Adverse Selection and Intermediation Chains [*]

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We propose a parsimonious model of over-the-counter trading under asymmetric information to study the presence of intermediation chains that stand between heterogeneously informed market participants. We show that moderately informed intermediaries can reduce trading inefficiencies due to asymmetric information by layering an adverse selection problem over multiple transactions. Informed market participants may prefer to trade through one or more of these intermediaries as they improve trade efficiency but also reduce the surplus accruing to uninformed traders. Our model makes novel predictions about optimal network formation when adverse selection problems impede the efficiency of trade.

Keywords: Intermediation Chains, OTC Trading Networks, Adverse Selection, Asymmetric Information
JEL Codes: G20, D82, D85

1 Introduction

In over-the-counter (OTC) markets securities regularly pass through several intermediate traders before reaching their ultimate buyer. Informed market participants interested in acquiring a security often trade with other institutions, potentially with different degrees of financial expertise, who effectively act as intermediaries between them and less informed parties. In this paper, we propose a parsimonious model of OTC trading with asymmetric information to analyze the involvement of multiple intermediaries who stand between buyers and sellers.

Our model shows how moderately informed traders can fulfill an important economic role in intermediating trade by *reallocating* an adverse selection problem over several layers of transactions. Gains to trade that would otherwise be destroyed due to adverse selection between two asymmetrically informed traders can be preserved if the least informed party trades with a moderately informed intermediary who then trades with the most informed party. In contrast to other intermediation theories, this simple idea can be extended to explain why trading often involves *multiple* intermediaries rather than just one dominant central dealer. We show that a socially optimal trading network involves intermediation chains that help sustain high liquidity in financial markets where adverse selection problems impede trading between the ultimate buyers and sellers of securities.

Our model considers two asymmetrically informed agents wanting to trade a security through bilateral bargaining in order to realize exogenous gains to trade (say, for liquidity reasons). For simplicity, one trader is assumed to be perfectly informed about the value of the security, while the other trader is uninformed. A standard result in models like ours is that trade may break down when the gains to trade available are small relative to the degree of information asymmetry concerning the value of the security. When this is the case, we show that involving a moderately informed agent — whose information quality ranks between that of the two end traders — to intermediate trade can improve trade efficiency. First, trading with the fully informed agent is easier for a moderately informed agent than it is for the uninformed agent. Similarly, the uninformed agent faces a smaller adverse selection problem when trading with the moderately informed intermediary. This simple intuition can be extended to show that trade efficiency can be improved by further reallocating the adverse selection problem over multiple transactions for which the difference in information quality between counterparties is small. However, involving many intermediaries is not always optimal since each trader involved needs to be privately incentivized to sustain trade and create a surplus. We solve for the socially optimal trading network and show how it depends on the degree of adverse selection, relative to the gains to trade, between the ultimate buyer and seller of a security. A long intermediation chain that is optimal for solving a specific adverse selection problem would often make liquidity more fragile and trading less efficient in a different situation. Our model thus speaks to how trading networks impact the ability of all involved parties to extract a surplus and their willingness to sustain socially efficient trade.

Our paper contributes to the literature in economics that studies how intermediaries can enhance trade efficiency. Intermediation can economize on transaction costs (see Townsend 1978), concentrate monitoring incentives (see Diamond 1984), and alleviate search frictions (see Rubinstein and Wolinsky 1987, Yavaş 1994, Duffie, Gârleanu, and Pedersen 2005). Our paper instead speaks to how intermediaries can serve to alleviate trading inefficiencies caused by informational frictions (see Akerlof 1970). We know already from Myerson and Satterthwaite (1983) that the involvement of an uninformed third party who subsidizes transactions can help to eliminate asymmetric information problems in bilateral trade. Biglaiser (1993) also shows that a fully informed middleman who offers a warranty on the quality of a good and cares about his reputation can improve trade efficiency. Li (1998) also studies a model in which a fully informed middleman is also trustworthy in equilibrium, not because of reputational concerns as in Biglaiser (1993), but because of the existence of a sufficiently large mass of informed buyers who can discipline a cheating middleman by forcing him to hold on to low-quality goods. Contrary to these models, our model considers the possibility that an intermediary's information set differs from that of the agents already involved in the transaction. In our static model without subsidies, warranties, or reputational concerns, the involvement of an intermediary who is either fully informed or totally uninformed does not improve trade efficiency. Also studying the role of reputational concerns is Babus (2012) who models OTC markets where agents meet sporadically and have incomplete information about other traders' histories. In equilibrium, a central intermediary becomes involved in all trades. This unique intermediary interacts repeatedly with traders and can heavily penalize anyone who previously defaulted on his obligations. Our model instead predicts the existence of multiple intermediaries who are all needed to reallocate a large adverse selection problem over several layers of transactions, where each trader is only slightly better or worse informed than his counterparty. The idea that moderately informed intermediaries can reduce trade inefficiencies due to adverse selection simply by layering the adverse selection over many transactions fundamentally differentiates our paper from these earlier papers.

Moreover, the prediction that more than one intermediary might be needed to mitigate large adverse selection problems is unique to our paper. It distinguishes it from the models described above and from market microstructure models with heterogeneously informed traders but where interdealer trading plays no role. Examples include Kyle (1985) and Glosten and Milgrom (1985), where competitive market makers learn from order flow data and intermediate trade between liquidity traders and informed traders, and Jovanovic and Menkveld (2012), where high frequency traders learn quickly about the arrival of news and intermediate trade between early traders who post a limit order and late traders who react to the limit order using information that became available since its posting.

Empirically, many finance papers document that interdealer trading, a key feature of our model, accounts for a substantial fraction of trading both in centralized and in decentralized markets.[1] For example, Lyons (1996) estimates that interdealer trading accounts for up to 85% of transaction volume in foreign exchange markets. According to a 2010 report by the Bank of International Settlements, interdealer transaction volume in those markets averages $1.5 trillion per day. Weller (2013) also shows that a median number of 2 intermediaries are involved between the initial seller and the final buyer of gold, silver, and copper futures contracts. Moreover, up to 10% of round-trip transactions require the involvement of at least 5 intermediaries.

While some empirical papers such as Hansch, Naik, and Viswanathan (1998) find that inventory levels explain part of the interdealer trading they observe, key features of interdealer trading still remain unexplained. Manaster and Mann (1996) find that the positive relationship between trader inventories and transaction prices they observe in futures trading data violates the predictions of inventory control models such as Ho and Stoll (1983). Manaster and Mann (1996, p. 973) conclude that the intermediaries they study are "active profit-seeking individuals with heterogeneous levels of information and/or trading skill," elements that are usually absent from inventory control theories.[2]

[1]See, e.g., Gould and Kleidon (1994) for Nasdaq stocks, Reiss and Werner (1998) and Hansch, Naik, and Viswanathan (1998) for London Stock Exchange stocks, Lyons (1996) for foreign exchange instruments, Hollifield, Neklyudov, and Spatt (2012) for securitized products, Li and Schüroff (2012) for municipal bonds, and Weller (2013) for metals futures.

[2]See also Glosten and Harris (1988), Stoll (1989), Foster and Viswanathan (1993), Hasbrouck and Sofianos (1993),

Our model simultaneously features asymmetric information and inventory management motives.[3] The intermediaries in our model are effectively averse to holding inventories (i.e., non-zero positions) since they are not the efficient holders of the security, that is, those who realize the gains to trade. Yet, information asymmetries may prevent them from offloading the security to potential buyers and creating a surplus.

Recent empirical evidence on the OTC trading of securitized products appears to lend support to the mechanisms we highlight in our paper. In particular, Hollifield, Neklyudov, and Spatt (2012) show that instruments that can be traded both by unsophisticated and sophisticated investors (i.e., "registered" instruments) are usually associated with higher spreads paid to dealers (often viewed as a measure of adverse selection), more interdealer trading, and a higher number of dealers involved in their trading than instruments that can be traded only by sophisticated investors (i.e., "rule 144a" instruments). They also show that the spread paid to dealers is positively correlated in the cross-section of round-trip transactions with the length of the transaction chain and with the proportion of interdealer trades. These findings are broadly consistent with our model's main prediction that larger information asymmetries require longer intermediation chains.

Our paper is also related to Duffie, Malamud, and Manso (2012) who endogenize information acquisition by traders, taking as given the search for counterparties, and Gofman (2011) who studies the inefficiencies in resource allocation that arise when traders face (non-informational) bargaining frictions in a sparse OTC network. However, in our paper we study the optimality of trading networks, taking as given the existence of an adverse selection problem. The involvement of moderately informed intermediaries reduces the informational asymmetries that each trading counterparty faces, but it does so at a non-trivial cost: it increases the number of strategic agents trying to capture a share of the gains to trade. In that sense, our paper also speaks to the topic of rent-extraction in the financial sector (see also Murphy, Shleifer, and Vishny 1991, Philippon 2010, Bolton, Santos, and Scheinkman 2012, Glode, Green, and Lowery 2012, Glode and Lowery 2013).

In the next section, we model a simple adverse selection problem between two asymmetrically informed traders. Then, in Section 3, we show that adding a moderately informed intermediary

Madhavan and Smidt (1993), and Keim and Madhavan (1996) for early evidence that informational asymmetries impact intermediated transactions.

[3] Madhavan and Smidt (1993) also combine asymmetric information and inventory management motives, but their model remains silent about the empirical phenomenon of intermediation chains. Our model features OTC trading, rather than centralized trading, and allows for multiple intermediaries.

can reduce the trading inefficiencies that arise in such a setup. The optimality of intermediation chains is studied in Section 4 as we allow for the involvement of multiple intermediaries. The last section concludes.

2 A Model of Adverse Selection

Two agents consider trading a security over the counter (e.g., a mortgage-backed security). A current owner values the security at v and a potential buyer values it at $v + \Delta$. Gains to trade of Δ are realized whenever the security ends up in the hands of the buyer — trade is efficient if it takes place with probability 1. The gains to trade Δ are constant and known to all agents, but the common value v is uncertain and can either be high, v_h, or low, v_l, with equal probabilities. We use σ to denote the spread $(v_h - v_l)$, which will later fully characterize the adverse selection problem.

Although the role intermediation plays in our model is relatively simple, multi-layered bargaining problems with asymmetric information are usually complex to study given the potential for multiple equilibria arising from the various types of off-equilibrium beliefs. However, we are able to make specific modeling assumptions that maintain the tractability of our results even in the presence of multiple intermediaries. First, Seppi (1990) argues that agents knowing the identity of their trading counterparties is an important distinction between OTC trading and centralized/exchange trading. Thus, in our model with asymmetric information, we assume that agents know how well informed their counterparty is, even though they do not know the specific information he has. Second, we assume that the seller of the security has no information about the value of the security whereas the buyer observes v. Assuming that the seller of an object is less informed about its value than a potential buyer could appear unnatural in the context of real assets such as used cars, but is often more realistic in the context of financial securities. A firm looking to offload its risk exposure to interest rates, foreign exchange rates, or commodity prices may very well have less expertise, data, and human capital required to value related financial products than any of the large financial institutions that end up insuring these risks. Third, we simplify the analysis by assuming that the uninformed agent makes an ultimatum offer to the informed agent. This assumption eliminates signalling concerns and ensures the uniqueness of our equilibrium, without the need for equilibrium refinements. Although these stark assumptions are not necessary conditions for the basic economic mechanism we highlight in this paper, they greatly contribute to the analytical tractability and transparency of the model.

These assumptions above imply that, without an intermediary, the seller chooses to quote the buyer one of two prices:

$$p_l \equiv v_l + \Delta,$$

or

$$p_h \equiv v_h + \Delta.$$

The buyer would accept to pay the low price p_l for the security with probability 1. He would, however, only accept to pay the high price p_h if he were to learn that the security is worth v_h. Hence, if the seller chooses to quote a price p_l, the seller's expected surplus is:

$$p_l - E[v] = \Delta - \sigma/2,$$

while the buyer's expected surplus is $\sigma/2$. The total surplus created by trade is Δ. If the seller instead chooses to quote a price p_h, the total surplus drops to $\Delta/2$ as trade only takes place with probability 1/2. However, the price the seller collects if trade occurs is higher, yielding an expected surplus of:

$$\frac{1}{2}(p_h - v_h) = \Delta/2$$

for the seller and zero for the buyer. Hence, for trade to occur with probability 1, the seller has to quote the low price p_l rather than the high price p_h, which only happens if:

$$\begin{aligned} \Delta - \sigma/2 &\geq \Delta/2 \\ \Leftrightarrow \sigma &\leq \Delta. \end{aligned}$$

Efficient trade requires a small σ, which quantifies the cost to the seller of quoting p_l and receiving a security worth $E[v]$. But if σ is high and there is too much adverse selection, trade breaks down with probability 1/2 and half of the surplus from trade is lost.

Note that, alternatively, asymmetric information could be attached to the gains to trade Δ

rather than to the common-value component v as is currently the case in our model. For example, gains to trade could be influenced by private information about a dealer's order flow. We know, however, from Myerson and Satterthwaite (1983) that asymmetric information leading to inefficient trading is a general result in bilateral bargaining. Closer to our current setup, Glode, Green, and Lowery (2012) derive results implying that the boundary for efficient trade would also be $\sigma \leq \Delta$ if the informed buyer was making an ultimatum offer rather than responding to it and if a restriction from Grossman and Perry (1986) on off-equilibrium beliefs was imposed. For $\sigma > \Delta$, trade would break down with some probability because the cost of adverse selection would swamp the gains to trade. The convenience of focusing on the situation in which the informed agent responds to a quoted price rather than making an informed bid for the security originates from the fact by avoiding signalling concerns a unique equilibrium bargaining outcome is achieved without having to impose restrictions on off-equilibrium beliefs.

3 Intermediated Trading

In this section we consider the involvement of an intermediary, who values the security at v just like the seller does, but who also receives a signal s about v that is accurate with probability $\mu \in (\frac{1}{2}, 1)$. Such signal has a correlation of $2\mu - 1$ with the true value v. Since $\mu > \frac{1}{2}$, the intermediary is better informed than the seller (who, without a signal, could correctly predict v with probability 1/2). Further, since $\mu < 1$, he is less informed than the buyer. Thus, adding an intermediary here does not help realize gains to trade with the seller more quickly, nor does it bring new information to the table. However, as we show below, the intermediary allows for higher trade efficiency by splitting the adverse selection problem into two layers of transactions. Ultimately, the intermediary's involvement affects trade efficiency and each agent's ability to extract a fraction of the surplus available. In this scenario, before reaching its ultimate buyer the security has to pass through the intermediary — the uninformed trader first bargains with the intermediary who, if he buys the security, then bargains with the fully informed trader. Consistent with how we model the scenario without an intermediary, we assume that whoever owns the security and tries to sell it makes a take-it-or-leave-it price quote to his counterparty. For now, we do not allow the seller to bypass the intermediary and make an offer directly to the buyer. Using the derivations below, we will be able to characterize the types of trading network that buyers and sellers would prefer to implement, given the degree of adverse selection that exists between these agents.

Solving the model by backward induction, we start with the situation in which the intermediary already owns the security and bargains with the informed buyer. Since the intermediary's information is dominated by the buyer's, this trade is similar to the one analyzed above in the sense that the intermediary faces an adverse selection problem. The intermediary chooses to quote the buyer one of two prices:

$$p_l = v_l + \Delta,$$

or

$$p_h = v_h + \Delta.$$

The buyer would accept to pay the low price p_l for the security with probability 1. He would, however, only accept to pay the high price p_h if he were to learn that the security is worth v_h. The expected surplus each agent extracts then depends on the signal the intermediary observes.

Conditional on observing a high signal, the intermediary expects the security to be worth $\mu v_h + (1-\mu)v_l$. When quoting the low price p_l, the intermediary's expected surplus is:

$$p_l - \mu v_h - (1-\mu)v_l = \Delta - \mu\sigma,$$

and the buyer's expected surplus is $\mu\sigma$. Instead, if the seller quotes the high price p_h, trade only takes place once the buyer observes v_h, which occurs with probability μ. The intermediary then gets an expected surplus of $\mu\Delta$ and the buyer gets no surplus. Hence, when the intermediary observes a high signal, efficient trade takes place at a price p_l between the intermediary and the buyer only if:

$$\begin{aligned} \Delta - \mu\sigma &\geq \mu\Delta \\ \Leftrightarrow \sigma &\leq \left(\frac{1-\mu}{\mu}\right)\Delta. \end{aligned}$$

Now, if the intermediary observes a low signal instead, the expected value of the security is

$(1-\mu)v_h + \mu v_l$. When quoting the low price p_l, the intermediary's expected surplus is:

$$p_l - (1-\mu)v_h - \mu v_l = \Delta - (1-\mu)\sigma,$$

and the buyer's expected surplus is $(1-\mu)\sigma$. If the seller quotes the high price p_h, trade only takes place once the buyer observes v_h, which occurs with probability $(1-\mu)$. The intermediary then gets an expected surplus of $(1-\mu)\Delta$ and the buyer receives no surplus. Hence, when the intermediary observes a low signal, efficient trade takes place at a quoted price p_l between the intermediary and the buyer only if:

$$\begin{aligned} \Delta - (1-\mu)\sigma &\geq (1-\mu)\Delta \\ \Leftrightarrow \sigma &\leq \left(\frac{\mu}{1-\mu}\right)\Delta. \end{aligned}$$

Note that efficient trade requires a discount in the price quoted to the buyer and such discount increases with the expected value of the security, conditional on the information collected by the agent trying to sell the security. A high signal makes it more costly for the seller to quote a low price p_l and sustain trade, and a low signal makes it less costly. It is also easier to have efficient trade between an intermediary who observes a *low* signal and the buyer than between the seller and the buyer. It is, however, harder to have efficient trade between an intermediary who observes a *high* signal and the buyer than between the seller and the buyer. This ordering can be restated by the following set of inequalities:

$$\left(\frac{1-\mu}{\mu}\right) < 1 < \left(\frac{\mu}{1-\mu}\right),$$

when $\mu \in (\frac{1}{2}, 1)$.

Now, we can show what happens when the seller trades with the intermediary, anticipating how trade subsequently occurs between the intermediary and the buyer. We can also compare the efficiency of these outcomes to what would happen without an intermediary. Depending on the degree of information asymmetry about the value of the security three different cases may arise under intermediated trading. In the first two cases, with low and high levels of information asymmetry respectively, an intermediary cannot improve the efficiency of trade over direct trading.

In the third case, which is characterized by moderate levels of information asymmetry, a trading network centered around a specific type of intermediary can however allow for more efficient trading.

Case 1: $\sigma \leq \left(\frac{1-\mu}{\mu}\right)\Delta$

When $\sigma \leq \left(\frac{1-\mu}{\mu}\right)\Delta$, trade always take place between an intermediary who owns the security and the buyer, which means that regardless of his signal the intermediary quotes p_l to the buyer. Knowing this, the seller then quotes the intermediary p_l and his expected surplus is

$$p_l - E[v] = \Delta - \sigma/2.$$

The intermediary gets no surplus from the trade, but the buyer extracts $\sigma/2$, just as in the case in which direct trading takes place with probability 1. The total surplus extracted is Δ. In this case, trade would also be efficient if no intermediary was involved, as $\sigma \leq \Delta$. The total surplus would then be Δ, with $\Delta - \sigma/2$ going to the uninformed trader and $\sigma/2$ going to the informed trader. The involvement of an intermediary thus leaves all agents' payoffs unchanged.

Case 2: $\sigma > \left(\frac{\mu}{1-\mu}\right)\Delta$

The other extreme case occurs when $\sigma > \left(\frac{\mu}{1-\mu}\right)\Delta$. Here, the adverse selection is so severe that even if the intermediary observes a low signal, he quotes a high price p_h, and trade breaks down whenever $v = v_l$. The expected value of the security to the intermediary is

$$p_h^{\mu} \equiv \mu p_h + (1-\mu)\, v_l,$$

after receiving a high signal and

$$p_l^{\mu} \equiv (1-\mu)\, p_h + \mu v_l,$$

after receiving a low signal. If the seller quotes p_l^{μ}, trade always takes place between the intermediary and the buyer and the seller's expected surplus from trade is:

$$p_l^{\mu} - E(v) = (1-\mu)\,\Delta - \left(\mu - \frac{1}{2}\right)\sigma.$$

The intermediary then gets an expected surplus of:

$$\frac{1}{2}p_h^\mu + \frac{1}{2}p_l^\mu - p_l^\mu = \left(\mu - \frac{1}{2}\right)(\Delta + \sigma),$$

and the buyer gets an expected surplus of zero. The total surplus extracted is then $\Delta/2$. The expected surplus for the seller if he quotes p_h^μ instead is:

$$\frac{1}{2}\left[p_h^\mu - (\mu v_h + (1-\mu)\, v_l)\right] = \frac{\mu}{2}\Delta.$$

The intermediary and the buyer then extract no surplus from the trade. The total surplus extracted is then $\frac{\mu}{2}\Delta$. The seller consequently quotes the intermediary a price p_l^μ rather than p_h^μ only if:

$$\begin{aligned}(1-\mu)\,\Delta - \left(\mu - \frac{1}{2}\right)\sigma &\geq \frac{\mu}{2}\Delta \\ \Leftrightarrow \sigma &\leq \left(\frac{1 - \frac{3\mu}{2}}{\mu - \frac{1}{2}}\right)\Delta.\end{aligned}$$

In this parameter region, we know that trade would be inefficient without an intermediary and the remaining surplus $\Delta/2$ would be going to the seller. Hence, adding an intermediary is either leaving all agents' payoffs unchanged (if μ is low enough) or it decreases the efficiency of trade and the seller's payoff.

Case 3: $\left(\frac{1-\mu}{\mu}\right)\Delta < \sigma \leq \left(\frac{\mu}{1-\mu}\right)\Delta$

In this region an intermediary who owns the security quotes p_l after observing a low signal and p_h after observing a high signal. Hence, the security is worth p_l to the intermediary after receiving a low signal and p_h^μ after receiving a high signal. The expected surplus for the seller when quoting a price p_l is:

$$p_l - E[v] = \Delta - \sigma/2.$$

The intermediary's expected surplus is:

$$\frac{1}{2}p_l + \frac{1}{2}p_h^\mu - p_l = \frac{\mu}{2}\sigma - \left(\frac{1-\mu}{2}\right)\Delta,$$

and the buyer's expected surplus is:

$$\frac{1}{2}\left[\mu v_l + (1-\mu)\, v_h + \Delta - p_l\right] = \left(\frac{1-\mu}{2}\right)\sigma.$$

The total surplus extracted is $\left(\frac{1+\mu}{2}\right)\Delta$. The expected surplus for the seller when quoting a price p_h^{μ} instead is:

$$\frac{1}{2}\left[p_h^{\mu} - (\mu v_h + (1-\mu)\, v_l)\right] = \frac{\mu}{2}\Delta,$$

while the intermediary and the buyer extract no surplus from the trade. The total surplus extracted is $\frac{\mu}{2}\Delta$. The seller will thus prefer to quote p_l only if:

$$\Delta - \sigma/2 \geq \frac{\mu}{2}\Delta$$

$$\Leftrightarrow \sigma \leq (2-\mu)\,\Delta.$$

To summarize, when the degree of information asymmetry between the buyer and seller renders direct trade to be inefficient, i.e., $\sigma > \Delta$, intermediated trading may enhance trade efficiency if the intermediary's expertise is moderate, that is, if:

$$\frac{\sigma}{\sigma+\Delta} \leq \mu \leq 2 - \sigma/\Delta.$$

In this case, the surplus from trade goes from $\Delta/2$ without an intermediary to $\left(\frac{1+\mu}{2}\right)\Delta$ with an intermediary. The seller quotes p_l to the intermediary, which is always accepted, and the intermediary quotes p_l to the buyer after observing a low signal and p_h after observing a high signal. The buyer then extracts $\left(\frac{1-\mu}{2}\right)\sigma$, which is more than the zero surplus he gets without an intermediary. Because trade takes place with probability 1 between the seller and the intermediary, the intermediary is able to extract a surplus $\frac{\mu}{2}\sigma - \left(\frac{1-\mu}{2}\right)\Delta$, which is strictly positive. Hence, the intermediary strictly prefers to be part of the trading network.[4] The seller extracts $\Delta - \sigma/2$, which

[4] The surplus from intermediating trade is also greater than the surplus the moderately informed agent would collect if he were outside the trading network and offered to credibly sell his signal to the uninformed agent, in the spirit of Admati and Pfleiderer (1988, 1990). The moderately informed intermediary is rewarded for improving trade efficiency, but he also extracts rents from the uninformed agent.

makes him worse off than without an intermediary since $\sigma > \Delta$. The seller is made worse off by the involvement of an intermediary, since the highest price he can then charge is p_h^μ rather than p_h.

In this region, the most efficient trading network is centered around an intermediary with $\mu = 2 - \sigma/\Delta$ as the resulting probability of realizing the gains to trade reaches $\frac{3}{2} - \frac{\sigma}{2\Delta}$. However, if the intermediary is not moderately informed as defined by the inequalities above, intermediated trade is weakly less efficient than direct trade. The only agent who might be better off in a trading network that includes an intermediary is the intermediary himself. The proposition below formalizes our main result about the optimality of intermediated trading.

Proposition 1 *When the level of information asymmetry satisfies* $\sigma \in \left(\Delta, \sqrt{2}\Delta\right]$*, trading through an intermediary whose expertise level satisfies* $\mu \in \left[\frac{\sigma}{\sigma+\Delta}, 2 - \sigma/\Delta\right]$ *produces a total surplus* $\left(\frac{1+\mu}{2}\right)\Delta$*, which is greater than* $\Delta/2$*, the highest surplus available when trading without an intermediary.*

Proof: See derivations above. ∎

Overall, neither the final buyer nor the original seller benefit from the intermediary's involvement when $\sigma \leq \Delta$. But when $\sigma > \Delta$, the informed trader strictly prefers a trading network with a moderately informed intermediary between him and an uninformed trader. The involvement of a moderately informed intermediary reduces the trading inefficiencies that adverse selection causes and increases the total surplus from trade. However, this comes at the cost of adding a strategic agent, the intermediary, who captures a share of the surplus and makes the uninformed trader worse off. If allowed, the seller would thus prefer to bypass the intermediary and make an ultimatum offer to the buyer. This deviation would lead to a lower social surplus than if trade goes through the intermediary. The socially optimal trading network centers around a moderately informed intermediary, and it is also *sparse*, in the sense that the seller cannot contact the buyer himself. Alternatively, the informed buyer would commit to ignore any offer coming directly from the uninformed seller, since the buyer is better off when trade goes through a moderately informed intermediary. The impossibility for retail investors and unsophisticated firms to contact the most sophisticated trading desks directly and to bypass the usual middlemen in reality suggests that sparse intermediated networks, or equivalent commitments by sophisticated trading desks, are sensible outcomes of our model.

3.1 Parameterized Example

Despite its simplicity, our model of intermediated trade exhibits two layers of adverse selection, giving rise to several cases that depend on parameter values for Δ, σ, and μ. The small number of key parameters, however, makes our model well-suited for a parameterization.

We first normalize the model by setting the value of gains to trade, Δ, equal to 1. Trade breaks down with probability 1/2 whenever $\sigma > 1$. The seller then extracts 0.5, whereas the buyer extracts no surplus. However, a moderately informed intermediary, say whose $\mu = 0.75$, could help facilitate trade between the uninformed seller (whose $\mu = 0.5$) and the informed buyer (whose $\mu = 1$).

For now, we focus on a parameterization with $\sigma = 1.2$. This situation corresponds to Case 3 above, that is, a situation with moderate information asymmetry. The seller knows that the intermediary will quote the low price after receiving a low signal — which the buyer accepts to pay with probability 1 — and quote the high price after receiving a high signal — which the buyer accepts to pay with probability μ. The seller then finds it optimal to quote the low price p_l to the intermediary, keeping trade efficient in the first stage and allowing him to extract a surplus of 0.4. The intermediary then extracts 0.325 and the buyer gets 0.15. Overall, this trading network improves the surplus generated in equilibrium by 0.375.

In Figure 1, we keep the parameterization identical to the example above except that we allow for various levels of σ. We compare how the surplus is allocated across agents in equilibrium for the direct trading network and for the intermediated trading network. The upper left graph shows that direct trading socially dominates intermediated trading for very high or very low levels of σ, but intermediated trading dominates for intermediate levels of information asymmetry, in particular when $1 < \sigma \leq 1.25$. This region is where our numerical example above is located. This is also the only region where one of the end-traders is strictly better off with an intermediary. Outside this region, the intermediary is either extracting too much surplus away from end-traders or he is not eliminating sufficiently the adverse selection problem. Trade efficiency is thus more fragile with high levels of σ, or adverse selection, when an intermediary is involved — the trading network that is socially optimal with moderate levels of information asymmetries magnifies trading inefficiencies when σ exceeds an endogenous threshold.

Figure 2 compares how the surplus is allocated across agents, but this time, we fix $\sigma = 1.2$ and

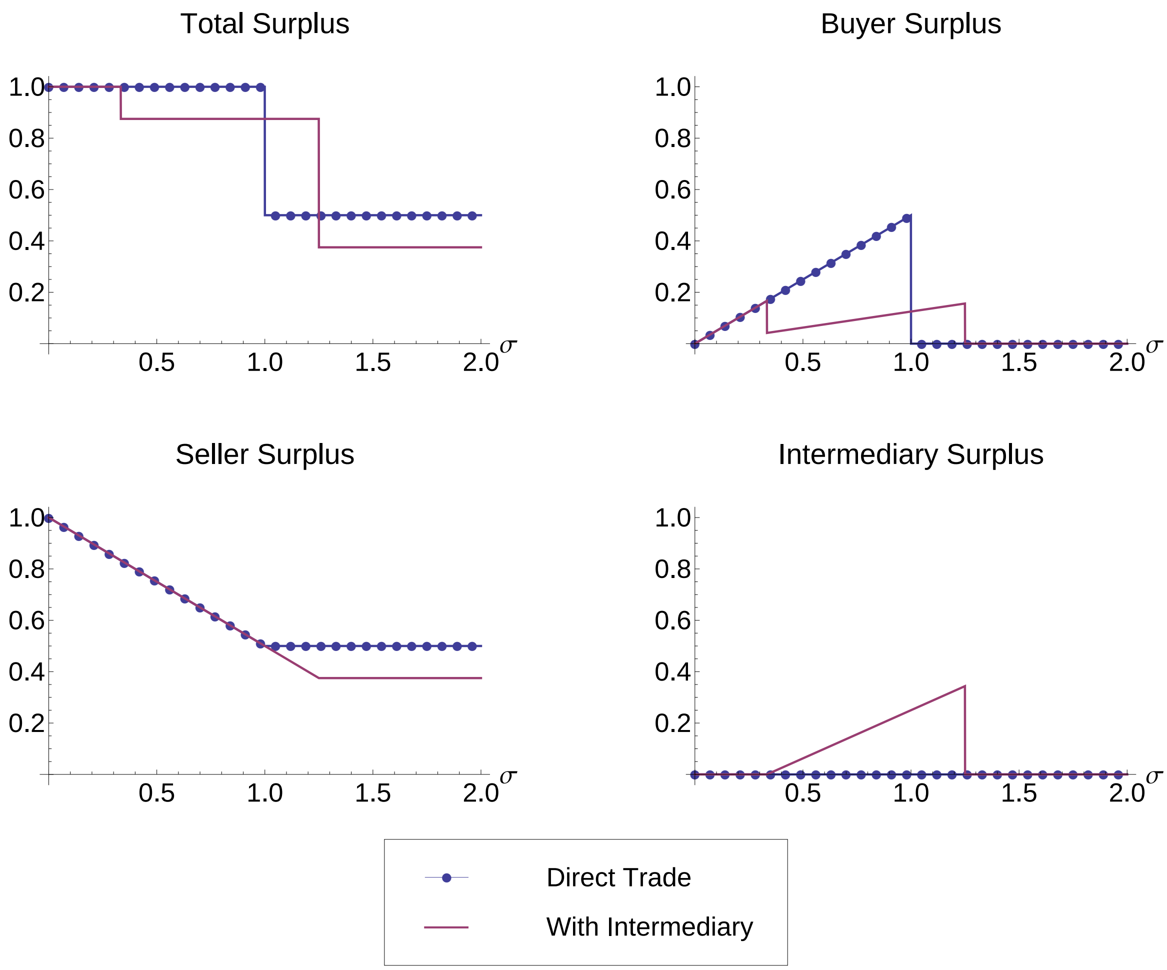

Figure 1. Surplus Extraction and Information Asymmetry. The plots show how the degree of information asymmetry impacts surplus extraction, given gains to trade of $\Delta = 1$ and an intermediary's expertise of $\mu = 0.75$.

vary μ from 0.5 to 1. The upper left graph highlights that the involvement of a moderately informed intermediary can improve trade efficiency, relative to inefficient direct trading (when $\sigma > \Delta$). It also shows that a highly informed intermediary can worsen trade efficiency, because his involvement now triggers adverse selection problems in both stages of the intermediated trade. A weakly informed intermediary, on the other hand, is unable to eliminate the adverse selection problem caused by an informed trader, hence the total surplus remains unchanged with or without his involvement. When the intermediary's μ is between 0.545 and 0.8, the seller is effectively paying adverse selection premia to both the buyer and the intermediary, whereas he would extract the full surplus available (i.e., 0.5) in a direct trade. The buyer's surplus is decreasing in the intermediary's expertise and

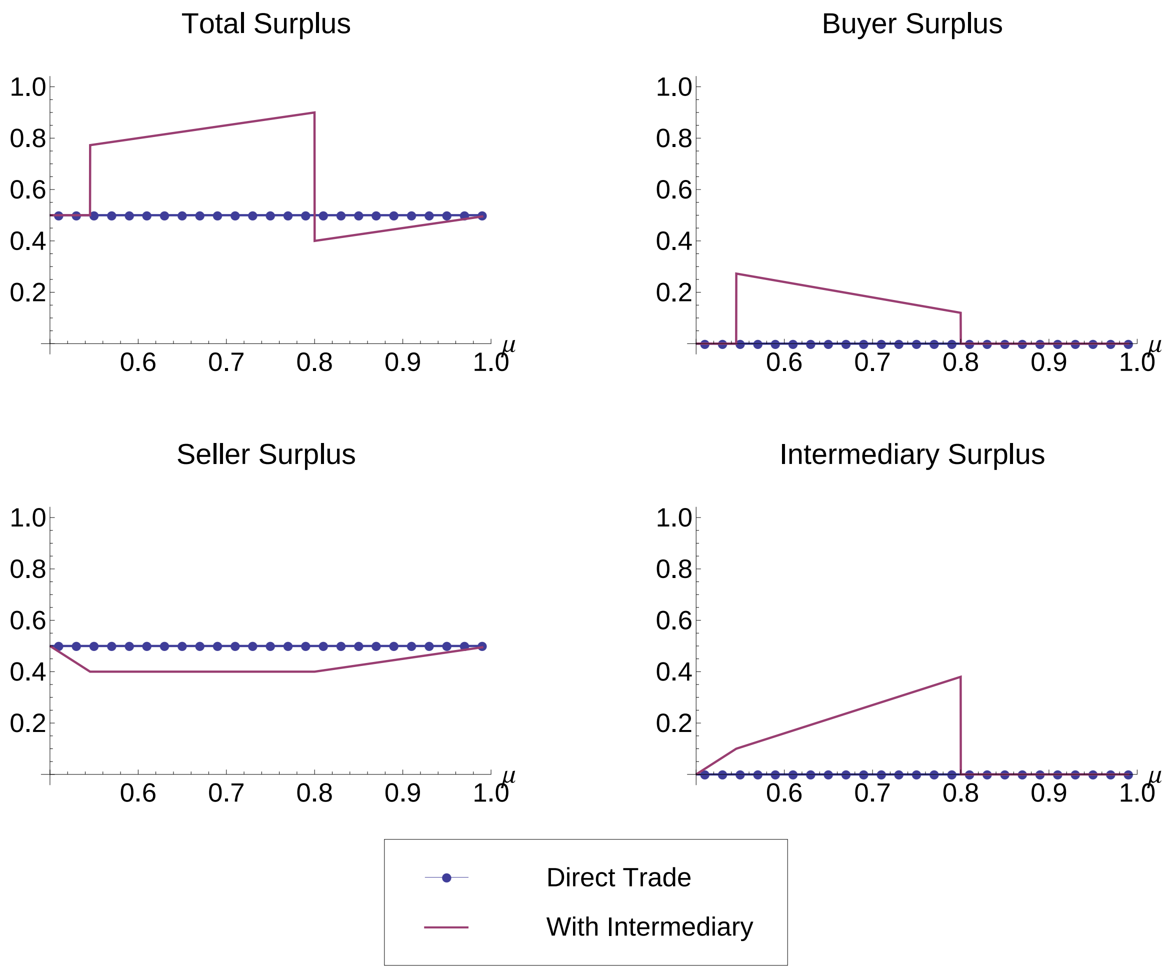

Figure 2. Surplus Extraction and Intermediary's Expertise. The plots show how an intermediary's expertise impacts surplus extraction, given gains to trade of $\Delta = 1$ and uncertainty in security value of $\sigma = 1.2$.

reaches a maximum of 0.273 when $\mu = 0.545$. The intermediary's surplus is, however, increasing in his own expertise and reaches a maximum of 0.38 when $\mu = 0.8$, which is also where trade is the most socially efficient possible given that $\sigma > \Delta$. At $\mu = 0.8$, the total surplus reaches 0.9, compared to 0.5 without an intermediary.

4 Intermediation Chains

In this section, we show that trading through multiple intermediaries can sometimes preserve gains to trade that would otherwise be lost with fewer intermediaries. A chain of two intermediaries is shown to reduce trading inefficiencies caused by adverse selection between the ultimate buyer and seller in situations where a single intermediary would not help. We also show through a numerical example that the same logic extends to adding a third intermediary. Larger information asymmetries require longer intermediation chains, which appears to be broadly consistent with recent empirical evidence on the OTC trading of securitized products by Hollifield, Neklyudov, and Spatt (2012). However, our model also highlights that as we lengthen the intermediation chain liquidity is affected more severely by "unexpected" changes in the level of information asymmetry σ.

Suppose that $\sigma > \Delta$, meaning that direct trading yields a trading probability of $1/2$. We already know that the involvement of one intermediary of type μ can increase the surplus from trade from $\Delta/2$ to $(1+\mu)\Delta/2$ if and only if:

$$\frac{\sigma}{\sigma+\Delta} \leq \mu \leq 2 - \sigma/\Delta.$$

However, whenever $\sigma > \sqrt{2}\Delta$, such interval for μ becomes empty. Involving a single intermediary does not solve the adverse selection problem; in fact, it might worsen it.

Now, consider instead a situation in which trade between the uninformed seller and the informed buyer first goes through an intermediary of type μ' and then goes through an intermediary of type μ ($\geq \mu'$). An implication of our analysis is that intermediaries should be distributed within the trading network in a hierarchal manner, that is, with the least informed intermediary trading directly with the least informed of the end traders and with the most informed intermediary trading directly with the most informed of the end traders.

For parsimony, we assume that the least informed of the two intermediaries, the μ' trader, receives a signal that is a noisier version of the μ-trader's signal. Specifically, the signal $s_{\mu'}$ is drawn from the following distribution: it is equal to the signal s_μ with probability $\rho \in (\frac{1}{2}, 1)$ and different with probability $(1-\rho)$. The precision of such signal thus satisfies:

$$\mu' = \rho\mu + (1-\rho)(1-\mu).$$

It is also easy to show that the correlation between the two intermediaries' signals is $2\rho-1$. Since the holder of the security is, as earlier, making an ultimatum price quote to the potential buyer he faces, the informational structure here ensures that the proposer's information set is always dominated by the responder's and that trading takes place without signalling. This property allows us to study, in a tractable and intuitive way, a sequential bargaining game with three transactions and with adverse selection among four agents.

The following proposition summarizes the main result for this section. We discuss its implications below but relegate the full proof of the proposition to the Appendix since the logic is similar to that in the scenario with only one intermediary.

Proposition 2 *When the level of information asymmetry satisfies $\sigma > \sqrt{2}\Delta$, trading through two intermediaries may produce a total surplus $\left(\frac{\rho+\mu}{2}\right)\Delta$, which is greater than $\Delta/2$, the highest surplus available when trade goes through one or zero intermediaries.*

Proof: See Appendix. ∎

The intuition behind this result is similar to what we have seen in Section 3. Adding layers of transactions among which the difference in information quality between counterparties is small can help reduce trading inefficiencies caused by adverse selection. As the initial adverse selection problem between the ultimate buyer and seller becomes worse, more layers of transactions and more asymmetrically informed intermediaries are necessary to improve the efficiency of trade. As in Section 3, the full analysis of this results requires to sequentially solve for optimal trading behavior in each transaction.

First, we need to look at the final transaction between the most informed of the two intermediaries and the fully informed buyer, which is identical to the final transaction in the setup with only one intermediary. From Section 3 we know that in parameter regions where direct trade breaks down with probability 1/2, trade also breaks down between the intermediary and the buyer whenever the intermediary observes a high signal. Inequality (1) also tells us that if $\mu < \frac{\sigma}{\sigma+\Delta}$, trade also breaks down whenever the intermediary observes a low signal, yielding a maximal probability of realizing the gains to trade of 1/2. Hence, the only way the involvement of two intermediaries can potentially help preserve more surplus than through direct trading is if the expertise of the better informed intermediary is high enough to satisfy: $\mu \geq \frac{\sigma}{\sigma+\Delta}$. In this case, the intermediary quotes p_l to the buyer after observing a low signal and p_h after observing a high signal.

The trading behavior between the two intermediaries is thus similar to Case 3 in Section 3. The main difference is that the proposer now receives a signal that is accurate with probability μ' instead of being uninformed. The proposer is, nonetheless, still choosing between quoting a low price p_l and a higher price $p_h^\mu = \mu p_h + (1-\mu)\, v_l$. If the intermediary of type μ' always quotes p_h^μ, the surplus from trade is at most $\Delta/2$. We show in the proof of the proposition that the most efficient trading price p_l will be quoted after a low signal whenever $\sigma \leq \left(\frac{1-(1-\rho)\mu}{1-\mu'}\right)\Delta$.

In the case in which the intermediary of type μ' quotes p_l after observing a low signal, but quotes p_h^μ after observing a high signal, the seller will prefer to quote the low price p_l whenever $\sigma \leq (2-\mu\rho)\,\Delta$. Since $\rho < 1$, this condition on σ is less restrictive than the condition that applies in Section 3 when only one intermediary is involved. It is therefore possible to simultaneously satisfy this condition and the condition that $\mu \geq \frac{\sigma}{\sigma+\Delta}$, even in situations where simultaneously satisfying analogous conditions for the setting with only one intermediary is impossible. When the current conditions are satisfied, trade takes place with probability 1 between the seller and the first intermediary, who then trades the security to a second intermediary with probability 1 after observing a low signal and probability ρ after observing a high signal. Then, the security is traded to the buyer with probability 1 if the μ intermediary holds the security and observes a low signal and with probability μ if he holds the security and observes a high signal. As in Section 3, because the uninformed seller is selling the security at a price p_l in equilibrium, the surplus he extracts is $\Delta - \sigma/2$ and is dominated by the surplus he would extract if there were no intermediary at all.

Overall, when information asymmetry is too severe for one intermediary to improve trade efficiency, trading through two intermediaries may still produce a surplus from trade of $\left(\frac{\rho+\mu}{2}\right)\Delta$, which is greater than the surplus created by trading through only one intermediary or through direct trading. Improving trading efficiency with two intermediaries is, however, impossible for extreme levels of information asymmetry. For example, if $\sigma > 1.75\Delta$, the adverse selection problem between the ultimate seller and buyer of the security is so severe that no pair of intermediaries can succeed in improving trading efficiency; the necessary condition $\sigma \leq (2-\mu\rho)\,\Delta$ cannot be satisfied. Hence, in that scenario reallocating the adverse selection problem across several more layers of transactions might be needed.

4.1 Parameterized Example

The following numerical example highlights how adding intermediaries helps improve trade efficiency as the adverse selection problem becomes worse. First, we go back to our earlier parameterization with $\Delta = 1$. As we argued earlier, without an intermediary the total surplus from trade would drop to 0.5 whenever $\sigma > 1$. Adding a moderately informed intermediary $\mu = 0.75$ can mitigate the adverse selection problem and increase the total surplus to 0.875 in the region $1 < \sigma \leq 1.25$. Outside that region, adding a second intermediary will be needed to improve the efficiency of trade.

When the adverse selection problem is so severe that $\sigma > 1.25$, the total surplus available from trading through one intermediary of type $\mu = 0.75$ is 0.375, which is lower than the surplus from direct trading. Trading through a second intermediary with $\rho = 0.75$, implying $\mu' = 0.625$, will nonetheless produce a surplus from trade of 0.75 in the region where $1.25 < \sigma \leq 1.437$. Numerically, we can show that a similar improvement in trade efficiency occurs over the region where $1.437 < \sigma \leq 1.577$ if a third intermediary with $\mu'' = 0.5625$ is added to the trading network.[5]

Figure 3 replicates Figure 1 by comparing surplus allocation for various levels of σ, except that it now includes trading networks with two and three intermediaries. The upper left graph shows that adding intermediaries to a trading network allows to sustain higher levels of trade efficiency as σ increases. The graph, however, also shows that direct trading socially dominates trading with one, two, or three intermediaries for very low or very high levels of σ. While trading through different numbers of intermediaries helps preserve more surplus in a given region, it also destroys more surplus than direct trading does if σ happens to be outside of that region. In that sense, long intermediation chains that are optimal in certain asset classes or market regimes can hurt trade efficiency if fundamentals related to information asymmetry change over time and if adjusting the trading network on the spot is difficult.[6]

[5]The third intermediary's expertise level, $\mu'' = 0.5625$, is computed by assuming that he receives a noisier version of the second intermediary's signal. Consistent with the case with only two intermediaries, the precision of that weaker signal satisfies: $\mu'' = \rho'\mu' + (1 - \rho')(1 - \mu')$, which is equal to 0.5625 if we set $\rho' = \rho = 0.75$.

[6]See Li and Schüroff (2012) who provide evidence of substantial stability in OTC dealers' trading relationships.

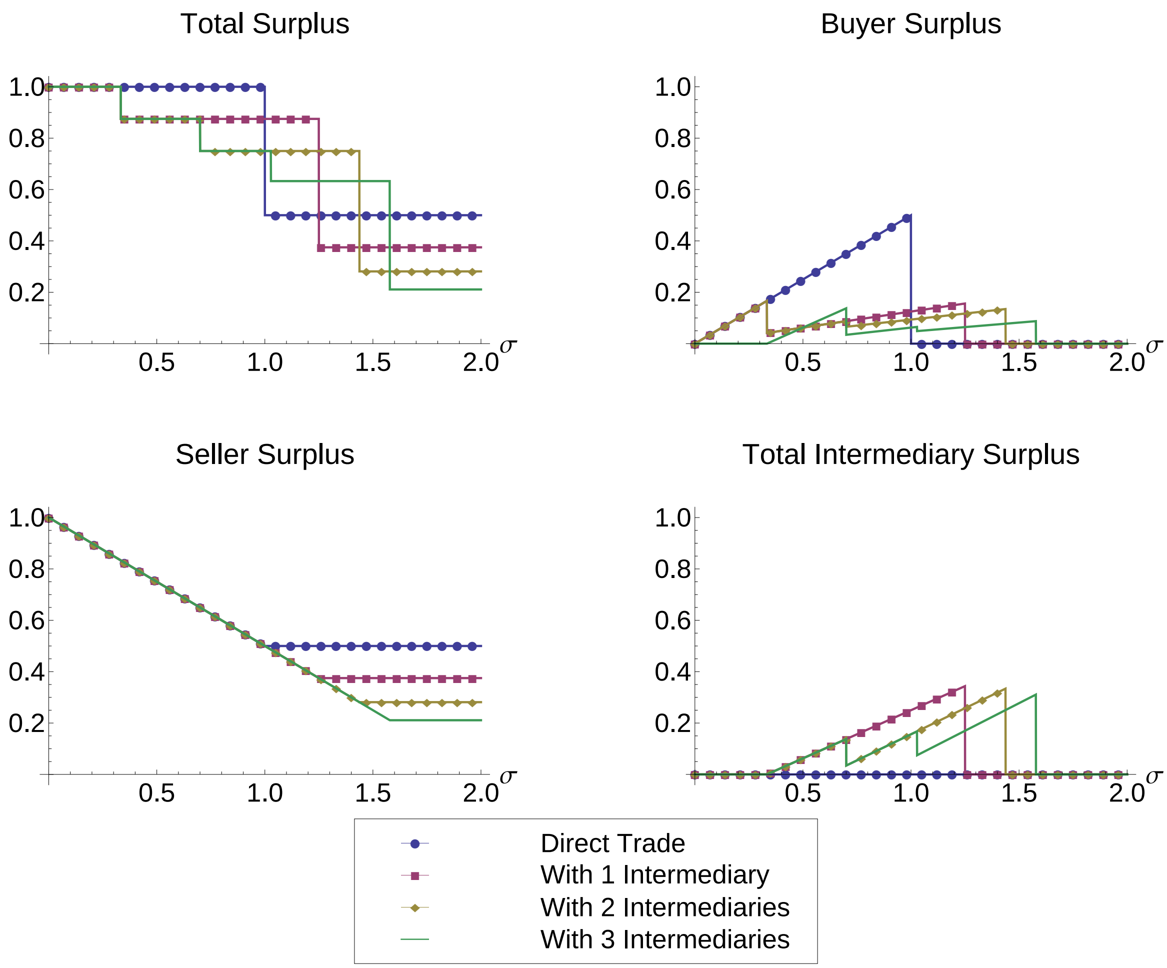

Figure 3. Surplus Extraction and Information Asymmetry with Multiple Intermediaries. The plots show how the degree of information asymmetry impacts surplus extraction, given gains to trade of $\Delta = 1$ and different trading networks: (i) direct trading, (ii) trading through one intermediary of type $\mu = 0.75$, (iii) trading through two intermediaries of types $\mu' = 0.625$ and $\mu = 0.75$, and (iv) trading through three intermediaries of types $\mu'' = 0.5625$, $\mu' = 0.625$, and $\mu = 0.75$.

5 Conclusion

This paper shows that chains of moderately informed intermediaries can help alleviate adverse selection problems that inhibit efficient trading between two heterogeneously informed agents. Complex trading networks with multiple intermediaries may be socially optimal because reallocating a large adverse selection problem over several layers of transactions reduces the downside each agent faces of being wronged by a better informed agent. However, involving moderately informed intermediaries also increases the number of strategic agents trying to capture a share of the gains to trade.

Hence, intermediation chains that are optimal in a given market regime or asset class can make liquidity more fragile and trading less efficient when shocks to fundamentals alter the degree of information asymmetry, or the expertise of traders.

Appendix

Proof of Proposition 2: As in Section 3 when one intermediary was involved between the buyer and the seller, the analysis of the current scenario with two intermediaries requires to sequentially solve for optimal trading behavior in each stage of transaction. We start with the final trade between the intermediary of type μ and the fully informed buyer.

μ-Intermediary Trading with Buyer

The final trade between the better-informed intermediary and the fully informed buyer looks exactly like the final trade in the earlier setup with only one intermediary. From Section 3 we know that in regions where direct trade breaks down with probability 1/2, trade should also break down between the intermediary and the buyer whenever the intermediary observes a high signal. Inequality (1) also tells us that if $\mu < \frac{\sigma}{\sigma+\Delta}$, trade also breaks down whenever the intermediary observes a low signal, yielding a maximal probability of realizing the gains to trade of 1/2.

Hence, we need $\mu \geq \frac{\sigma}{\sigma+\Delta}$ for two intermediaries to potentially help preserve more surplus than through direct trading. If that condition is satisfied, an intermediary holding the security quotes p_l after observing a low signal and p_h after observing a high signal.

μ'-Intermediary Trading with μ-Intermediary

Here, the proposer is choosing between quoting a low price p_l or a higher price $p_h^\mu = \mu p_h + (1-\mu)\, v_l$. Conditional on observing a high signal, his expected surplus is:

$$p_l - E[v|s_{\mu'}] = \Delta - \mu'\sigma,$$

from quoting the low price p_l and

$$Pr(s_\mu = v_h|s_{\mu'})\left[p_h^\mu - E[v|s_\mu = v_h]\right] = \rho\mu\Delta,$$

from quoting the higher price p_h^μ. Thus, trade is most efficient here when $\sigma \leq \left(\frac{1-\rho\mu}{\mu'}\right)\Delta$.

Conditional on observing a low signal, the proposer's expected surplus is:

$$p_l - E[v|s_{\mu'}] = \Delta - (1-\mu')\sigma,$$

from quoting the low price p_l and

$$Pr(s_\mu = v_h | s_{\mu'}) \left[p_h^\mu - E[v|s_\mu = v_h]\right] = (1-\rho)\mu\Delta,$$

from quoting the higher price p_h^μ. Thus, trade is most efficient here when $\sigma \leq \left(\frac{1-(1-\rho)\mu}{(1-\mu')}\right)\Delta$.

Once again, the most efficient trading price p_l is more likely to be chosen by the proposer after observing a low signal than a high signal; the constraint $\sigma \leq \left(\frac{1-\rho\mu}{\mu'}\right)\Delta$ being more restrictive than $\sigma \leq \left(\frac{1-(1-\rho)\mu}{(1-\mu')}\right)\Delta$. If this more restrictive condition is satisfied, trade takes place with probability 1 between the two intermediaries, implying that the maximal surplus from trade is $\left(\frac{1+\mu}{2}\right)\Delta$ overall, just as in the scenario with a single intermediary. Using the earlier assumption that $\mu \geq \frac{\sigma}{\sigma+\Delta}$, this constraint implies that:

$$\begin{aligned} \frac{\sigma}{\Delta} &\leq \frac{1-\rho\mu}{\rho\mu + (1-\rho)(1-\mu)} \\ &\leq \frac{1-\frac{\rho\sigma}{\sigma+\Delta}}{\frac{\rho\sigma}{\sigma+\Delta} + \frac{(1-\rho)\Delta}{\sigma+\Delta}} \\ &= \frac{1+(1-\rho)\frac{\sigma}{\Delta}}{(1-\rho)+\rho\frac{\sigma}{\Delta}}. \end{aligned}$$

And this last inequality can be rewritten as:

$$\frac{\sigma}{\Delta} \leq \sqrt{\frac{1}{\rho}} < \sqrt{2},$$

which means that one intermediary would also preserve a surplus of $\frac{1+\mu}{2}\Delta$. Moreover, the constraint $\sigma \leq \left(\frac{1-\rho\mu}{\mu'}\right)\Delta$ can be rewritten as:

$$\begin{aligned} \mu &\leq \frac{1-\mu'\frac{\sigma}{\Delta}}{\rho} \\ &< 2-\sigma/\Delta, \end{aligned}$$

where the second inequality follows from $\rho \in (\frac{1}{2}, 1)$ and $\mu' \in (\frac{1}{2}, 1)$. Thus, adding an extra transaction through the involvement of a second moderately informed intermediary does not improve the efficiency of trade relative to what we would get with a single intermediary, but it can improve efficiency relative to direct trade. Since we are now looking for the possibility that two intermediaries will improve trade efficiency above and beyond what one intermediary can do, we can rule out the case in which the intermediary of type μ' quotes p_l regardless of his signal.

Seller Trading with μ'-Intermediary

The final step in this analysis is to solve for what happens when the seller trades with the first intermediary, anticipating how trade will subsequently take place among other agents.

We already know that if the intermediary of type μ' always quotes p_h^{μ}, the surplus from trade is at most $\Delta/2$. We also know that if the intermediary of type μ' finds it optimal to always quote p_l, the most efficient scenario will be such that trade is effectively taking place as if there were only one intermediary. Hence, the only case in which trade efficiency could possibly be improved by the involvement of two intermediaries rather than a single one of them has to satisfy: $\left(\frac{1-\rho\mu}{\mu'}\right)\Delta < \sigma \leq \left(\frac{1-(1-\rho)\mu}{(1-\mu')}\right)\Delta$. In such case, the intermediary of type μ' quotes p_l after observing a low signal, but quotes p_h^{μ} after observing a high signal. The seller is then picking between quoting p_l and collecting an expected surplus of:

$$p_l - E[v] = \Delta - \sigma/2,$$

or quoting $p_h^{\mu'} \equiv \rho p_h^{\mu} + (1-\rho)((1-\mu)v_h + \mu v_l)$ and collecting an expected surplus of:

$$\begin{aligned}\frac{1}{2}[p_h^{\mu'} - E[v|s_{\mu'} = v_h]] &= \frac{1}{2}[\rho p_h^{\mu} + (1-\rho)((1-\mu)v_h + \mu v_l) - \mu' v_h - (1-\mu')v_l] \\ &= \frac{\mu\rho}{2}\Delta.\end{aligned}$$

The seller will prefer to quote the low price p_l only if:

$$\Delta - \sigma/2 \geq \frac{\mu\rho}{2}\Delta$$

$$\Leftrightarrow \sigma \leq (2-\mu\rho)\,\Delta.$$

Note that since $\rho < 1$ this condition on σ is less restrictive than the condition that applies when only one intermediary is involved. It is therefore possible to simultaneously satisfy that condition and the condition that $\mu \geq \frac{\sigma}{\sigma+\Delta}$ even though it was not possible to satisfy the analog of these conditions for the case with only one intermediary. If the current conditions are satisfied, the security is traded with probability 1 from the seller to the least informed intermediary, who then trades the security to the most informed intermediary with probability 1 after observing a low signal and probability ρ after observing a high signal. Then, the security is traded to the buyer with probability 1 if the μ intermediary holds the security and observes a low signal and with probability μ if he holds the security and observes a high signal. Overall, the surplus from trade is:

$$\frac{1}{2}\left[\rho+(1-\rho)\mu\right]\Delta+\frac{1}{2}\rho\mu\Delta=\left(\frac{\rho+\mu}{2}\right)\Delta,$$

which is greater than the surplus that would be created without a second intermediary. ∎

References

Admati, Anat R., and Paul Pfleiderer, 1988, "Selling and Trading on Information in Financial Markets," *American Economic Review* 78, 96-103.

Admati, Anat R., and Paul Pfleiderer, 1990, "Direct and Indirect Sale of Information," *Econometrica* 58, 901-928.

Akerlof, George A., 1970, "The Market for "Lemons": Quality Uncertainty and the Market Mechanism," *Quarterly Journal of Economics* 84, 488-500.

Babus, Ana, 2012, "Endogenous Intermediation in Over-the-Counter Markets," Working Paper, Imperial College London.

Bank of International Settlements, 2010, "Triennial Central Bank Survey: Report on Global Foreign Exchange Market Activity," Monetary and Economic Department, Basel, Switzerland.

Biglaiser, Gary, 1993, "Middlemen as Experts," *RAND Journal of Economics* 24, 212-223.

Bolton, Patrick, Tano Santos, and Jose A. Scheinkman, 2012, "Cream Skimming in Financial Markets," Working Paper, Columbia University.

Diamond, Douglas W., 1984, "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies* 51, 393-414.

Duffie, Darrell, Nicolae Gârleanu, and Lasse Heje Pedersen, 2005, "Over-the-Counter Markets," *Econometrica* 73, 1815-1847.

Duffie, Darrell, Semyon Malamud, and Gustavo Manso, 2012, "Information Percolation in Segmented Markets," Working Paper, Stanford University.

Foster, F. Douglas, and S. Viswanathan, 1993, "Variations in Trading Volume, Return Volatility, and Trading Costs: Evidence on Recent Price Formation Models," *Journal of Finance* 48, 187-211.

Glode, Vincent, Richard C. Green, and Richard Lowery, 2012, "Financial Expertise as an Arms Race," *Journal of Finance* 67, 1723-1759.

Glode, Vincent, and Richard Lowery, 2013, "Informed Trading and High Compensation in Finance," Working Paper, University of Pennsylvania.

Glosten, Lawrence R., and Lawrence E. Harris, 1988, "Estimating the Components of the Bid/Ask Spread," *Journal of Financial Economics* 21, 123-142.

Glosten, Lawrence R., and Paul R. Milgrom, 1985, "Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics* 14, 71-100.

Gofman, Michael, 2011, "A Network-Based Analysis of Over-the-Counter Markets," Working Paper, University of Wisconsin - Madison.

Gould, John F., and Allan W. Kleidon, 1994, "Market Maker Activity on NASDAQ: Implications for Trading Volume," *Stanford Journal of Law, Business & Finance* 1, 1-17.

Grossman, Sanford, and Motty Perry, 1986, “Perfect Sequential Equilibrium,” *Journal of Economic Theory* 39, 97-119.

Hansch, Oliver, Narayan Y. Naik, and S. Viswanathan, 1998, “Do Inventories Matter in Dealership Markets? Evidence from the London Stock Exchange,” *Journal of Finance* 53, 1623-1656.

Hasbrouck, Joel, and George Sofianos, 1993, “The Trades of Market Makers: An Empirical Analysis of NYSE Specialists,” *Journal of Finance* 48, 1565-1593.

Ho, Thomas, and Hans R. Stoll, 1983, “The Dynamics of Dealer Markets under Competition,” *Journal of Finance* 38, 1053-1074.

Hollifield, Burton, Artem Neklyudov, and Chester Spatt, 2012, “Bid-Ask Spreads and the Pricing of Securitizations: 144a vs. Registered Securitizations,” Working Paper, Carnegie Mellon University.

Jovanovic, Boyan, and Albert J. Menkveld, 2012, “Middlemen in Limit-Order Markets” Working Paper, New York University.

Keim, Donald B. and Ananth Madhavan, 1996, “The Upstairs Market for Large-Block Transactions: Analysis and Measurement of Price Effects,” *Review of Financial Studies* 9, 1-36.

Kyle, Albert S., 1985, “Continuous Auctions and Insider Trading,” *Econometrica* 53, 1315-1335.

Li, Yiting, 1998, “Middlemen and Private Information,” *Journal of Monetary Economics* 42, 131-159.

Li, Dan, and Norman Schüroff, 2012, “Dealer Networks,” Working Paper, University of Lausanne.

Lyons, Richard K., 1996, “Foreign Exchange Volume: Sound and Fury Signifying Nothing?,” in *The Microstructure of Foreign Exchange Markets*, National Bureau of Economic Research, 183-208.

Madhavan, Ananth, and Seymour Smidt, 1993, “An Analysis of Changes in Specialist Inventories and Quotations,” *Journal of Finance* 48, 1595-1628.

Manaster, Steven and Steven C. Mann, 1996, “Life in the Pits: Competitive Market Making and Inventory Control,” *Review of Financial Studies* 9, 953-975.

Murphy, Kevin M., Andrei Schleifer, and Robert W. Vishny, 1991, “The Allocation of Talent: Implications for Growth,” *Quarterly Journal of Economics* 106, 503-530.

Myerson, Roger B., and Mark A. Satterthwaite, 1983, “Efficient Mechanisms for Bilateral Trading,” *Journal of Economic Theory* 29, 265-281.

Philippon, Thomas, 2010, “Engineers vs. Financiers: Should the Financial Sector be Taxed or Subsidized,” *American Economic Journal: Macro* 2, 158-182.

Reiss, Peter C. and Ingrid M. Werner, 1998, “Does Risk Sharing Motivate Interdealer Trading?,” *Journal of Finance* 53, 1657-1703.

Rubinstein, Ariel, and Asher Wolinsky, 1987, “Middlemen,” *Quarterly Journal of Economics* 102, 581-594.

Seppi, Duane J., 1990, “Equilibrium Block Trading and Asymmetric Information,” *Journal of Finance* 45, 73-94.

Stoll, Hans R., 1989, "Inferring the Components of the Bid-Ask Spread: Theory and Empirical Tests," *Journal of Finance* 44, 115-134.

Townsend, Robert M., 1978, "Intermediation with Costly Bilateral Exchange," *Review of Economic Studies* 45, 417-425.

Weller, Brian, 2013, "Liquidity and High Frequency Trading," Working Paper, University of Chicago.

Yavaş, Abdullah, 1994, "Middlemen in Bilateral Search Markets," *Journal of Labor Economics* 12, 406-429.