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Limelight on Dark Markets: An Experimental Study of Liquidity and Information

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Limelight on Dark Markets: An Experimental Study of Liquidity and Information*

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Abstract

The goal of this paper is to study how informational frictions affect asset liquidity in OTC markets in a laboratory setting. The experiments replicate an OTC market similar to the one used in monetary and financial economics (Shi, 1995; Trejos and Wright, 1995; Duffie, Garleanu, and Pedersen, 2005): individuals are matched bilaterally and at random, there are gains from trades due to differences in technologies and endowments, and the terms of trade are determined through a simple bargaining protocol. Subjects buy commodities that have different private values with assets that have common values and can be subject to a private information problem. The asset plays the role of a medium of exchange, but this role can be affected by its lack of "recognizability." We study a benchmark experiment where the OTC bargaining game takes place under complete information, a set of experiments with adverse selection where the terminal value of notes are determined exogenously, and a set of experiments with hidden actions where subjects can produce fraudulent notes at some cost.

JEL Classification: G12, G14, E42, D82, D83

Keywords: liquidity, money, information, experiments

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“Cognizability: By this name we may denote the capability of a substance for being easily recognized and distinguished from all other substances. As a medium of exchange, money has to be continually handed about, and it will occasion great trouble if every person receiving currency has to scrutinize, weigh, and test it. If it requires any skill to discriminate good money from bad, poor ignorant people are sure to be imposed upon. Hence the medium of exchange should have certain distinct marks which nobody can mistake.” Jevons (1875, Chapter 5)

1 Introduction

Since at least Jevons (1875) it is commonly accepted that a key property of a monetary asset—broadly defined as a means of payment or collateral—is its *recognizability*, the fact that an asset can be authenticated at little cost. Assets that lack recognizability might not be universally accepted in payment for goods and services or as collateral to secure loans.¹ Such private information problems have played a crucial role in the unfolding of the 2007-08 financial crisis and the drying-up of liquidity in opaque, over-the-counter (OTC) markets. These markets where fixed income securities, bilateral loans, and credit derivatives are traded play a pivotal role for the financing of the economy. A case in point is the market for bilateral repurchase agreements (repos)—a market that allows banks to finance securities through short-term collateralized loans. Prior to the 2008 asset-backed securities (ABSs) were used as collateral, and trillions of dollars were exchanged on the repo market without any extensive due diligence (Gorton and Metrick, 2010). When market participants realized that ABSs could be of dubious quality and the private information of asset holders became relevant, assets that had served as collateral were subject to prohibitive haircuts and liquidity in money markets dried up dramatically.

Despite their crucial role, OTC markets are *dark markets*—a term coined by Duffie (2012)—for which relatively little information is made publicly available.² Little is known about the information held by market participants at the time of a trade and how this information affects trade outcomes. On the theory side, there

¹This idea is captured by Gresham’s law according to which in the presence of a private information problem only the lowest quality of a commodity money will circulate widely—a manifestation of a standard adverse selection problem. For a quick overview, see Dutu, Nosal, and Rocheteau (2005). Recently, Gorton and Metrick (2009) emphasized a closely related notion, “information-insensitiveness,” that applies to assets or securities serving as collateral. An asset is information insensitive if traders have no incentive to acquire private information about its future cash flows. Gorton and Metrick argue that liquidity crises occur when securities that are part of the liquidity of the economy suddenly become information sensitive.

²For a description of the transparency of different OTC markets, see Duffie (2012, Section 1.2.)

is a growing literature describing the functioning of OTC markets with pairwise meetings and bargaining—pioneered by Shi (1995) and Trejos and Wright (1995) in monetary economics, and Duffie, Gârleanu, and Pedersen (2005) in financial economics—but private information problems are usually assumed away. In reality, however, informational asymmetries are prevalent making the OTC market game complex. In Duffie’s (2012, p.2) words:

“An OTC bargaining game can be complex because of private information (...). The counterparties may have different information regarding the common-value aspects of the asset (for example, the probability distribution of the asset’s future cash flows), current market conditions, and their individual motives for trade.”

When the private information frictions are taken into account, one has to deal with the difficult task of selecting an equilibrium by refining out-of-equilibrium beliefs.³ In order to overcome some of these challenges the goal of this paper is to study how informational frictions affect asset liquidity in OTC markets in a laboratory setting.

The experimental approach allows us to generate our own observations on how agents trade in markets with bilateral meetings and bargaining under private information and to control market participants’ incentives and information. We investigate how different forms of informational asymmetries (both in terms of adverse selection and moral hazard) affect assets’ resalability, their role as medium of exchange, and allocative efficiency. We will ask if private information problems can generate endogenous trading frictions in OTC markets, whether they reduce the liquidity of assets, and under which conditions they lead to market breakdowns. We will also investigate whether mechanisms emerge endogenously to mitigate the informational asymmetries, such as asset retention.

The environment we use to represent an OTC market is directly inspired from the one used in monetary and financial economics (Shi, 1995; Trejos and Wright, 1995; Duffie, Gârleanu, and Pedersen, 2005): individuals are matched bilaterally and at random, there are gains from trades due to differences in technologies and endowments, and the terms of trade are determined through a simple bargaining protocol. The transaction involves individuals buying commodities—called widgets—that have different private values with assets—

³Models of OTC markets with private information include Rocheteau (2011), Li, Rocheteau, and Weill (2012), Camargo and Lester (2013), and Guerrieri and Shimer (2012).

called notes—that have a common value but that can be subject to a private information problem. The asset plays the role of a medium of exchange, but this role can be affected by its lack of "recognizability" or the uncertainty about the future cash flows of the asset.

The OTC bargaining game is a two-dimensional ultimatum game. In this game, in each match there is a proposer and responder. The proposer is endowed with 100 notes and the responder is endowed with 100 widgets. While the widgets have a higher value to the proposer than the responder—thereby generating a motive for trade—the notes have the same terminal value for both agents, which allows them to transfer wealth across subjects and be used as media of exchange.⁴ However, the terminal value of the notes can vary across matches, and proposer and responder can be symmetrically, or asymmetrically, informed about these values. The bargaining game instructs the proposer to make a take-it-or-leave-it offer to the responder, where the offer has two dimensions, a number of widgets for a number of notes.

In our benchmark experiment, the terminal value of a note is \$0.1 and it is common knowledge. The endowment of 100 notes implies a payment capacity of \$10. A widget is worth \$0.1 to a responder but \$0.2 to a proposer. With this informational setting, we find that the outcomes of the experiments are close to the predictions of the theory: almost three quarters of all offers are accepted, most trades are individually rational, and are close to the Pareto frontier that would require all 100 notes to be traded. On average a proposer offers 87 notes for 74 widgets. So only 13% of all notes stay idle, and the median notes offered is 100. The average price of a widget, defined as the number of notes exchange for a widget, across accepted offers was 1.21 notes, above the unit price predicted by theory, whereas the average price across rejected offers was 1.1. This outcome captures the standard fairness considerations found in the experimental literature on ultimatum games.

We study informational asymmetries in this setting by introducing two types of notes—blue and red ones—and by assuming that responders cannot observe the color of the notes offered by the proposers. The terminal value of a blue note is \$0.1, as in our benchmark experiment, while the terminal value of a red note is zero. Across sessions we vary the probability that a proposer is endowed with blue notes from 50%, to 70%, and 90%.

⁴The property according to which an asset or commodity has a common value to all traders for it to play a role as a medium of exchange has been emphasized by Engineer and Shi (1998, 2001) and Berentsen and Rocheteau (2003).

When using the theory to interpret the results from the experiments we focus on two perfect Bayesian equilibria of the OTC bargaining game: the best pooling equilibrium from the viewpoint of the proposer and the equilibrium obtained under the intuitive criterion of Cho and Kreps (1987). Under the pooling equilibrium, all offers are accepted at a pooling price that exactly compensates the responder from the possibility of the occurrence of red notes. In contrast, under the intuitive criterion a proposer with blue notes can break a pooling equilibrium by retaining a fraction of his/her notes in exchange for a better price. Since red notes are valueless, a separating equilibrium cannot exist and the only equilibrium outcome is such that all trades shut down—an extreme consequence of the adverse selection problem. In summary, according to the pooling equilibrium the private information problem should manifest itself by a lower price of the notes in pairwise meetings but the number of trades should be unaffected, whereas according to the intuitive criterion the private information problem should lead to all offers being rejected.

The outcomes of our experiments share features of both equilibria. The price of widgets across accepted offers decreases from 1.5 to 1.42 and 1.34 as the probability of blue notes increases. Since the pooling outcome of the OTC bargaining game under asymmetric information coincides with the outcome when proposers and responders are *symmetrically uninformed*, we ran the same experiments with symmetrically uninformed subjects and found prices varying from 2.4, to 1.59, and 1.53. Prices when subjects are asymmetrically informed are lower than when they are symmetrically uninformed. Our interpretation is that the proposers attempted to signal good quality notes by asking a low price for widgets. Furthermore, the fraction of accepted offers fell: the acceptance rates were 30%, 39%, and 47% for the three sessions described above and 73% when the value of notes were certain. However, we didn't find clear evidence that the signaling mechanism implied by the intuitive criterion can explain the large fraction of rejected offers. In particular, we obtained only slightly higher acceptance rates when subjects were symmetrically uninformed, namely 35%, 39%, and 58%. Furthermore, proposers with blue notes offered more notes than proposers with red notes in contrast with an asset retention mechanism. These results suggest that the uncertainty about the value of the medium of exchange matters for its liquidity regardless of whether information is symmetric or asymmetric. We view this result as consistent with the demand for absolute safety emphasized by Krishnamurty and Vissing-Jorgensen (2012) to explain the liquidity and convenience yield of Treasury debt and highly-rated corporate bonds. The results also illustrate how informational frictions generate search-like frictions despite

the fact that the matching technology is frictionless.

In all previous experiments, the frequency of occurrence of low-value notes was exogenous, chosen by Nature: whether a note was of high or low quality could not be attributed to some (hidden) action by the proposer. We conjectured that this feature might explain why the outcome of the treatment where agents are asymmetrically informed is similar to the one where they are symmetrically informed. In reality the existence of low-quality media of exchange or collateral often results from deliberate actions by some individuals, e.g., con artists printing counterfeits. In order to capture this idea we ran three experiments where the proposer has the possibility to produce fraudulent assets, i.e., red notes, at some cost. With this assumption we wish to capture phenomena like counterfeiting of currency or fraudulent practices in the finance industry.⁵ The proposer was endowed with \$10 and had the choice to buy either 100 blue notes for 10\$, or to buy 100 red notes for some amount of dollars that we interpret as the cost of fraud. Across sessions we vary this cost of fraud from \$0, to \$2 and \$6.

If the cost of fraud is strictly positive, the best (perfect Bayesian) equilibrium from the viewpoint of the proposer predicts that there is no fraud. The reason is that the proposer understands that he/she cannot benefit from fraud when it is anticipated. Moreover, the proposer can signal his/her good behavior by retaining a sufficiently large number of notes so that fraud is not worthwhile. If the cost of fraud is zero, theory predicts that there can be fraud, but no offer is accepted. In accordance with the empirical evidence, we found some amount of fraud in all experiments. However, fraud decreased monotonically with the cost of fraud: the fraction of proposer that acquired blue notes was 34% when the cost of fraud is \$0, 63% when the cost of fraud is \$2, and 92% when the cost of fraud is \$6. So a high cost of fraud eliminates counterfeit notes almost entirely. Surprisingly, even when fraud is costless, some subjects do hold blue notes and some offers are accepted. This illustrates the difficulty of generating a complete market freeze. Proposers with blue notes offered fewer notes and asked for lower prices than proposers with red notes, which could be interpreted as an attempt to signal their value. However, these signaling attempts were unsuccessful, since accepted and rejected offers contained roughly the same number of blue notes.

⁵Classical examples of fraud in monetary and financial affairs include the clipping of coins in ancient Rome and medieval Europe, and the counterfeiting of banknotes during the first half of the 19th century in the United States (see, e.g., Mihm, 2007). According to Gorton and Metrick (2010), prior to the 2008 financial crisis large volumes of repurchase agreements backed by securitized bonds were traded daily without extensive due diligence. These securitized bonds were subject to moral hazard problems, fraudulent practices, and lax incentives (Keys, Mukherjee, Seru, and Vig, 2010; Barnett, 2012).

The acceptance rates in treatment with hidden actions were low, namely 27%, 24%, and 46%.⁶ This finding is consistent with the theory that predicts that offers should be rejected with positive probability in order to discipline the proposers. The failure to trade is even stronger when the cost of fraud decreases. Under a \$2 cost of fraud, the proposer acquired valuable notes in 63% of the rounds, but only 24% of their offers were accepted. In the adverse selection case, the probability of red notes had to be equal to 50% in order to obtain such low acceptance rates. In summary, whether a private information problem is exogenous to the subjects or one that results from hidden actions matters for the liquidity of an asset: the latter exacerbates the illiquidity of the asset.

So far the payment capacity, or liquidity, of the proposers was taken as given. In our last four experiments we check how our results are affected when proposers are able to choose their payment capacity. This extension brings the model even closer to modern monetary theory as represented by the Lagos-Wright model. In the first three experiments, we let proposers choose the amount of notes (up to 100) they carry in a match. The purchase price of a note varies across sessions from \$0.1, \$0.11 to \$0.15 allowing us to change the cost of holding liquidity since the terminal value of a note is still \$0.1. In each of the three cases, proposers were endowed with \$10, \$11, and \$15 so that they could acquire 100 notes in maximum. The first case corresponds to the Friedman rule where there is no holding cost of money. Under the Friedman rule, proposers acquired in average 82 notes. In the other two cases, they acquired 61 and 62 notes. The fact that proposers choose to invest in blue notes even when their purchase price is greater than their resale price is in accordance with a rate-of-return dominance pattern and consistent with search-theoretic models where the cost of holding money is one of the key modelling choices. Finally, consistent with efficiency, in all three cases they offered in average almost all acquired notes.

In our last experiment, we give the choice to the proposers between acquiring blue notes that are costly to hold or orange notes that have a higher return but that are indistinguishable from red notes. We find that while one fourth of the subjects hold blue notes that are dominated in their rate of return, a large fraction of subjects choose red notes.

⁶Interestingly, in one treatment the proposer chose valuable notes in 92% of all rounds, which is comparable to the exogenous 90% of one of our adverse selection session. The acceptance rate under moral hazard is 46%, while the acceptance rate under adverse selection is 47%.

1.1 Related literature

The search-theoretic literature on adverse selection in decentralized asset markets with pairwise meetings includes Cuadras-Morato (1994) on the emergence of a commodity money, Velde, Weber, and Wright (1999), and Burdett, Trejos, and Wright (2001) on Gresham’s law, and Hopenhayn and Werner (1996) on the liquidity structure of asset returns. These papers restrict asset holdings to $\{0, 1\}$. The search-theoretic literature on the role of money in the presence of moral hazard problems includes Williamson and Wright (1994), Li (1995), Trejos (1997, 1999), and Berentsen and Rocheteau (2004). In these models, signaling is not possible because money holdings are restricted to $\{0, 1\}$ or allocations are restricted to those that are pooling. Banerjee and Maskin (1996) do not restrict asset holdings, but they study the emergence of commodity monies in an environment with Walrasian trading posts. The assumption of price-taking agents rules out the strategic considerations in the pairwise meetings that are the focus of this paper. In Lester, Postlewaite, and Wright (2011) describe a model with divisible assets, fiat money, and capital, where the recognizability problem takes the form of claims on capital that can be costlessly counterfeited and that are not accepted unless the buyer of the asset has the technology to authenticate them. Li, Rocheteau, and Weill (2012) consider a model of an OTC market where assets are subject to costly fraudulent practices and solve the bargaining game under incomplete information.

Our paper is related to the experimental literature on the role of goods and assets as media of exchange. This literature is reviewed in Duffy (2008, Section 4.1). Brown (1996) and Duffy and Ochs (1999) test the predictions of the search-theoretic model of Kiyotaki and Wright (1989) where the commodity that is used as money emerges endogenously. These studies suggest that the physical properties of commodities (e.g., their storage cost) matter the most for subjects’ trading decisions. Duffy and Ochs (2002) study a similar environment where fiat money is added. They find that fiat money can circulate if it has the lowest storage cost, and they do not find support for rate-of-return dominance. Our paper emphasizes a different property of monetary assets, their recognizability. Duffy and Puzzello (2011) is the first attempt to bring the Lagos-Wright environment in a laboratory setting to test whether subjects use gift exchange rather than monetary exchange.

Our paper is also related to the experimental literature on (ultimatum) bargaining games under private

information. Ultimatum games with asymmetric information include Kagel, Kim, and Moser (1996) where players have different information about each other's payoffs and Miltzkewitz and Nagel (1993) where one subject is uninformed about the size of the gains from trade. Similarly, Forsythe, Kennan, and Sopher (1991) study a bargaining game where agents have asymmetric information about the gains from trade and interpret strikes as the failures of the bargainers to agree on a division of the surplus. For a review of experimental work on bargaining under incomplete information, see Camerer (2003, Section 4.3).

Closer to what we do, Forsythe, Lundholm, Rietz (1999) consider an experiment where subjects are divided between buyers and sellers of assets, sellers hold assets of unknown quality, and buyers make offers that sellers can accept or reject. In contrast, in our model gains from trade arise because subjects can exchange a good of homogenous quality that they value differently. The asset that is commonly valued across subjects has a role as a medium of exchange but is subject to a private information problem. Moreover, we let the uninformed party make an offer, which opens up the possibility for signaling. Finally, our adverse selection treatment paper is related to the signaling model of corporate finance. Cadsby, Frank, and Maksimovic (1990) test the pecking order theory where firms can finance projects of heterogeneous qualities by issuing shares to investors. They find that the results accord with the theory.

2 OTC bargaining game under complete information

Our experiment aims to describe an OTC market where individuals are matched bilaterally and at random and bargain over the terms of trade. In each match, there are gains from trade due to different endowments and production technologies of matched individuals, and there is an asset playing the role of a medium of exchange. The bargaining game is a simple ultimatum game where the asset holder makes the offer. As shown in the monetary literature, under complete information this bargaining protocol maximizes the liquidity value of the asset.

The two players in the bargaining game are called *Proposer* and *Responder*. The proposer is endowed with 100 units of a divisible asset called *notes*. These notes pay off a certain amount of a numéraire good at the end of the period. A key property of notes is that they yield the same payoff irrespective of who is holding them; i.e., their value is common to all participants. However, notes might come in different qualities; i.e., they differ in the amount of the numéraire good that they pay off at the end of the period.

Later on, we introduce private information, by assuming that individuals may have different information about the quality of these notes.

A *Responder* is endowed with 100 units of an intermediate good called *widget*. Proposers and responders have access to different technologies to produce the numéraire good from widgets. A proposer can produce two units of the numéraire good per widget, while a responder can only produce one unit of the numéraire good per widget. This difference in productivities generates gains from trade for proposers and responders. The objective of this paper is to see how private information about the quality of the medium of exchange affects the frequency of trade, the size of the trades, and the divisions of the match surplus.

As a benchmark we consider the case where notes are homogenous and the proposer and the responder have complete information about the terminal value of notes; i.e., notes are perfectly recognizable. The trading mechanism is such that the proposer (the note holder) makes a take-it-or-leave-it offer to the responder. An offer is a pair $(\omega, n) \in [0, 100]^2$ where ω is the quantity of widgets received by the proposer from the responder and n is the quantity of notes delivered by the proposer to the responder. In the theoretical analysis we assume that all objects are divisible.⁷

Proposers and responders have the same preferences for the numéraire good and are risk-neutral. Consumption of one unit of the numéraire good yields one utile. If a proposer offers the trade (ω, n) and if the trade is accepted, he receives ω widgets and keeps $100 - n$ notes. Accordingly, his utility is

$$U_P = 2\omega + 100 - n.$$

For the responder, if a proposer offers the trade (ω, n) and if he accepts the trade, he will keep $100 - \omega$ widgets and receive n notes. Accordingly, his utility is

$$U_R = 100 - \omega + n.$$

Throughout this paper, we are interested to assess whether the trades that we observe in the laboratory satisfy (1) basic assumptions about rationality; (2) Pareto efficiency; and (3) some appropriate equilibrium notion.

⁷In the experiments, the players have to choose integers in $\{0, \dots, 100\}$.

Rationality For a proposer, a trade that yields a positive surplus satisfies $2\omega + 100 - n \geq 100$. Accordingly, the set of individual rational trades for a proposer is

$$P \equiv \left\{ (\omega, n) \in [0, 100]^2 : 2\omega - n \geq 0 \right\}, \quad (1)$$

where $S_P \equiv 2\omega - n$ is the surplus of the trade for the proposer. For a responder, a trade that yields a positive surplus satisfies $100 - \omega + n \geq 100$. Accordingly, the set of individual rational trades for a responder is

$$R \equiv \left\{ (\omega, n) \in [0, 100]^2 : n - \omega \geq 0 \right\}, \quad (2)$$

where $S_R \equiv n - \omega$ is the surplus of the trade for the responder.

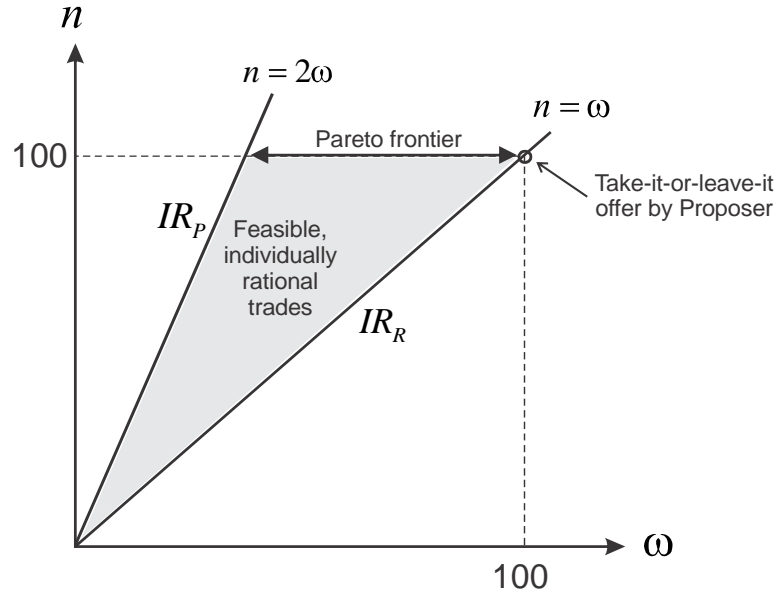


Figure 1: Bargaining game under complete information

The set of feasible, individual rational trades is then $S = P \cap R$; i.e.,

$$S \equiv \left\{ (\omega, n) \in [0, 100]^2 : 2\omega \geq n \geq \omega \right\}.$$

The set S is depicted in Figure 1 as the grey shaded area. The curve labelled IR_P is the set of trades that yields zero surplus to the proposer; i.e., $2\omega = n$, and the one labelled IR_R is the set of trades that yield zero surplus to the responder; i.e., $\omega = n$.

The first key benchmark for the experiments will be to assess whether the trades are in the set S , meaning that our subjects satisfy basic rationality assumptions.

Pareto efficiency Our second key benchmark will be to assess whether the trades are Pareto efficient. The Pareto frontier associated with this bargaining problem solves⁸

$$\mathcal{S}_P = \max_{\omega, n} (2\omega - n) \quad (3)$$

$$\text{s.t. } n - \omega \geq \mathcal{S}_R, \quad (4)$$

and $(\omega, n) \in [0, 100]^2$. Trades that are Pareto efficient are such that the proposer offers all his notes ($n = 100$) and asks for $\omega \in [50, 100]$ widgets. The proposer should use his full payment capacity (the 100 notes) and the transfer of widgets will determine the distribution of the gains from trade. The equation for the Pareto frontier in the utility space is $\mathcal{S}_R + 2\mathcal{S}_R = 100$. See top quadrant of Figure 2. So the proposer obtains a surplus equal at most to 100 while the maximum surplus of the responder is 50.⁹ The set of Pareto-efficient offers is represented in the bottom quadrant of Figure 2.

Equilibrium A third key benchmark is to assess whether our subjects play a subgame-perfect equilibrium. A utility maximizing proposer chooses a trade the trade (ω, n) that maximizes his surplus, $2\omega - n$, subject to the constraint that the offer is acceptable to the responder; i.e.; subject to (2). That is, he solves the following problem:

$$\max_{\omega, n} (2\omega - n) \quad (5)$$

$$\text{s.t. } n - \omega \geq 0,$$

and $(\omega, n) \in [0, 100]^2$. The solution is $\omega = n = 100$. The proposer's surplus is equal to 100 while the responder surplus is 0. This outcome corresponds to the unique subgame perfect equilibrium.¹⁰ Note that any allocation on the Pareto frontier can be the outcome of a Nash equilibrium.

⁸Note: On the one hand we define $\mathcal{S}_R \equiv n - \omega$, on the other hand we write $n - \omega \geq \mathcal{S}_R$. We need to change this.

⁹Notice that if proposers were not constrained by the number of notes they hold, e.g., they hold at least 200 notes, then the equation for the Pareto frontier would be $\mathcal{S}_R + \mathcal{S}_R = 100$ and all Pareto-efficient trades would be such that $\omega = 100$.

¹⁰When notes and widgets are indivisible there are other SPEs: one where $(\omega, t) = (99, 99)$ and another one where $(\omega, t) = (99, 100)$.

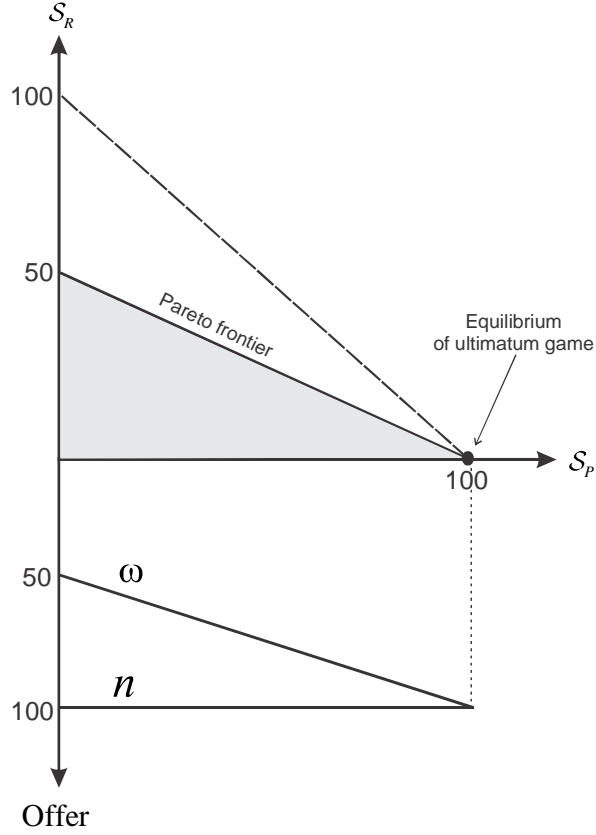


Figure 2: Pareto frontier of the bargaining set

3 Bargaining under adverse selection

We now introduce informational asymmetries in the OTC bargaining game by assuming that the terminal value of the notes that the proposer is endowed with is random. With probability, π , the proposer is endowed with notes that pay off one unit of numéraire each and with complement probability, $1 - \pi$, the proposer is endowed with low-quality notes that pay off $\rho < 1$ units of the numéraire good. Throughout the paper we refer to the high-quality notes as *blue* notes and the low-quality notes as *red* notes. We use the same neutral terminology in the experiments.

The proposer has private information regarding the terminal value of the notes. This assumption captures "learning by holding," the fact that for some securities the holder of the asset receives private information

about its future cash flows (Plantin, 2009).¹¹

With private information, the bargaining game has the structure of a signaling game: the informed party, the proposer, chooses the offer that the uninformed party can accept or reject. Typically, it admits a large number of Perfect Bayesian Equilibria (where strategies are optimal given beliefs, and beliefs are updated according to Bayes's rule whenever possible). For instance, if $\rho = 0$ then any offer (ω, n) that satisfies $2\omega - n \geq 0$ and $\pi n - \omega \geq 0$ is the outcome of a PBE. Any such equilibrium has the property that the proposer makes an offer that is accepted by the responder and any deviating offer is rejected. The equilibrium is sequentially rational because any deviating offer is attributed to someone holding red, valueless notes.

We will study two popular refinements of PBE. We will first characterize the equilibrium that would be obtained under the intuitive criterion of Cho and Kreps (1987). This refinement allows proposers to signal the quality of their assets by retaining some of them. Second, we will consider the best pooling equilibrium from the view point of a proposer with blue notes. This equilibrium is proposed by Mailath, Okuno-Fujiwara and Postlewaite (1993).

3.1 Red notes are pure lemons

We first consider the case where red notes are valueless counterfeits; i.e., $\rho = 0$. Under the intuitive criterion, there cannot exist a pooling equilibrium with $\omega > 0$ and $n > 0$. Intuitively, any proposed pooling equilibrium is destroyed by the fact that a proposer with blue notes could reduce the number of offered notes, while asking for a better price for those he is offering. While he benefits from such a deviation, a low quality notes owner offering the same deviation would be strictly worse off. According to the intuitive criterion, such a deviation should then be interpreted as coming from a blue notes owner and hence accepted by the responder.

To see this argument formally, suppose there is a pooling offer, $(\bar{\omega}, \bar{n})$, with $\bar{\omega} > 0$ and $\bar{n} > 0$ in a proposed equilibrium. For this offer to be accepted in equilibrium, it must be that the responder's surplus is positive if notes are of high quality, i.e., $\bar{n} - \bar{\omega} > 0$. In order to show that the pooling offer cannot be part of an equilibrium, consider the following deviating offer by the proposer: $\omega' = \bar{\omega} - \varepsilon$ and $n' = \bar{n} - 3\varepsilon$. The proposer offers fewer notes in exchange for fewer widgets. We assume that notes and widgets are divisible so that

¹¹One can think of a note as an asset-backed security where the underlying asset can be of high or low quality.

$\varepsilon > 0$ can be made arbitrarily small. The payoff of a proposer with blue notes is $2\omega' - n' = 2\bar{\omega} - \bar{n} + \varepsilon$. So the proposer with blue notes is made better off. The payoff of a proposer with red notes is $2\omega' = 2\bar{\omega} - 2\varepsilon$. The proposer with red notes is made worse off. Moreover, if notes are blue, the surplus of the receiver is $-\omega' + n' = -\bar{\omega} + \bar{n} - 2\varepsilon$. Provided that $\varepsilon < \frac{\bar{n} - \bar{\omega}}{2}$ this surplus is positive. According to the intuitive criterion the offer (ω', n') should be attributed to a proposer with blue notes and it should be accepted. Therefore, the proposed equilibrium is based on beliefs that violate the intuitive criterion.

In Figure 3, offers of the type (ω', n') are represented by the grey area. The curve labelled IR_P^L is the indifference curve for a proposer with red notes (the set of offers such that $\bar{\omega} = \omega$) and the one labelled IR_P^H is the indifference curve for a proposer with blue notes (the set of offers such that $2\omega - n = 2\bar{\omega} - \bar{n}$). The curve labelled IR_R is the set of trades that yield zero surplus to the responder who attributes the average quality to the notes; i.e., $\omega = \pi n$. It is clear from the figure that the set of offers that destroy a proposed pooling equilibrium is never empty. Since there cannot be a separating equilibrium, where the proposer with blue notes purchases widgets (otherwise the proposer with red notes would want to imitate the offer), the only equilibrium that survives the intuitive criterion is the one where no trade takes place; i.e., $\bar{\omega} = \bar{n} = 0$. This outcome corresponds to a situation where the adverse selection problem is so severe that it leads to a market breakdown.

Mailath, Okuno-Fujiwara and Postlewaite (1993) argue that in some cases pooling equilibria are more natural than separating ones. To see this consider the best pooling equilibrium from the view point of a proposer with blue notes. Assume that $\pi > 0.5$. The offer solves

$$\begin{aligned} & \max_{\omega, n} (2\omega - n) \\ & \text{s.t. } \pi n - \omega \geq 0. \end{aligned}$$

The solution is $n = 100$ and $\omega = 100\pi$. There are no pooling equilibria that would make both types of proposers better off and there is no separating equilibrium that would make a proposer with blue notes better off. Therefore, according to Mailath, Okuno-Fujiwara and Postlewaite (1993) such an equilibrium is a natural perfect Bayesian equilibrium to consider. In contrast, the no-trade equilibrium picked by the intuitive criterion is *defeated* by any active pooling equilibrium where the proposer with blue notes gets a positive surplus: both types of proposers would be better off in the pooling equilibrium relative to the no-

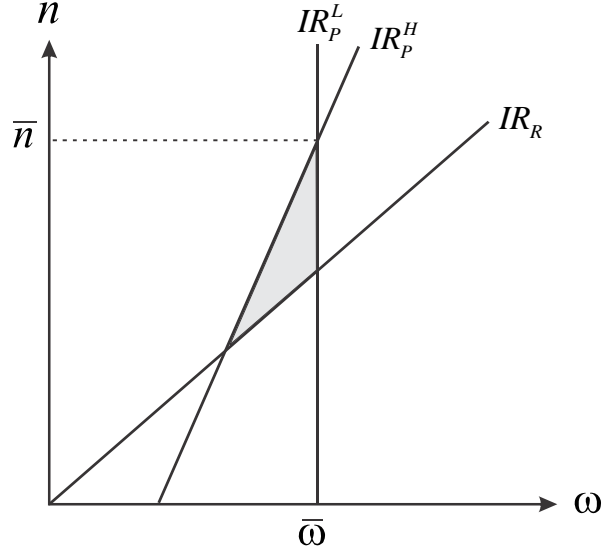


Figure 3: No pooling equilibrium under the intuitive criterion

trade equilibrium. Therefore, if a responder observes such a pooling offer he would have no way to attribute it a particular type of proposer and he would have no reason to update his prior belief, which would make the offer acceptable and break the no-trade equilibrium.

The offer corresponding to the best pooling equilibrium from the viewpoint of a Proposer with blue notes is illustrated in Figure 4. The curve labelled IR_R^1 is the set of offers that yield zero expected surplus to a responder who believes that the notes offered are blue with probability 1, and the one labelled IR_R^π is the set of offers that yield zero expected surplus to a responder who believes that the notes offered are blue with probability π . Finally, the curve labelled IR_P^H is the set of offers that yield zero expected surplus to a proposer holding blue notes. The grey area is the set of offers that are individually rational in a pure pooling equilibrium where responders do not update their prior beliefs. Not too surprisingly this set is smaller than the one in the game with complete information. The offer that maximizes the utility of the proposers among all pooling equilibria is located on the Pareto frontier of the game with complete information. Recall that in the complete information case, the best offer is $(\omega, n) = (100, 100)$. Thus, the surplus of the proposer with blue notes is smaller with adverse selection.

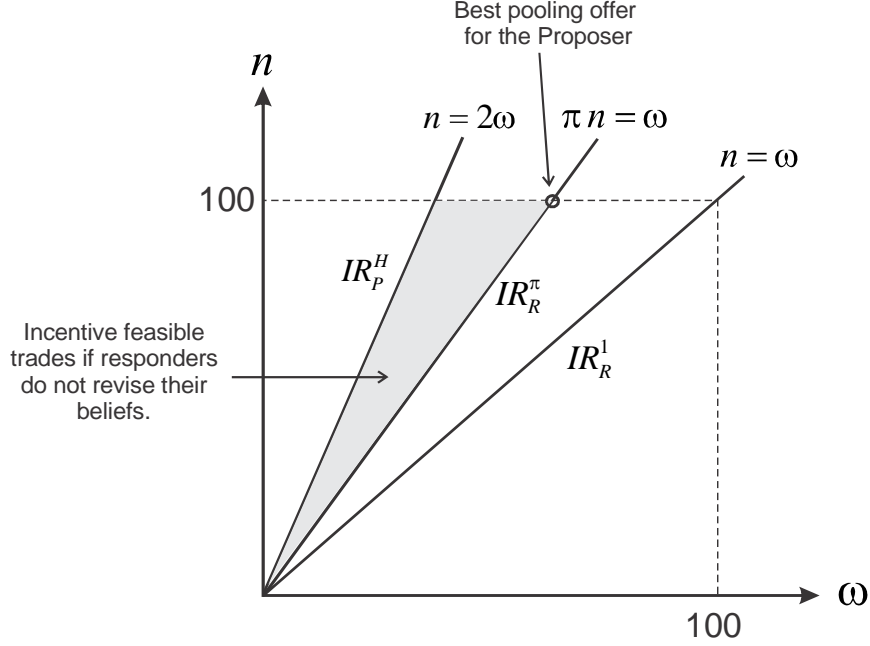


Figure 4: Adverse selection and pooling equilibria

3.2 Red notes are valuable

We now consider the case where red notes have a positive terminal value. Suppose that each red note yields $\rho \in (0, 1)$ units of the numéraire good at the end of the game. Under the intuitive criterion, for the same logic as explained above, no pooling equilibrium exists. The equilibrium selected by the intuitive criterion is the Pareto-dominant equilibrium among all separating equilibria. In this separating equilibrium, the holder of red notes makes the following offer:

$$(\omega^L, n^L) = \arg \max_{\omega, n} (2\omega - \rho n) \quad (6)$$

$$\text{s.t. } \rho n - \omega \geq 0, \quad (7)$$

and $(\omega, n) \in [0, 100]^2$. The solution is $n^L = 100$ and $\omega^L = 100\rho$. The proposer spends all his notes and asks for an amount of widgets that leaves no surplus to the responder. The surplus of the proposer is 100ρ . This offer is represented in Figure 5 at the intersection of the curve labelled IR_R^ρ and the feasibility constraint $n = 100$.

Let us turn to the holder of blue notes. He makes an offer that maximizes his surplus subject to the

responder's participation constraint and red-note holder incentive compatibility constraint:

$$(\omega^H, n^H) = \arg \max_{\omega, n} (2\omega - n) \quad (8)$$

$$\text{s.t. } n - \omega \geq 0 \quad (9)$$

$$2\omega - \rho n \leq 100\rho. \quad (10)$$

According to the incentive-compatibility condition, (10), the surplus of the proposer with red notes, who imitates the offer $2\omega - \rho n$, must be less than his surplus if he makes the offer $(\omega^L, n^L) = (100\rho, 100)$, which equals 100ρ . The solution of this program is such that (9) and (10) hold at equality; i.e., $n^H = \omega^H = \frac{\rho}{2-\rho}100$. With these offer, the surplus of the blue proposer is $\frac{\rho}{2-\rho}100$. The equilibrium offer is represented in Figure 5 at the intersection of the curve labelled IR_R^1 and the curve labelled IC_P^L .

It is worthwhile to note the following properties of the separating equilibrium. First, the proposer with blue notes retains a fraction $\frac{2(1-\rho)}{2-\rho}$ of his notes. Second, he purchases fewer widgets than the proposer with red notes. Third, as ρ increases; i.e., as the adverse selection problem becomes less severe, asset retention decreases. Finally, the separating outcome is independent of π .

Another interesting equilibrium is the best pooling equilibrium from the view point of a proposer with blue notes. The pooling offer solves

$$\begin{aligned} & \max_{\omega, n} (2\omega - n) \\ & \text{s.t. } [\pi + (1 - \pi)\rho] n - \omega \geq 0. \end{aligned}$$

and $(\omega, n) \in [0, 100]^2$. Provided that $\pi + (1 - \pi)\rho > 0.5$, the solution is $n = 100$ and $\omega = [\pi + (1 - \pi)\rho] 100$. The payoff of the proposer with blue notes is $\{2[\pi + (1 - \pi)\rho] - 1\} 100$. This payoff is larger than the one at the separating equilibrium if

$$\pi > \frac{1 - \rho}{2 - \rho}.$$

So a pooling outcome is more likely if the probability of blue notes is high and the value of the red notes is not too low.

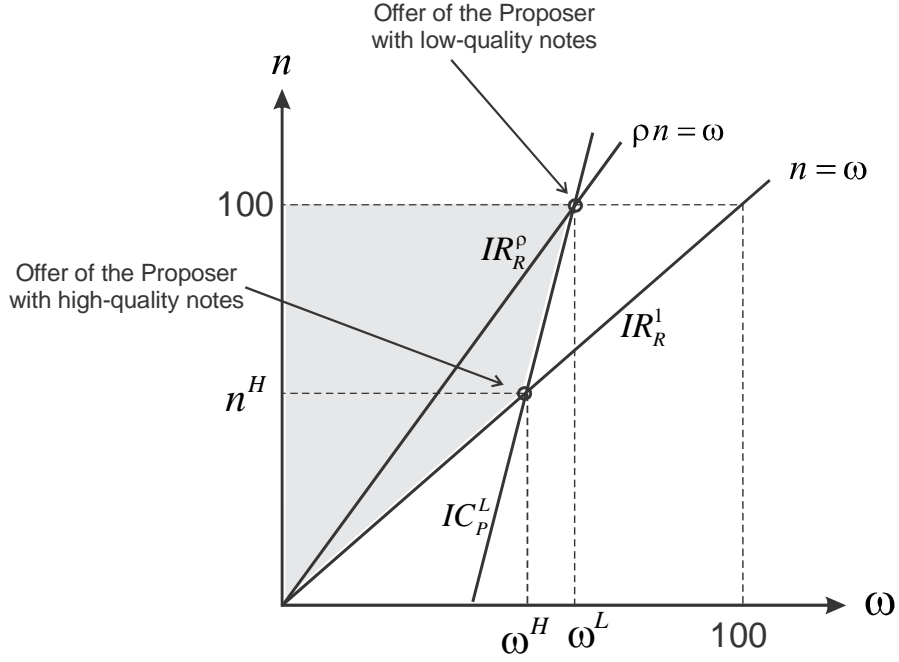


Figure 5: Separating equilibrium under adverse selection

4 Bargaining under the threat of fraud

We now consider a game where the quality of the notes is chosen by the proposer. This model captures a situation where a con-artist produces counterfeit notes or where a financial institution originates and securitized bad loans that are sold afterwards to other investors.

At the beginning of the game the proposer has the choice between purchasing 100 blue (genuine) notes at the unit cost of one in terms of the numéraire or 100 red (counterfeit) notes at a total cost, C . Red notes are worthless, and responders cannot distinguish blue from red notes. To analyze this bargaining game with hidden actions we adopt the methodology from In and Wright (2011) for signaling games with endogenous types. According to this methodology, one can look at a strategically equivalent game, the so-called *reverse-ordered game*. In this game, all observable moves are made first. In our context, in the reverse-ordered game the proposer chooses his offer first, and then he decides whether or not to acquire blue or red notes. The advantage of this methodology is that following an offer, there is a proper subgame that can be easily analyzed.

To see this, consider an arbitrary offer, (ω, n) , and suppose that this offer is accepted with probability p . Let η denote the probability that the proposer acquires blue notes after offering (ω, n) . Following this offer, it is optimal to acquire blue notes; i.e., $\eta = 1$, if

$$-100 + p[2\omega + (100 - n)] + (1 - p)100 > -C + p2\omega. \quad (11)$$

The left-hand side of inequality (11) is the proposer's expected payoff if he chooses to acquire blue notes: he pays 100 to purchase 100 blue notes, with probability p his offer is accepted, in which case he receives ω widgets and keeps $100 - n$ notes, and with probability $1 - p$ the offer is rejected, in which case the proposer ends up with 100 blue notes. The right-hand side of inequality (11) is the expected payoff of the proposer if he acquires red notes: the cost of red notes is C , and with probability p the offer is accepted, in which case he receives ω widgets. The incentive-compatibility constraint (11) can be rewritten as

$$pn \leq C. \quad (12)$$

Inequality (12) can be interpreted as a liquidity or resalability constraint.¹² It states that the expected value of the assets that are exchanged in a match has an upper bound, which is given by the cost to produce fraudulent assets. The responder has strict incentives to accept the offer if

$$\eta n - \omega > 0, \quad (13)$$

since ηn is the expected value of the notes and ω is the cost of giving up ω widgets.

In what follows, we characterize the equilibrium of the game. If the proposer's offer in the reverse-ordered game is such that $\omega < n < C$, then the unique Nash equilibrium in the subgame following that offer is such that $p = 1$ and $\eta = 1$. Intuitively, if $n < C$, then from (12), it is optimal to set $\eta = 1$. If $\eta = 1$, then from (13) it is optimal to accept the offer; i.e., to set $p = 1$. Thus, if the value of the offered blue notes is less than the cost of fraud and if the responder's surplus is positive, then there is no fraud and the offer is accepted.

If the proposer's offer in the reverse-ordered game is such that $n > C$ and $n > \omega$, then the equilibrium of the subgame following that offer involves mixed-strategies.¹³ In this mixed-strategy equilibrium, the responder is indifferent between accepting or rejecting the offer and the proposer is indifferent between

¹²If $pn > C$, then the proposer acquires red notes with certainty; i.e., $\eta = 0$.

¹³It is a matching penny game that has exactly one equilibrium in mixed strategies.

purchasing blue notes or red ones. In such a mixed-strategy equilibrium,

$$p = \frac{C}{n} \text{ and } \eta = \frac{\omega}{n}.$$

Intuitively, if $n > C$, then from (12), in order to induce the proposer to choose blue notes, we must have $p < 1$. Furthermore, if $n > \omega$, then from (13), in order to induce the responder to choose $p < 1$, we must have $\eta < 1$. An interesting property of this equilibrium is that as the number of notes offered increases, the probability of acceptance decreases and the probability of fraud increases.

Given the Nash equilibria of the subgames following all possible offers, the proposer will choose the offer that maximizes his expected payoff. Li, Rocheteau, and Weill (2011) show that there is no fraud taking place in equilibrium since any fraud would be anticipated by the responder and the transfer of notes would be discounted accordingly. The optimal offer of the proposer solves

$$\begin{aligned} \max_{\omega, n, p} & p(2\omega - n) \\ \text{s.t. } & n - \omega = 0 \\ & pn \leq C. \end{aligned}$$

The proposer maximizes his expected surplus subject to two constraints. The first constraint is the participation constraint of the responder, where it is assumed that the responder believes that the notes are blue. The second constraint is the resalability constraint (12).

If $C < 100$, the resalability constraint is binding. In this case, the solution is $pn = C$, $\omega = n$, $p \in [\frac{C}{100}, 1]$. This means that $\omega = n \in [C, 100]$ as indicated in Figure 6. If $n = \omega = C$, the offer is accepted with probability one, but the proposer cannot purchase more widgets than it costs to produce red notes. The proposer can offer to sell a larger number of notes, but then his offer will get rejected with positive probability; i.e., $p < 1$. So the model captures the notion that large note offers are less liquid; i.e., they have a greater probability of being rejected.

We illustrate the set of optimal offers in Figure 6. The grey area is the set of offers that satisfy the proposer and responder's individual rationality constraints and the proposer's incentive compatibility constraint when $p = 1$. Among this set of incentive-feasible offers the preferred one of the proposer is $n = \omega = C$. There are larger offers, $n = \omega > C$, that are payoff equivalent but they are rejected with positive probability, $p < 1$.

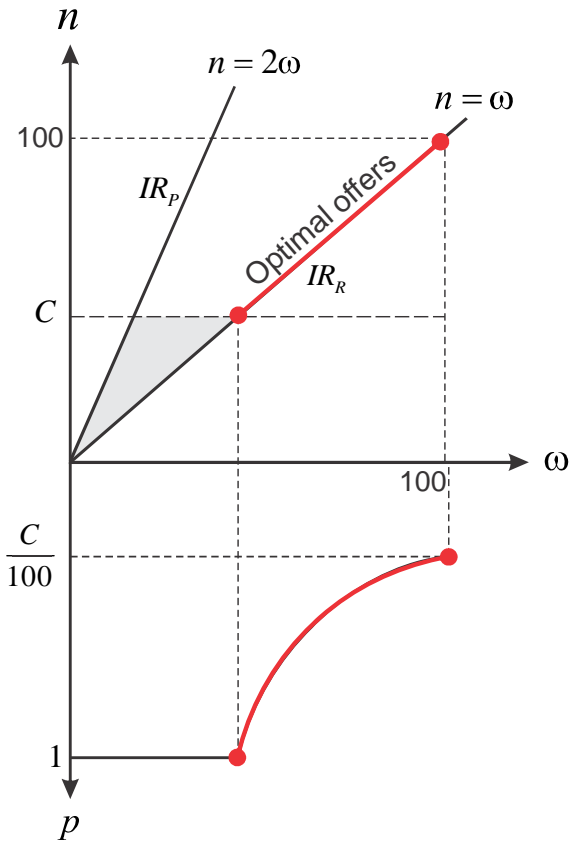


Figure 6: Bargaining under the threat of fraud

For instance, the proposer could make the complete information offer, $n = \omega = 100$, but in this case the offer would be accepted with probability $p = \frac{C}{100} < 1$.

5 Liquidity choices

In the last set of experiments we let subjects choose how much liquidity they want to hold and their portfolio of assets. The main objective of these sessions is to check whether subjects are willing to hold assets that are dominated in their rates of return.

Suppose first that Proposers are endowed with some amount of nonliquid wealth, W , that they cannot use for payments in bilateral trades. In the context of the experiment this nonliquid wealth takes the form of an account with some dollars. The Proposer has the possibility to spend some of his wealth to purchase

notes at some unit price $\phi < 1$ or to keep to his dollars on his account. The notes are redeemed at the end of the experiment for one unit of numéraire good. Given that $\phi < 1$, notes have a negative rate of return whereas the rate of return of the nonliquid wealth is 0.

First, purchasing more notes than the quantity that one intends to spend in a bilateral match is a strictly dominated strategy given the negative rate of return of notes. So suppose that Proposers purchase the amount of notes that they plan to offer in a match. The problem of the Proposer becomes

$$\begin{aligned} \max_{\omega, n} \quad & 2\omega - \phi n \\ \text{s.t.} \quad & n - \omega \geq 0. \end{aligned} \tag{14}$$

Moreover, ω cannot be greater than the amount of widgets held by the Responder and $\phi n \leq W$. It is clear from (14) that as long as $\phi < 2$, it is strictly optimal for the buyer to purchase $\min\{100, W/\phi\}$ notes, i.e., he will purchase enough notes to buy the 100 widgets of the Responder if he has enough wealth to do so. In the experiment we set $W = 150$ and $\phi = 1.5$ so that the buyer should spend all his wealth to buy exactly 100 notes.

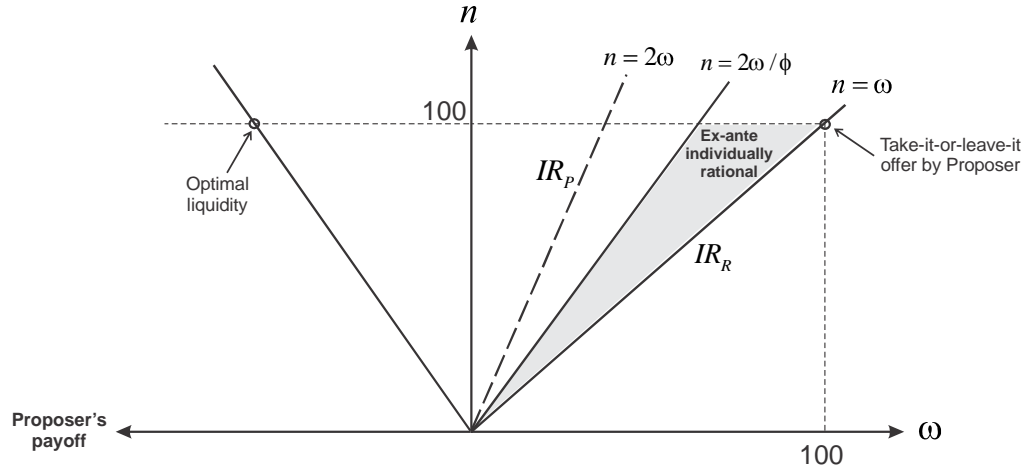


Figure 7: Liquidity choice

In the right panel of Figure 7 we represent by a grey area the set of offers that are individually rational taking into account the cost for the Proposer to acquire notes. This set shrinks at the cost of acquiring notes

increases. In the left panel we plot the proposer’s payoff, $n(2 - \phi)$, as a function of the number of notes he purchases. The optimal liquidity choice is equal to the number of notes that are required to compensate the Responder for his 100 widgets.

Finally, we consider an environment where Proposers can choose between three types of notes: blue, orange, and red notes. The Proposer can purchase 100 blue notes for a total cost of $C^b > 100$, 100 orange notes for a total cost of $C^o = 100$, and 100 red notes at zero cost, $C^r = 0$. Blue and orange notes are redeemed for one unit of numéraire good whereas red notes are worthless. So blue notes have a lower rate of return than orange notes. But Responder cannot distinguish orange notes from red ones. It should be clear that a strategy that consists in purchasing orange notes is weakly dominated by the one that consists in purchasing red notes. To see this, suppose that the Proposer purchases orange notes to make an offer (n, ω) such that $2\omega - n \geq 0$. If the offer is accepted, then the payoff of the Proposer is $-C^o + 100 - n + 2\omega = -n + 2\omega$. If he had purchased red notes his payoff would be 2ω , which is larger. If the offer is rejected, then the Proposer’s payoff is 0, which is the payoff he would get from purchasing red notes. So as long as the Proposer anticipates that the offer will be accepted with positive probability, he should purchase red notes. As a result it is optimal for the Responder to reject offers with red/orange notes that cannot be recognized. So in equilibrium Proposers should only accumulate blue notes despite their lower rate of return.

6 Experiment Design

6.1 Basics

We conducted multiple experiment sessions in a computer laboratory at a large public university with 370 students as human subjects.¹⁴ Students learned of experiments via posted advertisements and email announcements, and they registered to be in the subject pool through an online registration system. Days before each experiment session, an email was sent to the subject pool notifying them of our upcoming session. Interested students then signed up for a specific session on the subject pool web site. Those who signed up received a reminder email about the session the day before it was conducted. Subjects received a \$7 show-up payment plus salient earnings based on the decisions made, with final take-home amounts rounded up to the

¹⁴We conducted twenty one sessions but we only report thirteen for sake of clarity. For instance, we ran six sessions with unrepeatd one-shot games and found results roughly consistent with the results presented here.

nearest quarter. The average take-home amount across all sessions was about \$19 for about 75 minutes of participation. Table 1 displays basic information about the sessions and the subjects.

To facilitate experiment management, instruction, and data collection, we used the z-Tree software package (Fischbacher 2007). Each session consisted of three stages: instruction, decision making, and questionnaire. During the instruction stage, subjects read about the decision-making scenario and answered questions to test their comprehension about the payoffs associated with the different decision-making roles. After answering each question, the subject is told whether his or her answer was correct and a complete explanation of the correct answer. The instructions were identical across sessions except for minor changes in the description and questions that correspond to the specifics of the treatment.¹⁵

The decision-making stage consists of twenty rounds of one-shot interactions. Subjects are first randomly assigned into proposer and responder roles, which they maintain during all twenty rounds. They are then randomly and anonymously matched into the first one-shot interaction. For sessions in which nature chooses the terminal value of the notes, the terminal value is chosen by the computer independently across proposers in the round and independently within proposer across rounds. The information available to the subjects when making decisions depends on the specific treatment conditions described below. After completion of the first round, the subjects were rematched randomly and anonymously for the second round, and so on for the rest of the twenty rounds. At the end of the last round, the computer randomly selected one round, and all subjects were paid according to the decisions for that round. Each blue note is worth \$0.1 to both proposer and responder, and each widget is worth \$0.2 to the proposer and \$0.1 to the responder. Red notes have no value. To ensure that each session ends on time, decisions were made with explicit time constraints. Proposers were given 120 seconds in rounds 1-3 and 45 seconds in all other rounds, or else the computer would make an offer of 0 notes for 0 widgets. Responders were given 60 seconds in rounds 1-3 and 30 seconds in all other rounds, or else the computer would reject the offer. This time constraint was never binding for responders, but the time limit was reached among some proposers. See discussion below.

The questionnaire asks the subject to report personal information, such as sex, race, major, and so on. As shown in Table 1, the questionnaire data reveal a wide distribution of subjects, with higher proportions of females, engineering, and biological sciences students than in the university’s undergraduate population.

¹⁵In the Appendix, we present the instructions for a representative session.

6.2 Sessions, Treatments, and Hypotheses

The sessions correspond to fourteen treatment conditions in the five choice settings examined in the theory part of the paper. These settings are recapitulated in the following under the labels SI, SU, AS, MH, and L. We conducted a single benchmark Symmetric Informed (SI) session in which all proposers are commonly known to have blue notes. In the three Symmetric Uninformed (SU) sessions, neither proposer nor responder knows the color of the notes until after proposals and accept-reject decisions, but rather there is a commonly known probability at which a subject's notes are all blue or all red (iid across subjects). These sessions also allowed the proposers to use an on-screen calculator to calculate the final payoffs for different hypothetical offers before the actual offer was made. In the three Adverse Selection (AS) sessions, each corresponding to the same three probabilities of blue notes, $\pi \in \{0.5, 0.7, 0.9\}$, the proposer knows the color of her notes when making an offer, but the responder does not know the notes' color when deciding to accept or reject. The three AS sessions also had the on-screen calculator. In the three Moral Hazard (MH) sessions, the proposer chooses whether to have all blue or all red notes. Each of the three MH sessions considers one of three costs, $C \in \{0, 20, 60\}$, for purchasing 100 red notes. Note that the cost is expressed in tenth of dollars (or dimes) to make it comparable to the value of blue notes. The four Liquidity (L) sessions differ in the portfolio choice available to the proposer before making the offer. In L0, L1, and L2, the proposer chooses how many blue notes to purchase, with the cost of each note differing across the two sessions (\$0.10 in L0, \$0.11 in L1, \$0.15 in L2), and the responder knows the notes' color. In L3, the proposer chooses whether to have all blue notes for \$15, all orange notes for \$10, or all red notes for \$0. The responder can observe if the notes are blue but cannot distinguish between orange notes, which have the same value as blue notes, and red notes, which have no value.

6.3 Hypotheses

The Symmetric Informed and Symmetric Uninformed settings provide benchmarks from which to compare behavior in the other settings. We want to confirm that the subjects' behavior conforms to basic rationality principles and is consistent with behavior in simpler ultimatum games.

Hypothesis 1 (*Symmetric Information*)

Under symmetric information (SI and SU), for any π , proposers will offer 100 notes and ask for a number of widgets between 50π and 100π .

The theory for the Adverse Selection identifies multiple equilibria. We focus on two types of equilibria. Under the intuitive criterion of the Cho-Kreps refinement, proposers with blue notes attempt to signal their notes' quality by offering fewer notes but ask for a number of widgets per note similar to the one under complete information. A zero value for red notes ($\rho = 0$) leads to a complete collapse of trade. Under active pooling equilibria, proposers make offers that satisfy participation constraints given prior beliefs and all offers are accepted.

Hypothesis 2 (*Adverse Selection*)

Trades satisfy one of the following patterns:

1. (Intuitive Criterion) Either proposer offers no trade or offers are rejected.
2. (Pooling) For any $\pi \geq 0.5$, proposers will offer n notes and ask for between $0.5n$ and πn , and all these offers are accepted.

For the theory of Moral Hazard we distinguish two cases: one where the cost of fraud is zero and one where it is strictly positive. Under zero cost, acquiring red notes is a weakly dominant strategy, and therefore all offers should be rejected. If the cost is strictly positive, there are two cases. If the proposer retains a sufficiently large number of notes; i.e., $n \leq C$, then there is no fraud and all trades are accepted. In contrast, if $n > C$, then the probability that an offer is accepted is increasing in C , and the fraction of blue notes and their price are positively correlated.

Hypothesis 3 (*Moral Hazard*)

1. If $C = 0$, no offer should be accepted.
2. If $C > 0$, then $n \in [\omega, 2\omega]$.

- (a) If $n \leq C$, then there is no fraud and all trades are accepted.
- (b) If $n > C$, then an offer is accepted with probability C/n and the fraction of blue notes is ω/n .

The theory for the liquidity choices focuses on two cases. First, we check for the existence of liquidity premia when agents are symmetrically informed and there are only blue notes. Second, we investigate the rate of return dominance when notes with different recognizability properties are available.

Hypothesis 4 (*Liquidity choice*)

1. (Liquidity Premia) Proposers purchase notes despite the negative return.
2. (Rate-of-return Dominance) Proposers choose blue notes at higher rates than red notes despite the blue notes' higher rate of return, and orange notes (in L3) should not be purchased.

7 Experiment Results

7.1 Summary Statistics and Figures

Panel (a) of Table 2 presents various summary statistics for each session. Panels (b)-(d) report a reduced set of similar statistics when the data are partitioned into accepted and rejected offers or into blue notes and red notes. These statistics provide cursory evidence of many patterns for which we provide formal statistical tests later. For example, the number of notes offered is higher, the price of widgets – defined as the number of notes offered per widget – is lower, and the acceptance rate is higher under Symmetric Informed (SI) than in each of the Symmetric Uninformed (SU), Adverse Selection (AS), and Moral Hazard (MH) sessions, all of which point to informational darkness as a hindrance to trade at both the extensive and intensive margins. In all sessions, responders always made their decisions before their time limit expired, but there is some variation across sessions in how much time responders used. In the SI and SU sessions, proposers always made offers before time expired, but in the AS, MH, and L sessions, some proposers, ranging from 1% in MH2 and L1 to 10% in L3, did not make decisions within the allotted time.¹⁶

¹⁶The masses at (0,0) in some sessions reflect the default offer made for when the proposer's time expired before making an offer.

Figures 7 and 8 provide additional insights into the data. Figure 7 shows the average number of notes offered, the average number of widgets asked, and the average acceptance rate for each session by period. Every SI, SU, AS, and MH session shows a general trend of increasing notes offered over time. Widgets requested increase over time in the SI and SU sessions, and two of the three AS sessions (AS2 and AS3). No general trends in widgets offered are spotted in the other sessions. Acceptance rates generally exhibit larger variability than offer sizes, with much higher variability in acceptance rates in many of the AS and MH sessions than in session SI.

Figure 8 plots the distribution of offers by note type and acceptance for some representative sessions. The area of each circle corresponds to the number of observations with that notes-widget combination, and the same weighting scale is used across graphs. The dotted lines represent the bounds of individually rational offers with blue notes given a pooling equilibrium, and the inner, darker line is the average price (n/ω). We see larger variance in offers in SU2, AS2, and MH2 than in SI, which is confirmed in Table 2. Visual inspection also suggests that accepted offers have, on average, higher prices than rejected offers, a finding that holds up in all sessions except MH1 and L3 (see Table 2), both of which have very low acceptance rates.

7.2 Symmetric Information

The average number of notes offered under complete information (SI) is 87 out of 100 (see Table 2). We reject the hypothesis that the average notes equals 100 (test statistic 8.21). However, the median notes offered is 100 (not in table); 63% of offers include 100 notes. Overall, we see that subjects tend to offer 100 notes. The average widgets requested is 74, well within the [50,100] range predicted. Almost three-quarters of offers are accepted, thus indicating a high level of successful trades. As seen in Figure 8, every accepted offer had a price of widget greater than or equal to 1, and accepted offers have, on average, higher prices than rejected offers (also see Table 2). That some offers with price greater than 1 are rejected while offers with higher prices are more likely to be accepted is consistent with what is typically observed in ultimatum games, namely, that offers that share more of the surplus are more likely to be accepted. This behavior could be due to some subjects valuing fairness. The above evidence suggests that behavior is largely consistent with Hypothesis 1. The outcome is different from the unique subgame perfect equilibrium, where the entire surplus is captured by the proposer, possibly due to fairness considerations.

Many clear patterns are seen when comparing session SI with the SU sessions. We see a monotonic decrease in average notes offered as the probability of blue notes (π) decreases. As seen in Table 3, this difference is statistically significant when dropping from $\pi = 0.9$ to $\pi = 0.7$, but not significant when dropping further still to $\pi = 0.5$. Hypothesis 1 is strongly rejected with respect to the SU sessions; the intensive margin of trade is severely affected by the market darkness even though the darkness is symmetric. We also find a monotonic increase in average offered price for widgets as the probability of blue notes (π) increases. As shown in Table 3, these price increases from SI to SU3 to SU2 to SU1 are statistically significant. In sessions SU1, SU2, and SU3, accepted offers had an average price of 2.40, 1.59, and 1.53, and rejected offers an average price of 1.27, 1.34, and 1.19, respectively. Thus, as for SI, the responders required a sufficiently large surplus in order to accept a trade. Finally, the acceptance rates, 35%, 39%, and 58%, were significantly lower than for the benchmark SI.

A striking difference between SI and the SU sessions is in the rate at which offers satisfy the responder's individual rationality constraint. 99% of all offers in the SI session meet this constraint, but far fewer do in the SU sessions. Moreover, this number decreases significantly as the probability of blue notes drops: 98% in SU3, 89% in SU2, and 54% in SU1. Proposers had access to the online calculator, but it appears that their ability to use it to calculate viable offers was imperfect.¹⁷

In summary, introducing uncertainty about the value of the notes reduced significantly the subjects' ability to exploit the gains from trade, increased the frequency of rejected offers, reduced the size of the trade, and decreased the turnover of the asset.

7.3 Adverse Selection

Consistent with Hypothesis 2.1, there is a large number of offers that are rejected in each AS session. In AS1 70% of offers are rejected, while in AS2 61% and in AS3 53% are rejected. These rejection rates are much higher than in the SI session (27%), but they are slightly higher as the ones of the SU sessions; i.e., 65%, 61% and 42%.

Consistent with Hypothesis 2.2, the average number of notes and average number of offers accepted are

¹⁷We note, however, that we also conducted versions of SU1-SU3 in which no calculator was provided. In those no-calculator sessions we found even lower rates of satisfying the responders IR constraint. This suggests that the calculator did help, though it helped only imperfectly.

higher in session SI than in each of the AS sessions (Table 2), and these differences are statistically significant at high levels (Table 3). The differences are also shown visually in Figure 9, which plots the means and 95% confidence intervals for all sessions. These differences are consistent with the notion that responders are skeptical about the quality of the notes when they observe large note offers.

As the probability of blue notes (π) decreases, the average notes offered does not change significantly. Overall, there is asset retention in the form of fewer notes being offered in the AS sessions when compared with session SI. Tables 2 and 3 and Figure 9 also reveal that the average price offered generally increasing as π increases. The one exception is when comparing sessions AS2 and AS3. The predicted pattern is statistically significant in all cases except when comparing AS2 and AS1.

Overall, the behavior from the AS sessions is largely consistent with Hypothesis 2 but with some nuance. Trade is lower at both the extensive and intensive margins in the AS sessions than in session SI. However, subjects do not appear to have coordinated on a single equilibrium in the AS sessions. Consistent with a separating equilibrium, proposers with blue notes offer, on average, fewer notes. However, the differences are small, and proposers' apparent attempts to signal quality do not appear to be recognized by the responders. If the signals were recognized, then blue notes should be accepted at higher rates than red notes, but we actually see, in Table 2 and Figure 9, either no difference (AS1) or the opposite (AS2 and AS3). Whether subjects could coordinate on a single equilibrium without an explicit coordinating device if given more time is unclear.

It is also instructive to identify whether the changes from SI to AS are due to the *asymmetry* in information or due to *imperfection* of information. We can identify the role of asymmetry by comparing AS1 to SU1, AS2 to SU2, and AS3 to SU3. Figure 10 extracts time series from Figure 7 and recombines AS and SU sessions to facilitate visual inspection of each of these three comparisons. The formal statistical tests shown in Table 3 reveal that in average notes offered are higher in the SU session for $\pi = 0.7$ and $\pi = 0.9$, but not when $\pi = 0.5$ (SU1 vs. AS1), and the acceptance rate only differs when $\pi = 0.9$ (SU3 vs. AS3). However, prices are significantly higher under symmetrically uninformed than under asymmetric information for each level of π . These mixed results suggest that it is the presence of uncertainty that affects offer size and acceptance rates, while both uncertainty and asymmetry drive prices.

As in the SU sessions, we found that the rate at which offers satisfied the responder's individual rationality

constraint decreases as π decreases: 85% in AS3, 36% in AS2, and 15% in AS1. These are generally lower than in their SU counterparts.

In summary, asymmetric information generates similar phenomena than symmetric uncertainty: it significantly reduces the subjects' ability to exploit the gains from trade, it increases significantly rejection rates, it reduces the size of the trade, and it decreases the turnover of the asset. The similarities of the results for the asymmetric information experiments and the experiments with symmetric uncertainty might have some implication for what happened during the financial crisis of 2007/2008.

7.4 Moral Hazard

In accordance with Hypothesis 3.1, 72% of all offers are rejected. The fact that some offers are accepted can be rationalized by the fact that 34% of offers involved blue notes. It is puzzling, however, with $C = 0$ why some proposers acquired blue notes if they expected agents to accept some offers.

In all MH sessions, the percentage of proposers that select blue notes is statistically different than 100%. In the low cost of fraud sessions, MH1 and MH2, the blue notes rates are 34% and 63%, respectively. Only in the high-cost Session MH3 is the blue note rate over 90%. However, we note that 100% is strong standard. Even in the complete information setting (SI), we do not get 100% acceptance. From this perspective, the rate of blue notes purchases in session MH3 can be viewed as quite high. That being said, even though the rate of blue notes purchase in MH3 is high, the signals are not being accurately received by the responders who are more likely to reject offers and accept them in each of the MH3 sessions. We conclude that the threat of fraud dramatically hinders trade even when the theory predicts a no-fraud equilibrium.

We also observe that the average number of notes offered increases as we go from Session MH1 to MH2 to MH3. As seen in Tables 2, this pattern is evident in the data. However, the difference between MH1 and MH2 is not statistically significant at normal levels, as seen in Table 4. This could perhaps be due a diminishing effect of asset retention as the cost of fraud become very low or because the change in cost of fraud from MH1 to MH2 (0 to 2) is smaller than that from MH2 to MH3 (2 to 6). However, it is surprising that there is any trade in MH1 where the cost of red notes is \$0 and the theoretical prediction is that trade shuts down completely.

We find that acceptance rates increase as we raise the cost of fraud. The acceptance rate jumps up

dramatically from MH1 to MH3 and MH2 to MH3. The acceptance rate actually dropped slightly from Session MH1 to MH2, which counters the prediction, yet the difference is not statistically significant (see Tables 2 and 4). The lack of difference between MH1 and MH2 could be due to a diminishing effect of the cost of fraud at low levels or the small difference in the cost of fraud between those two sessions.

Hypothesis 2b predicts that responders will be more likely to accept low offers than high offers. In contrast to this hypothesis, in sessions MH2 and MH3, the average number of notes offered is higher for accepted offers than for rejected offers. However, these differences are never statistically significant at normal levels.

The general pattern is that the possibility of fraud hinders trade at both the extensive and intensive margins. Subjects do not coordinate on a no-fraud equilibrium even though proposers are retaining more assets as the cost of fraud decreases. We also note that the proposers are making offers with higher prices as the cost of fraud decreases. Thus, the behavior under the Moral Hazard setting shows important similarities to that in the Adverse Selection setting, i.e., we see proposers respond by both asset retention and price increases. Indeed, the responders react more to price than asset retention when deciding whether to accept or reject an offer. Though there is no statistically significant difference between the prices of accepted and rejected offers in Session MH1, there is in sessions MH2 and MH3 (test statistics -2.53 and -4.26, respectively).

7.5 Liquidity

When proposers choose their asset portfolios in the L1 and L2 sessions, Hypothesis 4(a) predicts that the liquid asset (i.e., blue notes) will be purchased despite their negative return. That average notes offered in L1 and L2 are significantly different from 0 at high significance levels, as shown in Tables 2 and 4 and Figure 9, implies that blue notes are purchased at levels significantly different from 0 (because notes offered must be weakly less than notes purchased). The purchase of blue notes is steady across rounds in both the L1 and L2 sessions, as seen in Figure 11. This finding matches the notion of rate-of-return dominance. In Session L0, which is provided for comparison with L1 and L2, the cost of blue notes implies no negative return if untraded. As would be expected, with a smaller risk associated with purchasing blue notes in L0, we observe a higher number of blue notes purchased in L0 than in L1 and L2. This difference is large and statistically significant (see Table 4). We also expect offers in L0 to be similar to those in SI. We find that notes offered

and the acceptance rate are both lower in L0 than in SI, though not dramatically so, and prices are not statistically different in L0 and SI. The difference stems in part from some proposers not buying 100 (blue) notes even without the risk. Yet we see that practically all notes purchased are offered and at prices similar to those in SI. We thus see behavior in L0 to be similar to SI conditional on the number of notes purchased.

Hypothesis 4(b) tests the limits of the rate-of-return dominance in session L3. The theory predicts that orange notes will not be purchased, which implies red notes will be identified in the equilibrium, thus making the purchase of blue notes the optimal choice. We find that 37% of the subjects, on average, choose to hold blue notes despite their being dominated in their rate of return. However, this is less than the 46% that choose red notes. Moreover, 17% choose orange notes, which runs counter to the prediction that orange notes will not be held. These data lead us to reject Hypothesis 4(b). We note, however, that the purchase of orange notes appears to trend downward in session L3, as seen in Figure 11. If subjects are indeed learning to avoid orange notes, then it is possible that with enough time, they will then learn to avoid red notes as well, thus leading all subjects to eventually hold only blue notes. Thus, although the data reject Hypothesis 4(b), there is also an indication that the subjects may eventually reach the predicted equilibrium but just have not done so yet.

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Table 1: Session and Subject Information

Information Setting		Sym. Informed	Symmetric Uninformed			Adverse Selection			Moral Hazard			Liquidity				All	Undergrad. Student Population
Session Identifier		SI	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3	L0	L1	L2	L3	—	—
Treatment Details		100% blue	50% blue	70% blue	90% blue	50% blue	70% blue	90% blue	red cost \$0	red cost \$2	red cost \$6	blue cost \$0.10	blue cost \$0.11	blue cost \$0.15	blue or orange/red	—	—
Number of subjects *		28	38	30	34	24	28	26	20	32	22	26	20	24	18	370	22,004
Percent female **		68%	55%	60%	41%	75%	82%	77%	50%	69%	68%	58%	60%	67%	67%	64%	54%
Percent with 1+ statistics		75%	68%	70%	59%	63%	61%	62%	55%	69%	50%	50%	40%	46%	50%	60%	—
Percent by Study Major**	Business or Econ.	11%	16%	33%	18%	17%	14%	15%	5%	13%	23%	15%	50%	21%	0%	18%	51%
	Other Social Science	14%	24%	10%	14%	33%	18%	24%	10%	28%	31%	11%	10%	4%	28%	33%	
	Physical Sci. or Engineer.	18%	24%	27%	24%	25%	19%	27%	20%	22%	18%	27%	5%	4%	33%	21%	
	Life Sci. or Biology	32%	29%	23%	29%	13%	15%	23%	45%	28%	23%	38%	20%	58%	28%	29%	
	Human. or Undec.	25%	8%	7%	15%	13%	25%	12%	20%	9%	5%	8%	15%	13%	11%	13%	
Average earnings ***		\$19.95	\$14.62	\$16.13	\$18.10	\$16.13	\$16.18	\$17.69	\$17.30	\$16.88	\$18.43	\$19.13	\$19.13	\$19.72	\$18.78		—

Notes: Percentages might not add to 100% due to round-off error. * includes only the subjects that completed entire duration of experiment. Two subjects left early in SIC and one left early in AS4. ** denotes information obtained from the questionnaire. *** includes the \$7 show-up payment and earning from exchange. Information about the undergraduate student population is as of Fall 2011.

Table 2: Summary Means (Standard Deviations), by Session

(a) All Offers														
	SI	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3	L0	L1	L2	L3
Notes Offered	86.89 (24.93)	71.41 (26.49)	73.15 (27.17)	79.60 (24.27)	73.29 (27.42)	58.06 (32.70)	71.95 (30.09)	54.86 (25.16)	58.49 (28.55)	73.77 (25.10)	81.79 (30.89)	59.93 (37.79)	59.30 (41.41)	68.42 (33.73)
Widgets Offered	74.18 (22.70)	46.70 (20.16)	52.52 (21.34)	59.60 (19.63)	54.8 (20.82)	48.76 (25.53)	58.43 (23.52)	37.94 (21.11)	45.80 (24.06)	62.43 (22.68)	72.30 (23.97)	48.90 (30.50)	54.39 (37.78)	45.14 (32.62)
Price	1.18 (0.15)	1.76 (1.11)	1.44 (0.35)	1.39 (0.38)	1.37 (0.35)	1.23 (0.40)	1.25 (0.27)	1.61 (0.79)	1.37 (0.68)	1.22 (0.31)	1.16 (0.32)	1.21 (0.23)	1.15 (0.91)	2.17 (1.80)
Offers Accepted	73%	35%	39%	58%	30%	39%	47%	27%	24%	46%	62%	64%	61%	32%
Percent Blue Notes	100%	51%	67%	91%	51%	77%	87%	34%	63%	92%	82.45* (30.50)	61.38* (37.59)	62.05* (40.17)	74%
Velocity Blue**	0.66	0.30	0.29	0.49	0.24	0.21	0.33	0.15	0.14	0.35	0.53	0.70	0.70	0.52
Velocity Red**	–	0.23	0.29	0.38	0.21	0.25	0.38	0.13	0.15	0.40	–	–	–	0.08/ 0.06**
% satisfy IRR	99%	28%	67%	88%	15%	36%	85%	98%	90%	90%	94%	97%	89%	96%
% Timer End Prop/Resp	0%/0%	0%/0%	0%/0%	0%/0%	4%/0%	6%/0%	3%/0%	3%/0%	1%/0%	2%/0%	1%/0%	7%/0%	10%/0%	4%/0%

(b) Accepted Offers														
	SI	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3	L0	L1	L2	L3
Notes	90.629 (19.39)	75.26 (26.49)	74.12 (26.31)	83.19 (20.46)	73.42 (27.64)	57.75 (32.55)	72.51 (29.28)	53.11 (25.46)	60.88 (27.38)	76.65 (23.05)	88.24 (22.99)	67.90 (37.28)	71.00 (35.27)	81.91 (27.06)
Widgets	75.86 (18.92)	39.04 (18.46)	48.00 (18.34)	56.20 (16.82)	49.85 (19.64)	41.33 (24.10)	54.50 (22.20)	36.91 (21.60)	40.72 (19.98)	60.31 (20.63)	73.24 (20.06)	53.76 (30.27)	61.55 (33.58)	55.61 (22.16)
Price	1.21 (0.14)	2.40 (1.62)	1.59 (0.39)	1.53 (0.36)	1.50 (0.24)	1.42 (0.27)	1.34 (0.19)	1.54 (0.36)	1.60 (1.02)	1.31 (0.24)	1.25 (0.28)	1.26 (0.21)	1.30 (1.05)	1.60 (0.90)
Percent Blue Notes	100%	56%	68%	93%	49%	69%	83%	42%	63%	92%	88.64* (22.66)	69.12* (36.80)	73.50* (34.19)	78%
% satisfy IRR	100%	54%	89%	98%	21%	56%	93%	100%	97%	98%	99%	100%	99%	100%

(c) Rejected Offers														
	SI	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3	L0	L1	L2	L3
Notes	76.68 (34.09)	69.33 (26.30)	72.53 (27.76)	74.72 (28.00)	73.23 (27.41)	58.26 (32.88)	71.45 (30.88)	55.49 (25.11)	57.75 (28.92)	71.32 (26.56)	71.31 (38.47)	46.07 (34.77)	40.78 (43.75)	65.89 (32.72)
Widgets	69.59 (30.44)	50.83 (19.86)	55.45 (22.65)	64.23 (22.14)	57.02 (21.00)	53.42 (25.36)	61.86 (24.17)	38.31 (21.00)	47.39 (25.03)	64.23 (24.23)	70.78 (29.28)	40.42 (29.21)	43.08 (41.33)	41.70 (31.64)
Price	1.10 (0.16)	1.42 (0.44)	1.34 (0.27)	1.19 (0.32)	1.32 (0.38)	1.11 (0.42)	1.18 (0.31)	1.63 (0.89)	1.29 (0.51)	1.15 (0.34)	1.02 (0.32)	1.12 (0.23)	0.82 (0.38)	2.33 (1.93)
Percent Blue Notes	100%	48%	66%	88%	50%	81%	90%	31%	64%	92%	72.39* (38.14)	47.92* (35.29)	43.96* (42.40)	73%
% satisfy IRR	97%	15%	52%	73%	13%	23%	77%	97%	87%	82%	85%	92%	73%	94%

Notes: * denotes average number of notes purchased in Sessions L0-L2. ** velocity is calculated as the number of notes traded divided by the number of notes available for trades. For Session L3, the velocity for orange is listed with the velocity for red.

Table 2: Summary Means (Standard Deviations), by Session (cont.)

	(d) Blue Notes													
	SI	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3	L0	L1	L2	L3***
Notes Offered	86.89 (24.93)	72.16 (27.54)	72.54 (26.43)	79.95 (24.74)	76.43 (26.69)	60.09 (32.90)	72.91 (30.69)	50.93 (29.19)	56.54 (30.95)	73.56 (24.61)	82.63 (29.19)	59.93 (37.79)	59.30 (41.41)	78.73 (32.35)
Widgets Offered	74.18 (22.70)	46.24 (20.82)	51.68 (20.72)	60.70 (19.19)	60.34 (20.82)	51.91 (25.63)	59.75 (23.87)	36.30 (21.50)	48.02 (26.44)	62.63 (22.72)	74.14 (21.40)	48.90 (30.50)	54.39 (37.78)	67.92 (31.53)
Price	1.18 (0.15)	1.81 (1.16)	1.46 (0.38)	1.38 (0.38)	1.32 (0.39)	1.19 (0.41)	1.23 (0.28)	1.45 (0.30)	1.24 (0.71)	1.22 (0.28)	1.13 (0.27)	1.21 (0.23)	1.15 (0.91)	1.19 (0.27)
Offers Accepted	73%	38%	40%	59%	30%	35%	45%	33%	24%	46%	59%	78%	61%	64%
% satisfy IRR	100%	30%	69%	87%	15%	29%	84%	96%	87%	90%	???	97%	89%	96%

	(e) Red Notes													
	SI	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3	L0	L1	L2	L3***
Notes Offered	–	70.63 (25.41)	74.39 (28.68)	76.00 (29.43)	70.03 (27.90)	51.34 (31.34)	65.53 (25.24)	56.84 (22.73)	61.87 (23.55)	76.06 (30.78)	–	–	–	62.04 (32.34)
Widgets Offered	–	47.17 (19.50)	54.20 (22.55)	54.77 (23.49)	49.16 (19.31)	38.32 (22.38)	49.71 (19.09)	38.76 (20.95)	41.96 (18.75)	60.11 (22.79)	–	–	–	27.52 (25.11)
Price	–	1.70 (1.06)	1.41 (0.25)	1.43 (0.37)	1.43 (0.30)	1.33 (0.37)	82.44 (31.12)	1.69 (0.93)	1.59 (0.57)	1.30 (0.55)	–	–	–	3.16 (2.22)
Offers Accepted	–	32%	38%	43%	31%	51%	59%	23%	24%	44%	–	–	–	44%
% satisfy IRR	100%	27%	62%	97%	15%	57%	88%	98%	94%	83%	–	–	–	98%

Notes: *** denotes that orange notes are omitted. **** denotes that all notes were blue.

Figure 7: Offers and Acceptance Rates, by Session and Period

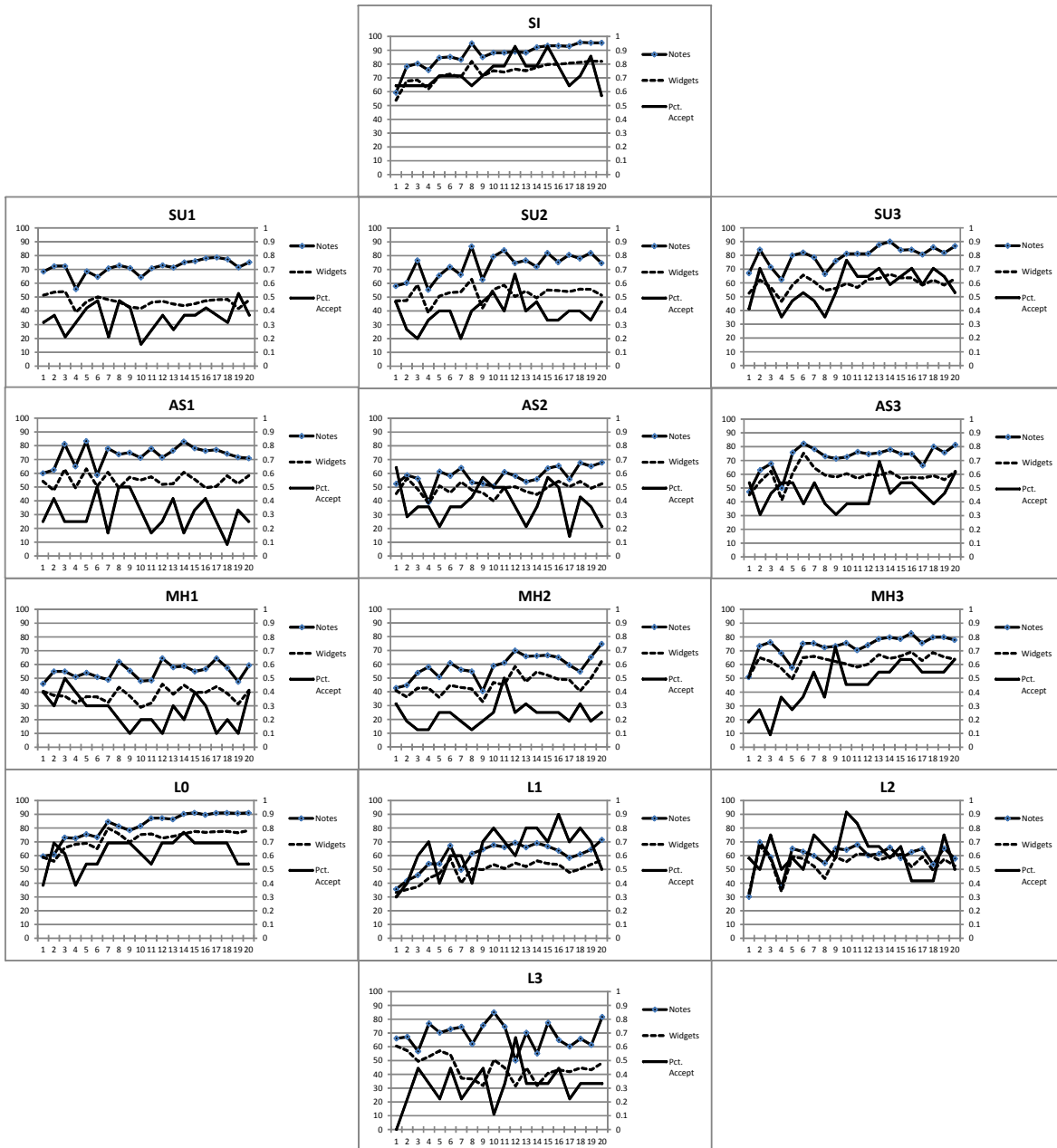


Figure 8: Offers by Acceptance and Type of Notes, Sessions SI, SU2, AS2, MH1, L1

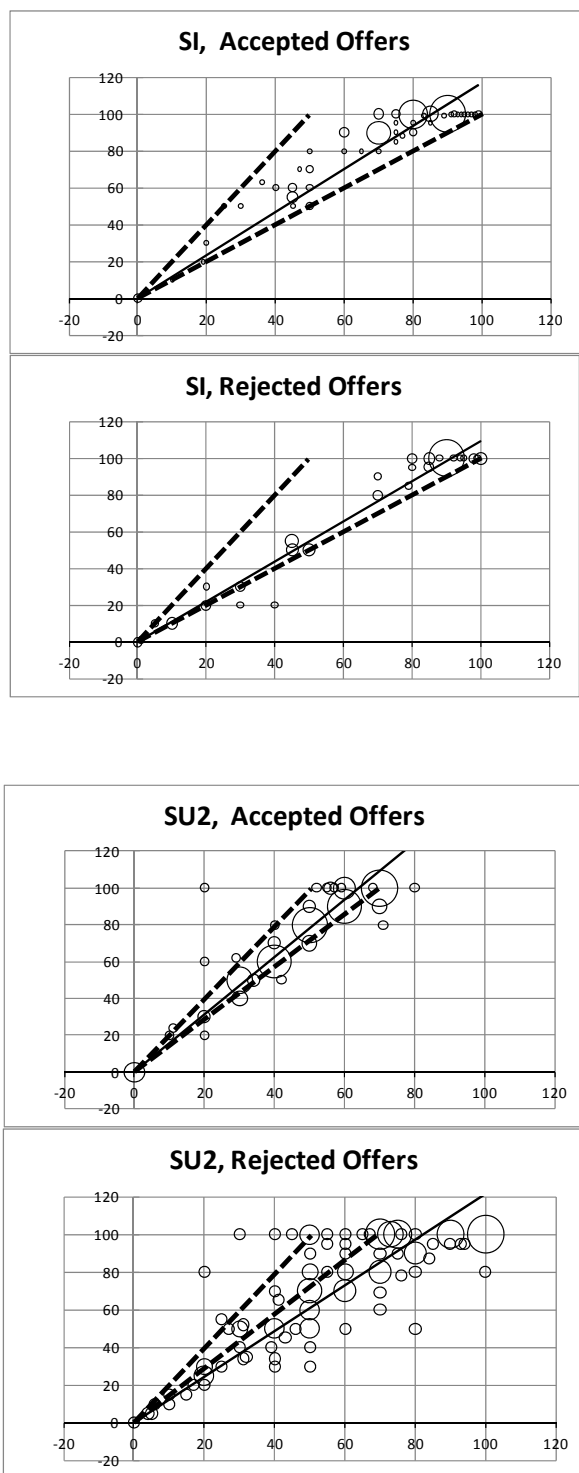


Figure 8 (cont.): Offers by Acceptance and Type of Notes, Sessions SI, SU2, AS2, MH1, L1

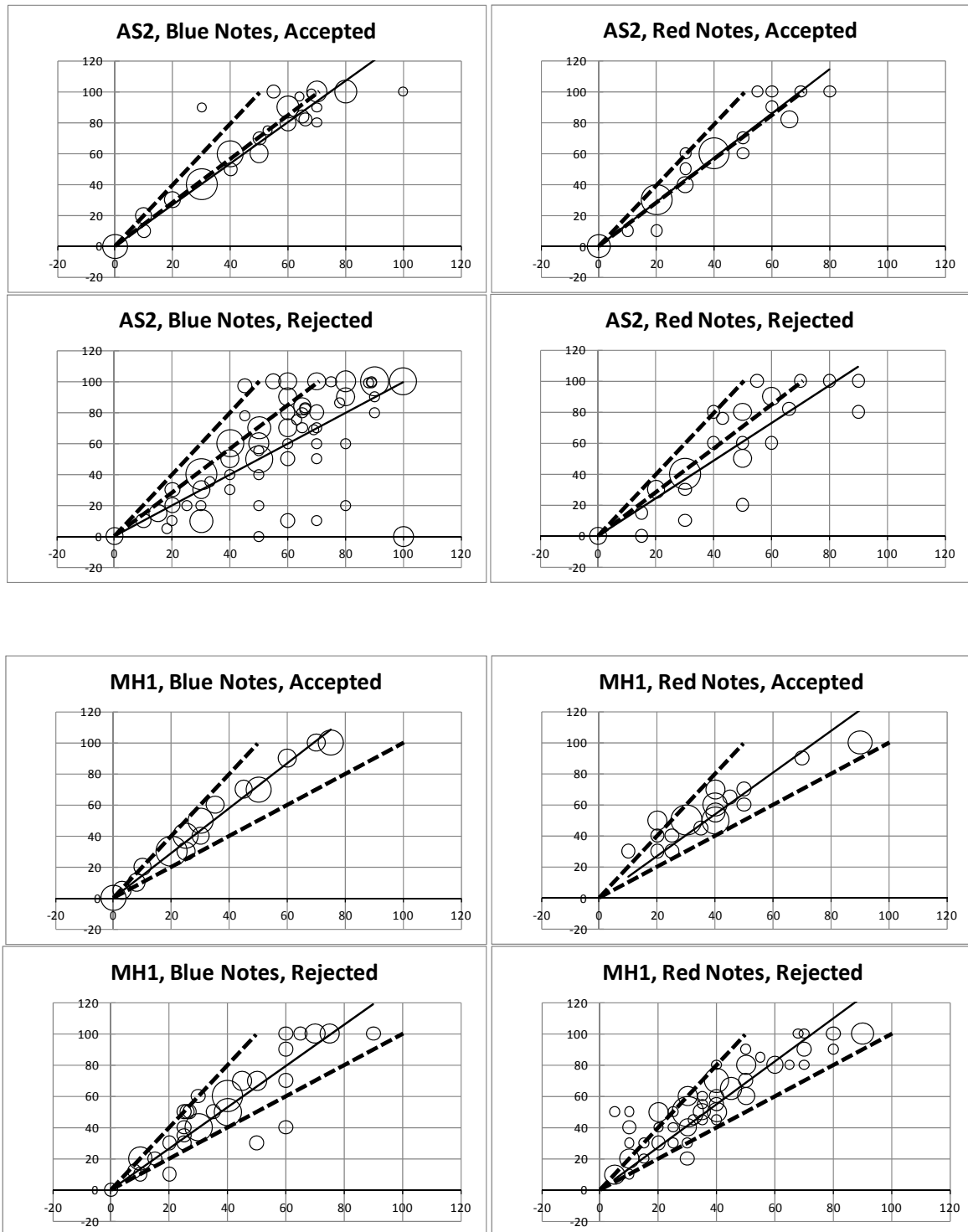


Figure 8 (cont.): Offers by Acceptance and Type of Notes, Sessions SI, SU2, AS2, MH1, L1

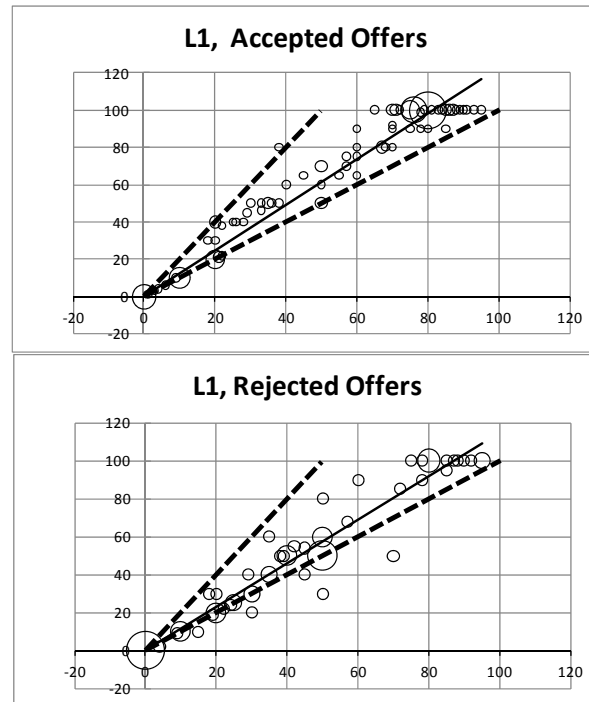


Table 3: T-test Statistics Comparing Means Across Sessions, SI, SU, and AS

(a) Notes

	SU1	SU2	SU3	AS1	AS2	AS3
SI	7.68***	6.35***	3.67***	5.88***	11.73***	6.26***
SU1		-0.84	-4.33***	-0.84		
SU2			-3.15**		6.02***	
SU3						3.35***
AS1					5.77***	0.52
AS2						-5.14***

(b) Prices

	SU1	SU2	SU3	AS1	AS2	AS3
SI	-9.77***	-11.44***	-8.95***	-7.59***	-1.59	-3.48***
SU1		5.17***	5.99***	6.16***		
SU2			1.76*		6.66***	
SU3						4.99***
AS1					4.34***	4.16***
AS2						-0.87

(c) Pct. Accept

	SU1	SU2	SU3	AS1	AS2	AS3
SI	10.59***	8.75***	4.13***	10.74***	8.79***	6.54***
SU1		-1.16	-6.23***	1.19		
SU2			-4.70***		0.19	
SU3						2.71***
AS1					-1.96*	-3.75***
AS2						-1.87*

Notes: Each t-test statistic tests that the row mean minus the column mean is equal to 0.

Table 4: T-test Statistics Comparing Means Across Sessions, SI, MH, and L

Symmetric Informed and Moral Hazard

(a) Notes

	MH1	MH2	MH3
SI	13.80***	13.01***	5.82***
MH1		-1.52	-7.70***
MH2			-6.57***
MH3			

(b) Prices

	MH1	MH2	MH3
SI	-7.51***	-4.70***	-1.77*
MH1		3.59***	6.45***
MH2			3.30***
MH3			

(c) Pct. Accept

	MH1	MH2	MH3
SI	11.39***	13.88***	6.37***
MH1		0.70	-4.22***
MH2			-5.37***
MH3			

Symmetric Informed and Liquidity L0, L1, L2

(a) Notes

	L0	L1	L2
SI	2.10**	8.81***	9.02***
L0		-6.65***	-6.84***
L1			0.17

(b) Prices

	L0	L1	L2
SI	1.08	-1.52	0.57
L0		2.03**	-0.20
L1			0.99

(c) Pct. Accept

	L0	L1	L2
SI	2.81***	2.25**	2.91***
L0		0.35	-0.15
L1			0.48

Symmetric Informed and Liquidity L3

(a) Notes: 9.02***

(b) Prices: 0.57

(c) Pct. Accept: 2.91***

Notes: Each t-test statistic tests that the row mean minus the column mean is equal to 0.

Table 5: T-test Statistics Comparing Blue and Red Means Across Sessions, SU, MH, and L

	SU1	SU2	SU3	AS1	AS2	AS3	MH1	MH2	MH3
Notes Offered	-0.56	0.54	-0.71	1.81*	-1.95*	-1.54	-1.45	-1.73*	-0.33
Price	-0.92	-1.35	-0.68	2.58**	2.51**	2.37**	-2.66***	-5.03***	-0.65
Offers Accepted	-1.39	-0.33	-1.63	0.31	2.25**	1.54	1.39	-0.06	0.13

Notes: Each t-test statistic tests that the blue mean minus the red mean equals 0.

Figure 9: Session Means and 95% Confidence Intervals, by Session

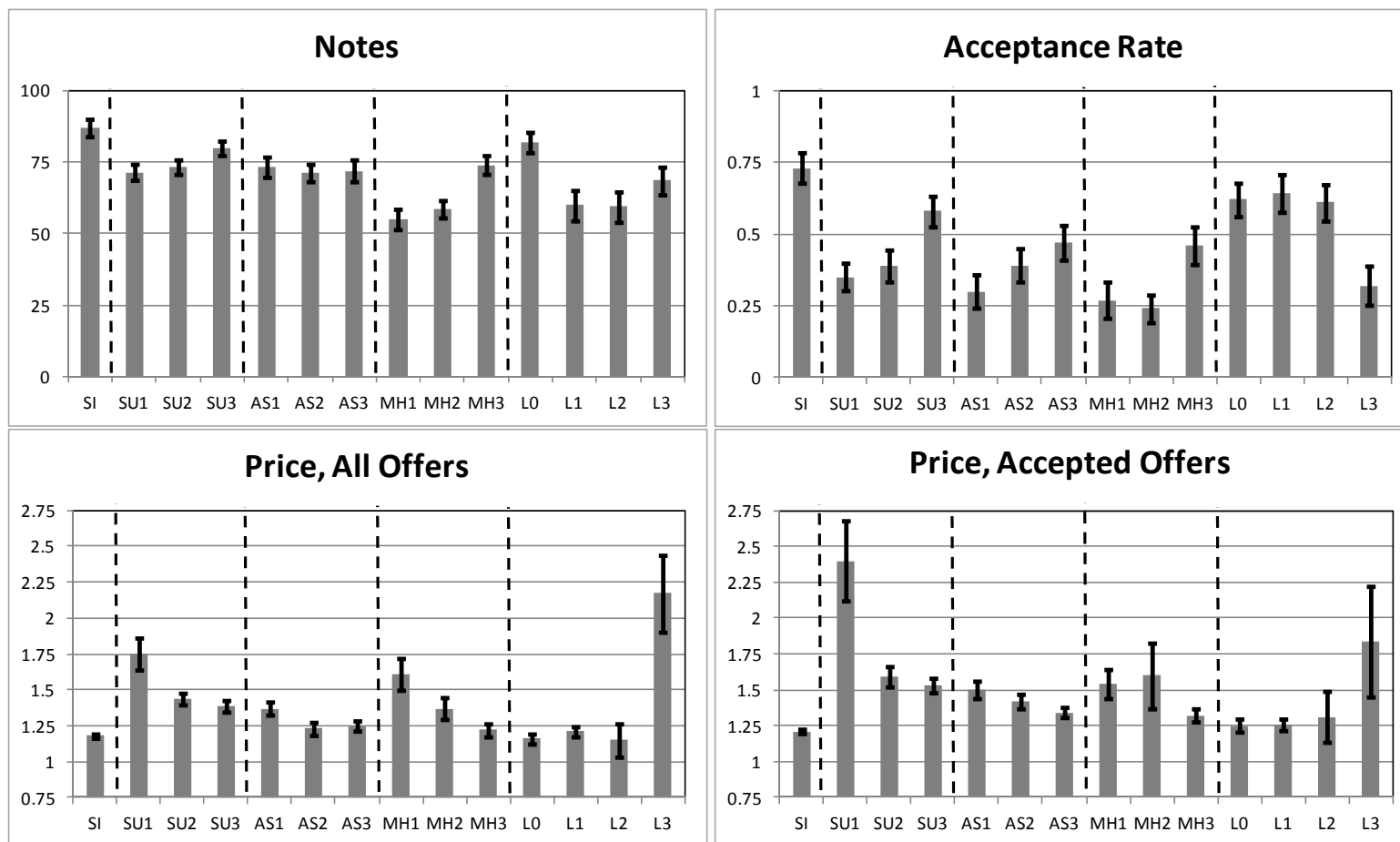


Figure 10: Comparisons of Means Between Uniformed and Asymmetric Information, by Period

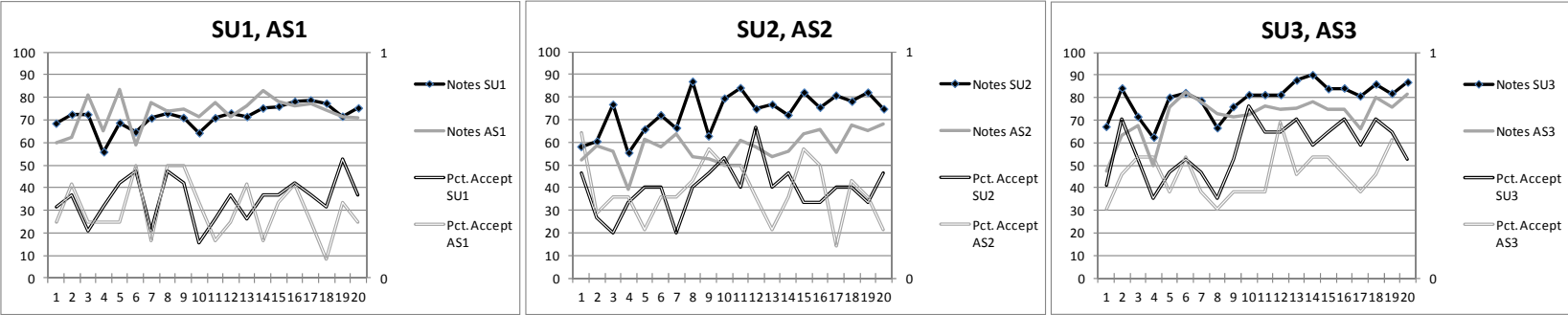


Figure 11: Notes Purchased by Round, Liquidity Sessions

