Ignorance, Debt and Financial Crises[+]

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Abstract

In this paper we provide a theory of money markets and private money. We show that preserving symmetric ignorance in liquidity provision is welfare maximizing and strictly dominates symmetric or even perfect information. A key property for the functioning of money markets is when agents have no need to ask questions and no incentive to produce private information about the value of the security. Debt is the optimal private money because it is least information acquisition sensitive. Bad public news (shock) about the fundamentals of assets that back debt can cause information-insensitive debt to become information-acquisition sensitive. The expected value of debt drops, but to prevent endogenous adverse selection agents reduce the amount of trade below the expected value of debt. The shock is amplified, leading to a financial crisis.

1. Introduction

In money markets investors trade hundreds of millions or even billions of dollars very quickly without the need to ask questions and conduct due diligence about the value of the security. Prime examples of cash equivalent securities or private money are treasuries, repo, asset backed commercial papers and money markets funds. For a long time period these markets had been working very well and so smoothly that the Finance and Economics profession seemed to have no incentive to ask "deeper" questions about what makes money markets liquid. Therefore, the breakdown of several types of these short term lending and borrowing markets during the recent financial crisis came as a big surprise and raises several questions about how money markets are functioning. Understanding the nature of liquidity provisions is central for the regulation of the banking and financial system.

In this paper we provide a theory of money markets and private money and derive three main results. We show that in liquidity provision preserving symmetric ignorance is welfare maximizing and strictly dominates symmetric or perfect information. We derive a measure that captures an agent's incentive to produce private information, called "information acquisition sensitivity". When trading a security with low information acquisition sensitivity, an agent has no need to ask questions. We argue that "no question asked" (NQA) is a key property for the functioning of over-the-counter trading in money markets. If the NQA property fails, this can cause costly delay or even the breakdown of trading and thus possibly the bankruptcy of financial institutions and firms. These trading inefficiencies arise if investors start worrying about potential asymmetric information and adverse selection. For example, an investor is concerned that other investors may want to conduct due diligence and know more than him. Or he is concerned that other investors are concerned that he knows more than them. Or he is concerned that all investors are conducting due diligence and reach different conclusion about the value of the security.[1]

As a second result, we show that debt is the optimal security for liquidity provision in money markets for two reasons. Debt is optimal because it minimizes an agent's incentive to produce private information about the payoff of the security. In other words, debt is least information acquisition sensitive and is best in implementing the NQA property. Secondly, debt is optimal because its value is least sensitive to the arrival of public information and thus maximizes the re-trade value when there is bad public news. A low re-trade value of a security is what investors who conduct trade for liquidity (management) reasons care a lot about. Therefore, we provide an explanation for why only debt-like securities are considered as cash equivalents and the only instruments traded in money markets.

Finally, our theory shows how these markets can break down. A public shock about the fundamental value of the underlying (pool of) assets that backed debt can create an incentive to produce private

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[1] The literature on stock trading is huge but there is little theoretical work on money markets. We argue that money markets work completely differently than stock markets. Equities are not hold for liquidity provision reasons but as longer term financial investments. Therefore, investor can wait to trade and conduct due diligence.

information. Bad public news about fundamentals (a shock) causes the market value of debt to drop. But more severely, it can cause information-insensitive debt to become information acquisition sensitive. Agents who are capable to produce information have an incentive to learn about tail risks. Other agents become "suspicious" in the sense of fearing about adverse selection. In order to prevent endogenous adverse selection, agents reduce the amount of trade below the expected value of debt. The shock is amplified, leading to a crisis.

Historically, systemic crises are associated with bank runs in the commercial banking system that creates private money for households and firms in the form of demand deposits which are backed by banks assets. The recent financial crisis was caused by runs on different parts of the wholesale and shadow banking system where private money takes the form of various types of money market instruments backed by different types of assets. Both demand deposits and money markets are vital for the real economy.

Systemic financial crises have the common feature that they involve debt. Yet current theories of crisis assume the existence of debt, and current theories of debt do not explain the origins of crises. In this paper we provide a theory of the existence and optimality of debt as private money, a theory that also shows that debt –while optimal-- is vulnerable to a crisis in which trade collapses. The breakdown of these markets is then a manifestation of the tail risk that is endogenously created by agents in the economy who optimally use debt in order to trade for liquidity reasons, precisely because it is best in maintaining symmetric ignorance by design.

The recent financial crisis has been blamed in part on the complexity and opacity of financial instruments, leading to calls for more transparency. On the contrary, we show that symmetric ignorance creates liquidity in money markets. Furthermore, we show that the public provision of information that is imperfect can trigger the production of private information and create endogenous adverse selection. Agents can most easily trade when it is common knowledge that no one knows anything privately about the value of the security used to transact and no one has an incentive to conduct due diligence and ask question about the value of the security. Information acquisition insensitive debt has the NQA property and is thus private money.

In the setting we explore there is a fixed cost of producing information. Debt minimizes the value of the private information that can be learned, so that this cost is not worth bearing. In fact, if it was possible to raise the cost of producing information, say by making the security more complicated that would be even better. A cost of infinity would be best. This contrasts starkly with many existing models of debt in a corporate finance setting. For example, in the model of Townsend (1979) a lender must pay a cost to determine the output of a borrower to see if the loan can be repaid. In that setting, the cost of producing information would be best if it were zero. The lender wants information. But, in the trading context is better if no party to the transaction engages in such due diligence.

The paper proceeds as follows. In Section 2 we very briefly review the relevant prior literature. In Section 3 we introduce and explain the model with three dates and three agents, A, B, and C. Agent B owns some non-storable goods at t=0 but wants to consume at t=1. At t=0 he wants to buy a security as a storage technology from agent A. The payoff of the security is backed by a project that agent A owns. At t=1 agent B uses his security to trade with agent C for agent C's t=1 consumption good. Between the two transactions a public signal arrives about the value of the underlying project. In Section 4 we analyze the B-C trade where agent B designs a security for use for trade with agent C, using the security he owns as collateral. In section 5 we analyze the optimal choice of collateral, that is, what security would agent B prefer to receive from agent A in the first transaction? Section 6 contains a discussion of some of the assumptions of the model and a discussion of extensions of the model to a lender-of-last-resort and rating agencies. Section 7 concludes.

2. Previous Literature

We build on several prior literatures. With regard to "liquidity," Diamond and Dybvig (1983) and Gorton and Pennacchi (1990) study liquidity provision but assume the existence of debt. Also important is Holmström (2008). Diamond and Dybvig (1983) associate "liquidity" with intertemporal consumption smoothing and argue that a banking system with demand deposits provides this type of liquidity. Gorton and Pennacchi argue that debt is an optimal trading security because it minimizes trading losses to informed traders when used by uniformed traders. Hence debt provides liquidity in that sense. In Gorton and Pennacchi the debt is riskless, and it is not formally shown that debt is an optimal contract. Since debt is riskless there is no crisis.

There is a large literature on the optimality of debt in firms' capital structures, based on agency issues in corporate finance. Closest to our work is DeMarzo and Duffie (1999). In their work the problem is to design a security that maximizes the payoff of a seller who will become (privately) informed prior to actually selling the securities. Since there is adverse selection, the demand curve of the uninformed buyers is downward-sloping. Prior to obtaining private information but anticipating the competitive separating signaling market equilibrium at the trading stage, the seller designs a security that trades-off the price and quantity effects. They show that under some conditions debt is the optimal security. The key driver for the optimality of debt for an informed seller is the "flat" part of the debt contract. The intuition is that the "flat" part excludes the smallest set of high type sellers and thus reduces the price sensitivity when the seller increases the quantity.[2]

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[2] See also Biais and Mariotti (2005) who extend DeMarzo and Duffie (1999) to a setting where buyers are strategic and derive an optimal screening mechanism at the trading stage rather than assuming a separating signaling equilibrium. DeMarzo (2005) shows that pooling reduces the adverse selection problem an uninformed agent faces when he sells to an informed intermediary while tranching increases the amount that the informed intermediary (seller) can sell to uninformed buyers subsequently. DeMarzo et al.(2005) analyze bidding with securities in auctions where bidders have private information about their private valuations of the object. Interestingly, in this pure private value environment, they derive the "opposite" result and show that debt is the "worst" security, i.e. it minimizes the expected revenue of the seller.

Our design problem is very different. Rather than analyzing how security design can mitigate exogenous adverse selection problems, we analyze optimal security design with endogenous information acquisition and ask which security is optimal in preserving symmetric information and minimizing endogenous adverse selection concerns. We design a security that maximizes the payoff of an uninformed agent who faces a potentially informed buyer in the secondary market. We show that it is not the "flat" part of a standard debt contract that is relevant for minimizing the incentive to produce information. The key driver for the optimality of debt when there is endogenous information production and potential adverse selection is the 45 degree line of the debt contract, i.e., the seniority of repayment. But we also show that the "flat" part of the debt contract becomes relevant (and a standard debt contract is uniquely optimal) when there is public information or (endogenous) adverse selection in equilibrium.[3]

In our setting efficient trade is inhibited by "transparency." There are a few papers that raise the issue of whether more information is better in the context of trading or banking. These include Andolfatto (2009), Kaplan (2006), and Pagano and Volpin (2009). Andolfatto (2009) considers an economy where agents need to trade, and shows that when there is news about the value of the "money" used to trade, some agents cannot achieve their desired consumption levels. Agents would prefer that the news be suppressed. Kaplan (2006) studies a Diamond and Dybvig-type model and in which the bank acquires information before depositors do. He derives conditions under which the optimal deposit contract is non-contingent. Pagano and Volpin (2009) study the incentives a security issuer has to release information about a security, which may enhance primary market issuance profits, but harm secondary market trading. All these authors assume debt contracts.

There is a very large literature on financial crises.[4] The concept of a "financial crisis" refers to a sort of "regime change" due to the simultaneous actions of a large number of agents, which causes real effects. The leading example is a banking panic, which occurs when a sufficiently large number of depositors choose to withdraw their deposits, relative to the cash available to the banks, forcing a suspension of convertibility. Broadly and briefly, there are various different theories of financial crisis. First, there are self-fulfilling expectations or sun spots theories, starting with Diamond and Dybvig (1983), and refined by Goldstein and Pauzner (2005) who apply the global games method of Carlsson and van Damme (1993). In these models, agents are unsure of other agents' actions or beliefs, and the crisis is an outcome of the coordination failure. Morris and Shin (1998) also use the global games modeling technique to model a coordination game in which each player's payoff depends on his own action and the actions of others, as well as unknown economic fundamentals. This view of crises focuses on a loss of confidence, which is related to beliefs about other agents.

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[3] Section 3 discusses further important differences.
[4] See Allen, Babus, and Carletti (2009) for a survey.

In the second theory there is no coordination failure, but there is asymmetric information in that market participants do not know which institutions are most at risk. A shock can occur which is big enough to cause some banks to fail, but agents do not know which banks will fail. Risk averse agents rationally respond by, for example, seeking to withdraw their money from all banks even though only a few are actually insolvent. See Gorton (1985, 1988) and Gorton and Huang (2006). Again, there is a loss of confidence in the sense that agents are no longer sure of banks' solvency. The disruption can be large, although the overwhelming majority of banks are solvent.

The financial crisis in our economy comes from an entirely different source than the theories in the existing literature. Crises in the existing literature are not linked to the optimality of debt, while our theory follows naturally from the optimality of debt. Beliefs about the actions of other agents matter in our theory in that the fear of others producing private information when there is a shock is what makes debt information-sensitive. Like Kiyotaki and Moore (1997) the value of collateral is important in our theory because the debt which is backed by that collateral can become information-sensitive due to the shock to the collateral value. A "loss of confidence" also plays an important role in our theory. It corresponds to the debt becoming information-sensitive when there is a shock, resulting in the fear of adverse selection. In our theory, the crisis is linked to the underlying rationale for the existence of debt as the optimal trading security and a crisis arises if debt that is designed to be information-insensitive becomes information acquisition sensitive.

3. The Model

Our modeling objective is to have a simple model that is able to capture the key features of a sequence of over-the-counter trades in money markets. In these markets an investor buys a security to store his wealth for a fixed period of time and is concerned about the fluctuations of the market value of the security as well as potential adverse selection at the date when he needs to resale the security. We will characterize the optimal security for this investor to hold as a parking space and discuss potential inefficiencies in these markets. For this purpose, we consider an exchange economy with three dates (t=0, 1, 2) and three agents {A, B, C} whose utility functions are given as follows:

$$U_A = C_{A0} + C_{A1} + C_{A2}$$
$$U_B = C_{B0} + \alpha C_{B1} + C_{B2}$$
$$U_C = C_{C0} + C_{C1} + C_{C2},$$

where $\alpha > 1$ is a constant and where C_{ht} denotes consumption of agent h at date t. The endowment of agent h is described by the vector $\varpi_h = (\varpi_{h0}, \varpi_{h1}, \varpi_{h2})$, where the second subscript refers to the time at which the endowment arrives. We assume that $\varpi_A = (0,0,X)$, $\varpi_B = (w,0,0)$, and $\varpi_C = (0, w_C, 0)$ where w and w_C are constants and X is a random variable, the payoff on a project (tree) owned by agent A initially. The random variable X is described by a continuous distribution function, F(x). So, agent A has no

endowment of goods at dates 0 and 1, but receives x units of goods at date 2, where x is a (verifiable) realization of the random variable X, a project. Agent B possesses w units of goods at date 0 and nothing at the other dates. Agent C has w_C units of goods at date 1. Goods are nonstorable. The agents start with identical information about the distribution of the random variable X, which has positive support on $[x_L, x_H]$.

The only reason for trade in this economy is that agent B's utility function gives him an extra benefit from consuming at date 1, i.e., $\alpha > 1$. Therefore, it is socially efficient for agent A to consume at date 0, for agent B to consume at date 1, and for agent C to consume at date 2. In order to implement the efficient allocation and for agent B to consume at t=1, agent B trades some of his t=0 goods to agent A at t=0 and in exchange agent A issues a security to agent B some of his (uncertain) t=2 project payoff. At t=1 agent B sells the security to agent C.

A. Securities

In order to trade, agents will need to write contracts which specify a price and a security. A security s(x) maps the outcome of X to a repayment s(x). For example, at date 1, agent B can use s(x) to trade for agent C's t=1 goods. The realization x of the project at date 2 is verifiable. The date 1 endowment w_C of agent C is non-contractible at t=0.[5]

Date 0 securities: We first describe the set of feasible securities at date 0. Let *S* denote the set of all possible securities, i.e., functions, s(x), which satisfy the resource feasibility (or limited liability) constraint, $0 \leq s(x) \leq x$. In addition, we assume s(x) non-decreasing.[6] Two examples are:

(i) Equity: $s(x) = \beta x$ where $\beta \in (0,1]$ is the share of x;

(ii) Debt: $s(x) = \min[x, D]$ where D is the face value of the debt.

In principle, agent A could promise whatever he wants, e.g. $s(x) > x_H$, but agent B would simply not believe it. Therefore, at date 0, the set of (feasible) contracts agent A can issue to agent B is $s \in S = \{s: s(x) \leq x\}$.

Date 1 securities: At t=1, agent B owns s(x). The set of feasible securities at date 1 that agent B can use to trade with agent C is given by $\hat{S} = \{\hat{s} : \hat{s}(s(x)) \leq s(x)\}$ where s(x) is the payoff of the security that agent B bought from agent A. In other words, agent B needs not simply trade the original security that he received from agent A to agent C. Let y=s(x). Agent B can *redesign* the security by issuing a

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[6] This is a standard assumption; weakly monotone securities avoid moral hazard problems of the debtor manipulating the payoffs (e.g., destroying some output) to minimize the payout to the creditors.

new security, $\hat{s}(y),$ using the original security as collateral; so, $0 \leq \hat{s}(y) \leq y.$ Two examples of feasible securities at t=1, which will play roles later, are:

(i) A "vertical strip," i.e., $\hat{s}(x) = \kappa s(x)$ where $\kappa \in [0,1]$ is a pro rata share of the original contract (i.e. agent B sells the fraction κ of his security to agent C.)

(ii) A tranche or "horizontal slice," is as follows. Suppose s(x)=min[x,D] was issued originally at t=1. Then, at t=1, agent B could create a new security using s(x) as the collateral. In particular, agent B could design a new bond $\hat{s}(x) = \min[s(x), \hat{D}],$ with $\hat{D} \leq D$.[7]

Regarding the set of date 1 securities, we only assume limited liability and allow $\hat{s}(y)$ to be non-monotonic in y.[8]

B. Information

There are two types of information, public information z about the distribution f(x) and private information (production) about the realization of x. We assume that at date 0 agents have symmetric information and the prior on X is given by the distribution $F(x,z_0)$ with density $f(x,z_0).$

Public News: At date 1, before agent B and agent C interact, a public signal z is realized. The signal z is publicly observed, but is non-contractible. Signal z induces the posterior distribution $F(x,z) \equiv F_z.$ We assume that the set of posteriors $\{F_Z\}$ satisfies the Monotone Likelihood Ratio Property (MLRP) or z and x are affiliated.[9] z can be discrete or continuous. For z continuous, g(z) is the density of z and the prior satisfies $f(x, z_0) = \int g(z) \cdot f(x \mid z)dz.$ If there are Z possible signals and signal z occurs with probability $\lambda_z,$ then the prior is: $f(x, z_0) = \sum_{z=1}^{Z} \lambda_z \cdot f(x \mid z).$ We assume the prior is an element of the set of posterior distributions.

Private Information Production: We assume that agent C is more sophisticated; only he can produce private information. If he pays the cost γ (in terms of utility), he learns about the true realization of x.

Agent B is supposed to represent an investor type in the economy who cannot produce information or who does not want to invest in costly information acquisition activities and thus wants to buy a security which gives other agents also the least incentive to acquire information so that he is not concerned about

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[7] This is a debt contract that writes-down the original face value D of the original debt contract to the new face value $\hat{D}$. The original bond is used as collateral for the new contract. In particular, the new debt contract is a senior tranche of the collateral, and agent B will hold the equity residual, with payoff $\max[s(x) - \hat{D}, 0].$ The new bond is a "horizontal slice" (a "tranche") of the collateral based on seniority.
[8] From a technical perspective, this is a key difference from DeMarzo and Duffie (1999) setting where at t=1 the seller becomes informed and he is only allowed to sell a fraction of the security that he has designed at t=0.
[9] See Milgrom and Weber (1982) for a definition of affiliation.

adverse selection when he re-trades the security. This is the notion of "liquidity provision" we have in mind. In liquidity management investors want to use private securities as a means of payments without the need to do any due diligence. Agent C is supposed to represent an investor type who has the financial technology to produce costly information about securities if it is profitable to do so. For example, in the case of asset backed securities (ABS) we assume that both agents may have access to all documents but agent C can build a data intensive simulation and valuation model of ABS while agent B has limited financial knowhow and cannot do this.

C. Sequence of Moves

The sequence of moves is shown in Figure 1. At t=0, agent B wants to buy a security to store his endowment. He makes a take-it-or-leave-it offer $(p_0, s(x))$ to agent A, the owner of the project (tree) X. The offer consists of a price p_0, i.e. the amount of t=0 goods agent B gives agent A, and a proposed security $s(x)$, a promise for A to deliver $s(x)$ units of goods at t=2. If agent A does not sell then there are no gains from trade at subsequent dates and the game ends. If there is trade, then at t=1, agent B owns $s(x)$ and makes a take-it-or-leave-it offer $(p_1, \hat{s}(y))$ to agent C, where y=s(x). In other words, agent B proposes to sell a security $\hat{s}(y)$ backed by y=s(x) for the price p_1 in terms of t=1 goods to agent C. If s(y)=y, then agent B wants to sell the whole s(x). Agent C decides whether to buy at the proposed conditions. Note, it is socially optimal for agent B to consume as much as possible at t=1, subject to the other agents getting their reservation utilities.

Figure 1

	A	B	C
t=0	p_0	$w-p_0$	0
t=1	0	αp_1	$w_c - p_1$
t=2	$x - s(x)$	$y - \hat{s}(y)$	$\hat{s}(y)$

One interpretation of what is happening in the model is as follows. Agent A originates loans, in an environment where there is no private information. Asset-backed securities are then designed to meet the demands of rational but less sophisticated investors (agent B) who use these assets to store their wealth, but who are concerned about facing potential adverse selection in the secondary market when they have to sell the security. Examples of B agents could include insurance companies or pension

funds. Or we can interpret agent B as a (regional) bank that has excess cash at t=0; the bank wants to store the cash by using s(x). At t=1, the bank wants to sell s(x) to agent C to raise cash. Since agent B cannot produce information, agent B wants to buy a security that is least prone to potential adverse selection.

4. Equilibrium of the B-C Game at t=1

We solve the game by backward induction and analyze the game between agent B and agent C at t=1 first. Suppose agent B owns s(x) at t=1. Let y=s(x). Agent B proposes the offer (p_1, $\hat{s}(y)$) to maximize his expected utility. Agent C decides whether to produce information at the cost γ (in terms of utilities) and then whether to buy. We first derive a new measure that captures agent C's incentive to produce information.

A. Information Acquisition Sensitivity

Suppose at t=1 agent B owns asset y with distribution F(y). As mentioned, agent B is not constrained to sell y, but can offer to sell to agent C any new contract $\hat{s}(y)$ that takes y as the underlying collateral. In other words, agent B can choose any security from the set $\{\hat{s} : \hat{s}(y) \leq y\}$ and a price, p_1, to maximize his utility subject to the constraints that agent C is willing to buy and can produce information. To save on notations we use p and s(y) in this section.

Suppose agent B proposes the contract (p, s(y)) to agent C, i.e. an agent C can buy the security s(y) at price p. The value of information for agent C is defined as $\pi = EU_C(I) - EU_C(NI)$, where $EU_C(I)$ is the expected utility based on the optimal transaction decision in each state under perfect information about x (I), and $EU_B(NI)$ denotes the expected utility of an optimal transaction decision based on the initial information, i.e. no information about the true state (NI). Since the cost of producing information is γ, agent C produces information if $\pi > \gamma$. Thus the value of information captures the incentive of an agent to acquire information about the payoff of the security. Therefore, we call π the information acquisition sensitivity (IAS) of security s(y).

Lemma 1 (Information Acquisition Sensitivity): Define $\pi_L(p) \equiv \int_{y_L}^{y_H} \max[p - s(y), 0] \cdot f(y)dy$ and

$\pi_R(p) \equiv \int_{y_L}^{y_H} \max[s(y) - p, 0] \cdot f(y)dy$. The value of information to agent C or the IAS π of s(y) is given as follows: (i) If $p \leq E[s(y)]$, then $\pi(p) = \pi_L(p)$. (ii) If $p \geq E[s(y)]$, then $\pi(p) = \pi_R(p)$.

__Proof__

Suppose agent C is uninformed. If $p \le E[s(y)]$, he buys s(y) and $EU_C(NI, trade) = w + E[s(y)] - p$.

If $p \ge E[s(y)]$, then $EU_C(NI, no\ trade) = w$. If agent C obtains information he buys (does not buy) in

state y where $p \le s(y)$ ($p \ge s(y)$). So $EU_C(I) = w + \int_{Q_>} (s(y) - p) \cdot f(y) dy$ where

$Q_> \equiv \{y \,|\, s(y) \ge p\}$. Define $Q_< \equiv \{y \,|\, s(y) \le p\}$. So $Q_< \cap Q_> = Q = [y_L, y_H]$. If $p \le E[s(y)]$,

$IAS = EU_C(I) - EU_C(NI, trade) = \int_{Q_>} (s(y) - p) \cdot f(y) dy - \int_{Q} (s(y) - p) \cdot f(y) dy = -\int_{Q_<} (s(y) - p) \cdot f(y) dy$

$= \int_{Q} \max[p - s(y), 0] \cdot f(y) dy$ If $p \ge E[s(y)]$, $IAS = EU_C(I) - EU_C(NI, no\ trade) = \pi_R$.**QED**

These results are very intuitive. For $p \le E[s(y)]$, an uninformed agent C is willing to buy. Information changes his trading decision and he does not buy in states x where s(y)<p. The value of information is that he avoids paying too much for the security in low states. Integrating over all x with p-s(y)>0 yields $\pi = \pi_L$. For $p > E[s(y)]$, an uninformed agent is not willing to buy. If he is informed, he will buy in states x where s(y)>p. The value of information is that he avoids the "mistake" of not buying the security in high states. Therefore, $\pi = \pi_R$. Note, at p=E[s(x)], the expected loss in low payoff equals the expected gains in high payoff states. So $\pi_L(p) = \pi_R(p)$. See Figure 2.

Figure 2

__Lemma 2:__ Consider the set of all securities with the same expected payoff. For any f(y) and price p, debt minimizes $\pi_L(p, s(y))$ and $\pi_R(p, s(y))$.

Proof

For $p \leq E[s(y)]$, the IAS of debt is the integral $\pi_L^D = A$ while the IAS of s(y) is the integral $\pi_L^S = A + B$ as depicted in Figure 3. Therefore, $\pi_L^D \leq \pi_L^S$ for any f(y). For $p \geq E[s(y)]$, the IAS of debt is $\pi_R^D = D + E$ while the IAS of s(x) is $\pi_R^S = E + F$. Note, we compare all securities with the same expected value, say V, i.e. E[s(y)]=E[s^D(y)]=V. For debt, the probability weighted integrals B+C+D+E=V while for s(x), C+E+F=V. This implies F=D+B. Since B>0, $\pi_R^D < \pi_R^S$.

QED

Figure 3

Dang, Gorton and Holmström (2011b) provides a full characterization of the IAS of a security and show that it is identical for the buyer and seller of a security. They also derive the full set of securities with the minimal IAS. Dang, Gorton and Holmström (2011a) show that IAS is an important determinant of haircuts in repo trading.

B. The Optimal Contract at t=1

The next proposition derives the contract $(p_1, \hat{s}(y))$ that maximizes agent B's expected utility and characterizes equilibrium behavior at t=1. Suppose agent B offers to sell y for p=E[y], then

$$\pi^{Max} \equiv \int_{y_L}^{y_H} \max[p - y, 0] \cdot f(y) dy.$$

**Proposition 1**: Agent B owns y=s(x) at t=1. Agent B proposes the following contract (p,s(y)) to agent C.

(i) If $\gamma \geq \pi^{Max}$, then any contract with E[s(y)]=min[w_C, E[y]] and p=E[s(y)] is optimal for agent B to sell. Agent C buys without information acquisition.

(ii) If $\gamma < \pi^{Max}$, then depending on { $\alpha, w_C, \gamma, F(y)$} agent B chooses either:

Strategy I (Avoid information acquisition): Offer a debt contract p_1=E[s(y)] such that agent C does not acquire information; or

Strategy II (Induce information acquisition): Choose a debt contract p_1>E[s(y)] that induces C to acquire information, and exactly covers C's cost of information production, γ, while maximizing $(\alpha - 1) \cdot p \cdot prob(trade)$.

**Proof**

(i) If $\gamma \geq \pi^{Max}$, it is easy to see that it is optimal for agent B to sell s(y) with E[s(y)]=min[w,E[y]] and p=E[s(y)] to agent C. Agent C buys and does not produce information and gets no rents.

(ii) If $\gamma < \pi^{Max}$, there are two cases. (a) $E[y] \leq w_C$ and (b) E[y]>w_C.

(a) $E[y] \leq w_C$. Agent C has enough endowment to buy the whole y. But if agent B sells s(y)=y for p=E[y], agent C acquires information. So agent B considers two strategies:

Strategy I: From Lemma 2, the maximum amount agent B can sell without triggering information acquisition is a debt contract with p_1=E[s^D(y)]=V such that

$$\int_{y_L}^{y_H} \max[V - s^D(y),0] \cdot f(y)dy = \gamma.$$

The face value D^I of the debt contract solves:

$$\int_{y_L}^{y_H} \min[y, D^I] \cdot f(y)dy = p_1.$$

See Figure 4.

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Figure 4

Agent B's expected utility is $EU = E[y] + \alpha p_1 - E[s^D(y)] = E[y] + \alpha p_1 - p_1$. If γ is small, then p_1 is small and agent B can consume little at t=1. Whenever agent B proposes a price higher than V, then $\pi_L \geq \gamma$.

Strategy II: Agent B proposes an offer that induces agent C to acquire information. Agent C does not always buy but if trade occurs agent B can get a higher price and consume more at t=1. We derive this strategy in three steps.

Step 1: A contract s(y) that induces agent C to produce information must have (i) $\pi_L \geq \gamma$, and (ii) $\pi_R \geq \gamma$ (i.e. if agent C buys in high states, he can cover his information cost). Since trading the efficient amount of s(y) for p=E[s(y)] triggers information production, we have $\pi_L > \gamma$ which implies $\pi_R > \gamma$ (Note that for p=E[s(y)], $\pi_L = \pi_R$.) Since agent B is maximizing his utility, he chooses a price and security with $\pi_R = \gamma$ which implies $p > E[s(y)]$. Consider the offer $(p_1, s(y))$ with $p_1 > E[s(y)]$ that triggers information production, i.e. $\pi_R \geq \gamma$. See Figure 5. Trade occurs and agent B consumes p_1 if agent C learns that $y \geq y'$. Otherwise there is no trade.

Figure 5

Step 2: Now we show that a debt contract with the same price and same IAS gives rise to a higher probability of trade. See Figure 6.

Figure 6

Trade occurs and agent B consumes p if agent C learns that $y \geq y''$. Since debt minimizes y'', the probability of trade is maximized. Therefore, debt with price p dominates any contract (p,s(y)) with

$$\pi_R^D = \pi_R = \gamma.$$

<u>Step 3</u>: Now we derive the optimal price and face value of debt. Agent B sells debt, i.e. $s^D(s(x)) = \min[s(x), D]$ with price p and face value D to maximize

$$EU_B = (1 - F(p))\alpha p - E[s^D(s(x)) \mid trade] + E[s(x)]$$

s.t.

$$\int_{x_L}^{x_H} \max[s^D(s(x)) - p, 0] f_Z(x) dx = \gamma \cdot$$

Note, for s(x)=x, we have:

$$E[s^D(x) \mid trade] = E[s^D(x) \mid x \geq p] = \int_p^{x_H} \min[x, D] f(x) dx$$

$$= \int_p^{x_H} p f(x) dx + \gamma = (1 - F(p)) p + \gamma \cdot$$

Substituting in yields

$$EU_B = (1 - F(p))\alpha p - E[s^D(s(x)) \mid trade] + E[s(x)]$$

$$EU_B = (1 - F(p))(\alpha p - p) - \gamma + E[x]$$

which agent B maximizes by choosing the optimal price.

<u>Optimal Choice</u>

Consequently, agent B chooses Strategy I if:

$$EU_B(I) = \alpha p^I - p^I + E[s(x)] \geq EU_B(II) = (1 - F(p)(\alpha p^{II} - p^{II}) - \gamma + E[s(x)].$$

Otherwise he chooses Strategy II.

(b) $E[y] > w_C$. If $w_C \leq V$, agent B sells debt with $E[s(y)] = w_C$ and $p = w_C$. Agent C does not acquire information. If $w_C > V$, agent B chooses either Strategy I or Strategy II. **QED**

Proposition 1 shows that depending on the gains from trade and the information cost, the best response of agent B is either to reduce trade and avoid adverse selection or induce information acquisition and trade more but face a positive probability of no trade. In both cases debt is the optimal security. This result is different from the equilibrium of a game where an uninformed buyer makes an offer and the security seller can learn. Dang, Gorton and Holmström (2011) show that there is never endogenous adverse selection in equilibrium even if the information cost is vanishingly small.

Corollary 1.1: Suppose agent C is privately informed ($\gamma = 0$). The optimal contract that agent B offers to sell to agent C is a debt contract $s^D(y)=[y,D]$ with face value D=p and price p that maximizes $(1-F(p))p$.

Proof

Under Strategy II, agent B chooses a price and face value D to maximize

$$\int\limits_{\{y:s(y)\geq p\}} p \cdot f(y)dy$$

where $\int\limits_{x_L}^{x_H} \max[\min[s(y),D]-p,0]f(y)=0$. Therefore, D=p. **QED**

5. The Optimal Choice of a Collateral Security at=0

Above we assumed that agent B owned arbitrary collateral, y=s(x), and used that as the backing for a security to trade with agent C. We now ask: what is the optimal collateral security y, that agent B wants to own when he re-trades with agent C at t=1. The game between agents A and B, taken by itself, is a standard corporate finance problem, although here there is no private information. Even if there is no adverse selection problem in the primary market, still the contract that is issued by agent A is very important from the point of view of agent B. This contract will change in value when the public signal arrives at t=1, and will be the collateral for a contract traded between agents B and C at t=1.

As mentioned above, Dang, Gorton and Holmström (2011b) analyze an optimal security design problem where an uninformed buyer faces a security seller who can acquire costly information. They show that it is optimal for the buyer to buy debt and there is never endogenous adverse selection in equilibrium in the primary market even if the information cost is vanishingly small. The buyer either reduces the amount of debt to buy or bribe the seller not to acquire information by paying a price higher than expected payoff of debt. In that model there is no secondary market and no re-trade. The present paper focuses on optimal security design for re-trade in secondary markets when there is interim public news and potential production of private production when the security is re-traded.

A. The Effects of Public News on the Fundamental Value

Suppose agent B has purchased s(x) from agent A at t=0. When there is a public signal z at t=1, it reveals that F(x|z) is the posterior distribution, and then the resale value of the security s(x) changes; this is the public news sensitivity. The value of s(x) at t=1 is given by:

$$V(z) = E[s(x) \mid z] = \int\limits_{x_L}^{x_H} s(x) \cdot f(x|z)dx .$$

Now we compare the new fundamental value $V^D(z)$ of debt with $V(z)$ the value of an arbitrary contract $s(x)$, where $E[s^D(x)]=E[s(x)]$ at t=0. We have assumed that (x,z) are affiliated. Affiliation and $s(x)$ non-decreasing implies that $V(z)$ and $V^D(z)$ are non-decreasing (see Milgrom and Weber (1982)). Furthermore, affiliation implies that $V(z)$ cuts $V^D(z)$ once from below (see Lemma 1 in DeMarzo, Kremer, and Skrzypacz (2005)).[10] So, looking at the value of debt, $V^D(z)$, and the value of any other feasible contract, $V(z)$ as functions of z, the situation is a portrayed below in Figure 7.

Figure 7

Note, agent C has at most w_C to trade; so we will compare $E[\min(V^D(z),w_C)]$ to $E[\min(V(z),w_C)]$ where the expectation operator is taken with respect to z. The optimal security is the one which delivers the highest value to agent B. For $w_C \le w$, it is apparent from the figure that this is debt; debt dominates for all $z_0 < z$ and both contracts are bounded by w for $z > z_0$. Now suppose agent C has $w_C > w$. See Figure 7.

The following arguments show that the truncated (blue) debt contract has a higher expected value than the truncated (green) arbitrary contract in the z-space. At t=0, $E[s^D(x)]=E[s(x)]$, i.e.

$$\int\limits_{z_L}^{z_H} V^D(z)dG(z) = \int\limits_{z_L}^{z_H} V(z)dG(z)$$

which implies that

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[10] We use their Lemma in DeMarzo et al. (2005) to derive the optimality of debt. Interestingly, they use the lemma to show that debt is the "worst" security for a seller to choose in a private value auction context.

$$A \equiv \int_{Z_L}^{Z_0} (V^D(z) - V(z))dG(z) = \int_{Z_0}^{Z_H} (V(z) - V^D(z))dG(z) \equiv B + C.$$

The truncation $\min[V(z), w_C]$ at z_C (where z_C is defined by $V^D(z_C) = w_C$) means

$$A = \int_{Z_L}^{Z_0} (V^D(z) - V(z))dG(z) > \int_{Z_0}^{Z_C} (\min[V(z), w_c] - V^D(z))dG(z) = B$$

Adding $D \equiv \int_{Z_C}^{Z_H} w_c dG(z)$ to the LHS and the RHS of the inequality and rearranging terms yields

$$\int_{Z_L}^{Z_0} V^D(z)dG(z) + \int_{Z_0}^{Z_C} V^D(z)G(z) + \int_{Z_C}^{Z_H} w_c dG(z)$$
$$> \int_{Z_L}^{Z_0} V(z)dG(z) + \int_{Z_0}^{Z_C} (\min[V(z), w_c]dG(z) + \int_{Z_C}^{Z_H} w_c dG(z)$$

which is equivalent to

$$\int_{Z_L}^{Z_H} \min[V^D(z), w_c]dG(z) > \int_{Z_L}^{Z_H} \min[V(z), w_c]dG(z) \quad \text{for all } w_C < V(z_H).$$

We have shown:

Proposition 2 (Debt maximizes trading capacity): Suppose there is a public signal at $t=1$ and that no agent can produce private information. The equilibrium has the following properties:

- At $t=0$, agent B buys debt from agent A with $E[s^D(x)] = w$ and $p = E[s^D(x)]$.

- At $t=1$, agent B sells the whole debt for the price $p_z = V(z)$, if $w_C \geq V^D(z)$. Otherwise he sells $\kappa s^D(x)$ such that $\kappa E_z[s^D(x)] = w_C$ for the price w_C and consumes $E_z[s^D(x)] - w_C$ at $t=2$.

Intuitively, this proposition states that bad interim news reduces what agent B can sell to agent C, since they trade the amount $V^D(z) < w_C$; and with good interim news agents B and C trade at most what agent C owns, i.e. the amount w_C. The proposition shows that debt maximizes what agent B can trade and consume at $t=1$, if there is bad news. Other securities may have a higher value if there is good news. But in that case agent C does not have enough goods to buy the whole security, i.e. $w_C < V^D(z)$. In other words, securities with a high variance of resale prices are less attractive for liquidity provision than those with low price fluctuations.

Corollary 2.1 (Welfare reducing public information): (i) Under imperfect public information z the utility of agent B is strictly less than under ignorance if $w_c < V^D(z_H)$. (ii) Under perfect public information the utility of agent B is strictly lower than under ignorance if $w_c < D$. (iii) If public information reduces welfare when debt is traded, than the welfare loss is higher when s(x) is traded.

Proof

If there is no public news agent B sells s^D(x) for the price $\int_{x_L}^{x^H} \min[x, D] f(x) dx$ to agent C. If agent B and C learns about z before trading, then $\int_{z_L}^{z_H} \min[V(z), w_c] dG(z) < \int_{z_L}^{z_H} \min[V^D(z), w_c] dG(z)$

$< \int_{z_L}^{z_H} V^D(z) dG(z) = \int_{x_L}^{x^H} \min[x, D] f(x) dx$. **QED**

In the rest of the paper we assume w_C=w.

In the context of liquidity provision we interpret w as the exact amount that agent B wishes to obtain at t=1. If we think of agent B as a bank, then we can interpret w is the amount of liabilities he has to repay. He does not benefit much from obtaining more than w but he may suffer a utility loss when he obtains less than w. If agent B is a consumer, he may need w to buy an indivisible consumption good. If he obtains less than w he is not able to buy the desired consumption good. If he obtains more than w then the marginal value is one for any extra amount he obtains.

Corollary 2.2: Suppose $w \geq E[X]$. Under perfect public information the utility of agent B is strictly lower than under ignorance if $w < x_H$.

These results show that even if agents have linear utility functions, welfare under ignorance is higher than the welfare in a setting where agents have symmetric and partial or perfect information. The reason for this observation is that the utility function of agent B, although linear, has a kink at the endowment level w of agent C. Therefore, if x>w, agent B must consume some x at t=3. Thus for x<w, the utility function of agent B has slope α and for x>w, the slope is 1. So although agent B's intertemporal utility function is linear in consumption, the fact that $w \in (x_L, x_H)$ induces concavity in agent B's utility function. Thus ignorance at the date of trade strictly dominates perfect information or partial information if $E[x|I] < w$ for some information I. In the example above, the information I reveals the true x. This is reminiscent of Hirshleifer (1971).

B. The Effect of Public News on Information Acquisition Sensitivity

Whether trading the security s(x) at t=1 triggers information acquisition by agent C or not depends on the date 1 information acquisition sensitivity, $\pi(z)$, of that asset relative to the information cost γ. Since ("fair") prices $p_z = E[s(x)|z]$ fluctuate with the public signal z, $\pi(z)$ (i.e., the information-sensitivity after F(x|z) has been revealed publicly) also changes with the public signal since:

$$\pi(z) = \int_{x_L}^{x_H} \max[p_z - s(x), 0] \cdot f(x|z)dx \text{ where } p_z = \int_{x_L}^{x_H} s(x) \cdot f(x|z)dx.$$

Since s(x) is non-decreasing, prices are monotonic in z because of FOSD. But the IAS, $\pi(z)$, of a security is a more complicated object. Even with the assumption of FOSD or MLRP, $\pi(z)$ is typically non-monotonic in z.

The intuition is the following: Bad news (a distribution with more mass in the left tail) reduces the price of the security, and thus the "area" between the price and s(x). But, on the other hand, that smaller area is evaluated with more probability mass. The overall effect is ambiguous. Similarly, good news increases the price but there is less probability mass on the left tail.

The following example and Figure 8 illustrate that $\pi(z)$ is non-monotonic. Suppose the set or posteriors is given as follows: $F_1 \sim u[0, 0.05]$, $F_2 \sim u[0, 0.1]$, $F_3 \sim u[0, 0.15]$,.., $F_{59} \sim u[0, 2.95]$, $F_{60} \sim u[0, 3]$, $F_{61} \sim u[0.05, 3]$,...., $F_{119} \sim u[2.95, 3]$, and $\lambda_i = \frac{1}{119}$. Then the prior is $F \sim u[0,3]$. At t=1, if debt with face value D=1 is issued then $p_1^D = E[s^D(x)] = \frac{5}{6}$, $\pi^D(m) \approx 0.116$. At t=2, if $F_z = F_{30} \sim u[0,1.5]$, then $p_2^D(30) = V^D(30) = \frac{2}{3}$ and $\pi^D(30) \approx 0.1482$. IAS is maximal at z=30. The thick blue curve depicts the information sensitivity of debt and the thin light blue curve depicts the fundamental value of debt as a function of the public signal.[11]

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[11] If X is either x_L or x_H and prob(x=x_L)=q, then IAS=(1-q)q(x_H-x_L) is single peaked and non-monotonic in q.

Figure 8

IAS and Fundamental Value of Debt

C. Equilibrium of the A-B-C Game

Now we are in the position to characterize the set of Perfect Bayesian Nash equilibria (BNE) in the full game with interim public news arrival about the distribution of x and the possibility of information acquisition by agent C. The proposition for the equilibrium of the whole game introduces a condition (i.e. $(\alpha - 1)w < \gamma$) which is a sufficient for the optimality of debt, i.e. debt point-wise dominates any s(x) in the z-space. The condition implies that the total surplus agent B can get is smaller than the information production cost. This means that in equilibrium there is no adverse selection. Yet there can be a collapse of trade.

Proposition 3   (Debt Equilibrium): Suppose $(\alpha - 1)w < \gamma$. Equilibrium trade has the following properties.

At t=1 agent B buys debt from agent A with face value D and price $p_1 = E[s^D(x)] = w$.

At t=2, agent B sells a (new) debt contract that does not induce information production. He sells $\hat{s}^D(x)$ with price p_2 and face value $\hat{D}$ where $p_2 = \min[p', w]$ and

$$\int_{x_L}^{p_I} (p'-x) f(x \mid z) dx = \gamma \text{ and } \int_{x_L}^{x_H} \min[x, \hat{D}] f(x \mid z) dx = p_2.$$

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Proof:

Step 1 (t=1)

Proposition 2 shows that at t=1 agent B (always) sells debt to agent C backed by whatever s(x). $(\alpha-1)w<\gamma$ implies that Strategy I strictly dominates Strategy II. Note, the maximum price agent C can pay is w. If agent B induces information production, trade occurs with probability strictly smaller than 1. So $(\alpha-1)\cdot prob(trade)\cdot w<(\alpha-1)w<\gamma$. In other words, the total surplus agent B can get is smaller than the information production cost. The best response is to avoid adverse selection by choosing Strategy I, i.e. reducing trading volume if this is needed to prevent information acquisition. Agent B chooses p_1 such that:

$$\int_{x_L}^{x_H}\min[p_1-s(x),0]f(x\mid z)dx=\gamma$$

and then chooses D^I such that:

$$\int_{x_L}^{x_H}\min[s(x),D^I]\cdot f(x\mid z)dx=p_1.$$

Step 2 (t=0)

It is easy to see that agent B buys a contract with E[s(x)]=min[w, E[x]] and pays p_0=E[s(x)] at t=0. In the worst case scenario of no trade at t=1, agent B can consume E[s(x)] at t=2. But he can do better when there is trade at t=1 so that he can consume at his preferred date 1. Suppose w<E[x]. (The other case is completely analogous.) We show that a t=0 debt contract dominates any s(x) at t=0. So consider an arbitrary s(x) with E[s(x)]=w and a debt contract $s^D(x)$ with E[s^D(x)]=w.

Case I: Suppose there is no adverse selection concern at t=1 when trading the whole s(x) for p_1=E[s(x)|z] at t=1. (i) Suppose selling the whole debt does not trigger information acquisition as well. Since there is no adverse selection concern, Proposition 2 shows that t=0 debt maximizes agent B's expected consumption at=1. (ii) Suppose selling the whole debt triggers information acquisition. In that case agent B creates a new debt contract $\hat{s}^D(y)$ backed by y=s^D(x) such that p_1=E[$\hat{s}^D(y)$|z]=E[s(x)|z]$\leq w$. Given any price p_1, $\pi^D(z)<\pi(z)$. See Figure 3. In other words, with a t=0 debt, agent B can replicate any outcome that he can achieve by buying s(x) at t=0.

Case II: Suppose there is adverse selection concern at t=1 when selling the whole s(x) for p_1=E[s(x)]. We now show that also in this case it is optimal for agent B to buy debt from agent A at t=0 since selling a debt contract at t=1 (backed by a t=0 debt contract) maximizes t=1 trading volume without

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triggering information production. At t=1, we know from Proposition 1, agent B sells debt with face value D backed by s(x). So

$$\pi_L(z) = \int_{x_L}^{x_H} \max[\, p_1 - \max[\, s(x), D], 0]\cdot f(x\,|\,z)dx\,.$$

Denote $\hat{p}$ as the price such that $\int_{x_L}^{x_H} \min[\hat{p} - s(x), 0]f(x\,|\,z)dx = \gamma$. Now suppose B buys debt with the same expected payoff as s(x) from agent A at t=0. If he sells a new debt contract backed by the t=0 debt for the price $\hat{p}$, then

$$\pi^D(z) = \int_{x_L}^{x_H} \max[\, \hat{p} - \max[\, x, D], 0]\cdot f(x\,|\,z)dx < \gamma$$

because $s(x) < x$ for some x$< \hat{p} \leq w$. Therefore, using a t=0 debt as collateral maximizes trade at t=1 without triggering information acquisition by agent C. In Figure 9 the maximal price p_1 agent B can get is denoted by p^S if he owns s(x). If he buys debt from agent A then the maximal price he can get at t=1 is $p^D>p^S$. **QED**

Figure 9

Proposition 3 states that at t=0 agent B buys debt from agent A. At t=1, depending on the public signal, the following outcomes can arise. If there is good news, i.e. $V^D(z) \geq E[s^D(x)]$ or news such that $\pi^D(k) < \gamma$ then there is efficient debt trading between agents B and C. In other words, agent B consumes the maximum he can afford to buy or what agent C owns, i.e. $c_{B2}=\min\{V^D(z),w\}$ at t=1. So

agent B sells his whole debt if $V^D(z) \le w$. He sells a fraction κ such that $\kappa V^D(z) = w$ if $V^D(z) > w$. Note, in these states agent B has many choices to create a security with expected payoff w. It is in this sense that there are many BNE but in all of them agent B consumes w at t=1.

With bad news that causes the IAS of the original debt contract to rise sufficiently, there is a collapse of trade. There is insufficient debt trading in the sense that agents B and C trade less than the (new) market value of agent B's debt. That is, the price that is traded is lower than the new conditional value of the debt (the "fundamentals"). This case corresponds to "systemic risk" in the sense that the outcome is worse than that caused only by the fundamentals, where the "fundamentals" correspond to the bad shock z. Instead of trading at the new expected value of the debt conditional on z, agents trade much less than they could or even not at all. In this sense there is a collapse of trade.

Proposition 3 is perhaps best understood with an example.

Numerical Example

Suppose $F_1 \sim u[0,0.8]$, $F_2 \sim u[0.8, 1.2]$, $F_3 \sim u[1.2, 2]$ and $\lambda_1 = \lambda_2 = \varepsilon$, and $\lambda_3 = 1 - 2\varepsilon$. Then the prior is $f(x)=5\varepsilon/4$ for $x\in[0,0.8]$, $f(x)=5\varepsilon/2$ for $x\in[0.8,1.2]$, $f(x)=5(1-\varepsilon)/4$ for $x\in[1.2, 2]$ and $f(x)=0$ else. Suppose $\varepsilon=0.00001$, $w=1$, $\gamma = 0.001$, and $\alpha = 1.001$. The subsequent numbers are exact up to the fourth decimal. Note, E[x]=1.6.

In this example, agent B buys debt with face value $D_0=1$ and price $p_0=1$. Equilibrium outcomes at t=1 are as follows.

(i)   If F_1 is the true distribution, then $V^D(1) = 0.4$. If he sells the whole debt for 0.4, then $\pi_1^D(1) = 0.1 > \gamma$. Agent B sells a new debt contract with face value $D_1(1) = 0.0411$ and $p_1(1) = E[\hat{s}^D(x)] = 0.04$. In other words, agent B sells a new debt contract, i.e. 10% percent of expected cash flow as a senior tranche.

(ii)   If F_2 is the true distribution, then $V^D(2) = 0.95$ and $\pi_1^D(2) = 0.0281$. Agent B sells a new debt contract with face value $D_1(1)=0.8293$ and $p_1(2) = E[\hat{s}^D(x)] = 0.8283$.

(iii)   If F_3 is the true distribution, then $V^D(3) = 1$ and $\pi_1^D(3) = 0$. Agent B sells the t=0 debt with D=1 for $p_1(3) = E[\hat{s}^D(x)] = 1$.

To summarize this example, if there is good news (i.e., F=F_3), there is efficient trade between agents B and C at t=1. If there is bad news (i.e., F=F_2), then the market price of debt drops from 1 to 0.95 and agent C buys a senior tranche of 87.2% of agent B's debt. This can be interpreted as a haircut of

12.8%. If there is very bad news (i.e., $F=F_1$), then the market price of debt is 0.4. Agent B offers to sell a senior tranche of 10% of its original debt for a price 0.04.[12]

To facilitate comparison, suppose agent B buys equity from agent A at t=0, i.e. agent B chooses $s^E(x) = \frac{5}{8}x$ and $p^E = E[s^E(x)] = 1$. At t=1,

> (i)   If F_1 is the true distribution, then $V^E(1) = 0.25$ and $\pi^E(1) = 0.0625$. Agent B sells debt backed by $s^E(x)$ for $p_1(1) = E[\hat{s}^D(x)] = 0.0316$.
>
> (ii)   If F_2 is the true distribution, then $V^E(2) = 0.625$ and $\pi^E(2) = 0.0313$. Agent B sells debt backed by $s^E(x)$ for $p_1(2) = E[\hat{s}^D(x)] = 0.5223$.
>
> (iii)   If F_3 is the true distribution, then $V^E(3) = 1$, $\pi^E(3) = 0.0625$. Agent B sells debt backed by $s^E(x)$ for $p_1(3) = E[\hat{s}^D(x)] = 0.7816$.

If agent B buys equity from agent A, then he is strictly worse off for all realization of the public signal z than the case where he buys debt from agent A at t=0 since trading the whole equity contract triggers information acquisition in all three signal states.

Corollary 3.1: The equilibrium amount of trade is monotonic in the public signal z.

Proof

Definition: Signal z is better than z' if

$$V(z) = \int_{x_L}^{x_H} s(x) \cdot f_z(x)dx \geq \int_{x_L}^{x_H} s(x) \cdot f_{z'}(x)dx = V(z').$$

If there is a need to write down debt, the equilibrium amount p' of trade given z' is given by

$$\int_{x_L}^{p'} (p'-x)f_{z'}(x)dx = \gamma$$

Trade of p' under signal z implies

$$\int_{x_L}^{p'} (p'-x)f_z(x)dx \leq \gamma$$

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because of affiliation and z is better than z'. If the inequality is strict and p'<w, than agent B trades and consumes p=E[s^D(x)|z]>p'=E[s^D(x)|z'] under signal z. Note, affiliation implies FOSD. **QED**

In general, public news that triggers a reduction in trade and consumption is a signal that results in $\pi(z) > \gamma$. We assume that the cost of producing information is a fixed amount, γ. Once the threshold $\pi(z) > \gamma,$ is crossed agents are concerned about potential adverse selection. This is the "loss of confidence" and the source of the suddenness of the financial crisis when information-insensitive debt becomes information-sensitive.

Proposition 4: Suppose $\gamma = 0$ (i.e. agent C is informed). At t=0, agent B buys debt from agent A with p=E[s(x)]=w. At t=1, agent B chooses a new debt contract s^D(s(x)) with face value D^I and price p_1 to maximize $(1 - F(p_1)) \cdot p_1$ where D^I=p$_1$.

Proof

A t=0 debt contract (strictly) dominates any s(x) since for any $\hat{p} \leq w$,

$$\alpha \int_{\{x:x \geq p_1\}} p_1 \cdot f(x \mid z)dx \geq \alpha \int_{\{x:s(x) \geq p_1\}} p_1 \cdot f(x \mid z)dx.$$

Note s(x)<x for x<w, the probability of obtaining any p_1 is maximized if agent B start with a t=0 debt contract. See Figure 6. **QED**

6. Discussion and Extensions

In this section we discuss some of the modeling assumptions and also some extensions of the model.

A. Model Assumptions

Proposition 3 derives the optimality of t=0 debt under the assumption that $(\alpha - 1)w < \gamma$, i.e. there is no endogenous adverse selection in equilibrium. The reason why we impose this sufficient condition for the optimality of debt is that it is not easy to calculate the ex ante probability of optimal endogenous adverse selection and the amount of trade. Suppose agent B wants to induce agent C to acquire information for some public information z. In order to do so, agent B must compensate agent C for information cost. Consider the following case. Suppose agent B has bought s(x) from agent A. At t=1, it is optimal to propose a price p$_1$=w which induces agent C to acquire information. If agent B owns a t=0 debt contract and proposes p$_1$=w at t=1 that induces agent C to acquire information, then we can show that debt dominates s(x). However, our assumptions do not guarantee that with a t=0 debt agent B can compensate agent C for information cost at price p$_1$=w, i.e. $\pi_R^D(p_1 = w \mid z) \geq \gamma$. More generally, our assumptions do not guarantee the sufficient condition that at a signal z, where it is

optimal to induce agent C to acquire information under both contracts, the optimal price p_1^{D*} under debt contract and p_1^{S*} under s(x) yields:[13]

$$EU^B(debt) = p_1^{D*} \cdot prob(s^D(x) \geq p_1^{D*} \mid z) \quad \text{s.t.} \int_{x_L}^{x_H} \max\left[s^D(x) - p_1^{D*}, 0\right] f(x \mid z) = \gamma$$

$$\geq$$

$$EU^B(s(x)) = p_1^{S*} \cdot prob(s(x) \geq p_1^{S*} \mid z) \qquad \text{s.t.} \int_{x_L}^{x_H} \max\left[s(x) - p_1^{S*}, 0\right] f(x \mid z) = \gamma.$$

Note, in this model we do not impose any distributional assumptions on F(x). Instead of assuming that $(\alpha - 1)w < \gamma$, we might impose some restrictions on F(x) and the signal structure {F(x|z)} to derive the optimality of debt.

Another assumption we made is that only agent C (i.e. the responder to an offer) can produce information. If at t=1, agent B can also produce information, then we have to analyze a much more complicated game since the proposer can be informed and in that case he can signal with prices and securities. In a standard signaling game, the informed agent is endowed with an asset y and only chooses a price p to signal his type y (i.e. the realization of y). Here both the price p as well as the function s(y) are endogenous variables in a signaling problem with common values.

Conceptually, agent C can calculate whether it would pay for agent B as the proposer to produce information at t=1. If it pays for agent B to learn, then there is no pure strategy equilibrium. Seeing a low price and some s(y), equilibrium requires agent C to first randomize his information production decision. If he does not produce information then he will also randomize his acceptance decision. See Dang (2008) for a discussion of this issue. In any mixed strategy equilibrium there is a (strictly) positive probability that no trade occurs. Therefore, if both agents B and C agents can produce information, the adverse welfare implications may be more severe. We think that it is plausible to assume that agents have different abilities to run simulation and valuation models of money market instruments even if they have access to the same documents.

Proposition 3 assumes that agent C has $w_C = w$ units of t=1 goods. This bounds what agent B can consume at his desired consumption date 1. In the context of liquidity provision we interpret w as the exact amount that agent B wish to obtain at t=1. If we think of agent B as a bank we can interpret w is the amount of liability he has to repay. He does not benefit much from obtaining more than w but he may suffer a utility loss when he obtains less than w. If agent B has a linear reference point utility function at consumption level w, then Proposition 3 holds even if agent C has unbounded endowments.

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[13] The necessary condition is that ∫ EU^B(debt|z)dG(z) ≥ ∫ EU^B(s(x)|z)dG(z) where EU^B(debt|z) and EU^B(s(x)|z) denote the expected utility under the optimal offer in state z.

Suppose $U_B = c_{B0} + \alpha \cdot \min[c_{B1}, w] + \max[c_{B1} - w, 0] + c_{B2}$ and $U_C = c_{C0} + c_{C1} + c_{C2}$. Then agents B and C have no incentive to trade more than w units of t=1 consumption goods. Figure 10 illustrates the utility function of agent B when he consumes c_{B1} units. Dang, Gorton and Holmström (2011) show that if an agent has a linear reference point utility function where the reference point is the investment amount, then it is optimal to hold a portfolio with minimal information acquisition sensitivity in a standard optimal portfolio choice setting.

Figure 10

B. Financial Crises and the Lender of Last Resort

Proposition 3 displays a financial crisis as one possible equilibrium outcome. A "crisis" occurs when the price at which agents B and C trade is below the "fundamental," the conditional expected value of the debt. This crisis is an optimal outcome, but not efficient. A lender-of-last resort or central bank could improve matters.

The lender-of-last-resort's role is to facilitate trade at the fundamental price. Although not in the model, one can see that this could be accomplished in several ways. The central bank could exchange information-sensitive debt for information-insensitive debt, possibly at a subsidized price to prevent information production, or, to make the private debt, which has become information-sensitive, information-insensitive. This prevents the crisis from being worse than the shock z. The lender-of-last-resort cannot overcome the shock, but can prevent the price from dropping below the value conditional on the shock. Without intervention welfare is lower because trade occurs at the "haircut" price that is below the conditional expected value to prevent adverse selection. So, another way to summarize the role of the lender-of-last-resort is that it should prevent trade at these "fire sale" prices. But, as presently constituted the model has no agents to tax at the final date to support the central bank's actions.

C. Security Design, Complexity and Transparency

Creating complicated securities can raise the cost of producing information ex ante, which can be welfare-improving as it makes the endogenous adverse selection prohibitively expensive. But, ex post if the public news causes a switch to information-sensitivity then there may be problems. In the financial crisis, many asset-backed securities were used as collateral for repo. These bonds are complicated. The internal workings of the cash flows from the underlying portfolios of loans are allocated in complicated ways, and the underlying loans themselves are complicated. See Gorton (2010). These asset-backed securities were also used as the assets in other the portfolios of other structures, such as collateralized debt obligations, asset-backed commercial paper conduits, and structured investment vehicles.

Asset complexity can facilitate trade as long as uninformed agents commonly and correctly believe that this makes information production by sophisticated agents unprofitable. But if public information about fundamentals makes the assets information-sensitive and thus information production profitable, then we argue that uninformed agents face difficulty in reselling these assets and this has a negative feedback effect on trade even between two agents that are known not to able to produce any information. There is a trade-off between creating liquidity for a sequence of trades and a sudden collapse of trade in a financial crisis. In our model assets are designed to minimize adverse selection concerns so as to facilitate intertemporal trade, but when these assets become information-sensitive less sophisticated agents are only willing to buy at very low prices or have no demand at all.

The information acquisition sensitivity (IAS) of a security is endogenous. This has implications for the discussion of transparency and welfare. The announcement of noisy public information (i.e. $f(x|z)$) can actually increase the IAS of a security and thus trigger endogenous adverse selection. In a market where agents have symmetric information introducing partial information can be welfare reducing by triggering endogenous lemons problem. In contrast, in a market with exogenous adverse selection at place providing (partial) information can reduce the lemons problem and increase trade and welfare. Our paper highlights that increasing transparency is not necessarily welfare improving, especially when the information provided is not very precise and some agents can act on these information while other cannot.

D. Rating Agencies

Rating agencies are a puzzle. Why do they exist? Equities are not rated. The standard version of "efficient markets" in equities has agents becoming privately informed and trading on their information. Prices are informative and there is no need for rating agencies. Why are debt markets different? Also, why do rating agencies only produce coarse signals, when as the critics have pointed out, risk is multi-dimensional? Our model can address these questions.

We argue that when trading in money markets agents have no need and incentive to ask questions. This raises the issue of how symmetric information about the payoff of the security is achieved in the first place. We can interpret rating agencies as a certification intermediary of the payoff distribution (i.e. $F(x)$) of the underlying assets that back debt. The announcement of $F(x)$ creates common knowledge and if debt is designed to be information acquisition insensitive then symmetric information is maintain because no agent has an incentive to produce information.

We can also address the question why ratings are coarse. One of the possible equilibrium outcomes is the possibility that agent C produces information and trade is reduced. The rating agency is a firm which commits to announce ratings just after the realization of the interim public news. For each possible distribution z that could be realized, the rating agency commits at date 1 to a set of partitions $\{I(z)\}$ of the support of distribution $F(x|z)$. These are the ratings. Upon the realization of distribution z, the agency truthfully announces the rating (partition that contains x).

How could this help? Imagine that the distribution that is realized is one for which agent C would choose to produce information. If the agency has chosen its partitions correctly, then conditional on the announcement of the partition/rating, the value of information to agent C can decline sufficiently so that he does not find it optimal to produce information; welfare is improved.[14]

7. Conclusion

Money markets are funding markets for firms and financial institutions to manage their short term cash and liability positions. The failure of these markets can cause the bankruptcy of these institutions. In money markets agents can trade billions of dollars very quickly without the need to ask questions and conduct due diligence about the security. We argue that maintaining symmetric ignorance is central for liquidity provision. The problem with trade with private money is that agents may have an inventive to produce private information and create adverse selection. We show that debt minimizes an agent's incentive to produce private information. Also, with respect to public news, debt retains the most re-trade value and minimizes the fluctuations of the resale price. Therefore, we show that information acquisition insensitive debt is private money.

Financial crises have been difficult to explain. Systemic crises concern debt. In such a crisis, agents holding debt somehow "lose confidence," usually modeled as a coordination failure. But, the coordination failure requires some mechanism other than debt per se, e.g., a sequential service constraint or a lack of common knowledge. We propose that crises and the optimality of debt for liquidity provision are inextricably intertwined. The crisis that can occur with debt is due to the fact

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[14] Dang and Felgenhauer (2012) analyze endogenous demand and supply of information in over-the-counter (OTC) markets and show that OTC traders have an incentive to look at the same rating reports as a coordination device to maximize the probability of efficient trade. This paper also shows why OTC traders have no demand for a finer rating system and that it is socially more efficient for the issuer of bonds to pay for rating services rather than having traders purchase costly rating reports.

that the debt is not riskless. But, it is not the risk per se that is the problem. Debt is designed so that no agent has an incentive to produce information about the states of the world where the risk will cause a low pay-out.

The crisis is not just the bad shock about fundamentals that back debts. Instead, the crisis is a bad enough shock to cause information-insensitive debt to become information acquisition sensitive. To avoid private information production agents can trade at a price that is less than the fundamental value of the debt conditional on the public news, so as to avoid triggering information production and endogenous adverse selection. Such a "write-down" of debt, to "fire sale" prices, can be preferred because it recovers information-insensitivity, but an inefficient amount is traded. A financial crisis is a manifestation of the "tail risk" that is endogenously created by agents in the economy in order to trade.

If maintaining symmetric ignorance is central for liquidity provision, then this has implications for the regulation of the banking and financial system. For example, should money market funds reveal their net asset value in a timely fashion? Should banks that create short term liabilities for trade, provide more information about the value of their assets on the balance sheet? Should the regulator announce the outcome of stress test of banks so that investors have better information about individual banks? We show that the public provision of imperfect information can reduce liquidity because it can make information insensitive debt become information acquisition sensitive and triggers endogenous adverse selection concerns. When agents have an incentive and need to ask questions about the value of cash-liked instruments, these financial instruments will lose their cash-liked property. Since money markets are vital for the real economy, more theoretical and empirical research about the markets for liquidity provision is needed.

References

Allen, Franklin, Ana Babus and Elena Carletti (2009), "Financial Crises: Theory and Evidence," European University Institute, working paper.

Andolfatto, David (2009), "On Informationally Efficient Markets and Efficient Outcomes in Monetary Economies," Simon Fraser University, working paper.

Biais, Bruno and Thomas Mariotti (2005), "Strategic Liquidity Supply and Security Design," *Review of Economic Studies*, vol. 72(3), 615-649.

Carlsson, Hans and Eric van Damme (1993), "Global Games and Equilibrium Selection," *Econometrica* 61, 989-1018.

Dang, Tri Vi (2008), "Bargaining with Endogenous Information," *Journal of Economic Theory 140*, 339-354.

Dang, Tri Vi and Mike Felgenhauer (2012), "Information Provision in Over-the-Counter Markets", *Journal of Financial Intermediation 21*, 79-96.

Dang, Tri Vi, Gary Gorton and Bengt Holmstrom (2011a), "Haircuts and Repo Chains", working paper.

Dang, Tri Vi, Gary Gorton and Bengt Holmstrom (2011b), "Information Acquisition Sensitivity", working paper.

DeMarzo, Peter (2005), "The Pooling and Tranching of Securities: A Model of Informed Intermediation," *Review of Financial Studies* 18(1), 1-35.

DeMarzo, Peter and Darrell Duffie (1999), "A Liquidity-Based Model of Security Design," *Econometrica* 67(1): 65-99.

DeMarzo, Peter, Ilan Kremer and Andrzej Skrzypacz (2005), "Bidding with Securities: Auctions and Security Design," *American Economic Review* 95(4): 936-959.

Diamond, Douglas and Philip Dybvig (1983), "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy*, vol. 91, 401-419.

Goldstein, Itay and Ady Pauzner (2005), "Demand-Deposit Contracts and the Probability of Bank Runs," *The Journal of Finance* 60, 1293-1327.

Gorton, Gary (1988), "Banking Panics and Business Cycles," *Oxford Economic Papers* 40, 751-81.

Gorton, Gary (1985), "Bank Suspension of Convertibility," *Journal of Monetary Economics* 15, 177-93.

Gorton, Gary and Lixin Huang (2006), "Banking Panics and Endogenous Coalition Formation," *Journal of Monetary Economics* 53, 1613-1629.

Gorton, Gary and George Pennacchi (1990), "Financial Intermediaries and Liquidity Creation," *Journal of Finance* 45(1): 49-72.

Hirshleifer, Jack (1971), "The Private and Social Value of Information and the Reward to Inventive Activity," American Economic Review 61(4): 561-574.

Holmström, Bengt (2008), "Discussion of 'The Panic of 2007,' by Gary Gorton," in Maintaining Stability in a Changing Financial System, Proceedings of the 2008 Jackson Hole Conference, Federal Reserve Bank of Kansas City, 2008.

Kaplan, Todd (2006), "Why Banks Should Keep Secrets," *Economic Theory* 27, 341-357.

Kiyotaki, Nobuhiro and John Moore (1997), "Credit Cycles," *Journal of Political Economy* 105(2): 211-248.

Milgrom, Paul and Robert Weber (1982), "A Theory of Auctions and Competitive Bidding," *Econometrica* 50: 1089-1122.

Morris, S. and H. S. Shin (2000), "Rethinking Multiple Equilibria in Macroeconomic Modeling," NBER Macroeconomics Annual 2000, ed. by B. Bernanke and K. Rogoff (Cambridge, MA: MIT Press).

Pagano, Marco and Paolo Volpin (2009), "Securitization, Transparency and Liquidity," working paper.

Townsend, Robert (1979), "Optimal Contracts and Competitive Markets with Costly State Verification," *Journal of Economic Theory* 21(2): 265-293.