}{1-q}\delta\right)(1-d).$$

The balance of this section establishes that for σ and $\frac{\theta}{\sigma}$ sufficiently large, the issuer does optimally post a price that lies within

$$\left[p^* - \gamma\,\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n},\, p^* + \gamma\,\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n}\right].$$

After the issuer posts a price, each investor's strategy is a mapping from her private signal into a probability to purchase the bond. Let $\Pi_{a_{-i}}(s)$ denote the expected profit from buying a bond for investor $i \in \{1;n\}$ when she receives a signal s and believes that the profile of other investors' strategies is $a_{-i} = (a_j(\cdot))_{j\in\{1;n\}\setminus\{i\}}$. We first establish the following result.

Lemma 2. *Let $\varepsilon > 0$. For σ sufficiently large, if two strategy profiles a_{-i} and b_{-i} satisfy*

$$a_{-i} \geq b_{-i},$$

then for all signals s:

$$\Pi_{a_{-i}}(s) \geq \Pi_{b_{-i}}(s) - \gamma\,\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n} - \varepsilon.$$

Proof of Lemma 2. Let

$$\pi_{a_{-i}}(x)$$

denote the expected profit from buying the bond for investor i if his or her fellow investors play the profile a_{-i} and conditionally on the realized state being x. For each signal s, we have:

$$\begin{aligned}
\Pi_{a_{-i}}(s) &= \int \pi_{a_{-i}}(x)\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx \\
&= \int_{\mathbb{R}\setminus\Gamma} \pi_{a_{-i}}(x)\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx \\
&\quad + \int_{\Gamma} \pi_{a_{-i}}(x)\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx \\
&\geq \int_{\mathbb{R}\setminus\Gamma} \pi_{b_{-i}}(x)\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx \\
&\quad + \int_{\Gamma} \pi_{a_{-i}}(x)\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx \\
&= \int_{\mathbb{R}} \pi_{b_{-i}}(x)\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx \\
&\quad + \underbrace{\int_{\Gamma} (\pi_{a_{-i}}(x) - \pi_{b_{-i}}(x))\frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}dx.}_{(A)}
\end{aligned}$$

This inequality stems from the fact that for $x \notin \Gamma$, the investment game is one of strategic complementarities. A higher probability that other investors invest raises the expected profit of investor i.

The following three remarks yield the lower bound for (A) claimed in Lemma 2:

1. That $\log f$ is uniformly continuous and $g(\cdot)$ has bounded support implies that the function
$$\mathbb{R} \times \mathbb{R} \to \mathbb{R}$$
$$(s,x) \longmapsto \frac{g(s-x)f\left(\frac{x}{\sigma}\right)}{\int g(s-y)f\left(\frac{y}{\sigma}\right)dy}$$
converges uniformly to $g(s-x)$ as $\sigma \to \infty$.
2. Moreover, for all opponents' strategy profiles c_{-i}, $\forall x \in \mathbb{R}$, $(1-q\delta)(1-d(x)) - p \leq \pi_{c_{-i}}(x) \leq (1-q^n\delta)(1-d(x)) - p$.
3. For all $x \in \Gamma$,
$$d(x) \geq d_{n-1}.$$

Thus, for σ sufficiently large,
$$\begin{aligned} A &\geq \gamma\,(q^n\delta - q\delta)(1-d_{n-1}) - \varepsilon \\ &= -\gamma\,\frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n} - \varepsilon. \quad \| \end{aligned}$$

An interpretation of Lemma 2 is that $\gamma\,\frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n}$ measures the distance between our situation and a game of global strategic complementarities. If the set Γ was empty, our game would be one of strategic complementarities, which would imply the following:
$$a_{-i} \geq b_{-i} \to \Pi_{a_{-i}} \geq \Pi_{b_{-i}}.$$

In the presence of congestion effects for some values of the state variable ($\lambda(\Gamma) \neq 0$), the mapping $a_{-i} \to \Pi_{a_{-i}}$ is no longer increasing, but Lemma 2 offers an upper bound on the importance of congestion effects, as measured by $\Pi_{b_{-i}} - \Pi_{a_{-i}}$.

This upper bound, in turn, yields the following partial characterization of the equilibria of the investment game. Define the function Ω over $\mathbb{R}$ as:
$$\Omega(s) = \int \left[\begin{array}{c} \sum_{k=0}^{n-1} \binom{n-1}{k} (1-G(u))^k \times \\ G(u)^{n-1-k} h(k, s-u) \end{array}\right] g(u)du,$$
where
$$h(k,x) = (1 - (q^{k+1} - 1_{\{d(x)\leq d_k\}}(q^{k+1} - q^n))\delta)(1-d(x)).$$

The function Ω is increasing, and
$$\lim_{+\infty} \Omega = 1 - q^n\delta,$$
$$\lim_{-\infty} \Omega = 0.$$

Lemma 3. *Let $\varepsilon > 0$. For σ sufficiently large, if an issuer posts a price $p \in (0, 1-q^n\delta)$, then any equilibrium of the investment game is such that:*

(i) *An investor who receives a signal s satisfying*

$$\Omega(s) \geq p+\gamma \frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n}+\varepsilon$$

almost surely buys the bond.

(ii) *An investor who receives a signal s such that*

$$\Omega(s) \leq p-\gamma \frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n}-\varepsilon$$

almost surely turns down the bond.

Proof of Lemma 3. Fix $\varepsilon > 0$ and $p \in (0, 1-q^n\delta)$ a posted price. Let $(a_i(\cdot))_{i\in\{1;n\}}$ describe an equilibrium of the investment game. Let

$$\overline{s} = \sup\{s \text{ s.t. } \exists i \in \{1;n\} \text{ s.t. } a_i(s) < 1\}.$$

This set is non-empty because not buying the bond is a dominant strategy for s sufficiently small. This set admits an upper bound because buying the bond is a dominant strategy for s sufficiently large.

If s is such that $\exists i \in \{1;n\}$ s.t. $a_i(s) < 1$, by definition, there must be an $i(s) \in \{1;n\}$ such that

$$\Pi_{a_{-i(s)}}(s) \leq 0.$$

Let $\{s_l\}_{l\in\mathbb{N}}$ be a sequence of elements of this set tending to $\overline{s}$. Because the number of investors is finite, there exists (at least) one $i_0 \in \{1;n\}$ such that for a subsequence $\{s_{\varphi(l)}\}_{l\in\mathbb{N}}$,

$$\forall l \in \mathbb{N}, \Pi_{a_{-i_0}}(s_{\varphi(l)}) \leq 0.$$

Letting $l \to \infty$,

$$\Pi_{a_{-i_0}}(\overline{s}) \leq 0.$$

By definition of $\overline{s}$, a strategy profile in which i_0's opponents buy the bond if and only if their signal is larger than $\overline{s}$ is smaller than the strategy profile a_{-i_0}. Lemma 2 therefore implies that for σ sufficiently large,

$$0 \geq \Pi_{a_{-i_0}}(\overline{s}) \geq \Pi_{1_{\{s\geq\overline{s}\}}}(\overline{s}) - \gamma \frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n} - \varepsilon.$$

Furthermore,

$$\Pi_{1_{\{s\geq\overline{s}\}}}(\overline{s}) = \int \left[\begin{array}{c} \sum_{k=0}^{n-1} \binom{n-1}{k} G^k(x-\overline{s})\times \\ (1-G(x-\overline{s}))^{n-1-k} h(k,x) \end{array}\right] \frac{g(\overline{s}-x) f\left(\frac{x}{\sigma}\right)}{\int g(\overline{s}-y) f\left(\frac{y}{\sigma}\right) dy} dx - p,$$

which converges uniformly to $\Omega(\overline{s}) - p$ as $\sigma \to +\infty$. Thus,

$$\Omega(\overline{s}) \leq p+\gamma \frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n}+2\varepsilon$$

for σ sufficiently large. This proves part (i) of Lemma 3. The proof of part (ii) of Lemma 3 is symmetric. ‖

To gain intuition for this result, consider the case in which the investment game is one of strategic complementarity:

$$\lambda(\Gamma) = \gamma = 0.$$

In this case, when σ becomes large, the common prior on $\widetilde{x}$ becomes diffuse, and we obtain the standard global game result that all equilibria converge to the cut-off equilibria in which investors buy the bond if and only if their signal is above a threshold s solving

$$\Omega(s) = p.$$

Lemma 3 shows that a weaker characterization of the equilibria can still be achieved in this set-up. This characterization is all the weaker because the departure from global strategic complementarities is important ($\gamma \frac{q\delta(1-q^{n-1})(1-q)}{1-q+\delta q^n}$ large).

This characterization of investment equilibria entails the following restriction on the set of rationalizable posted prices.

Proposition 2. *For σ and $\frac{\theta}{\sigma}$ sufficiently large, posting a price p such that*

$$p \notin \left[p^* - \gamma\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n}, p^* + \gamma\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n}\right]$$

is not optimal.

Proof of Proposition 2. Let p a posted price such that

$$p - p^* - \gamma\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n} = \varepsilon > 0.$$

We show that the probability that a bond is accepted at this price tends to 0 as σ and $\frac{\theta}{\sigma}$ tend to $+\infty$.

Let $\eta > 0$. We fix a σ such that Lemma 3 applies for ε. (Note that σ can be chosen so that Lemma 3 holds for all $\theta > 0$.) Take a compact set K sufficiently large that an investor's signal $x + y_i$ belongs to K with probability larger than $1-\eta$ for such a σ. For $\frac{\theta}{\sigma}$ sufficiently large, $\Omega(s) = p^*$ if $s \in K$. Lemma 3 implies that p is not accepted for signals smaller than $\sup K$. Thus, the bond is accepted with probability less than η by each investor.

A symmetric argument implies that for a price

$$p < p^* - \gamma\frac{\delta q(1-q^{n-1})(1-q)}{1-q+\delta q^n},$$

the bond is accepted with an arbitrarily large probability. This establishes Proposition 2. ||

The intuition for this result is simple. First, the condition that σ has to be sufficiently large is standard in global games. It implies that the private signals received by investors are sufficiently more accurate than the common prior. This condition ensures that the way an investor ranks her signal among all other signals has a low sensitivity to the realization of her signal (see, *e.g.* Morris and Shin, 2003). This ensures that there is a unique equilibrium if, in addition, strategic complementarities are global. This condition on the relative precisions of the prior and the private signals has recently been challenged by Angeletos and Werning (2006) and Hellwig, Mukherji and Tsyvinski (2006). Broadly, they note that if private information is aggregated in a large market, for instance through publicly observed prices, then public information cannot be arbitrarily less accurate than private information. This criticism is less relevant in the context of private placements. Such deals feature bilateral negotiations about a specific asset between the issuer and a small number of investors.

The condition on $\frac{\theta}{\sigma}$ implies that it is *ex ante* highly unlikely that an investor believes in a probability of default significantly different from d after receiving a signal. This pins down an optimal range of prices for the issuer that does not depend on her risk aversion: prices below this range are highly likely to be accepted, while prices above this range are highly likely to be turned down, so that any rational issuer would pick a price within this range under the conditions stated in Proposition 2. That the issuer gives up a liquidity premium to control the outcome of a global game is similar to the feature in Goldstein and Pauzner (2005) that the bank reduces the short-term interest rate to mitigate a coordination problem à la Diamond and Dybvig (1983) among depositors.

If an investor, after having received her signal, puts a high probability on the event

$$\{x \in \Gamma\},$$

then the iterated dominance argument used in global games has little bite. Conversely, our set-up becomes close to the global game situation when this posterior probability is uniformly small for all signals. In this case, global game techniques yield tighter bounds for rationalizable posted prices. The parameter γ is a uniform upper bound on the posterior measure of Γ. This parameter is small if:

- All else equal, Γ is small. This in turn occurs if d_0 and d_{n-1} are close to each other, namely if n is small, $q\delta$ is small, or q is close to 1.
- All else equal, investors have a sufficiently diffuse posterior on x. Since their prior is diffuse (σ large), this will be the case if, in addition, their signals are noisy ($G(\cdot)$ flat).

The remainder of the paper assumes that (at least) one of these conditions is satisfied, and focuses on p^* as the issuance price. At first order w.r.t. q,

$$p^* = \left(1 - \frac{q\delta}{n}\right)(1-d) + 0(q).$$

The liquidity premium is much larger than a n-th-order premium for aggregate risk but becomes negligible for a large n. I now discuss how the properties of the coordination premium implied by p^* relate to some empirical findings about bond spreads.

4. THE CREDIT SPREAD PUZZLE

An important open research question in asset pricing is the so-called credit spread puzzle. The credit spread puzzle refers to the fact that the expected returns that investors require to hold defaultable bonds are significantly higher than the ones predicted by widely accepted models. Consider for instance the excess spread that BBB-rated corporate bonds earn over higher quality (AAA or AA rated) corporate bonds. The historical values reported for the BBB–AAA spread are around 100 basis points, while the historical excess credit losses on BBB bonds over AAA or AA bonds are only around 20 basis points.[6] Most studies conclude that this 80 basis points differential does not square with risk premia or trading frictions in bond markets.

First, as argued by Chen, Collin-Dufresne and Goldstein (2008), frictions such as taxes, or the fact that trade is conducted through costly search and bilateral negotiations in decentralized corporate bond markets, are highly unlikely to account for this spread. While such frictions can

6. See Amato and Remolona (2003) or Huang and Huang (2003).

explain why AAA corporate bonds command a spread over Treasuries, it is unclear why they would lead to such a large pricing difference between BBB and AAA corporate bonds: these investment grade bonds are all traded in identical conditions by the same investors.

Second, the 80 basis point difference between excess expected credit losses and the BBB–AAA spread could in theory stem from risk premia. If bonds tend to default in "bad times"—when bondholders have a high marginal utility of consumption—then bondholders would require a large risk premium to bear default risk. Yet, the calibration of a large class of structural models with plausible risk premia conducted by Huang and Huang (2003) generates BBB–AAA spreads of 30 basis points that fall well short of historical values. Using the very volatile pricing kernel that Campbell and Cochrane (1999) used to reproduce the U.S. equity premium, Chen *et al.* (2005) found BBB–AAA spreads of less than 80 basis points. They need to assume additional sources of risk such as countercyclical default boundaries to fit the data. In this sense, the required return on bonds is more "puzzling" than that on equity since even the large countercyclical risk aversion that explains the equity premium does not account for the whole BBB–AAA spread.

In light of this puzzle, it is interesting to note that in this model, in which investors are price takers and risk-neutral and in which there are no transaction costs, learning by holding implies that sufficiently risky bonds ($d > d_0$) command a spread over safer bonds ($d < d_{n-1}$) above and beyond compensation for the higher expected credit losses. At first order w.r.t. q, the total promised yield on the risky bond is indeed

$$\underbrace{d}_{\text{Default component}} \quad + \quad \underbrace{\frac{q\delta}{n}(1-d)}_{\text{Coordination component}}. \tag{4}$$

Interestingly, for bonds such that $d > d_0$, the coordination component of the total spread is a smaller fraction of the entire spread when the probability of default is higher. This is consistent with the data. For instance, Amato and Remolona (2003) reported that expected credit losses constitute 12% and 57% of the total spread for BBB and B bonds, respectively.

In sum, the excess return generated by coordination risk both vanishes for virtually risk-free bonds and has a low sensitivity to risk for higher default levels. That the coordination premium varies in a highly non-linear fashion with credit risk is in line with empirical features of spreads on defaultable bonds.

As mentioned in the Introduction, learning by holding is particularly plausible in the case of privately placed bonds. I do not rule it out completely for public issuances, given that even public corporate bonds trade infrequently in a decentralized market and that most issuances end up held by a small number of sophisticated investors (Schultz, 2001). Still, one would expect that this phenomenon is by definition more pronounced for private bonds. Accordingly, Zwick (1980) and Carey *et al.* (1993) report that privately placed bonds earn a significantly higher spread than otherwise comparable publicly traded bonds.

Finally, Longstaff, Mithal and Neis (2005) found that the time variations of the non-default components of bond spreads are correlated with various proxies for changes in aggregate liquidity (changes in the yield spread between off-the-run and on-the-run Treasuries, inflows in money market funds, and new corporate bonds issuances.) In this model, increases in aggregate demand for liquidity such as an increase in q or δ for all investors also raise the coordination premium across all ratings. Coordination problems essentially amplify the consequences of liquidity shocks, so that the coordination premium is sensitive to aggregate changes in liquidity risk.

5. DISCUSSION

5.1. *Loss given default and liquidity*

For expositional simplicity, I have assumed that defaulted bonds are worthless. This section examines a simple extension in which the loss given default on bonds is not 100% but rather some $l \in [0, 1]$. That a defaulted bond has some recovery value reduces the cost of coordination. Insiders can split the claims to the cash flows generated by their bonds into two "tranches". They can issue a senior risk-free security that pays $1 - l$, and an equity tranche that bears the credit losses l in case of default. Such arrangements are commonplace in practice in securitization deals. The senior tranche is not information sensitive and can always be transferred to patient agents in the secondary market. Thus, its $t = 0$ spread reflects only aggregate liquidity risk. Conversely, the equity tranche is identical to the bonds with 100% loss given default studied in the previous section. Its $t = 0$ spread therefore features a coordination premium. Thus, the limiting price p^* becomes

$$p^* = \underbrace{(1 - q^n \delta)(1 - l)}_{\text{Senior tranche}} + \underbrace{\left(1 - \frac{q}{n}\frac{1 - q^n}{1 - q}\delta\right)(1 - d)l}_{\text{Equity tranche}}.$$

At first order w.r.t. q,

$$p^* = 1 - dl - \frac{q\delta}{n}(1 - d)l. \tag{5}$$

If the expected loss given default decreases with the credit rating (see, *e.g.* Schuermann, 2004, for evidence supporting this point), then the coordination premium in equation (5) $\frac{q\delta}{n}(1 - d)l$ may be larger in absolute terms as the credit rating is lower. The reduction of the loss given default when rating improves may counterbalance the increase in $1 - d$. In the data, the coordination premium is larger in absolute terms for lower ratings[7] (but is a smaller fraction of the total spread as already mentioned).

5.2. *Private information and liquidity*

For expositional simplicity, I have assumed an extreme form of learning by holding, in which bondholders perfectly learn the bonds' final pay-off. In this section, I let the magnitude of the informational advantage that insiders have over outsiders vary. Formally, I assume that insiders learn the date 2 pay-off with a probability $k \in (0, 1)$. The previous sections dealt with the $k = 1$ case. If $k < 1$, there are three date 1 states of nature in which insiders seek to transfer bonds to patient outsiders:

- The state in which all insiders are distressed and know the bond will not default.
- The state in which insiders know the bond will default.
- A third state in which all insiders are distressed and have not learned anything about the final pay-off.

The secondary market is efficient if trade with patient outsiders takes place in each of these three states. Accordingly, there are now two possible degrees of inefficiency. The secondary market may break down in either one or two of these states. First, it may be that distressed insiders who know that the bond will not default are not willing to trade, but when insiders are distressed and uninformed, they are willing to trade. Second, adverse selection may be so severe that even distressed and uninformed insiders are not willing to trade at date 1.

7. See, for example Huang and Huang (2003).

If there are $l \in \{1; n\}$ insiders at date 1, distressed insiders who know that the bond will not default are not willing to trade if

$$\frac{(1-d)q^l}{(1-kd)q^l+kd} < 1-\delta,$$

or

$$d > \frac{\delta q^l}{q^l+k(1-\delta)(1-q^l)}. \tag{6}$$

Similarly, if inequality (6) is satisfied, insiders who are distressed and uninformed are not willing to trade if

$$\frac{(1-k)q^l(1-d)}{(1-k)q^l+kd} < (1-\delta)(1-d),$$

or

$$d > \frac{\delta(1-k)}{(1-\delta)k}q^l.$$

To simplify the discussion, assume

$$q+k(1-q)(1-\delta) > \frac{k(1-\delta)}{(1-k)q^{n-1}}. \tag{7}$$

Condition (7) is satisfied if other things equal, k is sufficiently small. In this case, there exists d satisfying

$$\frac{\delta q}{q+k(1-\delta)(1-q)} < d < \frac{\delta(1-k)}{(1-\delta)k}q^n. \tag{8}$$

For such a d, the reservation price of an investor who expects l other investors to buy the bond is:

$$\begin{aligned}&(1-q^n\delta)(1-d)-q^{l+1}(1-q^{n-l-1})k\delta(1-d)\\&=(1-q^n(1-k)\delta)(1-d)-q^{l+1}k\delta(1-d).\end{aligned}$$

The second term on the R.H.S. is the expected cost of carrying the bond while impatient because of a secondary market breakdown. Such a breakdown occurs only if the insiders are all distressed and know that the bond will not default.

By contrast, if

$$d > \frac{\delta(1-k)}{(1-\delta)k}q,$$

then the reservation price of an investor who expects l other investors to buy the bond does not depend on k:

$$(1-q^n\delta)(1-d)-q^{l+1}(1-q^{n-l-1})\delta(1-d).$$

This is simply because in this case, the secondary market breaks down as soon as all insiders are distressed regardless of their degree of information.

Clearly, the equilibrium selection techniques introduced in Section 3 readily apply to the case of imperfect learning and yield the following result.[8]

8. The only modification of the proof is that the function $h(\cdot,\cdot)$ and the set Γ would have different expressions. But Γ would still be bounded, and $h(\cdot,\cdot)$ would still be increasing in its second argument, which is all that is needed.

Proposition 3. *In the model of Section* 3*, assume that insiders learn the date* 2 *pay-off at date* 1 *with probability* $k \in (0, 1)$ *only, and that* d *satisfies equation* (8)*. The limiting price* p^* *in Proposition* 3 *becomes*

$$p^* = \left(1 - (1-k)q^n\delta - \frac{q}{n}\frac{1-q^n}{1-q}k\delta\right)(1-d).$$

In particular,

$$p^* = 1 - d - k\frac{q\delta}{n}(1-d)$$

at first order w.r.t. q. A decrease in k reduces the coordination premium. In fact, a decrease in k plays the same role as a decrease in the loss given default l in equation (5). This is because decreases in k and l both reduce the fraction of the future cash flows that can possibly suffer from a lemons problem in case of coordination failure. Thus, decreases in k and l ease coordination for the same reason.

5.3. *Concluding remarks*

This analysis of learning by holding suggests an interesting new interpretation of the recent subprime mortgage crisis. The general realization in summer 2007 that CDOs backed by U.S. subprime mortgages would experience higher than expected credit losses had a surprisingly large destabilizing impact. Spreads surged and liquidity suddenly dried up in the subprime CDO market. This then triggered a money market breakdown and ultimately important disruptions in interbank markets because many short-term instruments were backed by highly rated subprime CDO tranches. Many observers argue that adverse selection does not explain this market breakdown. The rising concern about credit risk was symmetric and market wide: it is unlikely that any agent had inside information on the exact impact of future subprime delinquencies in summer 2007.[9] The view that gained momentum is that the subprime crisis is best explained by the rise of Knightian uncertainty.[10] In this view, liquidity crises arise when investors can no longer assign probabilities to future contingencies. This increase in immeasurable risk leads them to resort to very conservative "worst-case scenario" decision rules that cause market breakdowns.

The liquidity implications of learning by holding offer an alternative view on the subprime meltdown in which *neither* a lemons problem *nor* a sudden inability to measure subprime risk play a role. In this paper, liquidity spreads increase with respect to default risk in a highly non-linear fashion in the presence of learning by holding. Thus, it may be that a public and modest upwards revision of future subprime delinquencies had a disproportionate impact on the discount rates used to price subprime CDOs. This is because expected defaults crossed the threshold above which potential investors feared that *future* lemons problems would occur, once credit losses eventually materialize and worm their way through the financial system.

Viewing the subprime crisis as the rise of a coordination problem offers some guidance on ways to restore liquidity in securitization markets. It is the conjunction of learning by holding together with uncertainty over market participation—captured in our model by simultaneous investment decisions and a price-posting mechanism—that triggers possible coordination failures.[11] Accordingly, reducing uncertainty about market participation through the adoption of

9. See, for example Buiter and Sibert, "Is the Credit Crunch a Lemons Problem?" (http://blogs.ft.com/maverecon/2007/09/is-the-credit-c.html).

10. See "The Long and the Short of it", *The Economist*, 30 August, 2007. See also Caballero and Krishnamurthy (2008) for a formal approach.

11. A referee has pointed out that posting a pricing schedule that increases with the realized number of buyers is a simple theoretical solution to the coordination problem that we study. This contracting variable seems easy to manipulate in practice, however. The arranger could ask straw men to carry the assets for some time.

more organized trading mechanisms in CDO markets would improve liquidity. The key is that potential investors receive credible signals about current market thickness, so that they are not concerned about possible future lemons problem caused by learning by holding.

Acknowledgements. I thank the editor, Bernard Salanié, and two anonymous referees for very helpful comments. I have also benefited from discussions with Viral Acharya, Regis Breton, Rick Green, John Moore, Christine Parlour, Rafael Repullo, Hyun Shin, and Javier Suarez. Errors are mine.

REFERENCES

ACHARYA, V. and JOHNSON, T. (2007), "Insider Trading in Credit Derivatives", *Journal of Financial Economics*, **84** (1), 110–141.

AKERLOF, G. A. (1970), "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", *The Quarterly Journal of Economics*, **84** (3), 488–500.

ALLEN, F. and GALE, D. (1994), "Limited Market Participation and Volatility of Asset Prices", *The American Economic Review*, **84** (4), 933–955.

AMATO, J. D. and REMOLONA, E. M. (2003), "The Credit Spread Puzzle", *Bank for International Settlements Quarterly Review*, 51–63.

ANGELETOS, G.-M. and WERNING, I. (2006), "Crises and Prices: Information, Aggregation, Multiplicity, and Volatility", *American Economic Review*, **96** (5), 1720–1736.

CABALLERO, R. J. and KRISHNAMURTHY, A. (2008), "Collective Risk Management in a Flight to Quality Episode", *The Journal of Finance* (forthcoming).

CAMPBELL, J. Y. and COCHRANE, J. H. (1999), "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior", *The Journal of Political Economy*, **107** (2), 205–251.

CAREY, M., PROWSE, S., REA, J. and UDELL, G. (1993), "The Economics of the Private Placement Market" (Board of Governors of the Federal Reserve System, Staff Studies #166).

CARLSSON, H. and VAN DAMME, E. (1993), "Global Games and Equilibrium Selection", *Econometrica*, **61** (5), 989–1018.

CHEN, L., COLLIN-DUFRESNE, P. and GOLDSTEIN, R. S. (2008), "On the Relation between Credit Spread Puzzle and the Equity Premium Puzzle", *The Review of Financial Studies* (forthcoming).

DIAMOND, D. W. and DYBVIG, P. H. (1983), "Bank Runs, Deposit Insurance, and Liquidity", *The Journal of Political Economy*, **91** (3), 401–419.

DOW, J. (2004), "Self-Sustaining Liquidity in an Asset Market with Asymmetric Information", *Journal of Business*, **77** (4), 895–908.

DUFFIE, D., GARLEANU, N, and PEDERSEN, L. H. (2005), "Over-the-Counter Markets", *Econometrica*, **73** (6), 1815–1847.

GOLDSTEIN, I. and PAUZNER, A. (2005), "Demand Deposit Contracts and the Probability of Bank Runs", *Journal of Finance*, **60** (3), 1293–1328.

GOMES, A. R. and PHILLIPS, G. M. (2005), "Why Do Public Firms Issue Private and Public Securities?" (NBER Working Paper No. 11294).

HELLWIG, C., MUKHERJI, A. and TSYVINSKI, A. (2006), "Self-Fulfilling Currency Crises: The Role of Interest Rates", *American Economic Review*, **96** (5), 1769–1787.

HUANG, J.-Z. and HUANG, M. (2003), "How Much of the Corporate-Treasury Yield Spread is due to Credit Risk? A New Calibration Approach", 14th Annual Conference on Financial Economics and Accounting, Texas Finance Festival (http://ssrn.com/abstract=307360).

LONGSTAFF, F. A., MITHAL, S. and NEIS, E. (2005), "Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Swap Market", *The Journal of Finance*, **60** (5), 2213–2253.

LUCAS, D. J., GOODMAN, L. S. and FABOZZI, F. J. (2006), *Collateralized Debt Obligations Structures and Analysis* (Hoboken, NJ: Wiley Finance).

MORRIS, S. and SHIN, H. S. (1998), "Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks", *The American Economic Review*, **88** (3), 587–597.

MORRIS, S. and SHIN, H. S. (2003), "Global Games: Theory and Applications", in M. Dewatripont, L. Hansen and S. Turnovsky (eds.) *Advances in Economics and Econometrics* (Cambridge University Press).

MORRIS, S. and SHIN, H. S. (2004), "Liquidity Black Holes", *Review of Finance*, **8** (1), 1–18.

PAGANO, M. (1989), "Endogenous Market Thinness and Stock Price Volatility", *The Review of Economic Studies*, **56** (2), 269–287.

SCHUERMAN, T. (2004), "What Do We Know about Loss Given Default?", in *Credit Risk: Models and Management*, 2nd edn (London: Risk Books) 249–274.

SCHULTZ, P. (2001),"Corporate Bond Trading Costs: A Peak Behind the Curtain", *The Journal of Finance*, **56** (2), 677–698.

ZWICK, B. (1980), "Yields on Privately Placed Corporate Bonds", *The Journal of Finance*, **35** (1), 23–29.