

Financial Expertise as an Arms Race

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ABSTRACT

We show that firms intermediating trade have incentives to overinvest in financial expertise. In our model, expertise improves firms' ability to estimate value when trading a security. Expertise creates asymmetric information, which, under normal circumstances, works to the advantage of the expert as it deters opportunistic bargaining by counterparties. This advantage is neutralized in equilibrium, however, by offsetting investments by competitors. Moreover, when volatility rises the adverse selection created by expertise triggers breakdowns in liquidity, destroying gains to trade and thus the benefits that firms hope to gain through high levels of expertise.

THE FINANCIAL SECTOR ATTRACTS extremely qualified workers. [Philippon and Reshef \(2010\)](#) document that, when compared to other sectors of the economy, the growth in financial services in recent decades has been associated with increases in employees' academic education, task complexity, and compensation. This investment in financial expertise no doubt facilitates a range of important and productive roles that financial intermediaries serve in modern economies. These include improving risk sharing and risk management, overcoming frictions that interfere with efficient trade, and engineering securities that allow new clienteles to access capital markets.

Our paper points to incentives financial firms have to *overinvest* in financial expertise and suggests that these investments can have a destabilizing effect on financial markets. We develop a model in which the acquisition of expertise by financial firms, such as hiring Ph.D. graduates to design and value financial

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instruments of ever-increasing complexity, becomes an “arms race.” By this phrase, we mean three things:

- Investment in financial expertise confers an advantage on any one player (firm) when bargaining with counterparties in the trading process.
- This advantage is neutralized in equilibrium by offsetting investments made by competitors.
- Investment in financial expertise is destabilizing, in that it creates a risk of destruction of the gains to trade when there is an exogenous shock to the level of uncertainty in the economy.

In the model, traders (or financial intermediaries generally) acquire expertise in processing information about the values of assets traded. The resulting efficiency in acquiring information gives them an advantage in subsequent bargaining with competitors. Firms invest in expertise to the point where any additional investment would lead to breakdowns in trade because of adverse selection problems. We show that they will invest up to this level even when there is some probability of a jump in volatility, and that, when such a jump occurs, levels of expertise that are benign under normal circumstances impede trade and destroy value.

Financial expertise in the model is the ability to acquire more accurate information. This creates adverse selection. Under circumstances of high volatility in the model, this causes trade to break down for the usual reasons. Knowing that an intermediary might be better informed leads others to avoid trading with him because they know they will end up buying only when the value is low (or selling when it is high). Ironically, however, adverse selection is also the source of the benefits to expertise. Under normal circumstances of lower volatility, knowledge that an intermediary might be better informed improves the terms of trade for this intermediary. It leads counterparties to offer the intermediary a price that he is more likely to accept regardless of his information. This imposes a natural limit on investments in expertise. While financial expertise deters opportunistic bargaining, firms do not wish to appear too informed. With too much expertise, the price concessions required to overcome adverse selection can swamp the gains to trade. The limits this imposes on optimal levels of expertise, however, are too high for efficient trade to be sustained under high volatility. Thus, our model contributes to a better understanding of why financial crises tend to have their origins in newer sectors of the financial industry, where highly specialized expertise is particularly important. It also suggests that the employment of experts should fall following a jump in uncertainty, which might otherwise seem counterintuitive. With greater uncertainty one might expect more, not less, need for financial expertise.

Before the recent crisis financial firms had built extensive capacity devoted to transforming relatively straightforward securities, such as residential mortgages and credit card debt, into complex instruments through securitization. They then created trillions of dollars worth of derivative contracts based on these asset-backed securities. To facilitate this process, financial firms hired highly trained and highly compensated experts to design, value, hedge, and

trade the complex securities and derivatives. In this environment, it was arguably more difficult to value the securities being traded, which in our model gives financial experts an advantage in trade. Unfortunately, when housing prices fell and default rates rose, the complexity of the financial instruments made it extremely difficult to identify where in the system the riskiest or most impaired liabilities were located. Estimates for the fundamental value of these financial instruments became highly uncertain. Of course, uncertainty per se does not interfere with trade, as long as the uncertainty is symmetric. As our model illustrates, however, when firms acquire high levels of financial expertise, increases in uncertainty can exacerbate the importance of asymmetric information. The very expertise firms had developed may have worked against them in the crisis. Their advantage in valuing securities may have increased the asymmetric information they faced in dealing with relatively uninformed parties who were in a position to take the opposite side of their trades and supply liquidity. Our model provides an explanation for the sudden unwillingness of so many financial intermediaries to trade with each other, despite the apparent gains to trade. The model also explains why financial intermediaries, whose business it is to facilitate or intermediate trade, would voluntarily acquire expertise, knowing it has the potential to create adverse selection that can impede trade and thus destroy their business. Of course, it seems quite clear to most observers that the financial firms with the most experts were, along with many nonexperts, surprised and mystified by what was going on as the financial crisis unfolded. This observation is consistent with our model. When uncertainty rises in the model, experts know less about underlying values than previously, but the importance of their relative advantage over others increases and adverse selection disrupts trade.

In our model, the traded asset has an uncertain common, or intrinsic, value. One of the two parties also ascribes private benefits to the asset, which creates known and exogenous gains to trade. Financial expertise, and the information experts acquire, reduces uncertainty about the common value when bargaining. Thus, expertise is assumed to have no intrinsic social value. Furthermore, firms do not use the information their expertise yields in equilibrium. The threat to use it ensures they get a better price, which renders their information superfluous. Our assumption that financial expertise serves no broader purpose is not made in the interests of realism. Rather, it is intended to highlight a particular set of incentives and tensions that are likely to be particularly important in an industry where much of the competition is of a zero-sum nature. Similarly, we do not mean to imply that highly trained and compensated financial professionals literally “do nothing useful” for their pay. Rather, these arguments illustrate that part of their value to their firms, and thus part of their compensation, is due to their ability to deter others from opportunistic behavior. From a social perspective, financial experts might be viewed as overqualified for the routine activities associated with their work. By analogy, hiring the most highly paid divorce lawyers confers on any one party a huge unilateral advantage in bargaining, but if both parties hire similar lawyers they might well neutralize each other’s impact on the division of their clients’

assets. In equilibrium, the tasks they perform might be performed as competently by lawyers with less experience, expertise, and reputation who would charge less, but those lawyers would not serve to deter the other party's more expensive and experienced counsel.

In most models with adverse selection in finance, some party is exogenously asymmetrically informed.¹ If they could (publicly) avoid becoming informed, they would do so. For example, in the classic setting described in [Myers and Majluf \(1984\)](#), an owner–manager–entrepreneur wishes to finance investment in a new project by selling securities to outsiders who know less about the intrinsic value of his existing assets than he does. The positive net present value (NPV) of this new investment is common knowledge. The entrepreneur is assumed to have acquired his information through his past history managing the firm. This informational advantage, however, is an impediment to the entrepreneur in dealing with the financial markets, as it costs him gains to trade associated with the NPV of the new investment. If he could manage the firm's assets effectively without acquiring this information, he would do so in order to minimize frictions associated with financing.

Given the obvious value of precommitting not to acquire information, why do we see financial firms, whose major business is to intermediate and facilitate trading, investing vast resources in expertise that speeds and improves their ability to acquire and process information about the assets they trade? In our model, the acquisition of expertise becomes a prisoner's dilemma. It confers upon any one party an advantage in bargaining that protects him from opportunism by his counterparties. Looking forward, firms invest in expertise in anticipation of this advantage, but investments by other firms neutralize the advantage in equilibrium. Under normal circumstances these investments are wasteful, but they do not interfere with efficient trade. The problem occurs if uncertainty about asset values jumps, and firms cannot immediately adjust their levels of expertise. At that point, the adverse selection becomes too severe for efficient trade to be sustained.

To keep the analysis tractable, we model agents who are *ex ante* identical in terms of their ability to acquire expertise. We model competition between equals. The benefits expertise confers on a trader, however, and the limits to the acquisition of expertise that the model articulates still apply when some potential counterparties are uninformed or “noise” traders.

The model in our paper is naturally interpreted as trading in an over-the-counter market since trade involves bilateral bargaining rather than intermediation through a specialist or an exchange. Most of the complex securities associated with high levels of financial expertise are traded over the counter—including mortgage- and asset-backed securities, collateralized debt obligations (CDOs), credit default swaps (CDSs), currencies, and fixed-income products such as treasury, sovereign, corporate, and municipal debt. Several models of

¹ See the pioneering paper by Akerlof (1970) on adverse selection and more recent papers on its role in financial crises by Eisfeldt (2004), Kirabaeva (2009), Daley and Green (2010), and Kurlat (2010), among many others.

over-the-counter trading have been proposed in the literature, such as [Duffie, Garleanu, and Pedersen \(2005, 2007\)](#). In these models, search frictions and relative bargaining power are the sources of illiquidity. The search frictions are taken as exogenous. Investments in “expertise” that reduce search frictions would be welfare enhancing, and would lead to greater gains to trade. In contrast, adverse selection is the central friction in our model. Investments in expertise do not improve efficiency, and they put gains to trade at risk.

Other models such as [Carlin \(2009\)](#) and [Carlin and Manso \(2011\)](#) view financial complexity as increasing costs to counterparties. In these two papers, however, the financial intermediary directly manipulates search costs to consumers, so these costs are most naturally interpreted as hidden fees for mutual funds, bank accounts, credit cards, and other consumer financial products. We interpret financial expertise as a relative advantage in verifying the value of a common-value financial asset in an environment where the complexity of the security, or the opacity of the trading venue, makes this costly. That is, we take the complexity of valuation as given, and treat expertise as investment in talent and infrastructure that improves the speed, efficiency, or accuracy of ascertaining that value, rather than as the intentional obfuscation of useful information. Both forces could be at work in the financial industry, since the complexity of valuation and the transparency of information are clearly related.

Economists since [Hirshleifer \(1971\)](#) have recognized, that, in a competitive equilibrium, private incentives may lead agents to overinvest in information gathering activities that have redistributive consequences but no social value. Our model captures the potential these investments have to create adverse selection and thus destroy value beyond the resources invested directly in acquiring information.

The general notion that economic actors may overinvest in professional services that help them compete in a zero-sum game goes back at least to [Ashenfelter and Bloom \(1993\)](#), who empirically study labor arbitration hearings and argue that outcomes are unaffected by legal representation as long as both parties have lawyers. A party that is not represented, when his or her opponent has a lawyer, suffers from a significant disadvantage. In this setting, however, the investment in legal services is not destructive of value beyond the fees paid to the lawyers. In our setting, expertise in finance has the potential to cause breakdowns in trade since it creates adverse selection.

[Baumol \(1990\)](#) and [Murphy, Shleifer, and Vishny \(1991\)](#) draw parallels between legal and financial services in arguing that countries with large service sectors devoted to such “rent-seeking” activities grow less quickly than economies where talented individuals are attracted to more entrepreneurial careers. They do not directly model the source of rent extraction, as we do.

Other papers such as [Hauswald and Marquez \(2006\)](#), [Fishman and Parker \(2010\)](#), [Van Nieuwerburgh and Veldkamp \(2010\)](#), and [Bolton, Santos, and Scheinkman \(2011\)](#) propose settings in which banks and investors can overinvest in information acquisition, as they do in our model. The banks in [Hauswald and Marquez \(2006\)](#) acquire information about the creditworthiness of borrowers because it softens price competition between banks that compete

for market shares, whereas investors in [Fishman and Parker \(2010\)](#) acquire information about the value of multiple projects before choosing which ones to finance. However, information can be socially useful in both of these settings in efficiently allocating capital. Investors in [Van Nieuwerburgh and Veldkamp \(2010\)](#) allocate their information acquisition resources across financial assets and make portfolio decisions simultaneously. Investors tend to focus their information acquisition on a small set of assets they expect to include in their portfolio, leading to the appearance of portfolio underdiversification. Closer to our paper, [Bolton, Santos, and Scheinkman \(2011\)](#) model a labor market for workers who can choose to become entrepreneurs or financiers. Compared to the social optimum, too many workers become financiers as workers do not account for the negative externality that informed screening by financiers has on the bargaining power of entrepreneurs, who are all assumed to be uninformed. We model the interaction between financial intermediaries in their role as traders, where more expertise facilitates the (inefficient) acquisition of information about the assets to be traded and consequently improves bargaining positions.

The paper is organized as follows. In Section I, we describe the model of trading interactions in its simplest form. Section II considers the decision to invest in financial expertise. In Section III, we prove our main results, which illustrate the destabilizing effects of expertise. Section IV uses a parametric example in a multiperiod setting to illustrate some of the features of the model. Section V studies how allowing for revenues unrelated to over-the-counter trading but increasing in expertise affects the model's implications. In Section VI, we study the signalling game that arises when both parties to any one trading encounter come with private information obtained through financial expertise. We show that the central trade-offs from our basic model survive in pooling equilibria based on credible off-equilibrium beliefs, where play proceeds much as in the simpler case. Section VII concludes. Proofs are provided in the Appendix.

I. Financial Expertise as a Deterrent

In our model, financial expertise is the ability to efficiently and accurately process information about a financial asset under time pressure in response to an offer to trade. It can be viewed as both human capital and technological infrastructure that supports it. Again, we emphasize that it is clear that financial expertise has other roles and benefits to the firms that employ experts. We highlight this particular one here to show how it leads to incentives to overinvest in expertise that can be destabilizing.

This section develops a simple bargaining model that illustrates how expertise protects a trader from opportunistic bargaining by his counterparties, and results in more favorable terms of trade, even though the information acquired through expertise is not used in equilibrium—it simply acts as a threat or deterrent. We begin with a very simple setting to illustrate the intuition. At the

end of the section, we discuss which aspects of the problem are without loss of generality and which will be addressed in later sections of the paper. The bargaining game here is a subgame in a model that endogenizes the choice of expertise. For the moment, the levels of expertise that the traders bring to the bargaining process are taken as given.

Two risk-neutral traders, denoted i and j , come together to exchange a financial asset. The asset has both a common value component, v , and a private value component. One of the two parties is assigned the role of buyer, and we assume for the moment that this is agent j . Agent i is the seller. The buyer's valuation of the asset is $v + 2\Delta$, whereas the seller's valuation is simply the common value v . The private value component, Δ , is the source of gains to trade. Without it, trade would break down in this setting due to the standard "no-trade theorem." The private value could represent a hedging need, unique access to a customer who is willing to overpay for the asset, or any other source of value that is not shared by all parties. The gains to trade are common knowledge to both parties, but there is uncertainty about the common value. It is either high, v_h , or low, v_l , with equal probability. Notice that $v_h - v_l$ is a natural measure of the amount of uncertainty, or volatility, in this setting. As we show below, it plays an important role in bounding the equilibrium levels of expertise, and unexpected jumps in this quantity are the source of the destabilizing effects of expertise that we explore in Section III.

We give the buyer all the bargaining power in an ultimatum game. He makes a take-it-or-leave-it offer to buy the asset at a price p . We assume, at this point, that the buyer is uninformed about the value, v , and views the two possible outcomes as equally probable. This dramatically simplifies the analysis, while still allowing us to illustrate the central trade-offs, because it eliminates the complications that arise when the first mover in the game is privately informed, creating a signalling game. We study the more general case in Section VI and argue that the intuition we develop for the one-sided case survives in a robust class of equilibria.

The seller can use his expertise to obtain information about the asset's value before responding to the buyer's offer. Specifically, he receives a signal, $s_i \in \{H, L\}$, that the value of the asset is v_h or v_l . The accuracy of the signal depends on expertise. Specifically, the probability that his signal is correct is $\mu_i = 1/2 + e_i$, where $e_i \in [0, 1/2]$ denotes his expertise. The expertise is the result of investments made at an earlier stage of the game, described in the next section.

Suppose the seller's signal is uninformative ($e_i = 0$ and $\mu_i = 1/2$). Then we have an ultimatum game with symmetric information. The buyer offers $p = E(v)$, the lowest price the seller will accept. The buyer captures the entire surplus of 2Δ , and the seller earns no surplus. Trade always takes place in equilibrium, and the agent with the higher valuation always ends up with the asset—there is efficiency in allocations.

How does expertise, $e_i > 0$, help the agent responding to an offer in this game? If he is offered the unconditional value he turns down that price whenever his

signal is high. The gains to trade are then lost half the time, and at $p = E(v)$ the buyer is overpaying whenever trade does occur because he knows the seller has seen a low signal when he accepts.

The buyer, of course, anticipates this. One possible response would be to offer the lowest price he can, given that the seller will walk away unless he has a low signal. This price is the seller's valuation, given a low signal:

$$\begin{aligned} p^* &= E(v \mid s_i = L) \\ &= (1 - \mu_i)v_h + \mu_i v_l. \end{aligned} \tag{1}$$

At this price, trade breaks down whenever the seller gets a high signal. In this case, the buyer's expected payoff is

$$\frac{1}{2}(2\Delta + E(v \mid s_i = L) - p^*) = \Delta, \tag{2}$$

and the expected surplus for the seller is his reservation price of zero.

An alternative for the buyer is to offer a price higher than the unconditional expectation, in hopes that the seller will accept regardless of his signal. The lowest price at which the seller will always accept is

$$\begin{aligned} p^{**} &= E(v \mid s_i = H) \\ &= \mu_i v_h + (1 - \mu_i)v_l. \end{aligned} \tag{3}$$

If the buyer offers the higher price, p^{**} , trade always occurs, and the inefficient loss of gains to trade is avoided. He must share some of the surplus with the seller, however, to achieve this. The buyer's expected surplus is

$$\begin{aligned} E(v) + 2\Delta - p^{**} &= 2\Delta - (v_h - v_l) \left(\mu_i - \frac{1}{2} \right) \\ &= 2\Delta - (v_h - v_l)e_i. \end{aligned} \tag{4}$$

The seller's expected surplus at this price (unconditionally, across both possible realizations of his signal) is

$$\begin{aligned} E[p^{**} - E(v \mid s_i)] &= p^{**} - E(v) \\ &= (v_h - v_l) \left(\mu_i - \frac{1}{2} \right) \\ &= (v_h - v_l)e_i. \end{aligned} \tag{5}$$

Thus, the seller's expertise allows him to extract a higher price from the buyer in this situation, even though the seller does not act on his information once the offer is made.

It is obvious that p^* and p^{**} are the only candidate equilibrium offers, since the buyer strictly prefers a lower price, given the probability the seller accepts. The buyer's choice between these two prices is the one that yields the higher

expected payoff to him. Comparing (2) and (4), he offers the higher price p^{**} if

$$2\Delta - (v_h - v_l)e_i \geq \Delta, \quad (6)$$

or, equivalently, if

$$e_i \leq \bar{e} \equiv \frac{\Delta}{v_h - v_l}. \quad (7)$$

Remarks: The trade-offs from the buyer's perspective in this model are straightforward. If he pays a higher price, he preserves gains to trade but he must share some of those gains with the liquidity provider. As is evident in equations (4) and (5), the "bribe" the buyer must pay to keep the seller from responding to his information is increasing in the accuracy of that information, that is, in his financial expertise. This drives the arms race in our model. If the seller's level of expertise is too high, however, condition (7) tells us that the buyer will switch to a lower offer at which the seller earns no surplus and trade breaks down half the time due to adverse selection. This limits the arms race. The bound on expertise tightens if volatility, $v_h - v_l$, rises relative to the gains to trade, Δ . Therefore, investments in expertise that still allow for efficient trade under normal circumstances might inhibit trade and destroy value when volatility is abnormally high.

Note that the higher the seller's expertise, the higher the price required to keep him from using his information in responding to an offer, but given that he gets such an offer, the information in his signal is superfluous. In this sense, his expertise is not actually used in equilibrium aside from its role as a deterrent as long as $e_i \leq \bar{e}$. Above that boundary the effects of adverse selection outweigh the gains to trade, and liquidity breaks down.

The Appendix shows that exactly analogous expressions to those above hold when the first mover is a seller and the buyer observes a signal before accepting or rejecting the offer. The same bound on expertise, (7), ensures efficient trade takes place in the trading game. The only difference is that the price required to ensure trade always takes place is the buyer's valuation given a *low* signal. Thus, the same conditions on expertise must hold under a variety of protocols. We can assume that nature randomly assigns one agent to be the buyer and one to be the seller, and then the buyer always makes the ultimatum offer, or we can assume that nature randomly assigns the opportunity to make the offer to either the buyer or the seller. What is important for the subsequent analysis is that, at the point where agents invest in expertise, they are uncertain about whether they will be making an offer or responding to it. It is natural to think of the responder as a supplier of liquidity to the proposer, who needs liquidity because of some external opportunity or imperative. We can think, then, of intermediaries engaged in trading financial assets as sometimes in need of liquidity and sometimes being called upon to supply it on short notice.

In the game we have described up to this point, traders are bargaining over a fixed surplus of 2Δ , and the only role of expertise is to increase their share of this surplus. Thus, we are *assuming* expertise has no social value, not

proving it. We do this to highlight the incentives financial intermediaries who are engaged in this type of trading have to *overinvest* in financial expertise by showing that they do so even when it has no social value. In the actual economy, as opposed to in our abstract model, financial expertise surely does have social value. It is easy to imagine ways in which the gains to trade in our model, Δ , might be enhanced through financial expertise. Greater expertise in search could help match higher value buyers with lower value sellers. Better financial engineering could assist in identifying opportunities to more efficiently share risk or avoid taxes. The ability to bring information to trading decisions quickly could improve price efficiency and in this way lead to better coordinated investment and operating decisions by firms. Still, if the incentives we highlight are present along with these benefits of expertise, one would expect excessive investment in expertise by firms, and, as we will go on to show, this investment will be destabilizing. Section V provides a simple generalization of our model that shows how the incentives we study can coexist with other benefits of expertise.

We have modeled a game in which intermediaries with expertise are trading with other intermediaries with expertise. In actual financial markets, much of their trade is surely with uninformed nonexperts—what financial models often refer to as “noise” traders. Note that the model of the trading process up to this point highlights the value of expertise even when dealing with inexperienced counterparties. The threat implicit in the expert’s knowledge ensures price concessions when responding to an offer from an uninformed trader seeking liquidity. Of course, in the model the incentives to acquire expertise are symmetric, but it is easy to imagine that for some market participants their infrequent need to trade in complex securities requiring expertise to evaluate would mean that the marginal costs of additional investment would lead them to acquire much lower levels of expertise.

One way to think of the gains to trade in our model is that it ultimately derives from such noise traders. An intermediary identifies a third party with inelastic demand or an urgent need to trade, and then seeks liquidity from another intermediary in order to meet that third party’s needs. Obviously, financial intermediaries trading in over-the-counter markets would prefer to obtain liquidity from naive noise traders when they can, rather than from sophisticated counterparties they know will drive a harder bargain. As long as there are some times when they must resort to trading with each other when seeking or supplying liquidity, however, the deterrent role of expertise that we highlight will be relevant. Hedge funds, trading desks of Wall Street firms, and institutional investors all have incentives to build expertise to deter aggressive bargaining by counterparties.

More broadly, this trading game is a relatively simple mechanism in which the consequences of adverse selection are stark and straightforward to characterize. We are thus able to highlight the trade-off between bargaining power gained with expertise and the increased risk of illiquidity. The effects that adverse selection has on trading outcomes in this setting, however, are similar to those in more complex and general mechanisms. Trade “breaks down” when

parties bargaining are asymmetrically informed about valuations, even if it is common knowledge that there are gains to trade. For example, [Myerson and Satterthwaite \(1983\)](#) demonstrate that no bilateral trading mechanism (without external subsidies) achieves efficient ex post outcomes. Incentive-compatible individually rational mechanisms involve mixed strategies that with nonzero probability lead to inefficient allocations. [Samuelson \(1984\)](#) shows that, when only the responder is informed, exchange occurs if and only if the proposer can successfully make a take-it-or-leave-it offer, as we assume he can in our model. [Admati and Perry \(1987\)](#) show in pure-strategy bargaining games that asymmetric information results in costly delays in bargaining. [Dang \(2008\)](#) shows that, when a responder can acquire private information at a sufficiently low cost, efficient trade will break down with positive probability. Thus, illiquidity, or the loss of gains to trade in some circumstances, is a general feature of bilateral exchange mechanisms with asymmetric information. It is in no way unique to our setting.

II. Investing in Expertise

It is evident from the previous section that, if all traders come to the bargaining process with expertise below the bound \bar{e} , then trade is efficient: it takes place with probability one and the party with the highest private valuation obtains the asset. In this section, we consider the equilibrium choices of expertise, and provide conditions under which the unique equilibrium involves all traders investing up to this boundary. An arms race occurs. In the next section, we allow the volatility to vary stochastically, and show that the same levels of expertise are still the equilibrium. As a result, when volatility rises suddenly, liquidity breaks down.

We now treat the trading game described above as the second stage in a two-stage game. In the first stage, traders acquire expertise. The cost of resources that must be invested initially to attain expertise of e_i is $c(e_i)$. We assume that this cost is positive, twice continuously differentiable, convex, and monotonically increasing ($c'(e) > 0$, $c''(e) > 0$). At the point where they invest in expertise, agents are uncertain about their role in the trading subgame—whether they will be buying or selling, proposing a price, or responding to an offer. This is intended to capture the notion that firms routinely engaged in trading in financial markets are at times seeking liquidity and at other times able to supply it. At times they have a (potential) bargaining advantage, and at other times they must respond quickly to offers from others, which puts them at a disadvantage in bargaining. The previous section shows how expertise can be viewed as a deterrent in the latter situation.

Consider agent i 's best response assuming that his counterparty is agent j , and $e_j \leq \bar{e} = \frac{\Delta}{v_h - v_l}$. Then the analysis in the previous section tells us that agent i 's expected payoff in any subgame where he is the buyer (or more generally the proposer) is

$$2\Delta - (v_h - v_l)e_j \tag{8}$$

and his payoff when selling is

$$(v_h - v_l)e_i \quad (9)$$

as long as $e_i \leq \bar{e}$. Each of these outcomes occurs with probability one-half, so his ex ante expected payoff in such a subgame at the time when he invests in expertise is, for $e_i \leq \bar{e}$,

$$\Delta + \frac{1}{2}(v_h - v_l)(e_i - e_j). \quad (10)$$

Evidently, the effect of a trader's choice of expertise is independent of that of his opponent. More expertise increases his payoff when he is a seller and has no effect on his payoff when he is a buyer—that depends on his opponent's expertise, but in a Nash equilibrium trader i takes his counterparties' actions as given. His payoff increases linearly in his own expertise up to the boundary \bar{e} , where it drops discontinuously because above that point the adverse selection disrupts trade. If the marginal cost of investment in expertise does not rise too quickly, he will invest up to that point, but then so will agent j , so that the advantage offered by expertise is neutralized in equilibrium. Whatever bargaining advantage the trader gains as a seller through expertise, he loses as a buyer to the expertise of his counterparty. Trade is efficient, and the expected surplus earned by any trader ex ante is Δ , half the total gains to trade. The only destruction of value due to expertise is the wasted resources of $c(\bar{e})$ for each trader.

The conditions on the cost function that ensure a symmetric equilibrium at the upper boundary are straightforward. The expected payoff for agent i in any given trading encounter, assuming his counterparty is agent j , is

$$\frac{1}{2}e_i(v_h - v_l)I\left(e_i \leq \frac{\Delta}{(v_h - v_l)}\right) + \frac{1}{2}\left[\Delta + (\Delta - e_j(v_h - v_l))I\left(e_j \leq \frac{\Delta}{(v_h - v_l)}\right)\right], \quad (11)$$

where $I(\cdot)$ is an indicator function. The first term represents the expected payoff for agent i when he is a responder, which occurs with probability $\frac{1}{2}$, and the second term represents his expected payoff when he is a proposer. As is obvious from the equation, his choice of e_i will be independent of his counterparty's choice of expertise, e_j , $j \neq i$. Hence, agent i 's optimal investment in expertise will maximize

$$\frac{1}{2}e_i(v_h - v_l)I\left(e_i \leq \frac{\Delta}{(v_h - v_l)}\right) - c(e_i). \quad (12)$$

Assuming that all agents face the same cost function $c(\cdot)$, all agents acquire \bar{e} units of expertise if $c'(\bar{e}) \leq \frac{1}{2}(v_h - v_l)$. Otherwise all agents acquire \hat{e} , the level of expertise that satisfies

$$c'(\hat{e}) = \frac{1}{2}(v_h - v_l), \quad (13)$$

which is the first-order condition of [equation \(12\)](#). Furthermore, the strict convexity of the cost function ensures that no other expertise level can provide agent i with the same payoff as \bar{e} or \hat{e} , hence no mixed strategy equilibria will exist either. Therefore, the equilibrium is unique.

Remarks: We describe the competition to accumulate expertise as an “arms race” because, as in the military setting, there is a unilateral incentive for each agent to acquire expertise in order to enforce better bargaining outcomes, but these advantages are neutralized in equilibrium by offsetting investments by the other agents. In the basic setting that we have described thus far, the marginal benefits of additional expertise do not depend on the opponents’ expertise. In most military situations, this would not be the case; rather, any one state’s incentive to acquire additional arms falls once it has an arsenal sufficiently superior to its opponents to dictate outcomes. The benefits of additional expertise do interact with the opponent’s level of expertise in the model with two-sided private information that we develop in [Section VI](#), and in this respect it might be viewed as more closely conforming to an arms race in the classic sense.

III. Destabilizing Effects of Expertise

Thus far, we have considered a setting in which investments in expertise are wasteful, but have no consequences for trade or market liquidity. This is analogous to an arms race that achieves mutual deterrence, and never leads to a war.

Consider, however, that the bound on expertise that ensures efficient trade in the bargaining subgame is decreasing in $v_h - v_l$. Suppose firms invest in expertise in anticipation of the benefits to them under normal circumstances of relatively low volatility. Then any jump in volatility will lead to breakdowns in trade or illiquidity due to adverse selection if firms cannot costlessly and immediately adjust their expertise in response. In this section, we provide conditions under which this is the equilibrium outcome.

We assume that the common values are drawn from two possible regimes, high-volatility and low-volatility. In the normal, or low-volatility, regime, $v_h - v_l = \sigma$. This regime occurs with probability $1 - \pi$. The high-volatility regime occurs infrequently, with probability π . The two possible values are then further apart: $v_h - v_l = \theta\sigma$, where $\theta > 1$. Traders learn whether they are in the high- or the low-volatility regime before engaging in bargaining but after choosing their expertise level.

Now, consider the same steps as in the previous section when volatility is stochastic. The expected payoff for agent i in the trading subgame is given by

$$\begin{aligned} & \frac{1}{2} \left[(1 - \pi) e_i \sigma I \left(e_i \leq \frac{\Delta}{\sigma} \right) + \pi e_i \theta \sigma I \left(e_i \leq \frac{\Delta}{\theta \sigma} \right) \right] \\ & + \frac{1}{2} \left[\Delta + (1 - \pi)(\Delta - e_j \sigma) I \left(e_j \leq \frac{\Delta}{\sigma} \right) + \pi(\Delta - e_j \theta \sigma) I \left(e_j \leq \frac{\Delta}{\theta \sigma} \right) \right]. \quad (14) \end{aligned}$$

As before, the first term in brackets represents the expected payoff for agent i when he is a responder (seller) and the second term in brackets represents his expected payoff when he is a proposer (buyer). The independence of optimal strategies is again obvious from this expression. The effects of changes in e_i do not depend on e_j . Trader i 's choice of e_i will be independent from his opponent's expertise level e_j . Hence, agent i 's optimal investment in expertise will maximize

$$\frac{1}{2} \left[(1 - \pi)e_i\sigma I\left(e_i \leq \frac{\Delta}{\sigma}\right) + \pi e_i\theta\sigma I\left(e_i \leq \frac{\Delta}{\theta\sigma}\right) \right] - c(e_i). \quad (15)$$

When volatility is stochastic, there are four candidates for the equilibrium level of expertise:

- the highest level of expertise that allows efficient trade in the low-volatility regime: $\bar{e}_l \equiv \frac{\Delta}{\sigma}$,
- the highest level of expertise that allows efficient trade in the high-volatility regime: $\bar{e}_h \equiv \frac{\Delta}{\theta\sigma}$,
- the level of expertise that satisfies the first-order condition for the low-volatility regime: \hat{e}_l such that

$$\frac{1}{2}(1 - \pi)\sigma = c'(\hat{e}_l), \quad (16)$$

- the level of expertise that satisfies the first-order condition for the high-volatility regime: \hat{e}_h such that

$$\frac{1}{2} [(1 - \pi)\sigma + \pi\theta\sigma] = c'(\hat{e}_h). \quad (17)$$

The next proposition is our main result for the basic model. It shows that, if expertise is relatively inexpensive (low marginal cost) in comparison to its expected benefits in the low-volatility regime, so that \bar{e}_l is the equilibrium with $\pi = 0$, then the continuity of an agent's payoff function in π ensures that all agents acquiring \bar{e}_l in expertise remains the unique equilibrium whenever the high-volatility regime is sufficiently unlikely.

PROPOSITION 1: *Suppose that*

$$c'\left(\frac{\Delta}{\sigma}\right) < \frac{\sigma}{2}, \quad (18)$$

so that $\bar{e}_l = \frac{\Delta}{\sigma}$ is the unique equilibrium with a single, low-volatility regime (i.e., when $\pi = 0$). Then, for any $\theta > 1$, there exists a $\pi^\theta > 0$ such that, for any $\pi < \pi^\theta$, \bar{e}_l remains the unique equilibrium in the choice of expertise.

The upper bound on π is then given by

$$\pi^\theta = \min \left\{ 1 - \frac{2}{\sigma} c' \left(\frac{\Delta}{\sigma} \right), \frac{\left(1 - \frac{1}{\theta} \right) \Delta - 2 \left[c \left(\frac{\Delta}{\sigma} \right) - c \left(\frac{\Delta}{\theta \sigma} \right) \right]}{\left(2 - \frac{1}{\theta} \right) \Delta} \right\}. \quad (19)$$

The intuition behind the proof is that, if π is less than the first argument in the $\min\{\cdot, \cdot\}$ operator in (19), then the marginal gains from expertise in the low-volatility regime (which now has a lower probability than one) still exceed the marginal cost of expertise. The convexity of the cost function then allows us to rule out the two candidate equilibrium levels of expertise associated with the first-order conditions holding with equality, and limits the comparison to \bar{e}_l and \bar{e}_h . The second argument in the $\min\{\cdot, \cdot\}$ operator ensures that the probability of the high-volatility regime is sufficiently low that the extra cost of investing in the higher level of expertise, $c(\bar{e}_l) - c(\bar{e}_h)$, combined with the expected loss in gains to trade when volatility is high, do not offset the benefits of gaining a better price when responding to offers under low volatility.

Remarks: Our model predicts that financial intermediaries might find it optimal to acquire expertise even though it makes trade fragile in periods of high uncertainty. Acquiring expertise improves an intermediary's ability to assess an asset's value, and therefore amplifies the possibility of an adverse selection problem. The threat of facing a better-informed counterparty might force an intermediary to make him a better offer to ensure that trade takes place, but as volatility goes up the value of information also goes up and the buyer becomes unable to make an offer that would be simultaneously viable for him and always accepted by the seller. In the high-volatility regime, trade breaks down whenever the responder observes a high signal, which occurs half of the time. If the probability of the high-volatility regime is small enough, however, the gains to trade lost in the high-volatility regime are not as important as the increase in profits that added expertise, and the ensuing improved bargaining position, bring in the low-volatility regime. The intermediary finds it optimal to acquire the level of expertise that maximizes his expected profits in the more probable low-volatility regime, even though it leads to trade breakdowns and therefore lower profits in the infrequent high-volatility regime. Each financial firm acts in its own best interest but, in equilibrium, trade breaks down with an unconditional probability of $\frac{\pi}{2}$ and $\pi \Delta$ of the expected gains to trade are destroyed.

Of course, it is often the case that decisions that are good for one state might be bad for another. Similarly, information theorists have long understood that, although pooling can be sustained, despite adverse selection, in settings where the differences between outcomes are small, trade will break down when this difference is large. What is novel in our model is that the degree of adverse selection is a choice. Both the acquisition of expertise and its limits are

endogenous responses. The benefit of becoming informed is that, when called upon to supply liquidity, the supplier's share of the surplus stemming from his counterparty's private value is increasing in the supplier's expertise. The cost of becoming too informed is the increasing risk that, as the asymmetric information problem worsens, the counterparty will only offer the lemons price, which leaves the liquidity supplier with zero surplus. Large liquidity suppliers might want to appear informed to their counterparties since the implicit threat improves their bargaining position. This is the mechanism that motivates the acquisition of expertise. On the other hand, the same intermediaries might want to avoid appearing to be too informed relative to their counterparties, or else traders will avoid them. That is the mechanism that constrains expertise in the model. Facing this trade-off, intermediaries acquire the capacity to become informed, even though it puts their business at risk.

These trade-offs make the relationship between expertise, market instability, and uncertainty ambiguous, but by considering them we might still gain some insights into why liquidity crises emerged in particular sectors of the financial industry. On the one hand, high levels of uncertainty, $v_h - v_l$, make expertise more valuable as a threat at the margin, as is apparent from [equation \(10\)](#). On the other hand, the very power of expertise with higher levels of uncertainty makes the adverse selection more problematic, so that the bound on the equilibrium level of expertise, in [\(7\)](#), is tighter with more uncertainty. Note that, when uncertainty is low, investment in expertise will be limited to the technological cost of greater investment, captured in the model by the marginal cost condition [\(13\)](#), and the level of expertise will be below the threshold at which adverse selection interferes with trade. When this is the case, a jump in volatility must be much larger to trigger a drop in liquidity. For an arms race in expertise to lead to breakdowns in liquidity, therefore, we must have two forces at work. First, valuation must be sufficiently complex and uncertain to warrant investments in expertise to begin with and to raise the level of investment up to the point that liquidity is at risk. Second, volatility or uncertainty must jump in response to an exogenous shock. Recent financial crises appear to share the required characteristics. For example, the Long-Term Capital Management default and the crisis in the mortgage-backed and CDS markets all involved new strategies, technologies, or types of securities where the expert knowledge of some traders might have given financial firms a big advantage. They also involved surprises that raised uncertainty about intrinsic valuations: the Russian default and a national fall in housing prices.

In this model, the choice of expertise is made at an initial stage, before the volatility state is known. Our results thus highlight the fact that expertise becomes costly for firms when, for exogenous reasons, volatility increases. In the actual financial industry, of course, firms can and do adjust their "expertise" in response to changing conditions, as the layoffs following the recent financial crisis make very clear. The incentives we focus on would presumably survive as long as there were adjustment costs that would keep firms' response from being complete and instantaneous.

In this respect, the empirical implications of our model stand in marked contrast to other explanations for the value of financial expertise. Typically, other views of expertise imply that it has greater value when more uncertainty is present. For example, more uncertainty would seem to create more need to reallocate risk, and greater opportunities for financial firms to create value by facilitating this process. Indeed, it is often said that Wall Street “makes money off of volatility.” Yet we consistently see dramatic contractions in hiring and employment of professional employees in the financial sector following financial crises. These are also periods with both abnormally high volatility and the destruction of liquidity, despite apparent benefits to trade and a greater need to reallocate risk.

Our model offers a way to reconcile these seemingly contradictory phenomena. The one theoretically coherent explanation for an unwillingness to trade during periods of high volatility is increased adverse selection. Our model explains how expertise might exacerbate this problem. At the same time, the experts in our model do profit from volatility under normal conditions. Without some uncertainty in our model expertise has no value in trading interactions. Accordingly, in light of the incentives our model highlights, it should not be surprising that financial firms build expertise through periods of moderate volatility, knowing that this puts their business in jeopardy should uncertainty suddenly increase, and then contract in response to shocks that raise uncertainty.

The breakdown in trade triggered by a jump in volatility is due to the increase in the importance of the liquidity supplier’s private information in the presence of more uncertainty. It may seem to some readers implausible that the liquidity problems we observe during financial crises could be due to financial intermediaries knowing too much, when it appeared to many observers that the large financial intermediaries were themselves surprised and mystified by what was happening. Keep in mind, however, that the experts in our model are more mystified when volatility jumps. There is more uncertainty in the environment. They are just less mystified than their counterparties.

IV. Parameterization

In this section, we parameterize our model to better illustrate its implications. The earlier sections developed the model as a two-stage game with one trading encounter. This illustrates the central qualitative trade-offs, but the model is quantitatively more sensible if we view investments in expertise as made in anticipation of many trading interactions.

Accordingly, we assume there is a continuum of risk-neutral and infinitely lived financial intermediaries or traders. In each period t , $t = 1, \dots, \infty$, trader i meets a random counterparty drawn from the set of potential traders, and they bargain through the ultimatum game described in earlier sections. When they meet, agent i is assigned the role of buyer (proposer) or seller (responder) with equal probability, and his counterparty assumes the other role. Nature then determines the volatility regime, low with probability $1 - \pi$ or high with probability π . This is common knowledge to the traders. The common value, v ,

is drawn independently through time. Right before the first trading encounter, a trader i can invest resources, $c(e_i)$, to acquire financial expertise e_i , which will remain constant through time. The level of expertise is known to all parties at all times. Trading history, however, is anonymous to abstract from the effects of reputation building and the complications this would create in the game. Thus, a specific trader knows in any given encounter if he is dealing with a major investment bank or a municipal pension fund, but he does not know the outcomes of his counterparty's recent trades. Future expected payoffs are discounted at rate δ . This setting preserves the simplicity of the two-stage game, while allowing for more reasonable relative magnitudes of initial investment and periodic trading profits.

We specify the cost $c(e)$ of acquiring level of expertise e as given by $c(e) = \frac{\kappa}{2}e^2$. In this case, the threshold π^θ becomes

$$\pi^\theta = \min \left\{ 1 - 2(1 - \delta) \frac{\kappa \Delta}{\sigma^2}, \frac{\left(1 - \frac{1}{\theta}\right) - (1 - \delta) \left(1 - \frac{1}{\theta^2}\right) \kappa \frac{\Delta}{\sigma^2}}{\left(2 - \frac{1}{\theta}\right)} \right\}. \quad (20)$$

Note that both arguments in the $\min\{\cdot, \cdot\}$ operator are decreasing in $\frac{\kappa \Delta}{\sigma^2}$. If, instead, we take π as given, we can rewrite the two conditions ensuring that \bar{e}_l is the unique equilibrium in expertise as

$$\frac{\kappa \Delta}{\sigma^2} < \min \left\{ \frac{1 - \pi}{2(1 - \delta)}, \frac{1 - 2\pi - \frac{(1 - \pi)}{\theta}}{(1 - \delta) \left(1 - \frac{1}{\theta^2}\right)} \right\}. \quad (21)$$

Thus, the arms race equilibrium, which of course puts gains to trade at risk, is more likely to occur when these gains to trade, Δ , are low relative to the routine volatility, σ . Increasing the cost of acquiring expertise, κ , also works against the arms race equilibrium for obvious reasons.

Figure 1 plots the maximum probability for the high-volatility regime, π^θ , that supports the arms race equilibrium with trade breakdowns as a function of the magnitude of the jump, θ . The parameter values used in this figure are $\sigma = 1$ (base volatility is a free normalization), $\Delta = 0.2$ (ex ante gains to trade), $\delta = 0.9$ (discount factor), and $\kappa = 10$ (cost parameter). The lesson to be drawn from this figure is that the probability of a jump to the high-volatility regime, with a loss of half the gains to trade, can be quite substantial. It ranges from around 5% when the jump in volatility is 10% to around 15% when that jump is 50%. The relationship between π^θ and θ is increasing in this figure because, in the low volatility regime, a higher θ increases the differential in payoffs between \bar{e}_l and \bar{e}_h to a greater extent than the differential in costs of expertise. Essentially, when θ increases and the volatility levels in the two regimes get farther from each other, the loss in profits in the low-volatility regime that goes with lowering expertise to preserve efficient trade in the high-volatility regime increases. Saving the gains to trade in the high-volatility

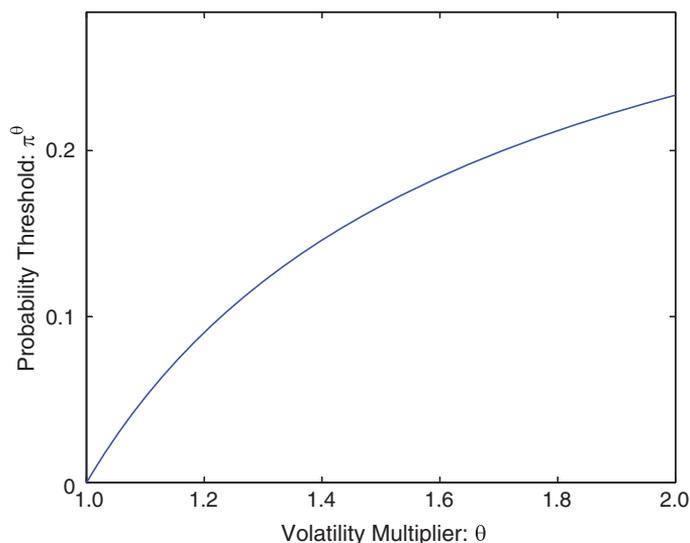


Figure 1. Bounds on π . The plot shows the maximum value of the probability of the high-volatility regime π against the increase in the volatility θ . For values of π below this bound, agents in the model invest in expertise to the maximum level, \bar{e}_l , even though this leads to breakdowns in trade when the high-volatility regime occurs. The figure is generated using discount rate $\delta = 0.9$, ex ante gain to trade $\Delta = 0.2$, cost parameter $\kappa = 10$, and low volatility $\sigma = 1$.

regime becomes costlier in terms of bargaining position in the low-volatility regime.

Figure 2 shows the relationship between the equilibrium level of expertise and the gains to trade when we set $\theta = 1.2$ and $\pi = 0.05$, and Δ is allowed to vary. When Δ is small enough for the inequality in (21) to hold ($\Delta < 3.55$), the equilibrium level of expertise is equal to \bar{e}_l , which is increasing in Δ . Once Δ becomes large enough, however, and (21) is violated ($\Delta \geq 3.55$), expertise drops discretely from $\bar{e}_l = \frac{\Delta}{\sigma}$ to $\bar{e}_h = \frac{\Delta}{\theta\sigma}$, which is also increasing in Δ but at a lower rate.

Intuitively, when gains to trade are small enough relative to the volatility in asset value, intermediaries are willing to acquire high levels of expertise even though this expertise leads to some trade breakdowns when volatility is high. On the other hand, when gains to trade get larger, the potential losses due to trade breakdowns become too important and intermediaries prefer to dial down on expertise to ensure that trade takes place even when volatility is high.

Remarks: Note that to keep the model tractable, and avoid having to deal with an extremely complicated dynamic game, we have specified that trading history is anonymous so that there is no opportunity for building a reputation. This is clearly an important limitation. Professional participants in over-the-counter markets surely do differ in the reputations as well as expertise they bring to bear in their dealings with others. First, we note that there is nothing

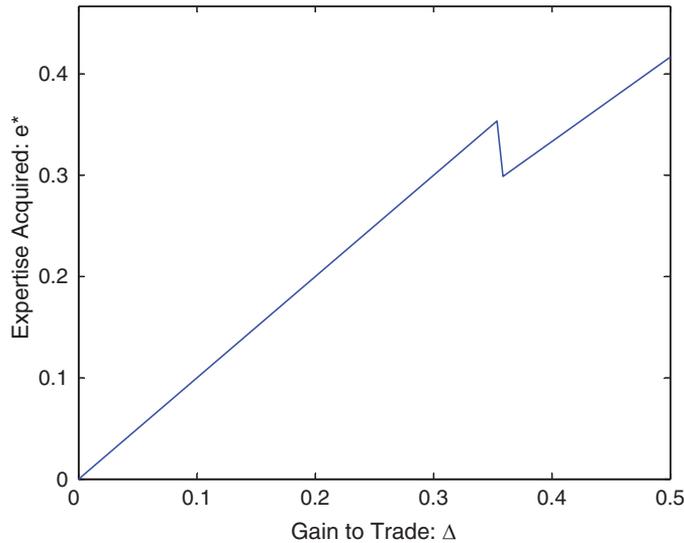


Figure 2. Expertise as a function of ex ante gain to trade Δ . The plot shows the relationship between the equilibrium level of expertise and the ex ante gain to trade. The figure is generated using discount rate $\delta = 0.9$, cost parameter $\kappa = 10$, low volatility $\sigma = 1$, jump in volatility $\theta = 1.2$, and probability of such jump $\pi = 0.05$.

“disreputable” in what the traders in our model are doing. They are simply bargaining. In equilibrium, nobody is misled or exploited on average. It is also not at all clear in which direction allowing for reputation would lead. On the one hand, building a reputation for tough bargaining, even at the risk of losing gains to trade, has a benefit in repeated interactions much like expertise in our model, and would exacerbate the risk of periodic breakdowns in liquidity. On the other hand, a reputation for fair dealing would mitigate the need for, and value of, expertise as a deterrent.

V. Other Benefits from Financial Expertise

The simple model we analyze so far focuses on the role of expertise in valuing and trading securities in an over-the-counter setting. Abstracting away all other benefits from financial expertise yields stark and intuitive results about the incentives of financial firms to acquire expertise before trading with other firms. Of course, in reality financial expertise has other benefits and produces revenues that are unrelated to trading but that affect firms’ decisions to acquire expertise.

Here we assume that, in addition to earning revenues from the trading game we model, a firm with expertise e earns revenue $r(e)$ unrelated to trading activities. This revenue is assumed to be positive, increasing, and weakly concave in expertise and represents, for example, compensation for investment banking

activities or for improving a client's risk management processes. In the two-stage model with only one trading encounter, the expected payoff for firm i is the payoff we have in equation (14) plus $r(e_i)$.

Adding other revenues to the benefits of expertise makes the acquisition of expertise more attractive for the financial firms in our model. Because it is unrelated to trading payoffs, adding $r(e)$, where $r'(e) > 0$, is equivalent to reducing the cost of expertise $c(e)$ by $r(e)$. Therefore, the earlier conditions required for expertise \bar{e}_l to be optimal are easier to satisfy when $r(e)$ enters the payoff function.

The novelty from adding $r(e)$ is that, under some circumstances, firms will not stop at \bar{e}_l when acquiring expertise. If $r(e)$ increases sufficiently quickly in the region where $e > \bar{e}_l$, the unique equilibrium will then be an arms race in expertise where all firms acquire a level of expertise \tilde{e} ($> \bar{e}_l$) that satisfies

$$r'(\tilde{e}) = c'(\tilde{e}). \quad (22)$$

In such settings, the marginal benefits of expertise are so high that firms continue to acquire expertise well past the previous equilibrium level \bar{e}_l even though it implies that trade breaks down half of the time in the low-volatility regime as well as in the high-volatility regime. The revenue gain [$r(\tilde{e}) - r(\bar{e}_l)$] from the higher expertise is larger than the expected loss in gains to trade in the low-volatility regime $\pi \Delta$ plus the cost savings [$c(\bar{e}_l) - c(\tilde{e})$]. Hence, firms maximize their total payoff, net of the cost of expertise, by picking the same level of expertise they would pick if expertise did not affect what happens in the trading game.

To summarize, accounting for other revenues generated by financial expertise strengthens the incentives of financial firms to acquire expertise, and breakdowns in trade are as frequent, if not more so, than in our earlier model without such revenues. Hence, for simplicity, we continue to abstract away from these revenues in the remainder of the paper.

VI. Signalling Game with Two-Sided Asymmetric Information

In the previous sections, we treat financial expertise as a capacity to accurately assess the value of an asset under time pressure in response to an offer to trade. We assume that the intermediaries or traders use this expertise in their role as liquidity suppliers. The party making the offer to trade is the source of private benefits, but does not receive an informative signal. This simplifies the analysis, since the first mover's offer does not convey private information, while still allowing us to illustrate the incentives that create an arms race. Intermediaries have private incentives to invest in expertise as a deterrent in bargaining, even though it risks the social surplus generated by trade.

Our goal in this section is to show that these trade-offs survive in the signalling game that arises when expertise informs the actions of both the proposer and the responder in any given trading encounter. When the proposing

party is informed, his offer influences the beliefs of the responder, and thus his willingness to accept. As is typically the case in such settings, there are many equilibria. Our approach is to show, first, that only pooling equilibria, where proposers with high signals offer the same price as proposers with low signals, support efficient trade. Second, we show that the conditions under which pooling equilibria exist restrict the level of traders' expertise in terms of volatility and that the ex ante expected payoffs in the pooling equilibrium to the traders are the same as in the subgame with an uninformed first mover—they are linear and increasing in their own expertise. Finally, we show that if play in the trading subgames proceeds in a manner in which beliefs are “credibly updated,” as defined by Grossman and Perry (1986), and in which gains to trade are preserved through efficient trade whenever possible, traders will increase their expertise in anticipation of this and volatility jumps will lead to breakdowns in trade, as in earlier sections.

The arguments presented in the text are aimed at verbally illustrating the logic. A more formal development is deferred to the Appendix.

A. Trading Subgame

Again, we develop in detail the case in which the first mover wishes to buy, and the responding liquidity supplier takes the role of a potential seller. As should be clear from previous sections, this is without loss of generality.

Let $s_b \in \{H, L\}$ denote the buyer's signal and $s_s \in \{H, L\}$ that of the seller. We take as given the probabilities $\mu_s = \frac{1}{2} + e_s$ and $\mu_b = \frac{1}{2} + e_b$, which increase with expertise, that the signals are correct. It is straightforward to demonstrate the following result.

LEMMA 1: *The only equilibria in which efficient trade always occurs are pooling equilibria in which the high-signal and low-signal proposers offer the same price, which is accepted by the seller.*

The next question, then, is whether pooling equilibria that support efficient trade exist. We focus on perfect sequential equilibria as proposed by Grossman and Perry (1986), and show that a bound on expertise, similar to that derived in earlier sections, must be satisfied for efficient perfect sequential equilibria to exist in the trading subgame. This bound then serves as a basis for our analysis of the arms race in expertise, and its potential to destroy gains to trade when volatility rises. We note that, under other sets of “reasonable” off-equilibrium beliefs, qualitatively similar upper bounds on expertise obtain.²

A perfect sequential equilibrium is described by Grossman and Perry (1986, p. 97) as an equilibrium “supported by beliefs p which prevent a player from deviating to an unreached node, when there is no belief q which, when assigned to the node, makes it optimal for a deviation to occur with probability q .” Intuitively speaking, this concept ensures that, whenever possible, the

² For example, when deviations by the buyer to a lower price are interpreted by the seller as uninformative about the buyer's signal.

off-equilibrium beliefs associated with a deviation by the buyer are updated following Bayes's rule given the best response(s) of the seller if he has such beliefs. The result helps restrict the behavior we should expect to take place when traders meet. There is at most one type of pooling equilibria that is perfect sequential.³ Since the price offered in these equilibria is the same as in the case with one-sided asymmetric information, equilibrium play proceeds as described earlier, and as in previous sections when the buyer does not receive a signal.

We conjecture an equilibrium of the following sort:

- The buyer always offers the lowest price at which the seller, knowing nothing about the buyer's signal, would accept regardless of his signal. This is, of course, the same price the buyer offers when uninformed, as in Section I

$$p^{**} = \mu_s v_h + (1 - \mu_s) v_l. \tag{23}$$

- Upon receiving an offer of a lower price the seller update his beliefs credibly, consistent with the definition in [Grossman and Perry \(1986\)](#).

Given that the buyer always offers p^{**} , when the seller accepts he receives the same unconditional expected payoff as he obtains with an uninformed buyer, which from equation (5) is $(v_h - v_l)(\mu_s - 1/2)$. Since the seller accepts this price regardless of his signal, the buyer learns nothing about the seller's signal.

In verifying that pooling at p^{**} is an equilibrium, the critical participation constraint and the incentive compatibility constraint are for the low-signal buyer. Satisfying the participation constraint for the low-signal buyer guarantees that the participation constraint for the high-signal buyer is satisfied. Both types of buyer pay the same price for the asset, but the expected value of the asset is weakly higher after seeing a high signal than a low signal. Also note that there is no incentive for either type of buyer to defect from the proposed equilibrium by offering a price higher than p^{**} , regardless of the seller's beliefs. At best, the seller would always accept, which he will do at p^{**} in any case, and the buyer will pay more. It remains, therefore, to verify that the buyer will never defect to a lower price.

The payoff to a low-signal buyer from offering p^{**} is

$$\begin{aligned} E(v \mid s_b = L) + 2\Delta - p^{**} &= 2\Delta + (v_h - v_l)(1 - \mu_b - \mu_s) \\ &= 2\Delta - (v_h - v_l)(e_b + e_s). \end{aligned} \tag{24}$$

This payoff needs to be at least zero for pooling at p^{**} to be an equilibrium. As long as the signals are informative (positive expertise), the buyer must surrender some of his surplus to the seller to induce him to accept the offer. With

³ Formally, since beliefs will be unrestricted following certain off-equilibrium path actions that are always unappealing to the buyer, regardless of his signal, there are multiple equilibria, but they are outcome equivalent. We maintain the convention of using uniqueness in this sense.

$\mu_b = 1/2$ and $e_b = 0$, this is the same expression as we obtain with an uninformed buyer, equation (4). Compared to the one-sided asymmetric information case, the buyer's expected payoff is now lower because his signal is low, and he knows he is overpaying by more relative to the common value.

If the buyer offers a price $p < p^{**}$, under reasonable beliefs the seller will only accept the offer after a low signal. Given this response, the buyer will offer the lowest price possible, which is $p^* = E(v | s_s = L)$. Now, however, the buyer's assessment of the probability that the seller accepts depends on the buyer's signal and its precision. Moreover, the information conveyed by this acceptance confirms the buyer's signal. Compared to the one-sided asymmetric information case, the buyer extracts less surplus, conditional on a trade occurring, whenever both signals are more informative than that of the seller alone. The buyer is overpaying ex post because the seller's acceptance confirms his signal.

The next proposition shows that, if we restrict traders to update their beliefs credibly, as in the definition of perfect sequential equilibria in Grossman and Perry (1986), the only equilibria with efficient trade that survive in the trading subgame will be pooling equilibria at a price of p^{**} . We also derive the boundary for the existence of an efficient perfect sequential equilibrium in the trading subgame.

PROPOSITION 2: *The only equilibria that involve efficient trade in the trading subgame and that are perfect sequential as defined in Grossman and Perry (1986) are pooling equilibria at p^{**} . Such efficient perfect sequential equilibria exist if and only if*

$$\frac{2\Delta}{v_h - v_l} \geq \frac{e_s + e_b}{\frac{1}{2} - 2e_s e_b}. \quad (25)$$

Now consider the ex ante expected payoffs to the buyer and seller from the trading subgame, in the pooling equilibrium, before knowing their signals. The buyer receives $2\Delta - p^{**}$ plus $E(v | s_b = H)$ or $E(v | s_b = L)$ with equal probability, or

$$2\Delta + (v_h - v_l) \left(\frac{1 - \mu_s - \mu_b}{2} + \frac{\mu_b - \mu_s}{2} \right) = 2\Delta - (v_h - v_l)e_s. \quad (26)$$

Since trade always takes place, the seller receives the remaining surplus of

$$(v_h - v_l)e_s. \quad (27)$$

Not surprisingly, since trade always occurs, and at the same prices as when the buyer is uninformed, the ex ante payoffs are the same as in the one-sided asymmetric information case. Agent i , then, before knowing whether he or his opponent, agent j , is buyer or seller, earns an expected payoff of

$$\Delta + \frac{1}{2}(v_h - v_l)(e_i - e_j). \quad (28)$$

Taking as given his opponent's levels of expertise, trader i will increase his expected payoff in any given trading encounter by increasing his expertise. The incentives to invest in expertise are similar to those in the simpler case of one-sided asymmetric information.

To summarize, in an equilibrium preserving efficient trade in the trading subgame, where both parties receive private signals, expertise plays the same role as in the simpler setting analyzed earlier. In particular, it deters opportunistic offers by the party initiating the trade, but the private incentives agents have to invest in expertise are limited by an incentive compatibility condition, and this bound decreases when volatility rises.

From the condition for the existence of a perfect sequential efficient equilibrium, expression (25) in Proposition 2, we immediately obtain the following results. First, there is a unique symmetric expertise pair $e^* = \frac{v_h - v_l}{4\Delta} \left[\sqrt{1 + \frac{4\Delta^2}{(v_h - v_l)^2}} - 1 \right]$ that satisfies the above condition with equality. This expertise level is greater than zero whenever $\frac{v_h - v_l}{\Delta} \in (0, +\infty)$. Second, regardless of whether expertise is symmetric, a slight increase in expertise by one trader crossing this boundary implies that the efficient perfect sequential equilibria cease to exist, whether that trader is a buyer or a seller. Finally, since the left-hand side of the condition is decreasing in $v_h - v_l$, an increase in volatility eliminates the efficient perfect sequential equilibria where traders have invested in expertise up to the boundary.

B. Choice of Expertise

We now investigate the possible equilibrium choices of expertise in the first stage, assuming that the costs of expertise are low and that high-volatility states are rare. If all traders anticipate that in the low-volatility regime play in the trading subgame will proceed according to a pooling equilibrium at p^{**} , then their expected payoffs will be linear in their own expertise and they will invest in expertise. However, at some boundary in expertise, any increase in expertise will prevent efficient trade from taking place and will destroy some of the gains to trade. The equilibrium in expertise associated with that boundary will involve efficient trade in low-volatility regimes and breakdowns in liquidity in the high-volatility regimes, regardless of the size of the jump in volatility, just as in the setup with one-sided asymmetric information.

However, there will be other types of equilibria. The multiplicity of possible beliefs and equilibria in the trading subgame when both parties have private information induces multiple equilibria in the choice of expertise. In these equilibria, play along the equilibrium path proceeds in the subgame according to the pooling equilibrium, but additional investment in expertise is deterred by beliefs about the opponent's strategic choices in response to an out-of-equilibrium increase in expertise.

Specifically, suppose both traders have low levels of expertise. Any trader can then improve his discounted expected payoffs by raising his investment in expertise as long as he anticipates pooling equilibrium outcomes in the trading subgame (in the low-volatility regime). An arms race then occurs. If instead he

anticipates that the response of his opponent to such an increase in his expertise will be to either play the strategies associated with separating equilibria in the trading subgame, which are inefficient, or to play efficient equilibria that provide the nondeviating trader with a larger share of the surplus, the resulting decrease in his expected payoff may be sufficient to discourage such a deviation from the lower equilibrium level of expertise.

For this reason, we impose the perfect sequential equilibrium refinement defined in [Grossman and Perry \(1986\)](#) on the expertise acquisition game and eliminate equilibria that rely on off-equilibrium threats with incredible beliefs. We further require that traders anticipate that, if both efficient and inefficient perfect sequential equilibria exist, the efficient equilibrium will prevail.⁴ We confine attention to the case in which the costs of expertise rise sufficiently fast above the symmetric threshold e^* that large increases in expertise are too costly to be profitable. Formally, we show that when both traders invest up to the symmetric threshold e^* , no trader has an incentive to deviate to a marginally higher level of expertise where trade breaks down with positive probability. This restriction on costs also allows us to focus on the most efficient symmetric equilibrium possible (that is, the equilibrium in which trade always takes place in the low-volatility state and investments in expertise are minimized). Under these restrictions, we obtain a unique prediction for investment in expertise, and small, infrequent increases in volatility will lead to breakdowns in trade in the high-volatility state. The arguments are detailed in the Appendix, which also provides statements and proofs of a proposition establishing that in a neighborhood of the pair $\{e^*, e^*\}$, where one of the parties deviates to a higher level of expertise, trade breaks down with positive probability in the low-volatility regime and surplus is destroyed in any perfect sequential equilibria. This threat, then, bounds the equilibrium choice of expertise to the highest level that supports efficient trade in the low-volatility regime.

To summarize, when the condition in Proposition 2 is violated, efficient trade cannot take place in the trading game with low volatility if beliefs are credibly updated. Instead, gains to trade are lost, and the ex ante payoffs to the traders before they know their roles as buyer or seller are smaller than if the condition in Proposition 2 holds. So as long as the costs of expertise do not rise too quickly and the high-volatility state does not occur too frequently, the equilibrium outcomes of the expertise game that survive the credible updating criterion of [Grossman and Perry \(1986\)](#) here will have traders investing in expertise up to the point where any further investment would lead to breakdowns in trade in the low-volatility regime, as in earlier sections where only the responder is informed. And, as long as the costs of acquiring expertise do not rise too slowly, we have shown that this is the unique prediction for expertise investment in a symmetric equilibrium. Infrequent, small shocks to volatility will still lead to breakdowns in trade.

⁴ This restriction can be motivated by a strong form of forward induction closely related to the updating rule imposed in [Grossman and Perry \(1986\)](#).

VII. Conclusion

The model in this paper illustrates the incentives for financial market participants to overinvest in financial expertise. Expertise in finance increases the speed and efficiency with which traders and intermediaries can determine the value of assets when they are negotiating with potential counterparties. The lower costs give them advantages in negotiation, even when the information acquisition has no value to society, and even when it can create adverse selection that disrupts trade if uncertainty about the volatility of fundamental values increases too quickly or unexpectedly to allow intermediaries to adjust or scale back their investment in expertise. If jumps in volatility are sufficiently infrequent, the gains to trade lost in the high-volatility regime will not be as important as the increase in profits that added expertise, and the ensuing improved bargaining position, bring in the low-volatility regime. The intermediary will find it optimal to acquire expertise that increases expected profits in the more probable low-volatility regime, even though the advantage gained is neutralized by similar investments by counterparties in equilibrium, and even though expertise decreases profits because of trade breakdowns when volatility jumps.

Some extensions to the model may warrant additional research. Financial expertise might also allow intermediaries to decrease the precision of information acquired by their counterparties, as well as increase the precision of their own information. Investment in expertise permits firms to create, and make markets in, more complex financial instruments. In our notation, we can view the precision of information about intrinsic value for agent i as $\mu(e_i, e_j)$, which decreases in i 's own expertise and increases in that of his counterparty. The logic of our analysis suggests that firms benefit from increasing the relative costs of their counterparties. The tension between the incentives to decrease others' signal precision, which would reduce adverse selection, and increase one's own signal precision, which would increase it, may help us to better understand innovation and evolution in financial markets.

In our model, intermediaries invest in expertise only once, and the volatility states are drawn independently through time. This illustrates the consequences that shocks to volatility have for liquidity. If volatility is persistent through time, and intermediaries can adjust, with some adjustment costs, their level of expertise in response to changing volatility, then shocks to volatility will still lead to breakdowns in liquidity, but they will also trigger contractions in "expertise" that can be interpreted as employment of financial professionals. Such a model might be informative about the nature of employment cycles in financial services.

Appendix A: One-Sided Asymmetric Equation

Symmetry of Trading Game

The arguments in the text derive expressions for the case in which the proposer buys. If the proposer sells, the highest price at which he can ensure

acceptance of his offer for any signal is

$$p^{**} = E(v | s_i = L) \quad (\text{A1})$$

and his payoff is

$$\begin{aligned} p^{**} - [E(v) - 2\Delta] &= 2\Delta - (v_h - v_l) \left(\mu_i - \frac{1}{2} \right) \\ &= 2\Delta - (v_h - v_l)e_i. \end{aligned} \quad (\text{A2})$$

The highest price at which trade will occur at least half the time is

$$p^* = E(v | s_i = H) \quad (\text{A3})$$

and the seller's payoff is

$$\frac{1}{2}(p^* - [E(v | s_i = H) - 2\Delta]) = \Delta. \quad (\text{A4})$$

Comparing these expressions for the seller's payoff to those for the buyer's payoff in the text reveals that they are identical. A comparison of the payoffs at price p^{**} and p^* then yields the same inequality for the level of expertise.

Proof of Proposition 1: If

$$\frac{1}{2}(1 - \pi)\sigma \geq c'(\bar{e}_l), \quad (\text{A5})$$

then

$$\pi \leq 1 - \frac{2}{\sigma}c'(\bar{e}_l). \quad (\text{A6})$$

Noting that $\bar{e}_l = \frac{\Delta}{\sigma}$, this inequality follows from the first argument within the $\min\{\cdot, \cdot\}$ operator in the expression for π^θ in the proposition.

This also implies, by the convexity of the cost function and $\bar{e}_l > \bar{e}_h$, the three following conditions:

$$\frac{1}{2}[(1 - \pi)\sigma + \pi\theta\sigma] > c'(\bar{e}_l), \quad (\text{A7})$$

$$\frac{1}{2}(1 - \pi)\sigma > c'(\bar{e}_h), \quad (\text{A8})$$

and

$$\frac{1}{2}[(1 - \pi)\sigma + \pi\theta\sigma] > c'(\bar{e}_h). \quad (\text{A9})$$

Thus, we can rule out as candidate equilibria levels of expertise where the first-order conditions hold with equality, \hat{e}_h and \hat{e}_l , and focus only on whether agents will prefer \bar{e}_l , which maximizes the payoff in the low-volatility regime

but leads to breakdowns in trade with probability 1/2 in the high-volatility regime, or \bar{e}_h , which maximizes the payoff without triggering breakdowns in trade in the high-volatility regime.

Comparing payoffs from the two levels of expertise, \bar{e}_l will be preferred if

$$\frac{1}{2}(1 - \pi)\bar{e}_l\sigma - c(\bar{e}_l) \geq \frac{1}{2}[(1 - \pi)\bar{e}_h\sigma + \pi\bar{e}_h\theta\sigma] - c(\bar{e}_h). \quad (\text{A10})$$

Notice that, due to the convexity of $c(\cdot)$, when we set $\pi = 0$ this inequality is satisfied and nonbinding whenever the inequality required for \bar{e}_l to be the equilibrium expertise level when $\pi = 0$ is satisfied, that is, condition (18) in the proposition. Thus, even if we allow for a small but positive probability π of high volatility, the term $\pi\bar{e}_h\theta\sigma$ ($= \pi \Delta$) above will be small and will not violate the inequality.

Multiplying both sides of the inequality by two yields

$$(1 - \pi)\bar{e}_l\sigma - 2c(\bar{e}_l) \geq (1 - \pi)\bar{e}_h\sigma + \pi\bar{e}_h\theta\sigma - 2c(\bar{e}_h), \quad (\text{A11})$$

which can be written as

$$\frac{[\bar{e}_l - \bar{e}_h]\sigma - 2[c(\bar{e}_l) - c(\bar{e}_h)]}{[\bar{e}_l + (\theta - 1)\bar{e}_h]\sigma} \geq \pi. \quad (\text{A12})$$

In summary, the following two conditions ensure that \bar{e}_l remains the unique equilibrium in expertise:

$$\frac{1}{2}(1 - \pi)\sigma \geq c'(\bar{e}_l), \quad (\text{A13})$$

and

$$\frac{1}{2}(1 - \pi)\bar{e}_l\sigma - c(\bar{e}_l) \geq \frac{1}{2}[(1 - \pi)\bar{e}_h\sigma + \pi\bar{e}_h\theta\sigma] - c(\bar{e}_h). \quad (\text{A14})$$

Since both conditions are continuous in π , then we know that, if these conditions are not binding when $\pi = 0$, they will not bind for small enough positive π .

Combining these requires $\pi < \pi^\theta$, where

$$\pi^\theta = \min \left\{ 1 - \frac{2}{\sigma}c'(\bar{e}_l), \frac{[\bar{e}_l - \bar{e}_h]\sigma - 2[c(\bar{e}_l) - c(\bar{e}_h)]}{[\bar{e}_l + (\theta - 1)\bar{e}_h]\sigma} \right\}, \quad (\text{A15})$$

which, when substituting for the values of \bar{e}_l and \bar{e}_h , is equal to expression (19) in the proposition.

Q.E.D.

Appendix B: Two-Sided Asymmetric Information

We first introduce some additional notation. When the buyer (proposer) is informed, we must consider the following conditional expectations and

probabilities for the low-signal buyer:

$$\begin{aligned}\psi_L^L &\equiv \Pr\{s_s = L \mid s_b = L\} \\ &= \mu_b \mu_s + (1 - \mu_b)(1 - \mu_s)\end{aligned}\tag{B1}$$

$$\begin{aligned}\phi_{LL}^l &\equiv \Pr\{v = v_l \mid s_b = L, s_s = L\} \\ &= \frac{\mu_b \mu_s}{\mu_b \mu_s + (1 - \mu_b)(1 - \mu_s)},\end{aligned}\tag{B2}$$

and for the high-signal buyer,

$$\begin{aligned}\psi_L^H &= \Pr\{s_s = L \mid s_b = H\} \\ &= \mu_b(1 - \mu_s) + \mu_s(1 - \mu_b)\end{aligned}\tag{B3}$$

$$\begin{aligned}\phi_{HL}^l &= \Pr\{v = v_l \mid s_b = H, s_s = L\} \\ &= \frac{\mu_s(1 - \mu_b)}{\mu_b(1 - \mu_s) + \mu_s(1 - \mu_b)}.\end{aligned}\tag{B4}$$

Next, we present proofs for Lemma 1 and Proposition 2.

Proof of Lemma 1: Suppose there is an equilibrium in which different types of proposers offer different prices. In such an equilibrium, for trade to be efficient, the responder needs to accept all of the proposer's offers. If the proposer anticipates such a response, then he should offer the price that is favorable to himself (lower if he buys, higher if he sells), regardless of his signal, a contradiction.

Q.E.D.

Proof of Proposition 2: Here, we consider all the possible prices that could trigger an equilibrium with efficient trade in the trading subgame and check if they can be sustained by beliefs that satisfy the credible updating rule of Grossman and Perry (1986). Since a pooling equilibrium involves both types of buyer offering the same price, the minimal price that a seller will always accept is $p^{**} = \mu_s v_h + (1 - \mu_s)v_l$. Prices below p^{**} cannot sustain an efficient equilibrium in the subgame.

Now, consider an efficient equilibrium with price $p > p^{**}$. Consider a deviation to some $p' \in (p^{**}, p)$. We compare the strategy-belief combinations for the seller. If the seller has a strategy of rejecting p' regardless of his signal, neither type of buyer will deviate from p , so the seller's beliefs are unrestricted, but the deviation is unattractive. If the seller always accepts, both types of buyer prefer to deviate and the seller's (credibly updated) posterior belief is that the deviation is equally likely to come from both types of buyer. Given these beliefs, the seller's best response is to accept. If the seller chooses to accept only after a low signal, either only the low-signal buyer wants to deviate to p' or both types want to deviate to p' . Thus, the seller must believe that p' comes from the low-signal buyer at least as often as from the high-signal buyer, and therefore his best response is to accept p' with probability one. Thus, the

buyer will always deviate to p' when beliefs are credibly updated, and a pooling equilibrium at $p > p^{**}$ cannot be a perfect sequential equilibrium in the subgame.

We now show that if the boundary in the proposition is violated, the buyer will have a profitable deviation when beliefs are credibly updated, and that, if the boundary is not violated, there exists perfect sequential equilibria with pooling at p^{**} . First, it is immediate that, regardless of his signal, the buyer will never deviate to a price higher than p^{**} . Now, suppose the low-signal buyer deviates to an offer infinitesimally above $E[v|s_s = L, s_b = L]$. Conjecture that this offer is accepted by the low-signal seller and rejected by the high-signal seller. The low-signal buyer will prefer to adhere to the pooling price p^{**} that is accepted by the seller, regardless of his signal, only if

$$2\Delta + E[v|s_b = L] - p^{**} \geq \psi_L^L 2\Delta, \quad (\text{B5})$$

which can be rewritten as the threshold in the proposition.

If this condition does not hold and as conjectured the seller accepts the deviation when his signal is low and rejects it when his signal is high, the low-signal buyer will prefer to deviate to the offer (infinitesimally above) $E[v|s_s = L, s_b = L]$. If the high-signal buyer does not prefer this deviation over offering the pooling price that is always accepted (which will be true around the threshold in the proposition), then the credibly updated belief is that the deviation comes from the low-signal buyer only and the low-signal seller's best response is then to accept the deviation. This makes deviating to an offer slightly above $E[v|s_s = L, s_b = L]$ profitable for the low-signal buyer. Since neither type of buyer can prefer to make an offer that the seller always rejects, conjecturing that the seller always rejects a deviation will not generate different credible beliefs. Hence, the only set of credible beliefs in the case in which the high-signal buyer does not want to deviate is that the deviation comes from the low-signal buyer only. If both the high- and low-signal buyers prefer the low offer when only the low-signal seller accepts, then there is some price above $E[v|s_s = L, s_b = L]$ such that the high-signal buyer prefers to adhere to the pooling price when he expects the high-signal seller to reject and the low-signal seller to accept, whereas the low-signal seller prefers to deviate. For any given possible deviation, it is impossible for the high-signal buyer to prefer to deviate from the pooling equilibrium while the low-signal buyer prefers to adhere. This is an immediate consequence of the fact that the increased payoff for the deviation conditional on trade is identical for both traders, but the probability of trade is reduced more for the high-signal seller than for the low-signal seller. A deviation to this price then implies that the low-signal seller must accept since the offer exceeds $E[v|s_s = L, s_b = L]$, so the deviation is preferred by the low-signal buyer. Thus, if the posited condition does not hold, the pooling equilibrium at p^{**} is not perfect sequential.

Now, if the condition in the proposition does hold, a deviation to $E[v|s_s = L, s_b = L]$ will not be preferred by either type of buyer when expecting the seller to accept if and only if his signal is low. Furthermore, it is immediate

that no high-signal seller will accept an offer of $p < E[v|s_s = H, s_b = L]$. Since the low-signal buyer does not prefer a deviation to $E[v|s_s = L, s_b = L]$ when only the low-signal seller accepts, no type of buyer can prefer an offer of $p > E[v|s_s = L, s_b = L]$ when only the low-signal seller accepts. Thus, credible updating does not restrict beliefs for deviations to prices less than $E[v|s_s = H, s_b = L]$. Thus, it remains to show that no deviation to a price $p \in [E[v|s_s = H, s_b = L], p^{**})$ is preferred by a buyer given that beliefs are credibly updated whenever possible. For such deviation to be attractive to the buyer, we need the high-signal seller to accept it with positive probability. If the high-signal seller always accepts the deviation, regardless of his own signal, then the buyer always has an incentive to deviate to p . And since $p < p^{**}$, the high-signal seller will always reject given credibly updated beliefs. Therefore, the buyer cannot anticipate that the seller will always accept, regardless of his signal. This leaves only the possibility that the high-signal seller is indifferent between accepting and rejecting the offer. Indifference implies that the seller believes that the offer is more likely to come from the low-signal buyer than from the high-signal buyer (since $p < p^{**}$). This is possible since the probability that the high-signal seller accepts can be chosen to make the high-signal buyer indifferent between adhering and deviating, whereas the low-signal buyer strictly prefers to deviate. Given these beliefs, however, it is still a best response of the high-signal seller to always reject the offer after the deviation, which makes deviating never profitable for the buyer. The requirement for perfect sequential equilibria is that, whenever possible, beliefs are credible following a deviation, and that the responding trader plays some best response to these beliefs, not necessarily the best response that generates these beliefs. So, the seller can reject any price $p \in [E[v|s_s = H, s_b = L], p^{**})$ while updating his beliefs credibly. Thus, the threshold presented is both necessary and sufficient for a pooling offer of p^{**} to trigger a perfect sequential equilibrium in the trading subgame.

Q.E.D.

In the discussion in the text following Proposition 2, we describe the [Grossman and Perry \(1986\)](#) restrictions on beliefs and explain why we require that, when both efficient and inefficient perfect sequential equilibria exist, traders anticipate that the efficient equilibria will prevail. Under these restrictions, investment up to the threshold that applies in the low-volatility regime, that is,

$$e^* = \frac{\sigma}{4\Delta} \left[\sqrt{1 + \frac{4\Delta^2}{\sigma^2}} - 1 \right], \quad (\text{B6})$$

will be the unique prediction of our model if we can show that, for any expertise pair $\{e_i, e_j\}$ that violates the threshold (25) in Proposition 2, a perfect sequential equilibrium exists and is unique in a sufficiently small neighborhood of the symmetric expertise level e^* where the boundary in (25) is violated by an increase in expertise. Note that uniqueness is not necessary but is sufficient to rule out a deviation above e^* . If there is a perfect sequential

equilibrium following a small deviation in expertise above e^* and that equilibrium is unique, then the deviator has to expect lower payoffs than at e^* . This is because for a small deviation payoffs accrue almost symmetrically to the deviator and nondeviator, and total payoffs are discretely less than they would be if neither trader had deviated as trade breaks down with positive probability. If there were multiple perfect sequential equilibria, it would be necessary to check whether one trader could anticipate higher payoffs following a deviation by expecting the perfect sequential equilibrium most favorable to the seller when he is the seller or to the buyer when he is the buyer. Furthermore, if there is no perfect sequential equilibrium, any sequential equilibrium of the trading subgame could be anticipated, including those that are efficient but not perfect sequential. The next proposition establishes the existence and uniqueness of the perfect sequential equilibrium slightly above e^* where the efficient trading equilibrium does not exist, and thus completes the argument.

PROPOSITION 3: *The unique perfect sequential equilibrium in a neighborhood around (e^*, e^*) with at least one $e_i > e^*$ involves the following actions:*

- *The high-signal buyer offers $p^h \equiv E[v|s_s = H, s_b = H]$.*
- *The low-signal buyer offers $p^l \equiv E[v|s_s = L, s_b = L]$.*
- *The seller always accepts p^h when offered.*
- *The low-signal seller always accepts p^l when offered.*
- *The high-signal seller always rejects p^l when offered.*
- *Trade breaks down with probability $\frac{1}{4} - e_b e_s$, destroying a surplus of $2\Delta[\frac{1}{4} - e_b e_s]$.*

Proof: Because we confine attention to a neighborhood around (e^*, e^*) , we can evaluate all prices and payoffs at (e^*, e^*) and rely on a basic continuity argument for $\mu_i = \frac{1}{2} + e_i$. For notational simplicity, we normalize $2\Delta = 1$, which is without loss of generality. We first show that the posited equilibrium is, in fact, a perfect sequential equilibrium.

We start by showing that, in any equilibrium with two prices (say p_h and p_l , where $p_h > p_l$), the high-signal buyer must offer $p_h = E[v|s_s = H, s_b = H]$ with positive probability. If $p^h > E[v|s_s = H, s_b = H]$, the seller will always accept regardless of his off-equilibrium path beliefs, so p^H cannot exceed $E[v|s_s = H, s_b = H]$. If $p^h \in (E[v|s_s = H, s_b = L], E[v|s_s = H, s_b = H])$, then the low-signal buyer will never want to offer p^h and the seller must therefore believe that the value of the asset is $E[v|s_s = L, s_b = H]$ when his signal is low and $E[v|s_s = H, s_b = H]$ when his signal is high. The seller thus strictly prefers to reject the offer after a high signal and accept the offer after a low signal, given that $E[v|s_s = H, s_b = L] = E[v|s_s = L, s_b = H]$ at (e^*, e^*) . Thus, p^h must be either $E[v|s_s = H, s_b = H]$ or $E[v|s_s = L, s_b = H]$. The buyer will prefer to make an offer of $E[v|s_s = H, s_b = H]$ whenever

$$1 + E[v|s_b = H] - E[v|s_s = H, s_b = H] > \psi_H^L. \tag{B7}$$

Directly comparing the payoff to each offer at (e^*, e^*) gives the condition

$$\begin{aligned} & \frac{1}{2} \left(2 + (v_h - v_l)^2 - \frac{(v_h - v_l)^3}{\sqrt{1 + (v_h - v_l)^2}} \right) \\ & > \frac{(v_h - v_l)(2 + (v_h - v_l)^2 - (v_h - v_l)\sqrt{1 + (v_h - v_l)^2})}{2\sqrt{1 + (v_h - v_l)^2}}, \end{aligned} \tag{B8}$$

which holds for all $(v_h - v_l) > 0$. Hence, the buyer will prefer $p^h = E[v|s_s = H, s_b = H]$ in the neighborhood around (e^*, e^*) . Since the high-signal seller can reject any offer below $E[v|s_s = H, s_b = H]$ if he believes that the offer only comes from a high-signal buyer, the posited equilibrium is confirmed to be a sequential equilibrium. In order to check that it is perfect sequential, it remains to show that there is no price the low-signal buyer can deviate to such that the seller is forced to update his beliefs to accept after a high signal.

Consider a deviation to a low price of $p^l \in (E[v|s_s = L, s_b = L], E[v|s_s = H, s_b = L])$. The high-signal seller will reject, regardless of his beliefs about the buyer's signal. Now, for $p^l \in (E[v|s_s = H, s_b = L], E[v|s_s = H])$, the high-signal seller will accept only if he believes that the low-signal buyer makes the offer sufficiently frequently relative to the high-signal buyer. If the high-signal seller accepts with probability one, then the high-signal buyer has an incentive to deviate to a low offer and beliefs must be updated such that the offer comes from the high-signal buyer with at least probability 1/2. The offer should then be rejected by the high-signal seller. Therefore, the high-signal seller cannot accept with probability one. If the high-signal seller mixes to make the high-signal buyer indifferent, defining α_h as the probability that the high-signal seller accepts p^l , we need

$$\begin{aligned} 1 + E[v|s_b = H] - p^h &= \psi_H^L(1 + E[v|s_s = L, s_b = H] - p^l) \\ &+ \psi_H^H\alpha_h(1 + E[v|s_s = H, s_b = H] - p^l). \end{aligned} \tag{B9}$$

Now we check if the low-signal buyer would prefer the deviation to p^l over what he would get in the equilibrium we propose. Solving for α_h gives a payoff to the low-signal buyer who offers p^l of

$$\begin{aligned} & \psi_L^L(1 + E[v|s_s = L, s_b = L] - p^l) \\ & + \psi_L^H \left(\frac{1 + E[v|s_b = H] - p^h - \psi_H^L(1 + E[v|s_s = L, s_b = H] - p^l)}{\psi_H^H(1 + E[v|s_s = H, s_b = H] - p^l)} \right) \\ & \times (1 + E[v|s_s = H, s_b = L] - p^l), \end{aligned} \tag{B10}$$

while adhering to the equilibrium strategy of offering p^l gives a payoff of ψ_L^L . Simple (but tedious) calculations show that, around (e^*, e^*) , the payoff to the low-signal buyer from offering p^l exceeds the payoff from offering p^l . Thus, the deviation to p^l must be assumed to come from the high-signal buyer, and must therefore be rejected. Deviations to prices above $E[v|s_s = H]$ cannot come from

a low-signal buyer even if the seller always accepts. Around (e^*, e^*) , the buyer would prefer to adhere to the low offer p^l than deviate to $E[v|s_s = H]$. Thus, the seller can credibly commit to reject such offers.

To summarize, if the high-signal seller rejects a deviation, such deviation cannot be preferred by the low-signal buyer over the equilibrium strategy. If the high-signal seller always accepts a deviation, then it becomes profitable for the high-signal buyer to deviate, and beliefs should be updated such that the high-signal seller rejects, making the beliefs that support always accepting not credible. Finally, if the high-signal seller mixes after a deviation, any frequency of accepting that makes the high-signal buyer indifferent between deviating and not deviating (which is necessary for the high-signal seller to have beliefs that lead him to mix) makes the low-signal seller prefer to adhere to $p^l = E[v|s_s = L, s_b = L]$. Therefore, the seller must believe that the deviation comes only from the high-signal buyer and he rejects the deviation with probability one. Since any off-equilibrium offer that is greater than or equal to $E[v|s_s = H]$ can at best make the low-signal buyer indifferent between adhering and deviating, even if the deviating offer is always accepted by the seller, this establishes that the posited equilibrium is perfect sequential.

We have already shown that any perfect sequential equilibrium with two prices must rely on a high price of $p^h = E[v|s_s = H, s_b = H]$. Hence, in order to establish uniqueness, we need to consider all sequential equilibria where the low-signal buyer offers $p^l > E[v|s_s = L, s_b = L]$ or the high-signal buyer offers p^h with probability less than one. First, consider any sequential equilibrium where the low-signal buyer offers $p^l > E[v|s_s = L, s_b = L]$ (or the low-signal buyer offers $p^l = E[v|s_s = L, s_b = L]$ but the low-signal seller mixes over accepting or rejecting p^l). Consider an off-equilibrium offer infinitesimally above $E[v|s_s = L, s_b = L]$. The set of buyer types that could benefit from such a deviation is either the low-signal buyer or both types of buyer. Consider first the case in which only the low-signal buyer benefits. Then, the low-signal seller will accept and the high-signal seller will reject. The low-signal buyer will prefer such deviation to offering p_l but the high-signal buyer will not, since around (e^*, e^*)

$$\begin{aligned}
 & 1 + E[v|s_b = H] - E[v|s_s = H, s_b = H] \\
 & > \psi_H^L(1 + E[v|s_s = L, s_b = H] - E[v|s_s = L, s_b = L]).
 \end{aligned}
 \tag{B11}$$

Suppose the buyer always prefers the deviation. From the expression above, we would need the high-signal seller to accept the offer slightly above $E[v|s_s = L, s_b = L]$ with positive probability. But the offer is below $E[v|s_s = H, s_b = L]$, and hence the high-signal seller will reject an offer slightly above $E[v|s_s = L, s_b = L]$ regardless of his beliefs about the buyer's signal. The only consistent beliefs following a deviation to an offer slightly above $E[v|s_s = L, s_b = L]$ are that such deviation can only come from the low-signal buyer and the offer will therefore be accepted by the low-signal seller with probability one, making the proposed sequential equilibrium not perfect sequential.

There remains one class of equilibria to check. There may exist sequential equilibria where the low-signal buyer offers a price $p^l \geq E[v|s_s = H, s_b = L]$ whereas the high-signal buyer mixes between p^l and $p^h = E[v|s_s = H, s_b = H]$. The seller will always accept the offer p^h , will accept the offer p^l after a low signal, and will mix between accepting and rejecting an offer p^l after a high signal. In any such equilibrium, the payoff to the low-signal buyer for adhering is given by

$$\psi_L^L(1 + E[v|s_s = L, s_b = L] - p_l) + \psi_L^H\alpha_h(1 + E[v|s_s = H, s_b = L] - p_l). \quad (\text{B12})$$

The value for α_h is given by the requirement that the high-signal buyer be indifferent between offering p^h and p^l :

$$1 + E[v|s_b = H] - E[v|s_s = H, s_b = H] = \psi_H^L(1 + E[v|s_s = L, s_b = H] - p_l) + \psi_H^H\alpha_h(1 + E[v|s_b = H, s_s = H] - p_l).$$

Substituting the implied α_h into the payoff function and noting that the payoff for deviating to an offer slightly above $E[v|s_s = L, s_b = L]$ is still ψ_L^L in any perfect sequential equilibrium, it follows that at (e^*, e^*) the low-signal buyer strictly prefers to deviate to the lower offer in anticipation of the low-signal seller accepting.

Now, consider the possibility that more than two prices are used. By the same logic as above, at least one of the prices offered by the low-signal buyer must be $E[v|s_s = L, s_b = L]$. But, for any price offered by the low-signal buyer above $E[v|s_s = L, s_b = L]$, an offer lower than this offer but slightly higher than $E[v|s_s = L, s_b = L]$ will be accepted by the low-signal seller by the arguments above, and will be a profitable deviation. Thus, this cannot be a perfect sequential equilibrium.

Finally, in the perfect sequential equilibrium proposed in the proposition, trade breaks down whenever the buyer receives a low signal and the seller receives a high signal. This takes place with probability $\psi_L^H/2$, which can be rewritten as $\frac{1}{4} - e_b e_s$.

Q.E.D.

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