Feedback, Investment, and Social Value of Financial Expertise*

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Abstract

We examine how an informational feedback loop between bilateral security trading and firm investment endogenously affects information production. A trader's acquisition of information about a firm's investment opportunity can create an endogenous trade surplus that materializes only if trade may potentially break down. Because an exogenous private gain to trade is lost if trade is disrupted, however, the trader may not acquire such socially valuable information. Consequently, the firm, which makes its investment decision based on the trading outcome, may take socially destructive actions to induce the trader to acquire the information. Welfare-enhancing policies are examined.

Keywords: Informational feedback; Financial expertise; Information acquisition; Endogenous adverse selection; Bilateral trading; Asymmetric information

JEL classification: D53; D82; D83; G14; G18

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1 Introduction

A farmer owns a plot of land. A farming company, which possesses a technology advantage that can lower the land's crop production costs by Δ, is interested in buying the land. The farmer, having farmed the land for many years, privately knows the soil's quality. Due to its information disadvantage, the farming company overpays for the land whenever trade occurs, which enables the farmer to appropriate a share of the trade surplus, Δ. Here, information about soil quality affects how the trade surplus is divided, but it does not affect the magnitude of the surplus. As put by Hirshleifer (1971), such information is mere foreknowledge that only has redistribution consequences but cannot be used to create value.

Meanwhile, an oil company is exploring surrounding areas in search of oil reserves. From soil tests conducted by the farmer when he initially purchased the land, the farmer knows that his land contains valuable oil reserves, but he cannot credibly convey that information to the oil company. Suppose the farmer declines a reasonably high offer from the farming company to buy his land. The oil company, initially unsure where to conduct a survey within the vast areas, observes the trade between the farmer and farming company break down despite a competitive offer being tabled. The oil company infers that there are likely valuable deposits underneath the farmer's land and, therefore, its adjacent areas. A focused survey in nearby areas ensues, and oil is found. This raises the value of the farmer's land, allowing him to raise more financing with better terms using his land as collateral. The farmer then uses the borrowed money to upgrade farm equipment and grow more crops, which justifies his initial rejection of the farming company's offer. In this case, the farmer's information about the land's oil reserves enables the oil company to effectively locate areas that actually contain oil. Thus, such information is socially beneficial because it creates value.

This example illustrates the incompleteness of the conventional argument that a party's private information in a bilateral bargaining game (like the one between the farmer and farming company) is socially detrimental because it may result in trade disruption and, hence, gains to trade not materializing. While the conventional argument holds when the party's private information is foreknowledge that only improves his bargaining power, it does not necessarily apply when information is socially valuable. On the contrary, trade must occasionally break down for the bargaining outcome to convey socially valuable information that enables value-enhancement actions to be taken (say, by a third party like the oil company). Indeed, information about oil reserves is conveyed to the oil company through the disruption of trade between the farmer and farming company. Although trade disruption destroys the trade surplus between the two traders (i.e., more efficient crop production), it simultaneously creates an additional surplus (i.e., increase in land value from the oil company's explorations).

The same principle applies to tradings of financial assets that involve bilateral bargaining. Several recent studies (reviewed below) show that inefficiencies may arise from traders acquiring private information if the information has no intrinsic social value. Such information merely gives one trader an advantage over his counterparty when bargaining over a fixed pie in a zero-sum game and may, therefore, disrupt trade and prevent gains to trade from materializing. However, as our example illustrates, the potential for trade to break down can actually create value when traders acquire information that is socially valuable and bargain over a pie of an endogenously determined size in a positive-sum game.

In this article, we propose a theory that captures the essence of the example and analyze various welfare-enhancing policy tools. In the model, two traders (buyer and seller) bilaterally trade a financial security issued by a firm. The firm's (hence, the security's) value is derived from its assets-in-place and an investment opportunity. The firm knows the value of its assets-in-place but not the value of the investment opportunity. Neither trader knows the value of the firm's assets-in-place or investment opportunity *a priori*. The buyer (he) attaches a private benefit Δ to the security (e.g., to satisfy a hedging need), which creates an exogenous gain to trade. The seller (she) may develop financial expertise that enables her to acquire and process information about the value of the firm's assets-in-place or investment opportunity. While greater expertise leads to more accurate information, it also creates adverse selection and may cause trade to break down as in Akerlof (1970).

Expertise about the firm's assets-in-place has no intrinsic social value given that the firm already knows the value of its assets-in-place and, therefore, can take no action based on the trading outcome to further enhance its value. Like in Glode et al. (2012), developing expertise about assets-in-place only improves the seller's ability to appropriate the surplus Δ from the buyer in a zero-sum trading game. Such expertise may even be socially destructive because it can impede trade and, therefore, destroy gains to trade. In contrast, expertise pertaining to the firm's investment opportunity may be socially valuable. Provided that the trading outcome reflects the seller's expertise and contains information about the investment opportunity, the firm can learn about its investment prospects from observing the trading outcome and then take action accordingly to further enhance its value. Different from Glode et al. (2012), developing expertise about the investment opportunity may create social value by enabling the firm to make better investment decisions, and the resulting surplus can be shared by the buyer and seller in a positive-sum trading game.

The effect of financial expertise and trade on the firm's investment decision generates a feedback loop whereby trade affects firm investment and security value, which in turn affects whether trade occurs and whether the firm invests. If the seller's private information indicates a profitable investment opportunity for the firm, then she holds the security and trade breaks down. The firm infers that the collapse of trade may reflect the seller's positive information about the investment opportunity and, therefore, invests. This raises the security's value and justifies the seller's decision to hold the security. Conversely, if the seller's information reveals poor investment prospects, then she sells the security; the firm infers negative information about its investment opportunity from the occurrence of trade and eschews investment (if the seller instead were to hold the security in this case, then the firm would erroneously interpret the trade disruption as indicating a good investment opportunity and invest, thereby destroying value and causing the seller to incur a loss from holding the security). In either case, expertise about the investment opportunity is socially valuable: it enables the firm to pursue value-enhancing investments in the former case and avoid value-destroying investments in the latter. The buyer offers a price that reflects the feedback loop between trade and investment, which in turn affects the likelihood of trade occurrence and firm investment.[1]

Importantly, trade must sometimes (but not always) break down for the trading outcome to convey any information about the investment opportunity. However, the breakdown of trade destroys private gains to trade Δ. This generates a tradeoff between the two types of surpluses in our model: while the realization of the investment surplus, which results from the firm learning from the trading outcome and making a better investment decision, requires *occasional* trade disruption, the preservation of the surplus Δ requires trade to *always* occur.

Because the seller derives value from both types of surpluses, this tradeoff affects both the type (i.e., whether expertise pertains to firm's assets-in-place or investment opportunity) and level of financial expertise that she chooses to develop. We show that the seller's choice of expertise is not always desirable to the firm. When Δ is sufficiently large, the seller may prefer to develop expertise about the firm's assets-in-place to strengthen her bargaining position over Δ.[2] However, such expertise generates information that is redundant for the firm (and, hence, socially useless) because the firm already knows the value of its assets-in-place. To induce the seller to develop expertise about the uncertain prospect of its investment opportunity, the firm may scale back production from its assets-in-place, which increases the relative contribution of the investment opportunity to firm value, thereby dampening the information advantage the seller would enjoy if she were to develop expertise about assets-in-place relative to the advantage she enjoys by developing expertise about the investment opportunity. Such scaling back is costly (both to the firm and socially), though, because it reduces valuable output from the firm's assets-in-place. Nonetheless, the firm chooses to scale back production in cases wherein the gain from learning about its future investment opportunity outweighs the loss from reduced output from its existing assets.[3]

[1]As shown in Appendix B, our analysis is robust to an alternative framework in which the buyer (instead of the seller) is informed and the firm invests if and only if trade occurs.

[2]Because the occasional disruption of trade, which destroys Δ, is necessary for the investment surplus to be realized when the seller develops expertise about the investment opportunity, the seller can achieve a greater expected payoff by appropriating a share of the trading surplus arising from Δ if she instead develops expertise about assets-in-place when Δ is sufficiently large.

[3]As constructed, our analysis pertaining to the firm's production strategy relies on an assumption that the

The firm's decision to scale back, however, can be socially suboptimal. Although scaling back production from assets-in-place induces the seller to develop socially useful expertise about the investment opportunity, trade occasionally must break down and, hence, the private gain to trade Δ occasionally must be lost for the firm to learn from the seller's expertise by observing the trading outcome. The loss of Δ reduces social welfare, but such loss is not taken into account by the firm (as the firm cares only about its own value but not about gains to trade among traders). Consequently, the firm scales back more often (i.e., under a broader set of parametric conditions) than is socially optimal.

In sum, our analysis of agents' equilibrium strategies shows that (i) traders may acquire socially useless foreknowledge instead of socially valuable information that can guide real decisions, and (ii) the firm's privately optimal response to such inefficiency, which entails dampening the value of foreknowledge, generates another sort of social inefficiency. In the remaining analysis, we examine two welfare-enhancing policies which target either firm production or private gains to trade.

First, we identify the region of parameters in which regulatory policies (e.g., production subsidies) may improve social welfare by encouraging the firm to not scale back production from its existing assets. Second, we show that, perhaps surprisingly, social welfare may also be improved by policies that deliberately reduce private gains to trade Δ (e.g., by imposing a Tobin tax on financial transactions). Reducing Δ directly increases the seller's incentive to acquire information about the investment opportunity because the failure to appropriate a share of (the reduced) Δ if trade were to break down (which is necessary for informed learning and, hence, the creation of the investment surplus) is less detrimental to the seller when Δ is smaller. As an indirect consequence, the firm is dissuaded from inefficiently scaling back production from its assets-in-place to induce the seller to develop expertise about the invest-

firm cannot simply disclose its knowledge about the value of its assets-in-place to the traders. While there are many reasons why firms may refrain from making voluntary disclosures (e.g., explicit costs or litigation risk; see Beyer et al., 2010), the assumption is not critical for our analysis. All results continue to hold in an alternative setup wherein the firm does not know the value of its assets-in-place (and, therefore, cannot disclose it), provided that the firm cannot take action to alter the value of its assets-in-place after learning from the trading outcome.

ment opportunity. In other words, the firm's scaleback of production and the policymaker's reduction of the private gain to trade act as substitutes for incentivizing the seller to acquire socially valuable information about the investment opportunity.[4] As a final step in our analysis, we compare the effectiveness of the two types of policies and identify conditions under which the policymaker should directly target firm production, reduce private gains to trade, or abstain from intervention.

Our analysis has implications for understanding market revaluations following unsuccessful takeover attempts and the complexity of security design. Our model suggests that the empirically documented market revaluation following a failed takeover attempt (e.g., Safieddine and Titman, 1999; Malmendier et al., 2016) could be attributable to favorable information revealed about the target by the unsuccessful takeover bid. Additionally, our model suggests that complex securities could be socially valuable if their complex payoff structures incentivize traders to acquire (and reveal through trade) *specific* (socially useful) information that they would otherwise have little incentive to uncover if they were instead trading a security with a simple payoff structure that depended on *aggregate* information. We discuss these implications in greater detail in our concluding remarks.

Related literature. Our article is closely related to a burgeoning literature studying incentives for individuals to acquire socially wasteful foreknowledge. In particular, our analysis builds upon Glode et al. (2012), who show that the existence of exogenous gains to trade in zero-sum games can lead to an "arms race" for trading expertise, whereby traders overinvest in producing socially useless information simply to strengthen their bargaining power. Although they acknowledge that trading expertise may convey social benefits, their main focus is to show that financial expertise can be socially detrimental because it creates adverse selection and, hence, may disrupt efficient trade. In contrast, we explicitly model and differentiate socially wasteful (trading) expertise from socially valuable (investment) expertise. We show that the latter type of expertise may generate *endogenous* gains to trade, but trade must break

[4]The former mechanism, as discussed above, is socially inefficient because the firm does not consider Δ when deciding on its production scale.

down with strictly positive probability for the trading outcome to convey socially valuable information and, thus, for such expertise to create value. While the potential for trade to break down is the channel through which financial expertise creates value in our model, it is also the very reason that expertise may destroy value in Glode et al. (2012).

Several other articles also show that economic agents tend to overinvest (from a social perspective) in financial expertise. Glode and Lowery (2016) study competition among financial firms for hiring workers as either bankers, who create surpluses for their firms, or traders, who appropriate the surpluses created by bankers at other firms in a zero-sum trading game. Competition increases the demand for traders and, consequently, their compensation relative to bankers even though bankers create value while traders do not. Bolton et al. (2016) show that opacity in over-the-counter (OTC) markets allows informed traders to extract greater informational rents than they can obtain on transparent exchanges, which attracts too much talent to OTC markets and the financial industry in general. Biais et al. (2015) model high-frequency traders who overinvest in fast trading technologies to outcompete other traders. This generates adverse selection and imposes negative externalities on slow traders, thereby leading to equilibrium inefficiencies. While these articles emphasize the private value of information in zero-sum trading games and find that agents typically *overinvest* in financial expertise, we focus on the generation of socially valuable information in a positive-sum game and find that agents often *underinvest* in expertise.

The point that trade may generate socially valuable information and lead to superior decision-making is also made by Bond and Eraslan (2010), who analyze a setting in which a traded asset's payoff depends on a decision taken by its eventual owner. While they study how trade conveys socially useful information, we focus on the tradeoff between the acquisition of socially useful versus useless information and how regulatory policies can influence traders to acquire socially valuable information. Importantly, the transmission of socially useful information is not contingent on trade occurring in our model, as trade disruption also conveys information. Dow and Gorton (1997) distinguish the feedback relation between "prospective prices" and investment decisions from the evaluative relation between "retrospective prices" and managerial incentives. Bresnahan et al. (1992) and Paul (1992) argue that the prospective role of stock prices may be clouded because traders care about the totality of a firm's projects but only information about an incremental (marginal) investment project is useful for guiding real decisions; however, they do not study informational feedback.

A handful of other articles model social value of information with focuses different from ours. Camargo et al. (2016) show that although government intervention in a frozen market afflicted with adverse selection may encourage trade, too much intervention can reduce traders' incentives to acquire information and, thereby, lower the information content of trade, which may ultimately be detrimental if the information has social value. Fishman and Parker (2015) demonstrate that an equilibrium in which agents do not acquire socially valuable information may be more efficient than an equilibrium in which agents become informed when the private benefits of being informed exceed the social value of the information. Similarly, Shavell (1994) shows that non-mandatory disclosure may lead to excessive information acquisition even when information is socially valuable.

Additionally, our article contributes to a growing literature on feedback effects in financial markets. Existing theories have examined the informational feedback from asset prices to real actions of various sorts (e.g., Dow and Gorton, 1997; Goldstein and Guembel, 2008; Bond et al., 2010; Goldstein et al., 2013; and Bond and Goldstein, 2015).[5] Many studies in this literature focus on the informational role of stock prices that are determined by market makers as in typical microstructure models. In contrast, we examine bilateral trading and show how the informational feedback loop between trading and investment endogenously affects the production of information. In particular, we demonstrate that socially valuable information that guides real decisions may be transmitted in the absence of trade, which differs from the traditional feedback literature where trade is positively correlated with information production. For example, Dow et al. (2017) show how a small decline in fundamentals may

[5] Luo (2005) and Chen et al. (2007) provide empirical evidence. Bond et al. (2012) offer a thorough review of both the theoretical and empirical literature on feedback effects in financial markets.

disrupt informed trading and, thereby, cause investment and firm value to collapse.

2 Model

Economic environment. Two risk-neutral traders exchange a financial security on a firm. We refer to the initial security owner as the seller ("she") and the non-owner as the buyer ("he"). The security has both a common value component and a private value component. The common value V is derived from the firm's assets-in-place and investment opportunity:

$$V = V_a + V_i(\omega, k). \tag{1}$$

For simplicity, we assume that the value of assets-in-place can be either low or high, $V_a \in \{\ell, h\}$, with equal probability. We normalize $\ell = 0$ and let $h = 2\gamma A$, where $A > 0$ is a known constant and $\gamma \in (0, 1]$ represents the firm's publicly observable production scale of its existing assets. The value of the investment opportunity, $V_i(\omega, k)$, depends on a state variable ω and the firm's investment decision $k \in \{0, 1\}$, where $k = 1$ if the firm invests and $k = 0$ if it does not. The state variable may be either good or bad, $\omega \in \{g, b\}$, with equal probability. We assume

$$V_i(g, 1) = I, \qquad V_i(b, 1) = -I, \qquad V_i(g, 0) = V_i(b, 0) = 0, \tag{2}$$

where $I > 0$ is a known constant. The non-negativity of V_a is an innocuous assumption (theoretically, it could be negative) and reflects the fact that a firm's tangible assets-in-place (e.g., property, plant, and equipment) typically have a positive value. The possibility of V_i being negative reflects the fact that a firm's costly explorations of uncertain growth opportunities may fail. The firm privately knows V_a but (like everyone else) does not know ω; as discussed below, the firm decides whether to invest based on information it learns about ω from observing the trading outcome of the security.

The seller's valuation of the security is simply the common value V, whereas the buyer's valuation is $V+\Delta$. The private value component, $\Delta > 0$, which may originate from the buyer's hedging needs or some other private source of value, generates a potential gain to trade. As is standard in the literature, Δ is public knowledge. An additional gain to trade may arise from the seller's expertise about ω (modeled below), which may help the firm improve its investment efficiency through learning from the trading outcome. As demonstrated below in Section 3.1.2, *occasional* trade disruption is necessary for the firm to learn about ω; this is a novel feature of our model. The setting can be interpreted as a model of trading in an over-the-counter market, wherein traders could be, for example, financial intermediaries and the security could be a derivative, structured note, corporate bond, or asset-backed security whose value depends on the firm's underlying assets and growth options.

Financial expertise. Before trading, the seller privately observes two signals, $s_a \in [0,1]$ about V_a and $s_\omega \in [0,1]$ about ω. These signals are realized according to some state-dependent distribution functions: s_a is drawn from $F_h(s_a)$ if $V_a = h$ and from $F_\ell(s_a)$ if $V_a = \ell$; similarly, s_ω is drawn from $F_g(s_\omega)$ if $\omega = g$ and from $F_b(s_\omega)$ if $\omega = b$. The corresponding continuous densities are $f_h(s_a)$, $f_\ell(s_a)$, $f_g(s_\omega)$, and $f_b(s_\omega)$. We assume that F_h dominates F_ℓ and that F_g dominates F_b in the Monotone Likelihood Ratio order, so $\frac{f_h(s_a)}{f_\ell(s_a)}$ and $\frac{f_g(s_\omega)}{f_b(s_\omega)}$ are strictly increasing in s_a and s_ω, respectively. Therefore, higher respective signals s_a and s_ω are suggestive of $V_a = h$ and $\omega = g$. For tractability, we adopt the following parameterization. Both s_a and s_ω are drawn from either strictly increasing or decreasing triangular distributions conditional on the true state, i.e., $f_h(s_a) = 2s_a$, $f_\ell(s_a) = 2(1-s_a)$, $f_g(s_\omega) = 2s_\omega$, and $f_b(s_\omega) = 2(1-s_\omega)$. Consequently, both s_a and s_ω are unconditionally standard uniformly distributed.[6]

The probability that the seller draws her signal s_j, $j \in \{a, \omega\}$, from the "correct" state-dependent distribution is $\mu_j = \frac{1}{2} + e_j$, where $e_j \in [0, \frac{1}{2}]$. With the complementary probability $1-\mu_j$, s_j is drawn from the "incorrect" distribution.[7] Both e_a and e_ω are publicly observable and represent the seller's financial expertise about V_a and ω, respectively. Expertise, which

[6]The density of the unconditional distribution of s_a (resp. s_ω) is $\frac{1}{2}f_h(s_a) + \frac{1}{2}f_\ell(s_a) = 1$ (resp. $\frac{1}{2}f_g(s_\omega) + \frac{1}{2}f_b(s_\omega) = 1$).

[7]As an example, suppose $\omega = g$: the seller draws s_ω from the distribution $F_g(s_\omega)$ with probability μ_ω, and from the distribution $F_b(s_\omega)$ with probability $1-\mu_\omega$.

is endogenously determined, arises from the seller's investment in information acquisition. Assuming that expertise is publicly observable simplifies the analysis and also conforms to reality, as the hiring of sophisticated and well-trained experts to design, value, and trade complex financial instruments is generally observable to the market. We assume that the seller incurs no explicit cost to obtain her expertise. This allows us to highlight how the implicit costs of expertise (i.e., the creation of adverse selection and the potential breakdown of trade) affect the generation and sharing of gains to trade and, ultimately, the seller's choice of expertise. Our results are not qualitatively affected if explicit costs are modeled. Furthermore, our conclusions do not depend on whether the seller or buyer develops expertise, as we show in Appendix B using an alternative framework in which the buyer develops expertise.

For tractability, we restrict the seller to developing expertise about either the firm's assets-in-place or investment opportunity, but not both. This assumption reflects the fact that many financial intermediaries and individual economic agents specialize to obtain a competitive advantage.[8] We also assume that if the seller happens to be indifferent between two levels of (a given type of) expertise, then she develops the lower level of expertise; this assumption does not affect the model's qualitative implications.

After observing s_a and s_ω, the seller updates her respective beliefs about V_a and ω to

$$\pi_a \equiv \Pr(V_a = 2\gamma A | s_a) = \frac{\mu_a f_h(s_a) + (1-\mu_a) f_\ell(s_a)}{f_h(s_a) + f_\ell(s_a)} = \mu_a s_a + (1-\mu_a)(1-s_a) \tag{3}$$

and

$$\pi_\omega \equiv \Pr(\omega = g | s_\omega) = \frac{\mu_\omega f_g(s_\omega) + (1-\mu_\omega) f_b(s_\omega)}{f_g(s_\omega) + f_b(s_\omega)} = \mu_\omega s_\omega + (1-\mu_\omega)(1-s_\omega). \tag{4}$$

[8] This is akin to the distinction between trading and banking modeled by Glode and Lowery (2016) where workers can be deployed as either traders ("surplus-appropriation" jobs) or bankers ("surplus-creation" jobs). Empirically, economic agents such as financial intermediaries (Carey et al., 1998), market makers (Schultz, 2003), and auditors (Cahan et al., 2008) tend to specialize. In academics, for instance, a majority of researchers tend to specialize in particular areas because they do not have the resources to excel in every field.

Clearly, $\frac{\partial \pi_a}{\partial s_a} > 0$ and $\frac{\partial \pi_\omega}{\partial s_\omega} > 0$. Thus, the seller's conditional valuation of the security is

$$V = 2\pi_a \gamma A + k[\pi_\omega I - (1 - \pi_\omega)I]. \tag{5}$$

Trade, investment and feedback. The trading game is played as follows. The buyer possesses all of the bargaining power. After observing the seller's levels of expertise, e_a and e_ω, he makes a take-it-or-leave-it offer to buy the security.[9] The seller then decides whether to accept or reject the offer; trade breaks down if the offer is rejected. In the case of indifference, we assume that the seller accepts the offer, allowing the private gain to trade Δ to materialize.

Prior to the seller developing expertise, the firm chooses the production scale of its assets-in-place, γ, which is publicly observable and may affect the seller's choice of expertise. Given its knowledge of the seller's expertise, the firm can infer the price offered by the buyer in equilibrium. After observing the trading outcome, the firm updates its belief about ω and subsequently makes its investment decision $k \in \{0, 1\}$.[10] We assume that the firm does not invest in the case of indifference; hence, the firm invests if and only if its expectation of π_ω conditional on the trading outcome strictly exceeds $\frac{1}{2}$. We also assume that the seller cannot directly communicate her information to the firm. The inability to communicate could be due to, for example, the information being of a proprietary or confidential nature or the existence of exogenous factors that compel the seller to not directly disclose her information.[11] Although critical for our analysis under the current framework in which the seller develops expertise,

[9] To avoid the complicated analyses associated with signaling, we assume, as in Glode et al. (2012) and Glode and Lowery (2016), that the uninformed trader (buyer in our model) moves first and proposes the offer. In a bilateral bargaining game with asymmetric information, the optimal bargaining strategy of the uninformed offeror is to make a take-it-or-leave-it offer when the offeree is informed (Samuelson, 1984).

[10] Abundant empirical evidence indicates that firms base real decisions on market trading outcomes in practice. In particular, Luo (2005) finds that firms appear to consider information contained in the market's reaction to merger and acquisition announcements when deciding whether to move forward with a proposed deal. Although over-the-counter markets are usually opaque, our conversations with hedge fund managers provide anecdotal evidence that firms are generally aware of and heed the trading activity of securities whose payoffs depend largely on the firm's performance.

[11] As an illustration, suppose the seller is a large financial institution with an investment banking division and a security trading division. If the investment banking division were to obtain from a client (call it A), subject to a confidentiality agreement, sector-specific private information relevant to the future profitability of another firm (call it B), then the trading division might conceivably trade B's security based on the information gleaned from A but could not communicate that information to B.

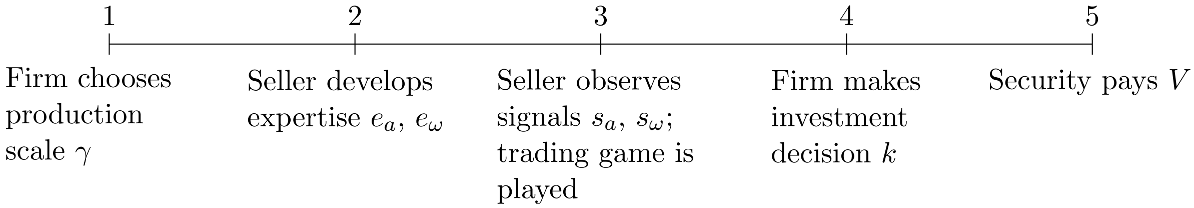

Figure 1: *Sequence of Events.*

this assumption is innocuous under an alternative framework examined in Appendix B (that generates results analogous to those in the current framework) in which the buyer develops expertise. This is because an informed buyer would have no incentive to communicate her information to the firm prior to trade, as information that enables the firm to improve its investment efficiency and, hence, its value makes the security more expensive to acquire.

Figure 1 summarizes the sequence of events. A feedback loop arises in our model because traders anticipate the firm's potential reaction to the trading outcome, which affects both the traders' and firm's strategies and, thus, the trading outcome itself.

3 Analysis

The model is solved backwards along the timeline illustrated in Figure 1. We first characterize the trading and investment outcomes in Section 3.1 (stages 3 and 4). We then examine the seller's choice of expertise in Section 3.2 (stage 2) and the firm's production scale in Section 3.3 (stage 1). Section 3.4 summarizes the equilibrium.

3.1 Trading and Investment

In this section, we examine the buyer's and seller's strategies and the firm's investment decision. Sections 3.1.1 and 3.1.2 analyze settings in which the seller develops expertise about the firm's assets-in-place V_a and investment opportunity ω, respectively, taking as given the firm's production scale γ.

3.1.1 Expertise about Assets-in-Place

We first analyze a setting in which the seller develops expertise about the firm's assets-in-place but not its investment opportunity. In this case, $e_\omega = 0$; hence, $\pi_\omega = \frac{1}{2}$, $\forall s_\omega \in [0,1]$. The firm does not invest ($k = 0$). This setting resembles a standard ultimatum bargaining game (e.g., Akerlof, 1970; Dang, 2008; Glode et al., 2012) wherein the seller may extract part of the security's private value component Δ from the buyer because the buyer's information disadvantage compels him to overpay for the security's common value component V.

The seller's conditional expectation of the security's value V (as given by (5)) becomes

$$\Phi_a = 2\pi_a \gamma A. \tag{6}$$

Because $\frac{\partial \pi_a}{\partial s_a} > 0$ and s_a is unconditionally uniformly distributed on $[0,1]$, $\Phi_a \sim U[\gamma A - \Omega_a, \gamma A + \Omega_a]$ from the buyer's perspective, where $\Omega_a \equiv 2e_a\gamma A$. The seller's information advantage over the buyer, measured by the width of the distribution of Φ_a, $2\Omega_a$, is increasing in the seller's expertise e_a. To analyze the trading game, we first determine the buyer's offer, taking as given the seller's expertise e_a. Then, we solve for the seller's optimal level of e_a.

Buyer's strategy. The buyer offers a price P_a to maximize his expected payoff from trade. Because the seller accepts the offer if and only if $\Phi_a \leq P_a$, the buyer's expected payoff conditional on offer acceptance is $\mathbb{E}[\Phi_a | \Phi_a \leq P_a] + \Delta - P_a = \frac{1}{2}(P_a + \gamma A - \Omega_a) + \Delta - P_a$. The buyer's payoff is zero if the seller rejects his offer. Thus, the buyer's objective is

$$\max_{P_a} \ \Pr[\Phi_a \leq P_a]\left[\tfrac{1}{2}(P_a + \gamma A - \Omega_a) + \Delta - P_a\right]. \tag{7}$$

The solution is characterized by the following lemma.

Lemma 1 (Buyer's offer with seller expertise about assets-in-place)**.** *Given the seller's exper-*

tise about the firm's assets-in-place, e_a, the buyer offers

$$P_a = \begin{cases} \gamma A - \Omega_a + \Delta & \text{if } \Delta < 2\Omega_a \\ \gamma A + \Omega_a & \text{if } \Delta \geq 2\Omega_a. \end{cases} \tag{8}$$

The buyer faces the following tradeoff. Offering a higher price allows him to secure the trade with a greater probability and, hence, better preserve the trade surplus Δ. However, he surrenders a larger share of that surplus to the seller when he offers a higher price because he tends to overpay more for the security. If Δ is sufficiently large ($\Delta \geq 2\Omega_a$), then the incentive to secure the trade dominates because the *entire* Δ would be lost if trade were to break down. The buyer offers a price equal to the seller's highest possible valuation given the seller's expertise ($P_a = \gamma A + \Omega_a$), and the seller always accepts the offer. Conversely, if Δ is smaller ($\Delta < 2\Omega_a$), then probabilistically losing Δ (due to the possibility of trade breaking down) becomes less consequential, and the buyer is motivated to retain a larger portion of the trade surplus (conditional on trade occurring) to compensate for his overpayment of the security. Therefore, he offers a price lower than the seller's highest possible valuation ($P_a = \gamma A - \Omega_a + \Delta < \gamma A + \Omega_a$), and trade may break down with probability $\Pr[\Phi_a > P_a] = 1 - \frac{\Delta}{2\Omega_a}$.

Seller's strategy. The seller anticipates the buyer's strategy and chooses her level of expertise e_a to maximize her ex ante expected payoff (before she observes her signals s_a and s_ω). As noted above, the seller's choice of e_a determines the distribution of Φ_a as perceived by the buyer and, hence, the buyer's offer. Ex post, the seller's signal s_a privately reveals the realized value of Φ_a to her. If $\Phi_a > P_a$, then the seller rejects the buyer's offer, and her ex ante expected payoff is $\mathbb{E}[\Phi_a | \Phi_a > P_a] = \frac{1}{2}(P_a + \gamma A + \Omega_a)$. Otherwise, the seller accepts the buyer's offer and receives P_a. Therefore, the seller's objective is

$$\max_{e_a} \ \Pr[\Phi_a \leq P_a] P_a + \Pr[\Phi_a > P_a] \tfrac{1}{2}(P_a + \gamma A + \Omega_a). \tag{9}$$

The seller's optimal level of expertise is characterized by the following lemma.

Lemma 2 (Seller's expertise about assets-in-place)**.** *The seller's optimal level of expertise about the firm's assets-in-place is*

$$e_a = \begin{cases} \dfrac{\Delta}{4\gamma A} & \text{if } \dfrac{\Delta}{\gamma A} < 2 \\ \dfrac{1}{2} & \text{if } \dfrac{\Delta}{\gamma A} \geq 2. \end{cases} \tag{10}$$

The seller's expertise determines her information advantage over the buyer. Although a bigger information advantage enables her to appropriate a larger share of the trade surplus Δ conditional on trade occurring, it also risks disrupting the trade. If Δ is sufficiently big ($\Delta \geq 2\gamma A$), then the buyer is eager to secure the trade to preserve Δ, and he offers a price equal to the seller's highest possible valuation, which is $\gamma A + \Omega_a = (1 + 2e_a)\gamma A$ for any e_a (Lemma 1; note that $\Delta \geq 2\gamma A$ ensures $\Delta \geq 2\Omega_a = 4e_a\gamma A$, $\forall e_a \in [0, \frac{1}{2}]$). Anticipating this, the seller develops the highest level of expertise, $e_a = \frac{1}{2}$, to extract the maximum amount of the trade surplus from the buyer. If Δ is smaller ($\Delta < 2\gamma A$), however, then the buyer would be unwilling to offer a price equal to the seller's highest possible valuation if the seller were to choose $e_a = \frac{1}{2}$ (Lemma 1). Consequently, trade could break down, in which case the seller would receive no trade surplus. To prevent trade from collapsing, the seller develops less expertise, $e_a = \frac{\Delta}{4\gamma A} < \frac{1}{2}$, thereby ensuring herself a share of the surplus Δ.

Equilibrium. The following theorem characterizes the equilibrium of the trading game when the seller develops expertise about assets-in-place.

Theorem 1 (Equilibrium with seller expertise about assets-in-place)**.** *The equilibrium depends on the relative sizes of Δ and γA. If $\frac{\Delta}{\gamma A} < 2$, then the seller chooses $e_a = \frac{\Delta}{4\gamma A}$, and the buyer offers $P_a = \gamma A + \frac{\Delta}{2}$. If $\frac{\Delta}{\gamma A} \geq 2$, then the seller chooses $e_a = \frac{1}{2}$, and the buyer offers $P_a = 2\gamma A$. Regardless of $\frac{\Delta}{\gamma A}$, trade always occurs, and the firm never invests.*

The equilibrium is reminiscent of that in Glode et al. (2012). In their binary-signal setting in which the seller's signal can take only two possible values, high or low, the seller chooses her expertise to ensure that trade always occurs and that the buyer always offers a price equal to the seller's valuation conditional on receiving a high signal. Similarly, in our continuous-signal setting, the seller chooses her expertise to ensure that the buyer, given his belief about the distribution of the security's value, $\Phi_a \sim U[\gamma A - \Omega_a, \gamma A + \Omega_a]$, always bids at the seller's highest valuation, $P_a = \gamma A + \Omega_a = \gamma A + \min\left\{\gamma A, \frac{1}{2}\Delta\right\}$, and trade always occurs.

3.1.2 Expertise about Investment Opportunity

Next, we analyze a setting in which the seller develops expertise about the firm's investment opportunity but not its assets-in-place. In this case, $e_a = 0$; thus, $\pi_a = \frac{1}{2}$, $\forall s_a \in [0,1]$. The seller's conditional expectation of the security's value V (as given by (5)) now becomes

$$\Phi_i(k) = \gamma A + k[\pi_\omega I - (1 - \pi_\omega)I]. \tag{11}$$

We write $\Phi_i(k)$ explicitly as a function of the firm's investment decision $k \in \{0,1\}$. Clearly, $\Phi_i(0) = \gamma A$. Because $\frac{\partial \pi_\omega}{\partial s_\omega} > 0$ and s_ω is unconditionally uniformly distributed on $[0,1]$, $\Phi_i(1) \sim U[\gamma A - \Omega_i, \gamma A + \Omega_i]$ from the buyer's perspective, where $\Omega_i \equiv 2e_\omega I$. The seller's information advantage over the buyer, measured by the width of the distribution of $\Phi_i(1)$, $2\Omega_i$, is increasing in the seller's expertise e_ω.

Like in Section 3.1.1, the trading game is solved backwards along the timeline in Figure 1. Here, however, the firm's investment decision depends on the trading outcome, which creates a feedback loop whereby the anticipated effect of trade on the firm's investment decision affects the trading outcome itself. We conjecture (and verify later in Theorem 2) that the firm invests ($k = 1$) if trade breaks down but does not invest ($k = 0$) if trade occurs.

Buyer's strategy. The buyer offers a price P_i, and the seller accepts the offer if and only if $\Phi_i(1) \leq P_i$. Conditional on acceptance, the buyer knows that the firm will not invest, so his payoff is $\gamma A + \Delta - P_i$. Conversely, if $\Phi_i(1) > P_i$, then the seller rejects the offer and trade breaks down, in which case the firm invests and the seller's expected payoff from retaining the security is $\Phi_i(1)$ while the buyer's payoff is zero. Therefore, the buyer's objective is

$$\max_{P_i} \ \Pr[\Phi_i(1) \leq P_i](\gamma A + \Delta - P_i). \tag{12}$$

The following lemma characterizes the buyer's optimal offer.

Lemma 3 (Buyer's offer with seller expertise about investment opportunity)**.** *Given the seller's expertise about the firm's investment opportunity, e_ω, the buyer offers*

$$P_i = \begin{cases} \gamma A + \frac{1}{2}(\Delta - \Omega_i) & \textit{if } \Delta < 3\Omega_i \\ \gamma A + \Omega_i & \textit{if } \Delta \geq 3\Omega_i. \end{cases} \tag{13}$$

The intuition for Lemma 3 is similar to that for Lemma 1. If the trade surplus Δ is sufficiently large ($\Delta \geq 3\Omega_i$), then the buyer offers a price equal to the seller's highest possible valuation given her expertise ($P_i = \gamma A + \Omega_i$) to secure the trade. Although this cedes a large fraction of Δ to the seller, the buyer does not want to bid lower because the entire Δ would be lost if trade were to break down. However, if Δ is smaller ($\Delta < 3\Omega_i$), then the possibility of losing the entire Δ is not as consequential and the incentive to limit the share of Δ extracted by the seller enters the buyer's calculation. Hence, he offers a price lower than the seller's highest valuation ($P_i = \gamma A + \frac{1}{2}(\Delta - \Omega_i) < \gamma A + \Omega_i$), leading to possible breakdown of trade, which occurs with probability $\Pr[\Phi_i(1) > P_i] = \frac{3}{4} - \frac{\Delta}{4\Omega_i}$.

Although qualitatively similar, there are two noteworthy quantitative differences between Lemmas 1 and 3. First, conditional on the same degree of information asymmetry in each case (i.e., suppose $\Omega_a = \Omega_i$),[12] the Δ-threshold at which the buyer offers a price equal to the seller's highest valuation (given the seller's expertise) is higher when the seller's expertise pertains to the investment opportunity ω ($3\Omega_i$; Lemma 3) than when it pertains to assets-in-place V_a ($2\Omega_a$; Lemma 1). In other words, the buyer is, *ceteris paribus*, less likely to bid at the seller's highest valuation when the seller develops expertise about ω. Second, conditional on offering

[12] Recall, the degree of information asymmetry in the case in which the seller develops expertise about the firm's assets-in-place (resp. investment opportunity) is $2\Omega_a$ (resp. $2\Omega_i$).

less than the seller's highest valuation, the buyer's offer is less sensitive to Δ when the seller's expertise pertains to ω ($\frac{\partial P_i}{\partial \Delta} = \frac{1}{2}$; Lemma 3) than when it pertains to V_a ($\frac{\partial P_a}{\partial \Delta} = 1$; Lemma 1).

These differences stem from the fact that expertise about ω may increase the aggregate trade surplus. When the seller develops expertise about V_a, her gain from trade comes from merely extracting a fraction of the *fixed* trade surplus Δ from the buyer. In contrast, trade may generate an *additional* surplus when the seller develops expertise about ω because the trading outcome in that case enables the firm to make a better investment decision. The resulting gain in investment efficiency increases the aggregate trade surplus. Because the equilibrium price determines how this larger aggregate surplus is allocated between the buyer and seller, the price offered by the buyer when the seller develops expertise about the ω generally differs from (and, in particular, becomes less sensitive to Δ than) the price he offers when the seller develops expertise about V_a.

Seller's strategy. Anticipating the buyer's strategy, the seller chooses her expertise e_ω to maximize her ex ante expected payoff (before observing her signals s_a and s_ω). After choosing e_ω but before observing s_ω, the seller knows that $\Phi_i(1) \sim U[\gamma A - \Omega_i, \gamma A + \Omega_i]$. Ex post, the signal s_ω privately reveals the value of $\Phi_i(1)$ to the seller. If $\Phi_i(1) > P_i$, then the seller rejects the buyer's offer, and her ex ante expected payoff is $\mathbb{E}[\Phi_i(1)|\Phi_i(1) > P_i] = \frac{1}{2}(P_i + \gamma A + \Omega_i)$, given that the firm invests if trade breaks down. Conversely, if $\Phi_i(1) \leq P_i$, then the seller accepts the buyer's offer and receives P_i. Therefore, the seller's objective is

$$\max_{e_\omega} \ \Pr[\Phi_i(1) \leq P_i]P_i + \Pr[\Phi_i(1) > P_i]\frac{1}{2}(P_i + \gamma A + \Omega_i). \tag{14}$$

The following lemma characterizes the seller's optimal level of expertise.

Lemma 4 (Seller's expertise about investment opportunity)**.** *The seller's optimal level of* *expertise about the firm's investment opportunity is*

$$e_\omega = \begin{cases} \frac{1}{2} & \text{if } \frac{\Delta}{I} < \frac{1}{3} \\ \frac{\Delta}{6I} & \text{if } \frac{1}{3} \leq \frac{\Delta}{I} < 3 \\ \frac{1}{2} & \text{if } \frac{\Delta}{I} \geq 3. \end{cases} \tag{15}$$

As mentioned above, there are two potential sources of gains to trade when the trading outcome affects firm investment. The first is the private value component of the security, Δ, as in the standard ultimatum bargaining game analyzed in Section 3.1.1. This gain materializes only if trade occurs. The second gain, which is novel to our analysis, originates from the firm's abandonment of a value-destroying investment when the trading outcome indicates a poor investment opportunity (i.e., bad ω). We refer to this gain, which arises from greater investment efficiency, as an "investment surplus." A necessary condition for the investment surplus to materialize is that the trading outcome is informative about ω, i.e., trade occurs if and only if the seller's signal s_ω is sufficiently low. Therefore, trade must break down with some strictly positive (but less than one) probability for the investment surplus to be realized. Greater expertise makes the trading outcome more informative about ω and, hence, increases the investment surplus, which depends on I. This benefits the seller, who obtains part of the larger surplus. However, greater expertise also increases the likelihood of trade breaking down and, hence, the other gain to trade Δ not materializing. Thus, the seller's optimal level of expertise depends on the relative sizes of the two potential surpluses.

If Δ is sufficiently big relative to I ($\frac{\Delta}{I} \geq 3$), then the seller's gain from preserving Δ (and extracting a share of it) outweighs her expected gain from greater investment efficiency. The buyer is also keen to secure the trade given a large Δ, so he offers a price equal to the seller's highest possible valuation for any level of her expertise (Lemma 3; note that $\frac{\Delta}{I} \geq 3$ ensures $\Delta \geq 3\Omega_i = 6e_\omega I$, $\forall e_\omega \in [0, \frac{1}{2}]$). The seller, therefore, develops the greatest possible expertise, $e_\omega = \frac{1}{2}$, to extract the largest share of Δ from the buyer as she can.

If Δ is smaller but still sizable relative to I ($\frac{1}{3} \leq \frac{\Delta}{I} < 3$), then the buyer would be unwilling to bid at the seller's highest valuation if the seller were to choose $e_\omega = \frac{1}{2}$, which could result in trade breaking down. Although the potential for trade to collapse is necessary to make the trading outcome informative and, hence, for the investment surplus to materialize, the seller's share of Δ still outweighs her share of the investment surplus when I is not sufficiently big. Therefore, like the setting wherein the seller's expertise pertains to V_a, here she develops less expertise about ω, $e_\omega = \frac{\Delta}{6I} < \frac{1}{2}$, to ensure trade and preserve her share of Δ.

Finally, and most interestingly, if Δ is sufficiently small relative to I ($\frac{\Delta}{I} < \frac{1}{3}$), then the seller focuses on gaining from the relatively large investment surplus rather than trying to preserve trade and appropriate a share of the relatively small Δ. Because the investment surplus materializes if and only if the seller sells the security upon receiving a low signal but holds the security upon receiving a high signal, developing expertise about ω can be construed as the seller acquiring a real put option on the security.[13] Because option value is increasing in the volatility of the underlying security's payoff (i.e., the variance of $\Phi_i(1) \sim U[\gamma A - \Omega_i, \gamma A + \Omega_i]$, which is $\frac{1}{3}\Omega_i^2 = \frac{4}{3}e_\omega^2 I^2$), the seller develops the highest level of expertise, $e_\omega = \frac{1}{2}$, to maximize the variance and, hence, the value of the real option.

Equilibrium. The following theorem characterizes the equilibrium of the trading game when the seller develops expertise about the investment opportunity.

Theorem 2 (Equilibrium with seller expertise about investment opportunity)**.** *The equilibrium depends on the relative sizes of Δ and I.*

1. *If $\frac{\Delta}{I} < \frac{1}{3}$, then the seller chooses $e_\omega = \frac{1}{2}$, and the buyer offers $P_i = \gamma A + \frac{1}{2}(\Delta - I)$. The seller rejects the offer and the firm invests if and only if $s_\omega > \frac{1}{4} + \frac{\Delta}{4I}$, so trade occurs with probability $\frac{1}{4} + \frac{\Delta}{4I} \in \left(\frac{1}{4}, \frac{1}{3}\right)$.*
2. *If $\frac{1}{3} \le \frac{\Delta}{I} < 3$, then the seller chooses $e_\omega = \frac{\Delta}{6I} \in \left[\frac{1}{18}, \frac{1}{2}\right)$, and the buyer offers $P_i = \gamma A + \frac{\Delta}{3}$. The seller always accepts the offer, and the firm never invests.*

[13]Interpreting expertise about ω as a real put option implicitly assumes that the seller's default position is to hold the security (so that the firm invests), in which case exercising the option entails selling the security to avoid exposure to the firm's value-destroying investment. Equivalently, expertise about ω can be also viewed as a real call option on the firm's investment opportunity if the seller's default position is to sell the security (so that the firm does not invest).

3. *If* $\frac{\Delta}{I} \geq 3$*, then the seller chooses* $e_\omega = \frac{1}{2}$*, and the buyer offers* $P_i = \gamma A + I$*. The seller always accepts the offer, and the firm never invests.*

An important difference between the equilibria characterized in Theorems 1 and 2 is that trade may break down when the seller develops expertise about the firm's investment opportunity ω, which generates socially valuable information, but not when she develops expertise about assets-in-place, which only creates foreknowledge about V_a. As discussed above, when the seller's expertise pertains to ω, the potential for trade to collapse is necessary to make the trading outcome informative and, hence, improve investment efficiency. Specifically, if Δ is sufficiently small relative to I ($\frac{\Delta}{I} < \frac{1}{3}$), then the seller accepts the buyer's offer when she receives a low signal ($s_\omega \leq \frac{1}{4} + \frac{\Delta}{4I}$) but retains the security when she receives a high signal ($s_\omega > \frac{1}{4} + \frac{\Delta}{4I}$). Therefore, trade indicates a poor investment opportunity whereas no trade indicates a good investment opportunity. This enables the firm to abandon value-destroying investments when trade occurs but pursue value-enhancing investments when trade breaks down.[14] Unlike the standard ultimatum bargaining game in Section 3.1.1 in which the trade surplus stems solely from the buyer's private valuation Δ, an additional trade surplus arises in this case from the seller's real option. This real option exists even as $\Delta \to 0$ because trade can create (social) value by deterring the firm from making an unprofitable investment.

Remarks. In the bargaining game considered in Section 3.1.1, the buyer acts as a liquidity demander who pays a premium to the seller to secure the trade and preserve the surplus Δ. The seller is able to extract some of the surplus from the buyer (via an inflated price) due to her position as a supplier of liquidity. The roles are reversed when the trade surplus originates largely from a potential improvement in investment efficiency (i.e., when the seller develops expertise about ω and $\frac{\Delta}{I} < \frac{1}{3}$). In this case, the seller demands liquidity to shed her exposure to a potentially value-destroying investment when she receives a low signal indicating poor

[14] Under the alternative framework considered in Appendix B wherein the buyer develops expertise, trade indicates a good investment opportunity whereas no trade indicates a poor investment opportunity. In that setting, the firm pursues its value-enhancing investment when trade occurs but abandons its value-destroying investment when trade breaks down.

investment prospects for the firm.[15] The buyer supplies liquidity and extracts some of the trade surplus from the seller by paying a price ($P_i = \gamma A - \frac{1}{2}I$ as $\Delta \to 0$) lower than the security's post-trade actual value (γA because the firm does not invest if trade occurs). The seller is willing to accept the low offer to avoid an even lower expected payoff that would materialize if she were to hold the security and the firm were to (erroneously) invest.

3.2 Seller's Choice of Expertise

Having analyzed the trading and investment subgames conditional on the seller developing expertise about the firm's assets-in-place V_a (Section 3.1.1) or investment opportunity ω (Section 3.1.2), we now move back one stage along the timeline illustrated in Figure 1 and examine the seller's choice between the two types of expertise, taking the firm's production scale γ as given. The seller chooses the type of expertise that yields her a higher expected payoff in the ensuing trading game. For simplicity, we assume that she develops expertise about ω rather than V_a in cases of indifference.

The seller's choice of expertise depends on the parameters. If $\frac{\Delta}{I} \geq \frac{1}{3}$, then, according to Theorems 1 and 2, trade always occurs and the firm never invests. The seller's payoff from developing expertise about V_a is $P_a = \gamma A + \min\left\{\gamma A, \frac{1}{2}\Delta\right\}$ (Theorem 1), whereas her payoff from developing expertise about ω is $P_i = \gamma A + \min\left\{I, \frac{1}{3}\Delta\right\}$ (Theorem 2). Hence, conditional on $\frac{\Delta}{I} \geq \frac{1}{3}$, the seller develops expertise about V_a if and only if $\min\left\{\gamma A, \frac{1}{2}\Delta\right\} > \min\left\{I, \frac{1}{3}\Delta\right\}$.

A more interesting outcome emerges when $\frac{\Delta}{I} < \frac{1}{3}$. If the seller develops expertise about V_a, then trade always occurs (Theorem 1) and, as stated above, her payoff is

$$P_a = \gamma A + \min\left\{\gamma A, \tfrac{1}{2}\Delta\right\}. \tag{16}$$

If, however, the seller develops expertise about ω and $\frac{\Delta}{I} < \frac{1}{3}$, then trade may break down

[15] The seller's demand for liquidity results from her inability to directly communicate information about ω to the firm. See the discussion on page 12.

(Theorem 2) and her expected payoff is (where $P_i = \gamma A + \frac{1}{2}(\Delta - I)$)

$$\Pr[\Phi_i(1) \leq P_i]P_i + \Pr[\Phi_i(1) > P_i]\mathbb{E}[\Phi_i(1)|\Phi_i(1) > P_i] = \gamma A + \frac{(\Delta + I)^2}{16I}. \tag{17}$$

Thus, when $\frac{\Delta}{I} < \frac{1}{3}$, the seller develops expertise about V_a if and only if $\min\left\{\gamma A, \frac{1}{2}\Delta\right\} > \frac{(\Delta+I)^2}{16I}$. The following theorem characterizes the seller's expertise choice given a production scale γ.

Theorem 3 (Seller's expertise choice for a given γ)**.** *Suppose $\frac{\Delta}{I} \geq \frac{1}{3}$. If $\min\left\{\gamma A, \frac{1}{2}\Delta\right\} > \min\left\{I, \frac{1}{3}\Delta\right\}$, then the seller develops expertise about assets-in-place, $e_a = \min\left\{\frac{1}{2}, \frac{\Delta}{4\gamma A}\right\}$ and $e_\omega = 0$; otherwise, she develops expertise about the investment opportunity, $e_a = 0$ and $e_\omega = \min\left\{\frac{1}{2}, \frac{\Delta}{6I}\right\}$. Conversely, suppose $\frac{\Delta}{I} < \frac{1}{3}$. If $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$, then the seller develops expertise about assets-in-place, $e_a = \min\left\{\frac{1}{2}, \frac{\Delta}{4\gamma A}\right\}$ and $e_\omega = 0$; otherwise, she develops expertise about the investment opportunity, $e_a = 0$ and $e_\omega = \frac{1}{2}$.*

Because trade always occurs and the firm never invests when $\frac{\Delta}{I} \geq \frac{1}{3}$ regardless of the seller's choice of expertise, we focus our discussion on the more interesting case wherein $\frac{\Delta}{I} < \frac{1}{3}$ and the seller's expertise choice affects equilibrium outcomes. According to Theorem 3, two conditions must hold for the seller to develop expertise about V_a instead of ω when $\frac{\Delta}{I} < \frac{1}{3}$. First, Δ must be sufficiently big relative to I (to satisfy the condition $(3 - 2\sqrt{2})I < \Delta$). The benefit to the seller from acquiring expertise about V_a instead of ω when $\frac{\Delta}{I} < \frac{1}{3}$ is that trade always occurs in the former case, which enables her to appropriate a share of the surplus Δ. For this benefit to be sufficiently attractive to the seller relative to the share of the investment surplus (which depends positively on I) that she could gain if she were to develop expertise about ω, Δ must be sufficiently big relative to I. Second, γA must be sufficiently large (to satisfy the condition $\Delta < 4\sqrt{\gamma AI} - I$). Conditional on acquiring expertise about V_a, a larger γA, *ceteris paribus*, increases the sellers information advantage over the buyer, which allows her to extract a larger share of Δ.[16] If one of these two conditions is not satisfied, then the seller develops expertise about ω.

[16]Recall, the sellers information advantage when her expertise pertains to V_a is measured by the width of the distribution of Φ_a (as given by (6)), which is proportional to γA.

3.3 Firm's Production Scale

Finally, we move back to the initial stage of the timeline illustrated in Figure 1 and examine the firm's choice of its scale of production from assets-in-place, γ. The firm can affect its value V (also the security's common value, as given by (1)) by adjusting γ, which, as we show below, influences the seller's expertise choice. The idea is as follows. By scaling back production (i.e., lowering γ), the firm increases the value of its growth option relative to the value of its assets-in-place. This may induce the seller to develop expertise about the investment opportunity, thereby enabling the firm to learn from the trading outcome and make a better investment decision. The firm faces a tradeoff, however, as lowering γ decreases the expected payoff from its assets-in-place.[17] In balancing this tradeoff, the firm's objective is to choose $\gamma \in (0, 1]$ to maximize the expected value of V. For simplicity, we assume that the firm scales back production only if doing so strictly increases firm value.

As Theorem 3 shows, whether the firm learns from the trading outcome depends on the relations between γA, I, and Δ. Therefore, the firm's decisions about whether to scale back and the extent to scale back production from its assets-in-place depend on the the underlying parameters, as well. There are three cases to consider.

Case 1. If $\frac{\Delta}{I} \geq \frac{1}{3}$, then trade always occurs regardless of the seller's choice of expertise. Hence, the firm is unable to learn about its investment opportunity, so it never exercises the growth option but instead maximizes its value by choosing a full scale of production from assets-in-place, i.e., $\gamma = 1$.

Case 2. If $\frac{\Delta}{I} < \frac{1}{3}$ but $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{AI} - I$ is not satisfied, then $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$ fails to hold, $\forall \gamma \in (0, 1]$. It follows immediately from Theorem 3 that the seller chooses $e_\omega = \frac{1}{2}$ and $e_a = 0$, $\forall \gamma$. As a result, $\Phi_i(1) \sim U[\gamma A - I, \gamma A + I]$ (see (11)) and

[17]The analysis pertaining to the firm's production strategy assumes that the firm cannot simply disclose V_a to induce the seller to develop expertise about ω. While firms may refrain from making voluntary disclosures for many reasons, the inability to disclose is not essential for our analysis. The results hold under an alternative setup where the firm does not know V_a (and, therefore, cannot disclose it), provided that the firm cannot take action to affect V_a after observing the trading outcome.

the buyer offers $P_i = \gamma A + \frac{1}{2}(\Delta - I)$ (Theorem 2). Therefore, the firm's expected value is

$$V = \Pr[\Phi_i(1) \leq P_i]\gamma A + \Pr[\Phi_i(1) > P_i]\tfrac{1}{2}(P_i + \gamma A + I) \tag{18}$$

because the security's expected payoff is either γA if trade occurs and the firm does not invest or $\mathbb{E}[\Phi_i(1)|\Phi_i(1) > P_i] = \frac{1}{2}(P_i + \gamma A + I)$ if trade breaks down and the firm invests. Because $\Pr[\Phi_i(1) \leq P_i] = \frac{1}{4} + \frac{\Delta}{4I}$ is independent of γ, V (as given by (18)) is strictly increasing in γ, so the firm's optimal production scale in this case is $\gamma = 1$.

Case 3. If $\frac{\Delta}{I} < \frac{1}{3}$ and $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{AI} - I$, then there are two possible Nash equilibria: one in which the seller develops expertise about assets-in-place V_a and another in which she develops expertise about the investment opportunity ω. In the former equilibrium, anticipating that the seller will develop expertise about V_a, the firm expects to learn nothing about ω from the trading outcome and, hence, chooses $\gamma = 1$, so $V = A$ (see (5); Theorem 1). Because the firm chooses $\gamma = 1$, the seller elects to develop expertise about V_a given that $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{AI} - I$ holds (Theorem 3). Thus, this is indeed an equilibrium.

In the latter equilibrium, the firm chooses $\gamma < 1$ to induce the seller to develop expertise about ω. According to Theorem 3, the seller elects to develop expertise about ω, i.e., $e_\omega = \frac{1}{2}$ and $e_a = 0$, only if $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$ does not hold, in which case firm value is given by (18) and is strictly increasing in γ. Therefore, the firm's optimal production scale in this case is the largest γ such that the condition $(3 - 2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$ does not hold, i.e., $\gamma = \frac{(\Delta+I)^2}{16AI} < 1$, where the inequality ($\frac{(\Delta+I)^2}{16AI} < 1$) follows from $\Delta < 4\sqrt{AI} - I$.[18] Substituting $\gamma = \frac{(\Delta+I)^2}{16AI}$ into (18) yields $V = \frac{1}{4}(\Delta + I)$.

The equilibrium that emerges depends on the relations between A, I, and Δ. If $\frac{1}{4}(\Delta + I) > A$ (equivalently, $\Delta > 4A - I$), then the equilibrium in which the seller develops expertise about ω emerges; otherwise, the equilibrium in which the seller develops expertise about V_a emerges. The following theorem summarizes the analysis and characterizes the firm's optimal production scale, denoted by γ^*.

[18] Recall, the case considered here is conditional on $\Delta < 4\sqrt{AI} - I$.

Theorem 4 (Firm's production strategy)**.** *If* $\max\left\{(3-2\sqrt{2})I, 4A-I\right\} < \Delta < \min\left\{\frac{1}{3}I, 4\sqrt{AI}-I\right\}$, *then the firm scales back its production from assets-in-place by a factor of*

$$\gamma^* = \frac{(\Delta + I)^2}{16AI} < 1; \tag{19}$$

otherwise, the firm produces at full scale, $\gamma^* = 1$*.*

The firm's production strategy is illustrated in Figure 2. In the dotted region (*Case 2*), the seller develops expertise about ω regardless of γ. Therefore, the firm produces at full scale $\gamma^* = 1$. In the lined region defined by $\max\left\{(3-2\sqrt{2})I, 4A-I\right\} < \Delta < \min\left\{\frac{1}{3}I, 4\sqrt{AI}-I\right\}$ (the latter equilibrium in *Case 3*), the firm scales back its production from assets-in-place to $\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$ in order to induce the seller to develop expertise about ω rather than V_a. Within this region, A is relatively small (i.e., $A < \frac{1}{4}(\Delta + I)$, as characterized by the region's upper boundary, $\Delta > 4A - I$), so the potential benefit to the firm from learning about its investment opportunity outweighs the loss associated with reduced production from assets-in-place. In the non-shaded region, the firm produces at full scale $\gamma^* = 1$ either because the loss from scaling back production outweighs the potential gain from learning about ω (when $A \geq \frac{1}{4}(\Delta + I)$; former equilibrium in *Case 3*) or because the firm never learns about ω from the trading outcome irrespective of its production scale (when $\Delta > \frac{1}{3}I$; *Case 1*).

Remarks. The most interesting region in Figure 2 is the lined region (latter equilibrium in *Case 3*), in which the information receiver, i.e., the firm, takes actions to influence the information production decision by the sender, i.e., the seller. To induce the seller to produce useful information about the investment opportunity ω rather than information about assets-in-place V_a that is redundant to the firm, the firm deliberately scales back production from assets-in-place. The decrease in production lowers the information advantage that the seller would obtain if she were to develop expertise about V_a (due to the reduced scale) and, therefore, strengthens her incentive to develop expertise about ω. This interaction between the information receiver and sender is related to Bond et al. (2010) and Bond and Goldstein

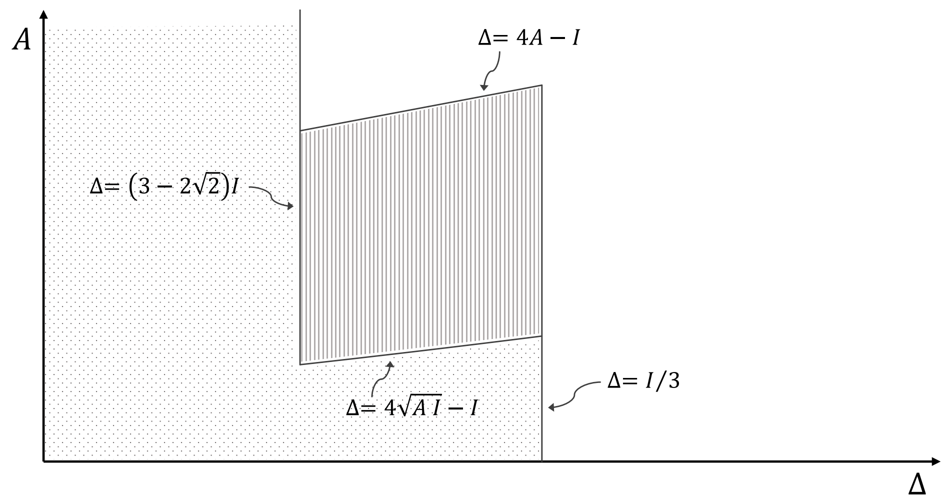

Figure 2: *Equilibrium Outcomes.* In the dotted region, the firm produces at full scale ($\gamma^* = 1$), the seller develops expertise about the investment opportunity ($e_a^* = 0$, $e_\omega^* = \frac{1}{2}$), trade may break down, and the firm may invest. In the lined region, the firm scales back production from assets-in-place to $\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$ to induce the seller to develop expertise about the investment opportunity, trade may break down, and the firm may invest. In the non-shaded region, the firm produces at full scale, the seller may develop expertise about either the investment opportunity or assets-in-place (depending on parameters), trade always occurs, and the firm never invests.

(2015). In their models, the market price of a security both affects and reflects an agent's decision whether to take an action that affects the security's value. The agent wants to improve learning by minimizing the *reflection* component while maximizing the *affection* component of the security price. The reflection (resp. affection) nature of security prices in their models resemble the information about asset-in-place (resp. investment opportunity) in our setting.

3.4 Summary of the Equilibrium

The analysis in Sections 3.1 - 3.3 describes the individual agents' equilibrium strategies. The following proposition summarizes the equilibrium outcomes (denoted by a superscript *), which depend on the parameters and correspond to the three regions in Figure 2.

Proposition 1 (Overall equilibrium)**.** *The equilibrium outcomes are as follows.*

1. *If either $\Delta \leq (3-2\sqrt{2})I$ or $\max\left\{(3-2\sqrt{2})I, 4\sqrt{AI}-I\right\} \leq \Delta \leq \frac{1}{3}I$, then the firm chooses $\gamma^* = 1$, the seller chooses $e_a^* = 0$ and $e_\omega^* = \frac{1}{2}$, trade occurs with probability*

$\frac{1}{4} + \frac{\Delta}{4I} \in (\frac{1}{4}, \frac{1}{3})$, *and the firm invests (and trade breaks down) if and only if the seller's signal* $s_\omega > \frac{1}{4} + \frac{\Delta}{4I}$.

2. *If* $\max\left\{(3-2\sqrt{2})I, 4A - I\right\} < \Delta < \min\left\{\frac{1}{3}I, 4\sqrt{AI} - I\right\}$, *then the firm chooses* $\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$, *the seller chooses* $e_a^* = 0$ *and* $e_\omega^* = \frac{1}{2}$, *trade occurs with probability* $\frac{1}{4} + \frac{\Delta}{4I} \in (\frac{1}{4}, \frac{1}{3})$, *and the firm invests (and trade breaks down) if and only if the seller's signal* $s_\omega > \frac{1}{4} + \frac{\Delta}{4I}$.

3. *In all other cases, the firm chooses* $\gamma^* = 1$, *trade always occurs, and the firm never invests. The seller chooses* $e_a^* = 0$ *and* $e_\omega^* = \min\left\{\frac{1}{2}, \frac{\Delta}{6I}\right\}$ *if* $\Delta > \frac{1}{3}I$ *and* $\min\left\{\gamma A, \frac{1}{2}\Delta\right\} \leq \min\left\{I, \frac{1}{3}\Delta\right\}$; *otherwise, she chooses* $e_a^* = \min\left\{\frac{1}{2}, \frac{\Delta}{4A}\right\}$ *and* $e_\omega^* = 0$.

Outcomes 1, 2, and 3 correspond to the dotted, lined, and non-shaded regions, respectively, in Figure 2.

4 Welfare Analysis and Policy Implications

We now evaluate utilitarian welfare and identify policy implications of our analysis. In Section 4.1, we characterize utilitarian welfare for the three equilibrium regions defined in Proposition 1. We then examine how regulatory policies may improve welfare in Section 4.2.

4.1 Welfare

We compute utilitarian welfare, denoted by W, corresponding to the three possible equilibrium outcomes summarized in Proposition 1. Under the set of conditions that leads to the first equilibrium outcome in Proposition 1 (dotted region in Figure 2), the firm produces at full scale and the seller develops expertise about the investment opportunity. Hence, the expected value of the firm's assets-in-place is A. Trade breaks down and the firm invests if and only if the seller's signal $s_\omega > \frac{1}{4} + \frac{\Delta}{4I}$; the corresponding investment surplus is $\pi_\omega I - (1-\pi_\omega)I = (2s_\omega - 1)I$.[19] Accordingly, the trade surplus Δ is realized if and only if

[19]Note that $\mu_\omega = \frac{1}{2} + e_\omega = 1$ (because $e_\omega = \frac{1}{2}$ in this region). Substituting this expression into (4) yields $\pi_\omega = s_\omega$.

$s_\omega \leq \frac{1}{4} + \frac{\Delta}{4I}$. Thus, utilitarian welfare in this case is

$$W = A + \int_{\frac{1}{4}+\frac{\Delta}{4I}}^{1} (2s_\omega - 1)I \, \mathrm{d}s_\omega + \int_{0}^{\frac{1}{4}+\frac{\Delta}{4I}} \Delta \, \mathrm{d}s_\omega = A + \frac{3(\Delta + I)^2}{16I}. \tag{20}$$

When the parameters are such that the second equilibrium outcome in Proposition 1 (lined region in Figure 2) emerges, the firm scales back production from assets-in-place to induce the seller to develop expertise about the investment opportunity, resulting in an expected value of $\frac{(\Delta+I)^2}{16I}$ for assets-in-place. Similar to the first outcome, the firm invests if and only if $s_\omega > \frac{1}{4} + \frac{\Delta}{4I}$, but Δ is realized if and only if $s_\omega \leq \frac{1}{4} + \frac{\Delta}{4I}$. Hence,

$$W = \frac{(\Delta + I)^2}{16I} + \int_{\frac{1}{4}+\frac{\Delta}{4I}}^{1} (2s_\omega - 1)I \, \mathrm{d}s_\omega + \int_{0}^{\frac{1}{4}+\frac{\Delta}{4I}} \Delta \, \mathrm{d}s_\omega = \frac{(\Delta + I)^2}{4I}. \tag{21}$$

Under the set of parameter values that lead to the third equilibrium outcome in Proposition 1 (corresponding to the non-shaded region in Figure 2), the firm produces at full scale and trade always occurs. Consequently, Δ is always realized, but the firm never invests. Therefore,

$$W = A + \Delta. \tag{22}$$

Scope for policy intervention. The analysis above shows that the level of utilitarian welfare depends on the agents' actions. Because the agents aim to maximize their own expected payoffs rather than utilitarian welfare, they may take socially suboptimal actions under certain conditions that we describe in greater detail below in Section 4.2. Hence, there are potential opportunities for policy intervention.

For instance, in the lined region in Figure 2, the firm scales back production from assets-in-place to induce the seller to acquire information about the investment opportunity ω. However, for the trading outcome to be informative about ω, trade must occasionally break down, in which case the buyer's private gain to trade Δ fails to materialize. Because the firm is indifferent as to whether Δ materializes, the firm's choice of production scale may lead to greater (probabilistic) trade disruption that is socially optimal.

Additionally, in the non-shaded region in Figure 2, the investment surplus never materializes because the firm learns nothing about its investment opportunity from the trading outcome. In the portion of this region wherein $\Delta < \frac{1}{3}I$, the seller develops expertise about assets-in-place V_a (Theorem 3); however, if the seller were instead to develop expertise about ω (as she does in the dotted region), then the resulting utilitarian welfare would be given by 20 rather than (22) and would be strictly greater than the level of welfare currently achieved in equilibrium. Thus, the seller develops expertise about ω under a smaller set of conditions than is socially optimal and, hence, underinvests in the generation of socially valuable knowledge.

4.2 Welfare Improvements: Role of Regulatory Policy

The previous section shows that the agents' privately optimal choices may be socially inefficient. In this section, we consider two possible policy responses: (i) a production policy that directly addresses the firm's inefficient choice of production scale in Section 4.2.1; and (ii) a policy that targets the the magnitude of the private gain to trade Δ and, thereby, indirectly influences both the seller's inefficient choice of expertise and the firm's inefficient choice of production scale in Section 4.2.2. We then compare the effectiveness of the policies in Section 4.2.3. To facilitate the analysis, we introduce a social planner whose objective is to maximize utilitarian welfare. For simplicity, we assume that the social planner does not enact any policies that do not strictly increase welfare.

4.2.1 Socially Efficient Production

According to Theorem 4, the firm lowers its production scale γ (from 1 to $\frac{(\Delta+I)^2}{16AI} < 1$) to induce the seller to develop expertise about the investment opportunity when $\max\{(3 - 2\sqrt{2})I, 4A - I\} < \Delta < \min\left\{4\sqrt{AI} - I, \frac{1}{3}I\right\}$ (lined region in Figure 2). Although this enables the firm to make a better investment decision, as discussed above, it sacrifices some production from assets-in-place. In this section, we evaluate how policies that influence production may improve welfare. Our analysis takes a reduced-form approach by assuming that the social planner can directly mandate the firm's choice of γ. In practice, this could be implemented by policies that, for example, subsidize or tax production inputs or outputs.

The social planner's objective is to choose γ to maximize utilitarian welfare, taking as given the traders' strategies (as characterized by Lemmas 1 - 4) but understanding how the choice of γ affects the type and level of financial expertise developed by the seller, the trading outcome, and the firm's investment decision. Specifically, the social planner's objective is

$$\max_{\gamma} \ \Pr[\Phi_i(1) \leq P_i](\gamma A + \Delta) + \Pr[\Phi_i(1) > P_i]\tfrac{1}{2}(P_i + \gamma A + I), \tag{23}$$

where $P_i = \gamma A + \frac{1}{2}(\Delta - I)$. The social planner's problem in (23) is similar to the firm's problem in (18), except that the social planner takes into account the private trade surplus Δ (first term in (23), $\Pr[\Phi_i(1) \leq P_i](\gamma A + \Delta)$) whereas the firm does not (first term in (18), $\Pr[\Phi_i(1) \leq P_i]\gamma A$). This important difference leads to a divergence between the socially efficient production policy and the firm's privately optimal production decision. The socially efficient production scale $\hat{\gamma}$ is characterized by the following theorem.

Theorem 5 (Socially efficient production policy)**.** *The socially efficient scale of production from assets-in-place is*

$$\hat{\gamma} = \frac{(\Delta + I)^2}{16AI} < 1 \tag{24}$$

if $(3 - 2\sqrt{2})I < \Delta < \min\left\{\frac{1}{3}I, I - 2\sqrt{AI}, 4\sqrt{AI} - I\right\}$*; otherwise,* $\hat{\gamma} = 1$*.*

The socially efficient production scale $\hat{\gamma}$ (as given by (24)) is identical to the firm's optimal scale γ^* (as given by (19)), as this is the largest scale that induces the seller to develop expertise about the firm's investment opportunity (instead of assets-in-place). Therefore, *conditional on it being socially optimal to scale back production*, the firm's choice of production scale is also socially efficient. Importantly, however, the social planner scales back production *under a narrower set of conditions* than the firm does. This is because scaling back production (hence,

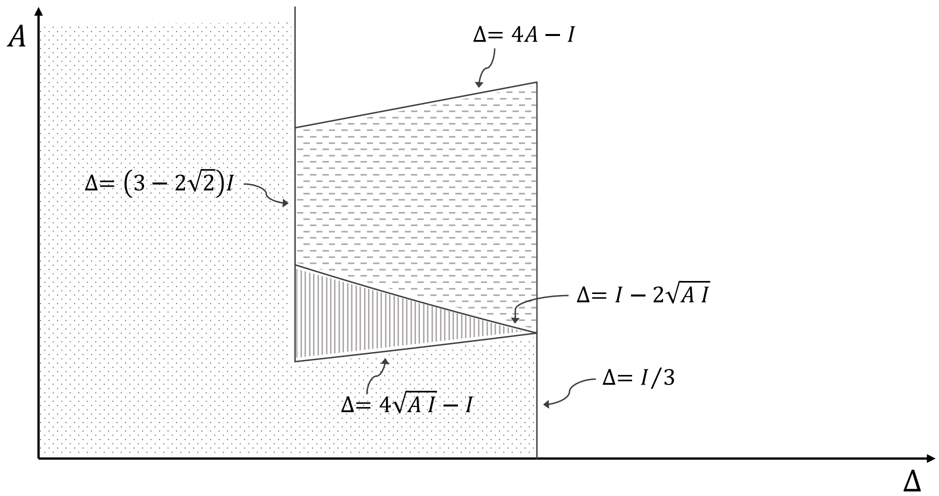

Figure 3: *Socially Efficient Production Policy.* In the dotted region, the firm produces at full scale ($\gamma^* = 1$), the seller develops expertise about the investment opportunity ($e_a^* = 0$, $e_\omega^* = \frac{1}{2}$), trade may break down, and the firm may invest. In the lined region, the firm scales back production from assets-in-place to $\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$ to induce the seller to develop expertise about the investment opportunity, trade may break down, and the firm may invest. In the dashed region, the social planner intervenes so that the firm produces at full scale ($\hat{\gamma} = 1$) instead of at the privately optimal scale ($\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$), the seller develops expertise about assets-in-place, trade always occurs, and the firm never invests. In the non-shaded region, the firm produces at full scale, the seller may develop expertise about either the investment opportunity or assets-in-place (depending on parameters), trade always occurs, and the firm never invests.

encouraging the seller to develop expertise about the investment opportunity) increases the likelihood of trade collapsing and, consequently, the private gain to trade Δ not materializing. Unlike the firm, the social planner takes into account the loss of Δ when trade breaks down and, thus, is less willing to scale back production. This difference is captured by the following corollary and graphically illustrated in Figure 3.

Corollary 1. *The firm scales back production from assets-in-place under a larger set of conditions than is socially optimal.*

Theorems 4 and 5 indicate that the firm, but not the social planner, chooses to scale back production from assets-in-place when $\frac{(\Delta-I)^2}{4I} < A < \frac{1}{4}(\Delta + I)$ and $(3 - 2\sqrt{2})I < \Delta < \frac{1}{3}I$. These two conditions define the dashed region in Figure 3.[20] Within this region, the social

[20]The first condition determines the region's lower boundary $\Delta > I - 2\sqrt{AI}$ and upper boundary $\Delta > 4A - I$. Note that $\frac{(\Delta+I)^2}{16I} < \frac{(\Delta-I)^2}{4I} < \frac{1}{4}(\Delta + I)$ holds given $\Delta < \frac{I}{3}$ ($\frac{(\Delta+I)^2}{16I} < \frac{(\Delta-I)^2}{4I}$ ensures that the lined region is

planner can intervene to raise utilitarian welfare by encouraging the firm to produce at full scale ($\hat{\gamma} = 1$) instead of at the privately optimal reduced scale ($\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$). In the lined region, the lower production scale chosen by the firm, $\gamma^* = \frac{(\Delta+I)^2}{16AI}$, is also socially optimal, so the planner need not intervene. The social planner intervenes in the dashed region but not in the lined region for the following reason. For a given A, which is proportional to the size of assets-in-place, the private gain to trade Δ is bigger in the dashed region than in the lined region. Thus, scaling back production has a higher social cost in the dashed region because it creates the potential for trade to collapse and, hence, Δ to not materialize (which is taken into account by the planner but not by the firm).

4.2.2 Socially Efficient Private Gains to Trade

The magnitude of the private gain to trade Δ affects utilitarian welfare in three distinct ways. First, the size of Δ directly affects welfare because Δ is a source of value for the buyer. Hence, conditional on trade occurring, a smaller Δ, *ceteris paribus*, results in lower welfare.

Second, the magnitude of Δ indirectly affects welfare by influencing the seller's choice of expertise. Recall, there are two potential sources of gains to trade: the buyer's private gain to trade Δ and the investment surplus arising from the seller's expertise about the firm's investment opportunity ω. When the seller develops expertise about the firm's assets-in-place V_a, her payoff is derived solely from appropriating a portion of Δ from the buyer in a zero-sum game. Conversely, when she develops expertise about ω, her payoff is derived from both her share of the investment surplus created and the portion of Δ that she extracts from the buyer in a positive-sum game. Because the size of Δ affects the seller's marginal rate of substitution between developing expertise about V_a versus ω, altering the magnitude of Δ may affect utilitarian welfare by altering the seller's choice of expertise. In particular, reducing Δ under appropriate conditions can raise utilitarian welfare if doing so incentivizes the seller to develop expertise about ω rather than V_a and, thereby, increases the aggregate trade surplus.

well defined, and $\frac{(\Delta-I)^2}{4I} < \frac{1}{4}(\Delta + I)$ ensures that the dashed region is well defined). The second condition determines the left and right boundaries.

The third way in which the size of Δ affects welfare is via its influence over the firm's production strategy. The analysis in previous sections shows that the firm may reduce its production scale to induce the seller to develop expertise about ω (Theorem 4). However, the firm scales back too often because it does not internalize the potential loss of the private gain to trade Δ (Corollary 1). To the extent that reducing Δ can induce the seller to develop expertise about ω, it may (under certain conditions) dissuade the firm from inefficiently scaling back production and, thereby, improve welfare. That is, the social planner's reduction of Δ and the firm's lowering of its production scale may act as substitutes for incentivizing the seller to develop expertise about ω.

In the remainder of this section, we investigate how policies targeting Δ may increase welfare. We adopt a reduced-form approach by assuming that the social planner can scale down Δ by a factor of $\alpha \in (0, 1]$ so that the buyer's private gain to trade reduces to $\widehat{\Delta} = \alpha\Delta$.[21] We permit the social planner to reduce but not enhance private gains to trade for two reasons. First, reducing private gains to trade is likely easier to implement in practice, for example, by imposing a Tobin tax or other type of transaction cost on bilateral financial transactions. Second, it offers a sharper contrast to Glode et al. (2012). In their model, financial expertise may be socially destructive because too much of it may disrupt trade and, hence, destroy private gains to trade. Based on this logic, they argue that one way to model the social value of expertise is to allow financial expertise to enhance private gains to trade. In contrast, the social value of financial expertise in our model arises from the feedback loop between trade and investment, and we show, perhaps surprisingly, that *utilitarian welfare may be improved by deliberately destroying private gains to trade.*

The social planner's objective is to choose the size of the private gain to trade $\widehat{\Delta} = \alpha\Delta$ to maximize utilitarian welfare,

$$\max_{\alpha} \ \Pr[\Phi_i(1) \leq P_i](\gamma A + \alpha\Delta) + \Pr[\Phi_i(1) > P_i]\tfrac{1}{2}(P_i + \gamma A + I), \tag{25}$$

[21] All results obtained heretofore continue to hold if Δ is replaced with $\widehat{\Delta}$.

subject to the firm's choice of production scale γ (Theorem 4) and the traders' strategies (Lemmas 1 - 4). The expression for utilitarian welfare that the social planner maximizes is the same as that given by (23), except that Δ is replaced with $\alpha\Delta$.

As stated above, there are two ways by which reducing Δ can improve welfare. First, it can induce the seller to develop expertise about the investment opportunity, which creates social value, instead of developing expertise about assets-in-place, which simply generates foreknowledge. Second, by strengthening the seller's incentive to acquire information about ω, which the firm wants to learn, it may prevent the firm from inefficiently scaling back production from its assets-in-place (Corollary 1; Figure 3). In choosing α, the social planner must balance these potential (indirect) benefits against the (direct) welfare loss associated with reducing the private gain to trade Δ. The following theorem characterizes the social planner's optimal policy.

Theorem 6 (Socially efficient private gains to trade)**.** *The social planner's policy regarding private gains to trade is as follows.*

1. *If either* $(3-2\sqrt{2})I < \Delta < \min\left\{\frac{3}{2}(3-2\sqrt{2})I, \sqrt{4I(A+\frac{3}{2}(3-2\sqrt{2})I)}-I\right\}$ *or both* $A < \frac{1}{8}(11-6\sqrt{2})I$ *and* $(3-2\sqrt{2})I \leq \Delta < \min\left\{\frac{I}{3}, \sqrt{4I(A+\frac{3}{2}(3-2\sqrt{2})I)}-I\right\}$*, then the socially efficient factor by which to scale the private gain to trade is*

$$\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta} < 1. \tag{26}$$

2. *If* $4A - I < \Delta < \frac{I}{3}$ *and* $A \geq \frac{1}{8}(11-6\sqrt{2})I$*, then the socially efficient factor by which to scale the private gain to trade is*

$$\hat{\alpha} = \frac{4A-I}{\Delta} < 1. \tag{27}$$

3. *In all other cases,* $\hat{\alpha} = 1$*.*

Figure 4 depicts the optimal social policy regarding private gains to trade and the corresponding equilibrium outcomes. The lighter and darker shaded regions correspond to cases 1 and 2, respectively, in Theorem 6 wherein the social planner reduces Δ. The lighter shaded region can be divided into two subregions (by the vertical dashed line): a leftward subregion where $\Delta < \frac{3}{2}(3-2\sqrt{2})I$ and a rightward subregion where $\Delta \geq \frac{3}{2}(3-2\sqrt{2})I$. In both subregions, the social planner scales down the private gain to trade by a factor of $\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta}$, but the reason differs in the two subregions. In the leftward subregion where Δ is relatively small, the planner scales down the private gain to trade to induce the seller to develop expertise about the investment opportunity ω because the resulting increase in investment efficiency outweighs the reduction in the private gain to trade. In the rightward subregion where Δ is larger, however, the social cost of reducing the private gain to trade outweighs the increase in investment efficiency that would result from the seller developing expertise about ω. Nevertheless, because the firm scales back production in this subregion (to induce the seller to develop expertise about ω) even though doing so is socially suboptimal, the planner may still improve utilitarian welfare by reducing the private gain to trade because doing so prevents the firm from suboptimally scaling back production.

Strikingly, in the darker shaded region where the size of assets-in-place is relatively large, the planner scales down Δ by a factor of $\hat{\alpha} = \frac{4A-I}{\Delta} > \frac{(3-2\sqrt{2})I}{\Delta}$ simply to deter the firm from scaling back production. Scaling down Δ by a factor of $\hat{\alpha} = \frac{4A-I}{\Delta}$ is insufficient to induce the seller to develop expertise about ω, but it is sufficient to prevent the firm from lowering its production scale because the firm must scale back production to a greater extent, which is costlier, to induce the seller to develop expertise about ω when Δ is smaller (Theorem 4). Although reducing Δ within this region prevents the firm from inefficiently lowering its production scale, it also incentivizes the seller to develop expertise about V_a rather than ω. Hence, the reduction of the private gain to trade in this region is purely a deadweight cost incurred to prevent the firm from making a socially suboptimal production decision. By contrast, in the rightward lighter shaded region (just below the darker shaded region) where the size of assets-in-place is smaller than in the darker shaded region, the planner must reduce Δ to a greater extent (because $\hat{\alpha} = \frac{4A-I}{\Delta}$ is increasing in A) to deter the firm from scaling

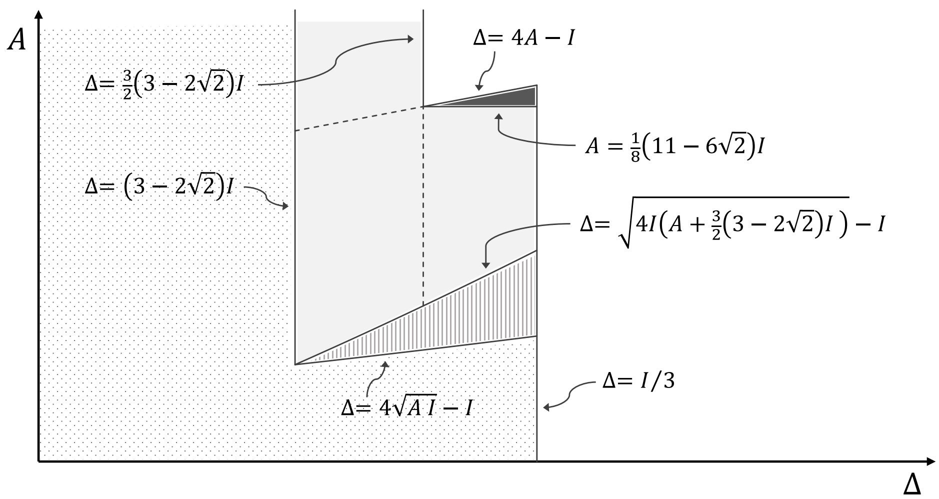

Figure 4: *Socially Efficient Private Gains to Trade.* In the dotted region, the social planner does not reduce the private gain to trade ($\hat{\alpha} = 1$), the firm produces at full scale ($\gamma^* = 1$), the seller develops expertise about the investment opportunity ($e_a^* = 0$, $e_\omega^* = \frac{1}{2}$), trade may break down, and the firm may invest. In the lined region, the social planner does not reduce the private gain to trade, the firm scales back production from assets-in-place to $\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$ to induce the seller to develop expertise about the investment opportunity, trade may break down, and the firm may invest. In the lighter shaded region, the social planner scales down the private gain to trade by a factor of $\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta} < 1$, the firm produces at full scale, the seller develops expertise about the investment opportunity, trade may break down, and the firm may invest. In the darker shaded region, the social planner scales down the private gain to trade by a factor of $\hat{\alpha} = \frac{4A-I}{\Delta} < 1$ to dissuade the firm from scaling back production, the firm produces at full scale, the seller develops expertise about assets-in-place, trade always occurs, and the firm never invests. In the non-shaded region, the social planner does not reduce the private gain to trade, the firm produces at full scale, the seller may develop expertise about either the investment opportunity or assets-in-place (depending on parameters), trade always occurs, and the firm never invests.

back production. Conditional on reducing Δ to such a level (i.e., the "diagonal" dashed line in the leftward lighter shaded region), it becomes optimal for the planner to further reduce Δ by a factor of $\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta}$ to induce the seller to develop expertise about ω because the benefit arising from greater investment efficiency outweighs the cost of further reducing the private gain to trade once Δ has already been partially reduced.

The dotted, lined, and non-shaded regions correspond to case 3 in Theorem 6 wherein the social planner does not reduce Δ. In the dotted region, the seller develops expertise about the investment opportunity and the firm produces at full scale regardless of the magnitude of Δ. Consequently, there is no role for regulation. In the lined region, the private gain to trade Δ is large relative to the size of assets-in-place A. Although reducing Δ in this region would incentivize the seller to develop expertise about the investment opportunity ω, the social planner does not intervene because the social cost of reducing the private gain to trade is greater than the cost of scaling back production from assets-in-place. Therefore, rather than reducing Δ, the planner allows the firm to scale back production to induce the seller to develop expertise about ω. The social planner also refrains from intervening in the non-shaded region where Δ is large because reducing Δ in that region would be too costly relative to the potential gain in investment efficiency.

4.2.3 Policy Comparison

As described in Sections 4.2.1 and 4.2.2, utilitarian welfare may be improved by policies targeting firm production and private gains to trade. In this section, we compare the effectiveness of the two types of policies and describe the conditions under which the social planner elects to intervene and implement one of the two regulatory polices.

Theorems 5 and 6 indicate that, under a wide range of parametric conditions, the two types of policies are (imperfect) substitutes. Graphically, a comparison of Figures 3 and 4 shows that a large fraction of the dashed region in Figure 3 where the social planner intervenes by directly dissuading the firm from scaling back production overlaps a big portion of the shaded region where the planner intervenes by reducing the private gain to trade. Within this overlapping region, the social planner selects the policy tool that results in greater utilitarian welfare. Outside of this overlapping region, the two types of policies are complementary because at most only a single type of policy may improve welfare. The following proposition describes the optimal regulatory policy.

Proposition 2 (Optimal policy). *The social planner's optimal intervention policy is as follows.*

1. *If* $(3-2\sqrt{2})I < \Delta < \min\left\{\frac{3}{2}(3-2\sqrt{2})I, \sqrt{4I(A+\frac{3}{2}(3-2\sqrt{2})I)} - I\right\}$*, then the socially optimal regulatory policy is to scale the private gain to trade by a factor of* $\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta}$.

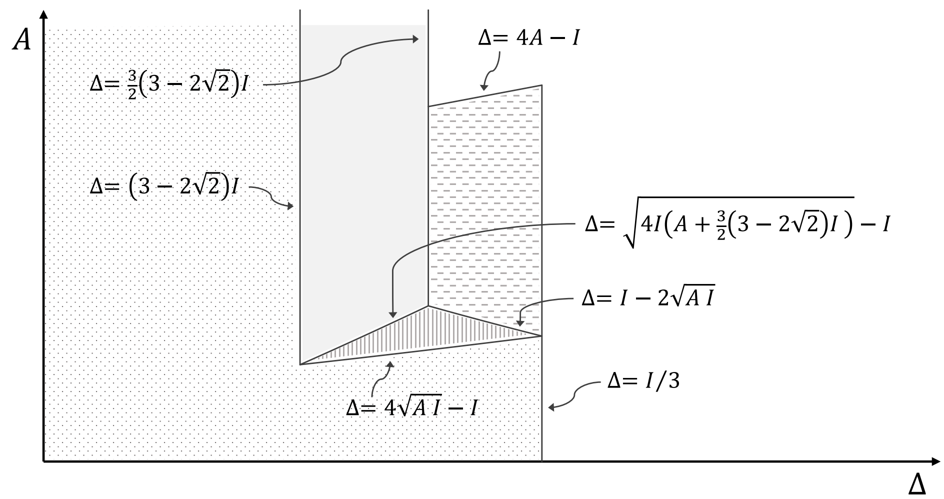

Figure 5: *Optimal Regulatory Policy.* In the dotted region, the social planner takes no action, the firm produces at full scale ($\gamma^* = 1$), the seller develops expertise about the investment opportunity ($e_a^* = 0$, $e_\omega^* = \frac{1}{2}$), trade may break down, and the firm may invest. In the lined region, the social planner takes no action, the firm scales back production from assets-in-place to $\gamma^* = \frac{(\Delta+I)^2}{16AI} < 1$ to induce the seller to develop expertise about the investment opportunity, trade may break down, and the firm may invest. In the dashed region, the social planner intervenes so that the firm produces at full scale ($\hat{\gamma} = 1$), the seller develops expertise about assets-in-place, trade always occurs, and the firm never invests. In the shaded region, the social planner scales down the private gain to trade by a factor of $\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta} < 1$, the firm produces at full scale, the seller develops expertise about the investment opportunity, trade may break down, and the firm may invest. In the non-shaded region, the social planner takes no action, the firm produces at full scale, the seller may develop expertise about either the investment opportunity or assets-in-place (depending on parameters), trade always occurs, and the firm never invests.

2. *If* $\max\left\{\frac{3}{2}(3-2\sqrt{2})I, 4A - I, I - 2\sqrt{AI}\right\} \leq \Delta < \frac{I}{3}$*, then the socially optimal regulatory policy is to scale production from assets-in-place by a factor of* $\hat{\gamma} = 1$*.*

3. *In all other cases, the socially optimal policy is to abstain from regulation.*

Figure 5 depicts the optimal regulatory policy and corresponding equilibrium outcomes. Like in Figures 3 and 4, the dotted, lined, and non-shaded regions indicate non-intervention by the planner, whereas the dashed and shaded regions signify policies targeting production and private gains to trade, respectively. When Δ is relatively small (i.e., $(3-2\sqrt{2})I \leq \Delta < \frac{3}{2}(3-2\sqrt{2})I$; shaded region), the planner opts to regulate private gains to trade because the cost of reducing Δ is small relative to the gain arising from improved investment efficiency. When Δ is larger (i.e., $\frac{3}{2}(3-2\sqrt{2})I \leq \Delta < \frac{I}{3}$; dashed region), however, reducing the private gain to trade is more costly and, as discussed in Section 4.2.2, the reason the planner would potentially reduce Δ in this region is merely to dissuade the firm from scaling back production. Because this objective can be achieved at a lower cost simply by implementing policies that directly target the firm's production scale, the planner elects to regulate production.

5 Concluding Remarks

We study how an informational feedback loop between bilateral security trading and firm investment endogenously affects information production. We distinguish between two types of information: foreknowledge information that merely strengthens the bargaining power of the information holder and socially useful information that can create value. In contrast with much of the extant literature, which generally concludes that the acquisition of foreknowledge information is detrimental to welfare because it creates adverse selection and can, therefore, impede efficient trade, we show that trade must occasionally break down for socially valuable information to be effectively communicated through the feedback loop and, thus, be utilized to create value. Because trade disruption destroys private gains to trade, though, traders may refrain from acquiring socially valuable information to prevent trade from breaking down. We evaluate various welfare-enhancing policies to encourage the acquisition of socially valuable information.

Our analysis offers a novel explanation for the empirical regularity, documented by Safieddine and Titman (1999), that failed corporate takeover attempts induce target management to improve operating performance by substantially increasing leverage. The traditional explanation (offered by Safieddine and Titman (1999) and others) is that the disciplinary role of debt commits target management to make improvements that would have been made by a potential acquirer. However, Malmendier et al. (2016) find that unsuccessful takeover bids often result in a substantial positive revaluation of the target firm because the bidder's offer reveals information about the target's stand-alone value that is *a priori* unknown to the market.[22] Together with this result, our theory provides an alternative explanation for the empirical regularity documented by Safieddine and Titman (1999): the fact that a target firm increases debt financing after a proposed takeover transaction breaks down could be due to the relaxation of financing constraints, made possible by the market's positive revaluation of the target based on information gleaned from the failed takeover attempt.

Our analysis also has implications for the efficient design of securities. The security design literature generally examines how the design of securities affects their liquidity under asymmetric information (Boot and Thakor, 1993; DeMarzo and Duffie, 1999; Biais and Mariotti, 2005). Although we do not formally model security design, our analysis suggests that tailoring payoff structures to be more sensitive to socially valuable information may induce traders to acquire such information and, consequently, improve welfare. Within the context of our model, this could be achieved by, for example, creating an additional security whose payoff depends entirely on V_i (growth option) but is independent of V_a (assets-in-place). The basic idea is as follows. Because the payoff of the security being traded in our model depends on $V = V_a + V_i$, the seller may not be able to generate a sufficient information advantage over the buyer if she develops expertise about V_i when the uncertainty about V_a is sufficiently high. The reason is that any information advantage regarding V_i is diluted by the absence of an information advantage about V_a. As a result, the seller may lack an incentive to acquire socially valuable information (about V_i). In contrast, if the security whose payoff depends solely on V_i is separately traded, then the dilution of her information advantage is prevented and, consequently, the seller's incentive to acquire information about V_i is maximized.

In practice, customizing asset payoffs to incentivize the acquisition of socially valuable information may require the creation of complex assets. In our model, for instance, the security payoff can be represented by the identity function $G(V) = V$. However, a new derivative on the existing security conceivably could be created to generate a different payoff $\widehat{G}(V) = V_i$. Provided that the original security cannot be directly split into two separate securities whose

[22] Their examination of unsuccessful takeover bids during 1980-2008 reveals that targets receiving cash offers are revalued on average by +15% after the transaction breaks down.

payoffs depend entirely on either V_a or V_i, the derivative security's design $\widehat{G}(\cdot)$ would likely need to be more complex than the original security's design $G(\cdot)$. Hence, our analysis implies that asset complexity might be socially valuable under certain circumstances. This implication differs from existing studies, which generally conclude that complexity is socially detrimental (Bernardo and Cornell, 1997; Arora et al., 2012; Carlin et al., 2013; Furfine, 2014). We leave a thorough investigation of this security design issue to future research.

References

Akerlof, G. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *Quarterly Journal of Economics 84*(3), 488–500.

Arora, S., B. Barak, M. Brunnermeier, and R. Ge (2012). Computational complexity and information asymmetry in financial products. *Princeton University, Working Paper*.

Bernardo, A. E. and B. Cornell (1997). The valuation of complex derivatives by major investment firms: Empirical evidence. *Journal of Finance 52*(2), 785–798.

Beyer, A., D. A. Cohen, T. Z. Lys, and B. R. Walther (2010). The financial reporting environment: Review of the recent literature. *Journal of Accounting and Economics 50*(2-3), 296–343.

Biais, B., T. Foucault, and S. Moinas (2015). Equilibrium fast trading. *Journal of Financial Economics 116*(2), 292–313.

Biais, B. and T. Mariotti (2005). Strategic liquidity supply and security design. *Review of Economic Studies 72*(3), 615–649.

Bolton, P., T. Santos, and J. A. Scheinkman (2016). Cream-skimming in financial markets. *Journal of Finance 71*(2), 709–736.

Bond, P., A. Edmans, and I. Goldstein (2012). The real effects of financial markets. *Annual Review of Financial Economics 4*(1), 339–360.

Bond, P. and H. Eraslan (2010). Information-based trade. *Journal of Economic Theory 145*(5), 1675–1703.

Bond, P. and I. Goldstein (2015). Government intervention and information aggregation by prices. *Journal of Finance 70*(6), 2777–2812.

Bond, P., I. Goldstein, and E. S. Prescott (2010). Market-based corrective actions. *Review of Financial Studies 23*(2), 781–820.

Boot, A. W. A. and A. V. Thakor (1993). Security design. *Journal of Finance 48*(4), 1349–1378.

Bresnahan, T. F., P. Milgrom, and J. Paul (1992). The real output of the stock exchange. In Z. Griliches (Ed.), *Output Measurement in the Service Sectors*, pp. 195–216. University of Chicago Press.

Cahan, S. F., J. M. Godfrey, J. Hamilton, and D. C. Jeter (2008). Auditor specialization, auditor dominance, and audit fees: The role of investment opportunities. *Accounting Review 83*(6), 1393–1423.

Camargo, B., K. Kim, and B. Lester (2016). Information spillovers, gains from trade, and interventions in frozen markets. *Review of Financial Studies 29*(5), 1291–1329.

Carey, M., M. Post, and S. A. Sharpe (1998). Does corporate lending by banks and finance companies differ? evidence on specialization in private debt contracting. *Journal of Finance 53*(3), 845–878.

Carlin, B. I., S. Kogan, and R. Lowery (2013). Trading complex assets. *Journal of Finance 68*(5), 1937–1960.

Chen, Q., I. Goldstein, and W. Jiang (2007). Price informativeness and investment sensitivity to stock price. *Review of Financial Studies 20*(3), 619–650.

Dang, T. V. (2008). Bargaining with endogenous information. *Journal of Economic Theory 140*(1), 339–354.

DeMarzo, P. and D. Duffie (1999). A liquidity-based model of security design. *Econometrica 67*(1), 65–99.

Dow, J., I. Goldstein, and A. Guembel (2017). Incentives for information production in markets where prices affect real investment. *Journal of the European Economic Association 15*(4), 877–909.

Dow, J. and G. Gorton (1997). Stock market efficiency and economic efficiency: Is there a connection? *Journal of Finance 52*(3), 1087–1129.

Fishman, M. J. and J. A. Parker (2015). Valuation, adverse selection, and market collapses. *Review of Financial Studies 28*(9), 2575–2607.

Furfine, C. H. (2014). Complexity and loan performance: Evidence from the securitization of commercial mortgages. *Review of Corporate Finance Studies 2*(2), 154–187.

Glode, V., R. C. Green, and R. Lowery (2012). Financial expertise as an arms race. *Journal of Finance 67*(5), 1723–1759.

Glode, V. and R. Lowery (2016). Compensating financial experts. *Journal of Finance 71*(6), 2781–2808.

Goldstein, I. and A. Guembel (2008). Manipulation and the allocational role of prices. *Review of Economic Studies 75*(1), 133–164.

Goldstein, I., E. Ozdenoren, and K. Yuan (2013). Trading frenzies and their impact on real investment. *Journal of Financial Economics 109*(2), 566–582.

Hirshleifer, J. (1971). The private and social value of information and the reward to inventive activity. *American Economic Review 61*(4), 561–574.

Luo, Y. (2005). Do insiders learn from outsiders? evidence from mergers and acquisitions. *Journal of Finance 60*(4), 1951–1982.

Malmendier, U., M. M. Opp, and F. Saidi (2016). Target revaluation after failed takeover attempts: Cash versus stock. *Journal of Financial Economics 119*(1), 92–106.

Paul, J. M. (1992). On the efficiency of stock-based compensation. *Review of Financial Studies 5*(3), 471–502.

Safieddine, A. and S. Titman (1999). Leverage and corporate performance: Evidence from unsuccessful takeovers. *Journal of Finance 54*(2), 547–580.

Samuelson, W. (1984). Bargaining under asymmetric information. *Econometrica 52*(4), 995–1005.

Schultz, P. (2003). Who makes markets. *Journal of Financial Markets 6*(1), 49–72.

Shavell, S. (1994). Acquisition and disclosure of information prior to sale. *RAND Journal of Economics*, 20–36.

Appendix A: Proofs

Proof of Lemma 1. Substituting $\Pr[\Phi_a \leq P_a] = \frac{1}{2} + \frac{P_a - \gamma A}{2\Omega_a}$ into (7) allows the buyer's problem to be rewritten as

$$\max_{P_a} \; y_a \equiv \left(\tfrac{1}{2} + \tfrac{P_a - \gamma A}{2\Omega_a}\right)\left[\tfrac{1}{2}(P_a + \gamma A - \Omega_a) + \Delta - P_a\right]. \tag{A1}$$

Note that $P_a \in [\gamma A - \Omega_a, \gamma A + \Omega_a]$ because the buyer will never offer more than $\gamma A + \Omega_a$ or less than $\gamma A - \Omega_a$. Additionally, $\frac{\partial y_a}{\partial P_a} = \frac{\Delta - P_a + \gamma A - \Omega_a}{2\Omega_a}$ and $\frac{\partial^2 y_a}{\partial P_a^2} = -\frac{1}{2\Omega_a} < 0$, so (A1) is a concave problem. Because $\frac{\partial y_a}{\partial P_a}|_{P_a = \gamma A - \Omega_a} = \frac{\Delta}{2\Omega_a} > 0$, the optimal solution is either at the boundary $P_a = \gamma A + \Omega_a$ or some interior given by the first-order condition $P_a = \Delta + \gamma A - \Omega_a$. The former is the solution if and only if $\frac{\partial y_a}{\partial P_a}|_{P_a = \gamma A + \Omega_a} = \frac{\Delta - 2\Omega_a}{2\Omega_a} \geq 0$, i.e., $\Delta \geq 2\Omega_a$. □

Proof of Lemma 2. There are two cases to consider, depending on the relation between Δ and Ω_a. First, suppose $\Delta \leq 2\Omega_a$, so $P_a = \Delta + \gamma A - \Omega_a$ (Lemma 1; note that $\Delta + \gamma A - \Omega_a = \gamma A + \Omega_a$ when $\Delta = 2\Omega_a$). The seller's objective function (9) can be rewritten as $\gamma A + \frac{\Delta^2}{8 e_a \gamma A}$, which is decreasing in e_a. Thus, the seller chooses the smallest e_a such that $\Delta \leq 2\Omega_a = 4 e_a \gamma A \leq 2\gamma A$, or $e_a = \frac{\Delta}{4\gamma A}$. Second, suppose $\Delta \geq 2\Omega_a$, so $P_a = \gamma A + \Omega_a$ (Lemma 1). The seller's objective function (9) can be rewritten as $\gamma A + 2 e_a \gamma A$, which is increasing in e_a. Hence, the seller chooses the largest e_a such that $\Delta \geq 2\Omega_a = 4 e_a \gamma A$, or $e_a = \frac{\Delta}{4\gamma A}$, provided that $\Delta < 2\gamma A$ because e_a cannot exceed $\frac{1}{2}$; if $\Delta \geq 2\gamma A$, then $e_a = \frac{1}{2}$. □

Proof of Theorem 1. If $\frac{\Delta}{\gamma A} < 2$ (resp. $\frac{\Delta}{\gamma A} \geq 2$), then $\Omega_a = 2 e_a \gamma A = \frac{\Delta}{2}$ (resp. $\Omega_a = \gamma A$), so the buyer offers $P_a = \gamma A + \frac{\Delta}{2}$ (resp. $P_a = 2\gamma A$) according to Lemma 1. This is the seller's highest possible valuation given her expertise e_a. Therefore, the seller always accepts the offer, and the trade surplus Δ is always preserved. The firm does not invest given that the seller has no expertise about ω. □

Proof of Lemma 3. Substituting $\Pr[\Phi_i(1) \leq P_i] = \frac{1}{2} + \frac{P_i - \gamma A}{2\Omega_i}$ into (12) allows the buyer's problem to be rewritten as

$$\max_{P_i}\ y_i \equiv \left(\tfrac{1}{2} + \tfrac{P_i - \gamma A}{2\Omega_i}\right)(\gamma A + \Delta - P_i). \tag{A2}$$

Note that $P_i \in [\gamma A - \Omega_i, \gamma A + \Omega_i]$ because the buyer will never offer more than $\gamma A + \Omega_i$ or less than $\gamma A - \Omega_i$. Furthermore, $\frac{\partial y_i}{\partial P_i} = \frac{\Delta + 2(\gamma A - P_i) - \Omega_i}{2\Omega_i}$ and $\frac{\partial^2 y_i}{\partial P_i^2} = -\frac{1}{\Omega_i} < 0$, so (A2) is a concave problem. Because $\frac{\partial y_i}{\partial P_i}|_{P_i = \gamma A - \Omega_i} = \frac{\Delta + \Omega_i}{2\Omega_i} > 0$, the optimal solution is either at the boundary $P_i = \gamma A + \Omega_i$ or some interior given by the first-order condition $P_i = \gamma A + \frac{1}{2}(\Delta - \Omega_i)$. The former is the solution if and only if $\frac{\partial y_i}{\partial P_i}|_{P_i = \gamma A + \Omega_i} = \frac{\Delta - 3\Omega_i}{2\Omega_i} \geq 0$, i.e., $\Delta \geq 3\Omega_i$. □

Proof of Lemma 4. There are three cases to consider, depending on the relation between Δ and I. First, if $\Delta \geq 3I$, then $\Delta \geq 3\Omega_i$ because $I \geq \Omega_i$. Lemma 3 indicates that $P_i = \gamma A + \Omega_i$, so $\Pr[\Phi_i(1) \leq P_i] = 1$, and the seller's objective function (14) reduces to $\gamma A + \Omega_i$. The optimal solution is $e_\omega = \frac{1}{2}$. Second, if $3\Omega_i \leq \Delta < 3I$, then Lemma 3 again indicates that $P_i = \gamma A + \Omega_i$, so $\Pr[\Phi_i(1) \leq P_i] = 1$. Moreover, $3\Omega_i \leq \Delta$ implies $e_\omega \leq \frac{\Delta}{6I}$. The seller's problem (14) becomes

$$\max_{e_\omega}\ \gamma A + \Omega_i, \qquad \text{s.t. } e_\omega \leq \tfrac{\Delta}{6I}, \tag{A3}$$

and the optimal solution is $e_\omega = \frac{\Delta}{6I}$. Third, if $\Delta \leq 3\Omega_i$, then Lemma 3 indicates that $P_i = \gamma A + \frac{1}{2}(\Delta - \Omega_i)$, so $\Pr[\Phi_i(1) \leq P_i] = \frac{1}{4} + \frac{\Delta}{8e_\omega I}$ (note that $\gamma A + \frac{1}{2}(\Delta - \Omega_i) = \gamma A + \Omega_i$ when $\Delta = 3\Omega_i$). Additionally, $\Delta \leq 3\Omega_i$ implies $e_\omega \geq \frac{\Delta}{6I}$. The seller's problem (14) becomes

$$\max_{e_\omega}\ \left(\tfrac{1}{4} + \tfrac{\Delta}{8e_\omega I}\right)\left(\gamma A + \tfrac{\Delta}{2} - e_\omega I\right) + \left(\tfrac{3}{4} - \tfrac{\Delta}{8e_\omega I}\right)\left(\gamma A + \tfrac{\Delta}{4} + \tfrac{e_\omega I}{2}\right), \qquad \text{s.t. } \tfrac{\Delta}{6I} \leq e_\omega \leq \tfrac{1}{2}. \tag{A4}$$

It can be verified that (A4) is a convex problem, so the optimal solution must be one of the boundaries, either $\frac{\Delta}{6I}$ or $\frac{1}{2}$. The seller's objective function (A4) becomes $\gamma A + \frac{\Delta}{3}$ if $e_\omega = \frac{\Delta}{6I}$, which is equivalent to (A3), and $\gamma A + \frac{(\Delta + I)^2}{16I}$ if $e_\omega = \frac{1}{2}$. Note that

$$\gamma A + \tfrac{(\Delta + I)^2}{16I} < \gamma A + \tfrac{\Delta}{3} \iff \tfrac{1}{3} < \tfrac{\Delta}{I} < 3, \tag{A5}$$

and the seller chooses the lower level of expertise $e_\omega = \frac{\Delta}{6I}$ when (A5) holds with equality. Summarizing the different cases yields (15). □

Proof of Theorem 2 . If $\frac{\Delta}{I} < \frac{1}{3}$, then $e_\omega = \frac{1}{2}$ (Lemma 4) and $P_i = \gamma A + \frac{\Delta - I}{2}$ (Lemma 3). The seller accepts the offer if and only if $\Phi_i(1) = \gamma A + [\pi(s_\omega)I - (1-\pi(s_\omega))I] \leq \gamma A + \frac{\Delta - I}{2}$, i.e., $s_\omega \leq \frac{1}{4} + \frac{\Delta}{4I}$. Given that $s_\omega \sim U[0,1]$, trade occurs with ex ante probability $\frac{1}{4} + \frac{\Delta}{4I}$. Alternatively, if $\frac{1}{3} \leq \frac{\Delta}{I} < 3$, then $e_\omega = \frac{\Delta}{6I}$ (Lemma 4) and $P_i = \gamma A + \frac{\Delta}{3}$ (Lemma 3), which is the seller's highest possible valuation given $e_\omega = \frac{\Delta}{6I}$. The seller always accepts the offer. Finally, if $\frac{\Delta}{I} \geq 3$, then $e_\omega = \frac{1}{2}$ (Lemma 4) and $P_i = \gamma A + I$ (Lemma 3). This is the highest possible value, so the seller always accepts the offer.

The firm invests only when its posterior beliefs about s_ω exceed $\frac{1}{2}$. Because trade always occurs when $\Delta \geq \frac{1}{3}$, the firm learns nothing from the trading outcome, so it maintains its prior belief about s_ω and does not invest. Conversely, if $\Delta < \frac{1}{3}$, then the firm's posterior belief about s_ω is $\frac{1}{2}[(\frac{1}{4} + \frac{\Delta}{4I}) + 1] > \frac{1}{2}$ if the seller rejects the offer and $\frac{1}{2}[0 + (\frac{1}{4} + \frac{\Delta}{4I})] < \frac{1}{2}$ if the seller accepts the offer. □

Proof of Theorem 3 . Theorems 1 and 2 indicate that trade always occurs and that the firm never invests when $\frac{\Delta}{I} \geq \frac{1}{3}$. Because trade always occurs, the seller's expected payoff from developing expertise about V_a is $P_a = \gamma A + \min\left\{\gamma A, \frac{1}{2}\Delta\right\}$ (Theorem 1), whereas her expected payoff from developing expertise about ω is $P_i = \gamma A + \min\left\{I, \frac{1}{3}\Delta\right\}$ (Theorem 2). Hence, the seller develops expertise about V_a if and only if her payoff from doing so, $\min\left\{A, \frac{1}{2}\Delta\right\} > \min\left\{I, \frac{1}{3}\Delta\right\}$.

If $\frac{\Delta}{I} < \frac{1}{3}$, then (16) and (17) indicate that the seller's expected payoff from acquiring expertise about ω is greater than her payoff from acquiring expertise about V_a if and only if $\frac{(\Delta+I)^2}{16I} \geq \frac{\Delta}{2}$ (resp. $\frac{(\Delta+I)^2}{16I} \geq \gamma A$) when $\Delta < 2\gamma A$ (resp. $\Delta \geq 2\gamma A$). Thus, given $\frac{\Delta}{I} < \frac{1}{3}$, necessary and sufficient conditions for the seller to develop expertise about ω rather than V_a are $\Delta \geq \max\left\{4\sqrt{\gamma AI} - I, 2\gamma A\right\}$ or both $\Delta \leq (3 - 2\sqrt{2})I$ and $\Delta < 2\gamma A$.

Suppose $2\gamma A \leq (3 - 2\sqrt{2})I$. If $\Delta < 2\gamma A$, then, obviously, $\Delta \leq (3 - 2\sqrt{2})I$. Conversely, if $\Delta \geq 2\gamma A$, then $\Delta \geq \max\left\{4\sqrt{\gamma AI} - I, 2\gamma A\right\}$ because $4\sqrt{\gamma AI} - I > 2\gamma A \iff (3 - 2\sqrt{2})I <$

$2\gamma A < (3+2\sqrt{2})I$. Therefore, the seller develops expertise about ω if $2\gamma A \leq (3-2\sqrt{2})I$. Alternatively, suppose $2\gamma A > (3-2\sqrt{2})I$. Because $4\sqrt{\gamma AI} - I > 2\gamma A \iff (3-2\sqrt{2})I < 2\gamma A < (3+2\sqrt{2})I$, the seller develops expertise about ω, conditional on $2\gamma A > (3-2\sqrt{2})I$, if and only if $\Delta \leq (3-2\sqrt{2})I$ or $\Delta \geq 4\sqrt{\gamma AI} - I$. Finally, because $\gamma A > \frac{(\Delta+I)^2}{16I}$ implies $\gamma A > \frac{1}{2}(3-2\sqrt{2})I$ when $\Delta > (3-2\sqrt{2})I$, the seller develops expertise about ω, conditional on $\frac{\Delta}{I} < \frac{1}{3}$, unless $(3-2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$. □

Proof of Theorem 4. The proof is contained within the text surrounding Theorem 4 in Section 3.3. □

Proof of Proposition 1. The proof follows immediately from Theorems 1, 2, 3, and 4. □

Proof of Theorem 5. It follows from Theorem 4 that there are two candidate choices for $\hat{\gamma}$: are $\hat{\gamma} = 1$ or $\hat{\gamma} = \frac{(\Delta+I)^2}{16AI}$. If the social planner scales down production from the firm's assets-in-place, then the seller develops expertise about ω. Substituting $\Pr[\Phi_i(1) \leq P_i] = \frac{1}{2} + \frac{P_i - \gamma A}{2\Omega_i}$, $P_i = \gamma A + \frac{1}{2}(\Delta - I)$, and (24) into (23) allows utilitarian welfare to be rewritten as $\frac{(\Delta+I)^2}{4I}$. Conversely, if the planner does not scale down assets-in-place (and the firm does not invest), then utilitarian welfare is $A + \Delta$. Hence, a necessary condition for the planner to scale down is $\Delta < I - 2\sqrt{AI}$ because $\frac{(\Delta+I)^2}{4I} \leq A + \Delta \iff I - 2\sqrt{AI} \leq \Delta \leq I + 2\sqrt{AI}$ and $\Delta < \frac{I}{3} < I + 2\sqrt{AI}$. Combining this condition with the ones in Theorem 4 implies that the planner scales down if and only if $(3-2\sqrt{2})I < \Delta < \min\left\{I - 2\sqrt{AI}, 4\sqrt{AI} - I, \frac{I}{3}\right\}$. □

Proof of Corollary 1 . The proof follows immediately from Theorems 4 and 5. □

Proof of Theorem 6. Suppose $\frac{\Delta}{I} < \frac{1}{3}$. Absent the firm scaling back production, the seller develops expertise about V_a if and only if $(3-2\sqrt{2})I < \Delta < 4\sqrt{AI} - I$ (Theorem 3), in which case utilitarian welfare is $A + \Delta$ (see (20)). Hence, to induce the seller to develop expertise about ω, the social planner chooses the largest α such that the condition is not satisfied, or $\alpha = \frac{(3-2\sqrt{2})I}{\Delta}$, because (23) is increasing in Δ. If the planner scales down to this level, then utilitarian welfare is $A + \frac{3}{2}(3-2\sqrt{2})I$, which is obtained by substituting $\Pr[\Phi_i(1) \leq P_i] = \frac{1}{2} + \frac{P_i - \gamma A}{2\Omega_i}$, $P_i = \gamma A + \frac{1}{2}(\Delta - I)$, $\gamma = 1$, and (26) into (23). Alternatively, if the firm would otherwise scale back production, which occurs whenever $\max\{(3-2\sqrt{2})I, 4A-I\} < \Delta < 4\sqrt{AI}-I$ (Theorem 4) and yields utilitarian welfare $\frac{(\Delta+I)^2}{4I}$ (see (21)), then the planner may choose $\alpha = \frac{4A-I}{\Delta}$ to prevent the firm from scaling back but not to induce the seller to alter his type of expertise. Welfare in this case, which is obtained by substituting (27) into (20), is $5A - I$.

When $(3-2\sqrt{2})I < \Delta < 4\sqrt{AI}-I$ and $\Delta \leq 4A-I$, then the planner chooses $\alpha = \frac{(3-2\sqrt{2})I}{\Delta}$ if and only if $A + \frac{3}{2}(3-2\sqrt{2})I > A + \Delta \iff \Delta < \frac{3}{2}(3-2\sqrt{2})I$. Note that $\frac{1}{4}(\Delta+I) < \frac{(\Delta+I)^2}{16I}$ when $\frac{\Delta}{I} < \frac{1}{3}$. When $\max\{(3-2\sqrt{2})I, 4A-I\} < \Delta < 4\sqrt{AI}-I$, then the planner chooses $\alpha = \frac{(3-2\sqrt{2})I}{\Delta}$ if and only if both $A + \frac{3}{2}(3-2\sqrt{2})I > \frac{(\Delta+I)^2}{4I} \iff \Delta < \sqrt{4I(A+\frac{3}{2}(3-2\sqrt{2})I)} - I$ and $A + \frac{3}{2}(3-2\sqrt{2})I > 5A - I \iff A < \frac{1}{8}(11-6\sqrt{2})I$. Note that $A > \frac{(\Delta+I)^2}{4I} - \frac{3}{2}(3-2\sqrt{2})I \iff A > \frac{(\Delta+I)^2}{16I}$ when $\Delta > (3-2\sqrt{2})I$. When $\max\{(3-2\sqrt{2})I, 4A-I\} < \Delta < 4\sqrt{AI}-I$, then the planner chooses $\alpha = \frac{4A-I}{\Delta}$ if and only if both $5A - I \geq A + \frac{3}{2}(3-2\sqrt{2})I$ and $5A - I > \frac{(\Delta+I)^2}{4I} \iff \Delta < 2\sqrt{5AI - I^2} - I$. Note that $\frac{(\Delta+I)^2}{20I} + \frac{1}{5}I < \frac{1}{8}(11-6\sqrt{2})I$ when $\frac{\Delta}{I} < \frac{1}{3}$. □

Proof of Proposition 2. Restrict attention to the parametric specifications in Theorems 5 and 6 under which regulation improves utilitarian welfare. The respective utilitarian welfare when the social planner regulates production and regulates private gains to trade is $A+\Delta$ (see (22)) and either $A + \frac{3}{2}(3-2\sqrt{2})I$ if the planner scales down the private gain to trade by a factor of $\hat{\alpha} = \frac{(3-2\sqrt{2})I}{\Delta}$ or $5A - I$ if the planner scales down the private gain to trade by a factor of $\hat{\alpha} = \frac{4A-I}{\Delta}$ (see proof of Theorem 6). Because $A + \Delta > A + \frac{3}{2}(3-2\sqrt{2})I \iff \Delta > \frac{3}{2}(3-2\sqrt{2})I$, the planner prefers to regulate production over scaling down the private gain to trade by a factor of $\alpha = \frac{(3-2\sqrt{2})I}{\Delta}$ if and only if $\Delta > \frac{3}{2}(3-2\sqrt{2})I$. Because $A+\Delta > 5A - I \iff \Delta > 4A - I$, the planner prefers to regulate production over scaling down the private gain to trade by a factor of $\alpha = \frac{4A-I}{\Delta}$. □

Appendix B: Alternative Trading Game

In this appendix, we analyze an alternative trading game in which the buyer, rather than the seller, develops expertise. The setup we consider mirrors the one described in Section 2.

We assume that the seller receives a private gain to trade Δ if and only if trade occurs. In this setting, Δ can be interpreted as the value that accrues to the seller if she is able to sell the security to satisfy her liquidity needs. The seller proposes a take-it-or-leave-it offer to the buyer, who accepts if and only if the security's expected payoff conditional on his signal is no less than the price proposed by the seller (in the case of indifference, we assume that the buyer accepts the offer).

We first examine separately the cases in which the buyer develops expertise about assets-in-place and the investment opportunity. We then analyze the buyer's choice of expertise and the firm's production scale. Finally, we discuss policy implications. We omit all proofs because they closely resemble those in Appendix A.

Expertise about Assets-in-Place. We first consider the case in which the buyer develops expertise about assets-in-place. The firm does not learn about its investment opportunity from the trading outcome, so it never invests.

The seller offers a price P_a to maximize her expected payoff. Because the buyer accepts the offer if and only if $\Phi_a \geq P_a$, where the buyer's valuation is Φ_a is given by (6), the seller's objective is

$$\max_{P_a} \ \Pr[\Phi_a < P_a]\tfrac{1}{2}(\gamma A - \Omega_a + P_a) + \Pr[\Phi_a \geq P_a](P_a + \Delta). \tag{B1}$$

The following lemma characterizes P_a.

Lemma B.1 (Seller's offer with buyer expertise about assets-in-place)**.** *Given the buyer's expertise about the firm's assets-in-place, e_a, the seller offers*

$$P_a = \begin{cases} \gamma A + \Omega_a - \Delta & \text{if } \ \Delta < 2\Omega_a \\ \gamma A - \Omega_a & \text{if } \ \Delta \geq 2\Omega_a. \end{cases} \tag{B2}$$

The buyer anticipates the seller's strategy and chooses his level of expertise to maximize his expected payoff. Because the buyer receives nothing if he rejects the seller's offer, his objective is

$$\max_{e_a} \ \Pr[\Phi_a \geq P_a]\left[\tfrac{1}{2}(P_a + \gamma A + \Omega_a) - P_a\right]. \tag{B3}$$

The following lemma characterizes e_a.

Lemma B.2 (Buyer's expertise about assets-in-place)**.** *The buyer's optimal level of expertise about the firm's assets-in-place is*

$$e_a = \begin{cases} \dfrac{\Delta}{4\gamma A} & \text{if } \dfrac{\Delta}{\gamma A} < 2 \\ \dfrac{1}{2} & \text{if } \dfrac{\Delta}{\gamma A} \geq 2. \end{cases} \tag{B4}$$

The equilibrium mirrors the one in Section 3.1.1. If Δ is sufficiently large ($\Delta \geq 2\gamma A$), then the seller offers a price equal to the buyer's lowest possible valuation to ensure trade. Knowing this, the buyer develops the greatest possible expertise. Conversely, if Δ is smaller ($\Delta < 2\gamma A$), then the buyer develops a lower level of expertise to prevent trade from collapsing. The following theorem characterizes the equilibrium of the trading game.

Theorem B.1 (Equilibrium with buyer expertise about assets-in-place)**.** *The equilibrium depends on the relative sizes of Δ and γA. If $\frac{\Delta}{\gamma A} < 2$, then the buyer chooses $e_a = \frac{\Delta}{4\gamma A}$, and the seller offers $P_a = \gamma A - \frac{\Delta}{2}$. If $\frac{\Delta}{\gamma A} \geq 2$, then the buyer chooses $e_a = \frac{1}{2}$, and the seller offers $P_a = 0$. Regardless of $\frac{\Delta}{\gamma A}$, trade always occurs, and the firm never invests.*

Expertise about Investment Opportunity. Next, we consider the case in which the buyer develops expertise about the investment opportunity. The firm learns from the trading outcome and invests if and only if trade occurs, which indicates a good investment opportunity.

The seller offers a price P_i. The buyer accepts the offer if and only if $\Phi_i(1) \geq P_i$, where the buyer's valuation $\Phi_i(1)$ is given by (11). Because the firm does not invest if trade breaks down, the seller's objective is

$$\max_{P_i} \ \Pr[\Phi_i(1) < P_i]\gamma A + \Pr[\Phi_i(1) \geq P_i](P_i + \Delta). \tag{B5}$$

The following lemma characterizes P_i.

Lemma B.3 (Seller's offer with buyer expertise about investment opportunity). *Given the buyer's expertise about the firm's investment opportunity, e_ω, the seller offers*

$$P_i = \begin{cases} \gamma A + \frac{1}{2}(\Omega_i - \Delta) & \text{if } \Delta < 3\Omega_i \\ \gamma A - \Omega_i & \text{if } \Delta \geq 3\Omega_i. \end{cases} \tag{B6}$$

The buyer selects his level of expertise to maximize his expected payoff. Because the firm invests if and only if trade occurs, the buyer's objective is

$$\max_{e_\omega} \ \Pr[\Phi_i(1) \geq P_i]\left[\tfrac{1}{2}(P_i + \gamma A + \Omega_i) - P_i\right]. \tag{B7}$$

The following lemma characterizes e_ω.

Lemma B.4 (Buyer's expertise about investment opportunity). *The buyer's optimal level of expertise about the firm's investment opportunity is*

$$e_\omega = \begin{cases} \dfrac{1}{2} & \text{if } \dfrac{\Delta}{I} < \dfrac{1}{3} \\ \dfrac{\Delta}{6I} & \text{if } \dfrac{1}{3} \leq \dfrac{\Delta}{I} < 3 \\ \dfrac{1}{2} & \text{if } \dfrac{\Delta}{I} \geq 3. \end{cases} \tag{B8}$$

The equilibrium is analogous to the one in Section 3.1.2. If Δ is sufficiently big ($\Delta \geq 3I$), then the seller offers a price equal to the buyer's lowest possible valuation to secure the trade, and the buyer develops the greatest possible expertise. If Δ takes an intermediate value ($\frac{1}{3}I \leq \Delta < 3I$), then the buyer develops a lower level of expertise to prevent the trade from breaking down. If Δ is sufficiently small ($\Delta < \frac{1}{3}I$), then the buyer develops the greatest possible expertise to maximize the value of her real option. The following theorem characterizes the equilibrium of the trading game.

Theorem B.2 (Equilibrium with buyer expertise about investment opportunity)**.** *The equilibrium depends on the relative sizes of* Δ *and* I*.*

1. *If* $\frac{\Delta}{I} < \frac{1}{3}$*, then the buyer chooses* $e_\omega = \frac{1}{2}$*, and the seller offers* $P_i = \gamma A - \frac{1}{2}(\Delta - I)$*. The buyer accepts the offer and the firm invests if and only if* $s_\omega > \frac{3}{4} - \frac{\Delta}{4I}$*, so trade occurs with probability* $\frac{1}{4} + \frac{\Delta}{4I} \in (\frac{1}{4}, \frac{1}{3})$*.*

2. *If* $\frac{1}{3} \leq \frac{\Delta}{I} < 3$*, then the buyer chooses* $e_\omega = \frac{\Delta}{6I} \in [\frac{1}{18}, \frac{1}{2})$*, and the seller offers* $P_i = \gamma A - \frac{\Delta}{3}$*. The buyer always accepts the offer, and the firm never invests.*

3. *If* $\frac{\Delta}{I} \geq 3$*, then the buyer chooses* $e_\omega = \frac{1}{2}$*, and the seller offers* $P_i = \gamma A - I$*. The buyer always accepts the offer, and the firm never invests.*

Buyer's Choice of Expertise. If $\frac{\Delta}{I} \geq \frac{1}{3}$, then trade always occurs and the firm never invests. The buyer's expected payoff from developing expertise about assets-in-place V_a is $\frac{1}{2}\left(P_a + \gamma A + \min\left\{\gamma A, \frac{1}{2}\Delta\right\}\right) - P_a = \min\left\{\gamma A, \frac{1}{2}\Delta\right\}$ (Theorem B.1), whereas his expected payoff from developing expertise about the investment opportunity ω is $\frac{1}{2}\left(P_i + \gamma A + \min\left\{I, \frac{1}{3}\Delta\right\}\right) - P_i = \min\left\{I, \frac{1}{3}\Delta\right\}$ (Theorem B.2). Therefore, conditional on $\frac{\Delta}{I} \geq \frac{1}{3}$, the buyer develops expertise about V_a if and only if $\min\left\{\gamma A, \frac{1}{2}\Delta\right\} > \min\left\{I, \frac{1}{3}\Delta\right\}$.

The more interesting outcome emerges when $\frac{\Delta}{I} < \frac{1}{3}$. If the buyer develops expertise about V_a, then trade always occurs and his expected payoff, as stated above, is $\min\left\{\gamma A, \frac{1}{2}\Delta\right\}$. However, if the buyer develops expertise about ω, then trade may break down and his expected payoff is $\Pr[\Phi_i(1) \geq P_i]\left[\frac{1}{2}(P_i + \gamma A + \Omega_i) - P_i\right] = \frac{(\Delta+I)^2}{16I}$. Hence, when choosing his type of expertise, the buyer here faces the same tradeoff as the seller does in Section 3.2. Consequently, the buyer in this setting develops expertise about the investment opportunity rather than assets-in-place under the same conditions as the seller does in Section 3.2.

Theorem B.3 (Buyer's expertise choice for a given γ)**.** *Suppose* $\frac{\Delta}{I} \geq \frac{1}{3}$*. If* $\min\left\{\gamma A, \frac{1}{2}\Delta\right\} > \min\left\{I, \frac{1}{3}\Delta\right\}$*, then the buyer develops expertise about assets-in-place,* $e_a = \min\left\{\frac{1}{2}, \frac{\Delta}{4\gamma A}\right\}$ *and*

$e_\omega = 0$; otherwise, he develops expertise about the investment opportunity, $e_a = 0$ and $e_\omega = \min\left\{\frac{1}{2}, \frac{\Delta}{6I}\right\}$. Conversely, suppose $\frac{\Delta}{I} < \frac{1}{3}$. If $(3-2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$, then the buyer develops expertise about assets-in-place, $e_a = \min\left\{\frac{1}{2}, \frac{\Delta}{4\gamma A}\right\}$ and $e_\omega = 0$; otherwise, he develops expertise about the investment opportunity, $e_a = 0$ and $e_\omega = \frac{1}{2}$.

Firm's Production Scale. The firm chooses its production scale γ to maximize its value V. If $\frac{\Delta}{I} \geq \frac{1}{3}$, then the firm never learns about its investment opportunity ω from the trading outcome because trade always occurs. Thus, similar to the framework in Section 3.3, the firm maximizes V by choosing $\gamma = 1$.

If $\frac{\Delta}{I} < \frac{1}{3}$, however, then the firm invests if and only if trade occurs. Therefore, similar to the framework in Section 3.3, the firm's objective is to maximize

$$V = \Pr[\Phi_i(1) < P_i]\gamma A + \Pr[\Phi_i(1) \geq P_i]\tfrac{1}{2}(P_i + \gamma A + I). \tag{B9}$$

Because the conditions under which the buyer develops expertise about ω (Theorem B.3) are the same as those under which the seller develops expertise about ω (Theorem 3), the firm will scale back production by a factor of γ^* as given by (19) if it elects to induce the buyer to develop expertise about ω. Substituting P_i and the probability of trade occurrence as characterized in Theorem B.2 along with (19) into (18), it is evident that the firm scales back production from assets-in-place if and only if $\frac{1}{4}(\Delta + I) > A$ and $(3-2\sqrt{2})I < \Delta < 4\sqrt{\gamma AI} - I$, which are the same conditions under which the firm scales back in the framework considered in Section 3.3. Thus, the firm's production strategy in this alternative setting is identical to the one characterized in Theorem 4.

Welfare and Policy Implications. Like in the framework considered in Section 4, utilitarian welfare depends on the underlying parameters. If the parameters are such that the buyer develops expertise about ω and the firm learns from the trading outcome, then the trade surplus Δ is realized and the firm invests if and only if $s_\omega > \frac{3}{4} - \frac{\Delta}{4I}$. Accordingly, utilitarian welfare is

$$W = A + \int_{\frac{3}{4}-\frac{\Delta}{4I}}^{1} \Delta + (2s_\omega - 1)I \, \mathrm{d}s_\omega = A + \frac{3(\Delta + I)^2}{16I}. \tag{B10}$$

Alternatively, if the parameters are such that the firm scales back production from assets-in-place to induce the buyer to develop expertise about ω, then utilitarian welfare is

$$W = \frac{(\Delta + I)^2}{16I} + \int_{\frac{3}{4}-\frac{\Delta}{4I}}^{1} \Delta + (2s_\omega - 1)I \, \mathrm{d}s_\omega = \frac{(\Delta + I)^2}{4I}. \tag{B11}$$

Finally, if the parameters are such that trade always occurs and the firm never invests, then utilitarian welfare is

$$W = A + \Delta. \tag{B12}$$

For the same reasons discussed in Section 4.1, there is scope for policy intervention when the buyer develops expertise instead of the seller. When regulating production from assets-in-place, the social planner's objective is

$$\max_{\gamma} \ \Pr[\Phi_i(1) < P_i]\gamma A + \Pr[\Phi_i(1) \geq P_i]\big[\Delta + \tfrac{1}{2}(P_i + \gamma A + I)\big]. \tag{B13}$$

If the planner scales back production from assets-in-place to $\hat{\gamma}$ to induce the buyer to develop expertise about ω, then utilitarian welfare is given by (B11); if not, then utilitarian welfare is given by (B12). Comparing these expressions indicates that $A < \frac{(\Delta-I)^2}{4I}$ is a necessary condition for the planner to scale back production. Hence, the conditions under which the firm inefficiently scales back production, i.e, $\frac{(\Delta-I)^2}{4I} < A < \frac{1}{4}(\Delta+I)$ and $(3-2\sqrt{2})I < \Delta < \frac{1}{3}I)$, are the same as those in Section 4.2.1. Therefore, the planner's production policy is identical to that described in Theorem 5.

When regulating private gains to trade, the planner's objective is

$$\max_{\alpha} \ \Pr[\Phi_i(1) < P_i]\gamma A + \Pr[\Phi_i(1) \geq P_i]\big[\alpha\Delta + \tfrac{1}{2}(P_i + \gamma A + I)\big]. \tag{B14}$$

It is straightforward to show that substituting appropriate values for γ, the probability of trade occurrence, and P_i as characterized in Theorems 4 and B.2 into (B14) generates an identical expression for utilitarian welfare as substituting the analogous values characterized in Theorems 4 and B.2 into (25). Thus, the social planner faces the same tradeoffs regardless of whether the buyer or seller develops expertise. Hence, the planner's policy regarding private gains to trade is identical to that described in Theorem 6.