The Sale of Ideas: Disclosure, Property Rights and Contracting

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The Sale of Ideas: Strategic Disclosure, Property Rights, and Contracting

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Ideas are difficult to sell when buyers cannot assess an idea's value before it is revealed and sellers cannot protect a revealed idea. These problems exist in a variety of intellectual property sales ranging from pure ideas to poorly protected inventions and reflect the nonverifiability of key elements of an intellectual property sale. An expropriable partial disclosure can be used as a signal, allowing the seller to obtain payment based on the value of the remaining (undisclosed) know-how. We examine contracting after the disclosure and find that seller wealth is pivotal in supporting a partial disclosure equilibrium and in determining the payoff size.

1. INTRODUCTION

What makes ideas difficult to sell? Unless the idea is revealed, a potential buyer cannot accurately assess its value. Once the idea is known, however, a buyer may have little incentive to pay the seller (Arrow, 1962). Yet we observe sellers making idea disclosures in settings where there is little or no protection for the ideas. This paper provides an equilibrium analysis of disclosures and of private market transactions in ideas when property rights are absent.

The essence of the dilemma raised by Arrow is present in a wide range of market transactions involving intellectual property (IP). Pure ideas pose obvious difficulties in this regard, but the problem is also important in the sale of technological inventions. In most such cases, some portion of the underlying "invention" is hard to protect from buyer expropriation so the inventor may have a difficult time obtaining a payment approaching the private value of the invention. Other examples of market transactions in which this dilemma is common are the sale of business opportunity ideas, consulting services, trade secrets, and ideas for movie or television shows.

This market exchange problem can be traced to an inability of the seller to contract with a buyer on the source and extent of a transferred idea.[1] Because payment cannot occur simultaneously with the revelation of the idea, some form of contract is needed to facilitate the exchange. In a sale of conventional tangible property, the property and its transfer is

1. IP also suffers from imitation and spillover problems which affect the buyer's private value of the invention. Our concern is with the primary sale of information when both parties have a strong incentive to solve the exchange problem. If contracts could be written on all contingencies, parties immediate to the exchange could contract around issues of potential buyer unauthorized use and therefore no legal protection (*e.g.* patents) beyond contract enforcement would be required for the exchange.

easily verifiable. With an intangible property such as IP, the source and the amount of IP may be quite difficult for a third party to verify, especially if the buyer could plausibly have developed the IP on its own. In such cases writing a contract on which party exchanged what information is problematic since provisions based on unverifiable contingencies lack force.[2]

Given this contracting problem, how are ideas sold and why are expropriable disclosures made? We argue that a seller can use partial disclosure in conjunction with a bond to signal the full value of an idea to buyers who will then compete for the portion of the idea that was withheld.[3] Precontract partial disclosure exposes the seller to a moral hazard expropriation problem over that disclosure. Because the economic impact of this problem changes depending on the value of the seller's idea and the bond that is put at risk, the amount of self-determined exposure to expropriation signals the full value of the idea. After inferring this value, buyers are led to compete more aggressively with contract offers to attract the seller. These offers take the form of contracts written on verifiable contingencies such as downstream profit or revenue outcomes (which include equity or option contracts as special cases). In effect, the seller circumvents the adverse selection problem (buyer uncertainty about value) by exposing a portion of its idea to an extreme moral hazard problem (buyer ability to expropriate).[4]

Because partial disclosures "give away" a portion of the idea, less remains to be sold. How much payment, then, can the seller receive? We find that the size of the bond (sometimes referred to in practice as "skin in the game") is a key factor in the seller's payoff: as the bond decreases, more disclosure is needed in equilibrium, and more disclosure implies lower seller payoffs. This result has implications for wealth-constrained sellers and how they allocate their resources. If, for example, an inventor were to invest all available resources in idea creation, then the ensuing lack of wealth will hamper rent appropriation from a market sale of the resulting discovery. This consideration might cause a seller to go to market earlier, as further costly development may not be justified in terms of incremental appropriable gains. Additionally, a seller may find it desirable to seek a connection with a financial intermediary such as a venture capitalist prior to taking the invention to a buyer.

2. In this paper we adopt a stark distinction between verifiable and unverifiable contract contingencies and assume that no unverifiable contingency will be contracted over (or will have any economic force). The limitations on contractual contingencies studied here can be circumvented with strong legal IP rights which make the question of the source of the underlying know-how irrelevant. It is quite common, however, for IP to lack strong legal protection, see, *e.g.* Anand and Khanna (2000) and Levin *et al*. (1987). The literature on patent breadth and circumvention (*e.g.* Klemperer (1990), Lerner (1994), Eswaran and Gallini (1996), Scotchmer (1996)) can be interpreted as addressing the extent of IP protection (against, *e.g.* circumvention), but does not emphasize the nexus of valuation uncertainty and expropriation. See also Katz and Shapiro (1987) who discuss innovation incentives when property rights cannot prevent imitation.

3. Partial disclosure can take many forms. Demonstration of a prototype at a trade show at which the buyers are not given full documentation or allowed to take apart the product is one form. Withholding important implementation ideas in a sales pitch to a venture capitalist is another. These partial disclosures frequently take place in an environment where the seller has limited property rights or is forced to waive them to gain a buyer audience. Examples of bonds include a low salary to the seller coupled with vested stock options (Hellmann, 1998), a small firm when transferred as part of the sale, or legally protected IP.

4. Contracting limitations in our analysis rest on an underlying adverse selection problem—asymmetric information regarding the extent of the seller's idea. The contracting problem addressed here relates to the literature that has focused on settings with relationship-specific investments and the moral hazard problem of inefficient investment when contracts are incomplete (see, *e.g.* Hart (1995), Tirole (1999)). In an IP context, the moral hazard investment issues lead to questions regarding the incentive for creation of ideas. Aghion and Tirole (1994), in particular, employ an incomplete contracts framework to examine the allocation of property rights for an innovation and the associated investments in R&D by a research unit and customer.

Our starting point is an adverse selection problem regarding the seller's idea, for which the simple solution (full disclosure) is blocked by a combination of the nonverifiability of the source and extent of ideas and buyer expropriation incentives. Moreover, in the absence of adverse selection, nonverifiability and the absence of property rights create no limitation and the seller could appropriate the full value of the innovation. The contracting problem addressed here is thus manifested differently than in the moral hazard framework. See also Bernheim and Whinston (1998) and Maskin and Tirole (1999) on how apparent incompleteness of contracts does not necessarily interfere with optimal contracting.

We model an idea (henceforth, also an “invention”) as a stock of technical knowledge which has no direct end-user value but increases the likelihood of a successful commercial innovation of a fixed value; each piece of knowledge is incrementally valuable and can be released in any amount.

These interactions are captured in an extensive-form equilibrium analysis involving a seller and two *ex ante* symmetric competing buyers. The seller has private information about the amount of know-how constituting the idea and different possible seller types possess different amounts of know-how. Buyers also have some know-how (which is common knowledge). The seller may disclose a portion of its total know-how, after which buyers make contract bids to the seller. Disclosures made with no contract in place can be freely used. After the bidding and final transfer of the seller’s know-how, innovation success is determined and then buyers compete in a Bertrand market where only unique possession of the innovation leads to positive profits. We use these profit contingencies as the basis for contracting.

An essential feature of partial disclosure separating equilibria is the difficulty associated with separating nearby types and the limitations this incentive compatibility (IC) constraint places on seller payoffs. The difficulty posed by IC is illustrated by the polar case in which no seller bond is possible. Given separation, competitive bidding determines the expected payoff offered to a correctly inferred type and this payoff will increase with type. Because each type prefers a higher payment in the monopoly state (and the seller payment could not be negative in the zero-profit state) all types will choose to mimic as high a type as is feasible. But then partial disclosure cannot separate because partial disclosure implies that a slightly lower type will be able to (and will prefer to) mimic the higher type.

The disclosure equilibrium we analyze exploits the differential incentives of each possible seller type based on the payments offered in each contingency and the probability that the state obtains. Holding the expected payoff constant, IC becomes easier to meet as the difference in contract payments to the seller between the states increases. In equilibrium, a larger disclosure results in the buyers offering a contract with a larger payment wedge. This feature is essential for providing stronger disclosure incentives to sellers with more IP (single-crossing property). With a larger payment wedge, a seller with more total know-how has an advantage in leveraging the value of undisclosed know-how because such a seller has a greater ability to increase the likelihood of the monopoly state. One upshot of this logic is that the size of the bond is pivotal for determining the disclosure incentives across types. The incentive to deviate is so strong that increases in overall gross profits in the system can be completely dissipated. While such issues are standard in signaling models, our model provides a twist in that the signal is freely usable know-how, thereby creating the link between the adverse selection and moral hazard problems.

Bhattacharya and Ritter (1983) (BR), a pioneering work on the problem of public disclosure of valuable knowledge, show how a firm can signal its private value to capital markets and obtain lower-cost equity financing for its innovation efforts by publicly disclosing part of its valuable knowledge. Disclosed knowledge also becomes available to competitors, however, and this reduces expected profits for the firm since competitors are then more likely to innovate successfully.

Our analysis of the sale of ideas also focuses on a signaling dimension for partial disclosure, a key insight developed by BR. Three economic forces differentiate our problem of selling ideas from that of capital market access. First, in a sale contract the potential buyer can expropriate disclosed knowledge. Second, a common concern of buyers in the sale context is that some (or even most) potential sellers have no valuable IP. Finally, and perhaps most importantly, payment for an IP sale is determined largely through the contracting relationship designed by the parties. These aspects of the sale problem lead us to focus on the economic relationship between contract terms and the amount of disclosure. Simple equity contracts as assumed in the capital market problem of BR have only one degree of freedom (which is used to ensure an appropriate expected return to the investor) and therefore cannot be adjusted strategically to impact the amount of disclosure.[5] BR also assume that the lowest-type inventing firm has valuable IP, easing a critical constraint that sellers with no value should get zero expected payment. Equity contracts with no bond cannot support a partial disclosure equilibrium in our sale context where the lowest type may have no value.[6]

In practice, sellers sometimes choose a private disclosure strategy or shop the idea sequentially among buyers. In Section 4 we explore a private disclosure game and find that the seller's payoff in that case derives from a threat to sell via public disclosure since, without such a threat, the expropriation incentive of the buyer is strengthened.

In our previous work on the problem of selling ideas via private disclosure (Anton and Yao, 1994) partial disclosure was not an option. In that model the seller makes a full pre-contract private disclosure of the idea and is paid based on the credible "blackmail" threat to destroy the "monopoly" profits of the receiving firm by selling the idea to a competitor. As full disclosure implies that there is no remaining idea to buy from the seller, the buyer offers a contract that is entirely designed to eliminate gains to trade for the seller with a competing buyer. By contrast, partial disclosure implies that a disclosure has strategic content in the form of a signal about the full idea and that the seller's payoff derives from exclusive revelation of the undisclosed part of the idea to the winning buyer.

We describe the public disclosure model in the next section. The analysis of that equilibrium follows in Section 3 and an extension of the model to a private disclosure setting is provided in Section 4.

2. THE MODEL

We examine the market exchange of ideas between a seller, S, and two buyers, B^1 and B^2. All parties are risk neutral and maximize net income. Play occurs in three stages. First, the seller makes an initial know-how disclosure. Second, buyers make contract offers and the seller makes decisions concerning contract acceptance and the revelation of the remaining know-how. Finally, innovation outcomes are determined and payoffs are realized.

To provide a setting for the problem, suppose that each buyer is a firm pursuing an innovation which, if successful, will result in a commercializable product. Each buyer has an internal R&D capability that yields a successful innovation with probability $\alpha > 0$. We assume a "Bertrand-style" payoff structure across the four possible innovation outcomes (both succeed, both fail, or one fails while the other succeeds) in which a uniquely successful firm earns a gross payoff of $\Pi > 0$ while an unsuccessful firm always earns a gross payoff of zero. If both firms succeed, each firm earns zero. The analysis extends to richer payoff structures.

The seller may possess an idea or intellectual property ("IP" or "know-how") that, if acquired, would improve the chance of a successful innovation by a buyer. In practice, IP takes many different forms, such as scientific and technical knowledge, production technology or marketing information. We do not model IP at this primitive level. Instead, we assume that different types of IP can be assessed in terms of an associated probability of a successful innovation and index types of IP by that probability. By revealing IP that a buyer does not initially possess, the seller can increase the chance of successful innovation.

5. Sale to a potential user is also complicated by direct expropriation because disclosure changes the economic position of the buyer, not just the overall total profit surplus available to the contracting parties.

6. d'Aspremont *et al*. (2000) focus on a related problem in which (in our terms) the seller can use the idea and disclosed knowledge is verifiable for contracting. They do not consider bonds (say, via seller wealth) and, in contrast to our results, do not find a partial disclosure equilibrium. See also Milgrom and Roberts (1986) and Okuno-Fujiwara *et al.* (1990) who also explore related strategic disclosure issues but without transfer of valuable know-how.

We suppose that the IP possessed by the seller is the realized value θ of a draw from a c.d.f. F with support $[\underline{\theta}, \overline{\theta}] \subseteq [0, 1]$. The value of θ is private information of the seller. A feasible disclosure, r, of know-how by a seller of type θ then satisfies $r \leq \theta$, so that the seller cannot disclose more know-how than it has. Disclosures impact the chance of success as follows. If $\theta \leq \alpha$, then the seller has no IP that is valuable to either buyer. Consider $\theta > \alpha$ and suppose that the seller has disclosed know-how of $r_i > \alpha$ to each buyer B^i. Then, the expected gross payoff to B^i is given by $r_i(1 - r_j)\Pi$, $i = 1, 2$, and $j \neq i$, which is the probability that B^i succeeds and B^j fails multiplied by Π. A disclosure of $r_i \leq \alpha$ is superseded by α, the initial buyer IP, and has no impact on expected payoffs. In this setting, higher types have all of the know-how of lower types. Note that buyers may have additional (unmodeled) IP that is necessary for innovation but not known to the seller.

The payoff structure reflects a complete absence of property rights on IP and, hence, poses a moral hazard problem for the seller: any disclosed information can be used by a buyer and there are no legal obstacles, such as patent, copyright, or trade secret protection that prevent this use. We focus on the case in which $\underline{\theta} = \alpha$ and $F(\alpha) \geq 0$, so there may be an atom at the lowest type. In this "full support" case the adverse selection problem is potentially severe as buyers expect that some sellers have no valuable IP.[7]

Monetary payments between the seller and a buyer are governed by a contract, (R_M, R_0), where R_M is a payment to the seller in the event that the buyer earns the (monopoly) gross payoff of Π and R_0 is the payment when the buyer earns a gross payoff of zero. We allow for negative payments in the contract, but such a payment cannot exceed the wealth (or available bond) of the seller, which is assumed to be $L > 0$. Thus, $R_M \geq -L$ and $R_0 \geq -L$ defines the feasible set of (R_M, R_0) contracts. For simplicity we assume exclusive contracting: the seller cannot accept offers from both buyers. As discussed below, our results are robust to nonexclusive and simple menu-offer contracting alternatives. We focus on the case of $\alpha\Pi > L$ where the seller has relatively small financial resources. Limited wealth is an important feature of the buyer–seller relationship, so we also explore how relatively large L impacts the adverse selection problem.

In our model know-how disclosed by the seller is not contractible.[8] The only verifiable event for contractual contingencies is the payoff success of the innovation. Contracts contingent on disclosed information are not feasible. Since a buyer can observe and assess the value of any IP disclosed by the seller, the choice of which (R_M, R_0) contract to offer may, however, be influenced by the observed disclosure.

Contract offers must account for adverse selection with respect to the seller's IP. For example, if the seller initially discloses no IP of value $(r = \alpha)$ and a buyer offers a contract, then the payment R_M must be executed whenever a success occurs (Π is realized). Thus, R_M is paid regardless of whether the seller subsequently revealed valuable IP (*e.g.* $\theta > \alpha$) or IP of no value. Similarly, if $r > \alpha$ is disclosed initially, the buyer must again account for the risk that a seller with no incremental IP $(\theta = r)$ is attracted by the contract offer.

The structural elements specified above form the basis for the potential exchange of IP between the seller and buyers. The game proceeds as follows:

1. The seller, S, privately observes a draw $\theta \in [\underline{\theta}, \overline{\theta}]$ according to a c.d.f. F. The value of θ is the IP possessed by S.

7. One can imagine that the support extends to types below α. As the analysis shows, this is simply a reinterpretation of an atom at α and we fix the support at $\underline{\theta} = \alpha$ for simplicity.

8. In addition to the difficulties of third-party verification of a contingency, problems may arise in the definition of contingencies. It may not be possible to define in advance the form of verifiable IP information disclosures, especially given the difficult to envision nature of invention. Further, specification of what is transferred may itself transfer information (see, *e.g.* Spier, 1992).

2. S, having observed θ, chooses a disclosure r of IP that is observed by B^1 and B^2, the buyers. Feasible disclosures satisfy $r \leq \theta$. The disclosure r can be used freely by either buyer to pursue the innovation.
3. Each B^i having observed r, offers the seller a contract (R_M^i, R_0^i). Feasible contracts satisfy $R_M^i \geq -L$ and $R_0^i \geq -L$ for $i = 1, 2$.
4. S chooses which contract to accept, if any, and then chooses a revelation of any remaining IP, t_i, where $r \leq t_i \leq \theta$ for $i = 1, 2$, to the buyers.
5. The innovation success or failure for each B^i is realized along with payoffs and contract payments, according to the success probability implied by the underlying IP input, $\max\{\alpha, t_i\}$.

We solve for a perfect Bayesian equilibrium (PBE) for this dynamic game of incomplete information. A strategy for the seller specifies (initial) disclosure, contract acceptance, and (final) revelation. Initial disclosure is given by $\varphi : [\underline{\theta}, \bar{\theta}] \rightarrow [0, \bar{\theta}]$, where $r = \varphi(\theta)$ is the initial disclosure by a type-θ seller. In equilibrium, the choices of which of two contract offers to accept and the amount of revelation always reduce to straightforward payoff comparisons for the seller. A strategy for each buyer involves a choice of contract offer given an observed initial disclosure by the seller. Buyer beliefs regarding the seller's type following an initial disclosure of $r \in [0, \bar{\theta}]$ take the form of a c.d.f. on $[\underline{\theta}, \bar{\theta}]$ that is consistent with φ and the disclosure constraint ($\varphi(\theta) = r$ implies $\theta \geq r$) under Bayes' rule.

Our focus is on PBE in which the disclosure strategy is separating, meaning that φ is a one-to-one function. Then, each equilibrium disclosure of r has a unique inference of $\varphi^{-1}(r)$ for the buyer's belief regarding the seller's IP. We refer to a separating PBE as a "disclosure" equilibrium and say there is "partial disclosure" when $\varphi(\theta) < \theta$ and "full disclosure" when $\varphi(\theta) = \theta$.

3. DISCLOSURE EQUILIBRIUM

We begin by developing the basic properties of the contract bidding competition for a given seller disclosure. We then derive the disclosure equilibrium and discuss uniqueness, the extent of disclosure, nonexclusive contracting, and seller rent appropriation.

3.1. *Basic properties*

Lemma 1 characterizes contract competition following a given disclosure.

Lemma 1. *Consider a disclosure equilibrium and let $r = \varphi(\theta)$ be the observed disclosure by the seller. Then, for $\theta > r \geq \alpha$, the contracting stage satisfies*

(*i*) *each buyer offers a contract such that $R_M^i \geq R_0^i$ and*

$$\theta(1 - r)(\Pi - R_M^i) - [1 - \theta(1 - r)]R_0^i = r(1 - \theta)\Pi \tag{1}$$

(*ii*) *the seller, who is indifferent between offers, accepts one contract, say from B^i, and then reveals fully and exclusively to B^i, with $t_i = \theta$ and $t_j = r$;*

(*iii*) *the payoff to the seller is $\Pi^S = (\theta - r)\Pi$ and the payoff to each buyer is $\Pi^B = r(1 - \theta)\Pi$.*

Proof. All proofs are found in the appendix. ||

Lemma 1 indicates that the seller garners the remaining (expected) rents in the system (*i.e.* the added value to the buyer of the seller's remaining know-how). This result is an implication of competitive bidding in which symmetrically positioned buyers are pushed to indifference between winning and losing. Using r to signal type is costly because it gives know-how to both competitors, thereby raising the expected payoff to the loser of the auction and lowering the amount that either bidder is willing to pay for the incremental know-how.

The contract not only induces the seller to reveal θ to the winning bidder but also provides the incentive not to reveal anything beyond r to the losing buyer. The expected payment of $(\theta - r)\Pi$ can be interpreted as consisting of the pure value of the additional IP to the winner, $(\theta - r)(1 - r)\Pi$, and the loss to the loser from having the opposing buyer acquire IP, $(\theta - r)r\Pi$. This second component is a variation on the "blackmail" threat analyzed in Anton and Yao (1994).

The results in Lemma 1 are based on the presumption that a seller discloses at least α. Lemma 2 shows that the lowest type seller, $\underline{\theta}$, never discloses more than α in equilibrium, while higher types disclose valuable IP.

Lemma 2. *Consider a disclosure equilibrium. Then $\varphi(\theta) > \alpha$ for each $\theta > \underline{\theta}$. Further, for the lowest-type seller, $\underline{\theta}$, we have $\varphi(\underline{\theta}) \leq \alpha$ and $\Pi^S(\underline{\theta}) = (\underline{\theta} - \alpha)\Pi$. Thus, in the case of $\underline{\theta} = \alpha$, we have $\Pi^S(\underline{\theta}) = 0$.*

A disclosure of less than α has no direct value for a buyer and is feasible even for sellers with very little know-how. If such a disclosure leads to an inference that the seller has know-how in excess of $\underline{\theta}$, then the type $\underline{\theta}$ will prefer this disclosure to that of $\varphi(\underline{\theta})$ because the benefit of being perceived to have more know-how has no associated cost when the disclosure is below α. The payoff for $\underline{\theta}$ is thus based on the minimum possible know-how a seller may possess. As a convention, we set $\varphi(\underline{\theta}) = \alpha$.

3.2. *Analysis and equilibrium*

In equilibrium, a seller of type θ discloses $r = \varphi(\theta)$ and earns $\Pi^S(\theta) = [\theta - \varphi(\theta)]\Pi$. Consider the incentive of θ to deviate to $\hat{r} \neq r$. Such a disclosure is feasible as long as $\theta \geq \hat{r}$. Upon observing $\hat{r}$, the buyers infer the seller is of type $\hat{\theta} = \varphi^{-1}(\hat{r})$ and each buyer offers a contract, say $(\hat{R}_M, \hat{R}_0)$, as described by Lemma 1. By accepting this offer, the deviation payoff is given by

$$\theta(1 - \hat{r})\hat{R}_M + [1 - \theta(1 - \hat{r})]\hat{R}_0. \tag{2}$$

Since $\hat{R}_M \geq \hat{R}_0$ holds, we know θ has an incentive to reveal fully and exclusively.

A seller who can reveal a significant amount of know-how benefits from a larger spread between $\hat{R}_M$ and $\hat{R}_0$ because the probability weight on the payoff $\hat{R}_M$ is larger. A seller with less than $\hat{\theta}$ to reveal prefers a smaller spread, with $\hat{R}_M$ closer to $\hat{R}_0$. These differential incentives across seller types relate to the incentive to disclose know-how and, in turn, make separation possible. To see this use Lemma 1 and (1) to solve for $\hat{R}_M$ in terms of $\hat{R}_0$, and substitute into (2) (for a type θ who discloses $\hat{r}$) to find

$$U(\theta, \hat{\theta}, \hat{r}, \hat{R}_0) \equiv (\hat{\theta} - \hat{r})\Pi\left(\frac{\theta}{\hat{\theta}}\right) - \hat{R}_0\left(\frac{\theta}{\hat{\theta}} - 1\right).$$

Thus, $U(\theta, \hat{\theta}, \hat{r}, \hat{R}_0)$ is the payoff a type θ can obtain by disclosing (a feasible) $\hat{r}$ when buyers infer the seller is type $\hat{\theta}$ and offer a contract (with $\hat{R}_0$) that has an expected value of $(\hat{\theta} - \hat{r})\Pi$ for a type $\hat{\theta}$ seller.

Consider how $\hat{R}_0$ affects the incentive to deviate. While a seller with relatively large know-how, $\theta > \hat{\theta}$, prefers a smaller $\hat{R}_0$, a seller with $\theta < \hat{\theta}$ finds the deviation less attractive if the contract offer at $\hat{r}$ has a small $\hat{R}_0$ payment. Thus, if we let $\hat{R}_0$ decline into the negative range and approach $-L$, a seller with less know-how finds the upward deviation progressively less attractive. In combination, this makes it possible to reduce $\hat{r}$, which increases the equilibrium payoff of $(\hat{\theta}-\hat{r})\Pi$ for $\hat{\theta}$, without increasing the incentive to mimic sellers with higher know-how. Thus, contracts which maintain a large payment spread via large negative payments in R_0 can maintain separation incentives with less disclosure.[9]

To solve for a disclosure equilibrium, we seek a disclosure strategy φ and a contract offer specification for how R_0 varies with disclosures such that $\varphi(\theta)$ is an optimal disclosure for each θ. The above discussion suggests a simple approach: set $R_0 = -L$ at each disclosure and then solve for φ to eliminate the disclosure deviation incentive. An optimal disclosure then satisfies the IC condition of $\Pi^S(\theta) \geq U(\theta, \hat{\theta}, \varphi(\hat{\theta}), -L)$ for each θ and feasible disclosure $\varphi(\hat{\theta}) \leq \theta$. Proposition 1 shows that an equilibrium with these features exists.

Proposition 1. *Consider the case of $\underline{\theta} = \alpha$ and suppose that $\alpha\Pi > L$. Then an equilibrium with partial disclosure exists and is given by the disclosure strategy*

$$\varphi(\theta) = \frac{L}{\Pi} + \left(1 - \frac{L}{\alpha\Pi}\right)\theta,$$

for $\alpha \leq \theta \leq \overline{\theta}$, the contract offer of $R_0 = -L$, $R_M = \left(\frac{1}{\alpha[1-\varphi(\theta)]} - 1\right)L$, and the implied acceptance and revelation strategy for the seller from Lemma 1.

Corollary 1. *The seller's expected payoff for type θ is $\Pi^S(\theta) = \frac{\theta-\alpha}{\alpha}L$. Each buyer's expected payoff* (*pointwise in θ*) *is $\Pi^B(\theta) = (1-\theta)[\theta\Pi - \Pi^S(\theta)]$.*

This disclosure equilibrium has a simple structure in which each seller type discloses a fraction $\varphi(\theta)$ of the full know-how of θ. The disclosure increases (linearly) with θ and satisfies $\varphi(\alpha) = \alpha$, so that the lowest type of $\underline{\theta} = \alpha$ earns a zero payoff. Higher types earn a positive payoff as buyers bid to acquire the residual know-how $\theta - \varphi(\theta)$. Equilibrium also requires the slope of the disclosure function to be positive which is implied by $\alpha\Pi > L$.

An interesting property of this equilibrium is that disclosure is a substitute for the lack of large seller wealth. As L increases from 0 to $\alpha\Pi$, the slope of the disclosure function implies less disclosure for a given θ and increased seller profits (Lemma 1). This occurs because larger L allows R_0 to be more negative which, for any given expected payoff, increases the spread between R_M and R_0.[10] The larger spread alters the incentive to deviate since a lower (higher) type than θ would now find the disclosure of $r = \varphi(\theta)$ to be less (more) attractive than before. This relaxes the IC constraint. As L increases, less disclosure is required and the seller's payoff increases. Hence, disclosure can be interpreted as a costly strategic substitute for posting a bond.

A second feature of the equilibrium is that disclosure incentives lead to a dissipation of seller rents with regard to the system monopoly profit of Π. For a given disclosure function, an increase in Π implies that $(\theta - r)\Pi$ is larger and the buyers have a greater willingness-to-pay (WTP) for the incremental IP of $\theta - r$. Competitive bidding would then translate this higher

9. These deviation incentives are closely related to the familiar single-crossing property in signaling models. The disclosure-inference tradeoff for a type-θ seller, an $(\hat{r}, \hat{\theta})$ indifference curve, can be constructed from $U(\theta, \hat{\theta}, \hat{r}, \hat{R}_0)$ as follows. We show later (see the proof of Proposition 2 in the appendix) that the payment $\hat{R}_0$ is non-increasing in $\hat{r}$ in any disclosure equilibrium. This implies that the payment wedge $\hat{R}_M - \hat{R}_0$ is non-decreasing in $\hat{r}$. From this, it is straightforward to show that the $(\hat{r}, \hat{\theta})$ indifference curves for U are upward sloping and that the slope is non-increasing in the type θ. This provides higher types with a stronger incentive to disclose know-how and obtain a contract with a larger payment wedge. Thus, single-crossing is satisfied.

10. Intuitively, posting a larger bond imposes no "contracting cost" on the seller. As implied by Lemma 1, the only effect of an extra ΔL in the contracting stage is to increase the payment spread as a smaller $R_0 = -(L + \Delta L)$ requires a larger R_M to maintain the expected value of the contract at $[\theta - \varphi(\theta)]\Pi$. The extra ΔL is simply "returned" in expectation to the seller.

WTP into contract offers that deliver the entire remaining surplus to the seller without regard to IC. Thus, to maintain IC, equilibrium disclosure increases, dissipating the increased WTP of the buyers. This feature highlights the key role of IC in determining seller payoffs. This role is not limited to competitive bidding settings: in Section 3.5 we describe a seller-offer model in which IC is again the critical constraint.

Full, rather than partial, dissipation depends on the structure of our model and occurs in part because the payoff to a seller with no IP must be zero. This anchor limits the payoff to downward disclosure deviations and, in conjunction with IC constraints that are pushed to equality when $R_0 = -L$ across all disclosures, leads to full dissipation.[11] While the weak IC property emerges from the model's innovation probability structure, a structure that results in linearity of φ in θ is neither necessary nor sufficient for full dissipation.[12]

A seller can capture the full monopoly surplus if wealth L is sufficiently large. In cases where $L > \alpha\Pi$, separating equilibria involve only a portion of the seller's wealth and the limiting case with $R_0 = -\alpha\Pi$ has $\Pi^S(\theta) = (\theta - \alpha)\Pi$ and vanishing disclosure. An interpretation of this limiting case is that the seller "acquires" a buyer for the lump-sum price of $\alpha(1-\theta)\Pi$, which coincides with the value of the "losing" firm (see Proposition 1), and becomes the full residual claimant of the buyer's gross profit flows. When buyers cannot independently innovate, $\alpha \to 0$, it is common knowledge that a seller with IP is the only source of value and the limiting contract converges to the full equity contract of $(R_M, R_0) = (\Pi, 0)$.

The economic rationale for limiting the contractual bond when L exceeds $\alpha\Pi$ derives from the necessity of providing disclosure incentives via the contract payment wedge. When $L > \alpha\Pi$, a contract with $R_0 = -L$ necessarily has a large wedge since R_M must be large enough to maintain an expected seller payoff of $(\theta - r)\Pi$. This increases the incentive pressure from downward disclosure deviations. To maintain disclosure incentives, buyers would then be forced to offer contracts that provide a seller payoff in excess of the total surplus.[13] Instead, we apply Proposition 1 with $R_0 < L$ when $L > \alpha\Pi$, thereby maintaining the incentives of higher types for disclosure by limiting the size of the contract payment wedge.

At the other extreme, with small L, the ability of the seller to capture surplus in our separating equilibrium is limited. As long as the support of the type distribution includes α, the weak IC structure of incentives and the requirement that a type with no valuable IP must earn a zero-payoff forces seller payoffs in a disclosure equilibrium to zero as $L \to 0$.[14] Might the seller fare better in a pooling equilibrium?

As is often the case in disclosure models, a pooling equilibrium can be supported (with positive seller profits) at no disclosure by specifying sufficiently pessimistic beliefs for the buyers (*e.g.* all disclosures of IP, except for the minimum, are interpreted as a full disclosure). But in our

11. The literature on signaling with a continuous type space (*e.g.* Mailath, 1987) provides guidance on this point. In general, a partial disclosure equilibrium will satisfy a fundamental signaling differential equation. In our setting, when $R_0 = -L$ for all disclosures, this is given by $\varphi'(\theta) = \frac{-U_2(\theta,\hat\theta,\varphi(\hat\theta),-L)}{U_3(\theta,\hat\theta,\varphi(\hat\theta),-L)}\,|_{\hat\theta=\theta}$. The partial derivative ratio of $\frac{U_2}{U_3}$ is the benefit of being inferred to be a seller with more IP relative to the cost of disclosing more IP. Evaluated at an arbitrary $(\theta,\hat\theta,\hat r,-L)$ point, this ratio is given by $\left(\frac{L}{\Pi} - \hat r\right)\hat\theta$ and it is independent of the actual type θ. This independence implies that IC is pushed to weak equality (single-crossing holds weakly). As examined in the proof of Proposition 2, when R_0 varies with the disclosure then IC is strict (single-crossing is strict). Thus, when R_0 is decreasing as disclosure increases and approaches $-L$, we can find an equilibrium with strict IC that is arbitrarily close to that of Proposition 1.

12. With $N > 2$ potential buyers, equilibrium disclosure is nonlinear in θ but full dissipation continues to apply. When $\underline{\theta} > \alpha$, equilibrium disclosure is linear in θ and $\Pi^S(\theta) = (1 - \alpha/\underline{\theta})\theta\Pi + (\theta/\underline{\theta} - 1)L$, so dissipation is partial.

13. For example, consider the minimum disclosure of α and the contract $(R_M, R_0) = ((\alpha^{-1} - 1)L, -L)$ which has an expected value of zero for type α. The downward deviation payoff for type θ is $\theta R_M + (1-\theta)R_0 = \left(\frac{\theta}{\alpha} - 1\right)L$ and this exceeds $(\theta - r)\Pi$ for any $r \geq \alpha$ when $L > \alpha\Pi$.

14. When the lowest type has valuable IP and dissipation is partial, the seller earns a positive payoff as L vanishes.

context, pooling equilibria have features that make them unlikely to exist in practice. Informally, the beliefs required for pooling always have an "inverted" structure. Observing no disclosure, buyers must infer that the seller has, on average, valuable IP to sell even though no disclosure is the only feasible choice for a seller with no valuable IP. Observing disclosure, buyers must infer that the seller has, on average, relatively less remaining IP to sell, even though only a seller type with valuable IP can make a disclosure. As a measure of the pessimism required, it is straightforward to show that a belief based on the updated mean cannot support pooling for a variety of distributions. A second feature is that pooling is not robust to settings where the distribution of seller types is endogenous (*e.g.* "free entry") as might be expected when zero value-added sellers are able to earn a positive payoff in equilibrium.

The important economic point of this section is that the structure of the disclosure equilibrium reflects the endogenous trade-off between the adverse selection regarding the extent of the seller's IP and the moral hazard associated with disclosed and expropriable IP. The terms of the trade-off depend on how much wealth the seller has to put at risk. Disclosure benefits the seller by overcoming the adverse selection problem for contract bidding.[15] Thus, a seller with more IP discloses more in equilibrium and the moral hazard cost rises to balance the increased benefit of reducing adverse selection.

3.3. *Uniqueness of disclosure*

Here we discuss why we emphasize the $R_0 = -L$ equilibrium. First, consider the boundary condition (BC) for the contract offer at the smallest disclosure:

Condition BC At the disclosure α, each buyer offers the contract (R_M, R_0) where $R_0 = -L$ and $R_M = \left[\frac{1}{\alpha(1-\alpha)} - 1\right]L$.

Suppose that α, which equals $\varphi(\alpha)$, has been disclosed and that one buyer, say B^i, offers a contract with $R_0^i > -L$. Suppose further that B^j believes there is some chance that the seller does have valuable IP (the type is above α). Then, by increasing the payment in state M while pushing the payment in state 0 down slightly toward $-L$ (preserving the expected payment of zero for a type α), buyer B^j offers a contract that is strictly preferable to (R_M^i, R_0^i) for any type above α. Such a type would then accept the offer from B^j and reveal fully and exclusively to B^j. It is straightforward to verify that B^j can always profit from such an offer even for an arbitrarily small chance that a higher seller type is present. Intuitively, a slight move in the contract direction suggested by BC is a "safe" offer that ensures a buyer will attract any seller with valuable IP. Pursuing this logic, both buyers are pushed to offer a payment of $-L$ in state 0.[16]

Proposition 2. *Consider a disclosure equilibrium for the case where $\underline{\theta} = \alpha$. Suppose that BC holds at $\varphi(\alpha)$. Then φ from Proposition 1 is the unique equilibrium disclosure strategy. Let ϕ be a disclosure strategy in any disclosure equilibrium in which BC is not satisfied. Then $\phi(\theta) > \varphi(\theta)$ for all $\theta \in [\underline{\theta}, \overline{\theta}]$.*

15. In equilibrium, the buyer payoff is $\Pi^B(\theta) = (1-\theta)\varphi(\theta)\Pi$ so that the seller has a positive impact via disclosure of $r = \varphi(\theta)$ and a negative impact via revelation of θ. When buyer innovation is likely ($\alpha > 1/2$), disclosure and revelation by the seller make the monopoly state progressively more unlikely and, as $\alpha(1-\alpha)\Pi > (1-\theta)\varphi(\theta)\Pi$ with $\alpha > 1/2$, both buyers suffer relative to the case of no seller. When $\alpha < 1/2$, both buyers benefit from the existence of a seller when θ is near α, provided L is sufficiently small; otherwise the buyers do worse.

16. The argument here is essentially that of a "tremble" in the disclosure strategy of a seller. One can formalize this in a discrete model as follows. If r is observed, suppose that beliefs of each buyer are that the seller is type θ_k with probability $p_k > 0$ where $r = \theta_0 < \theta_1, \ldots, < \theta_N$ and $\sum_{k=0}^{N} p_k = 1$ (for any discrete set of types). One can show that the unique contracting equilibrium has each buyer offering $R_0 = -L$ and R_M defined by $\sum_{k=0}^{N} p_k(\theta_k - \theta_0)\Pi = \sum_{k=0}^{N} p_k[\theta_k(1-\theta_0)(R_M + L)] - L$. As $p_k \to 0$ for all $k \geq 1$, the unique limit is the contract with $R_0 = -L$ and R_M set so that θ_0 has a payoff of zero; BC is the case of $\theta_0 = \alpha$.

Corollary 2. *Across the set of all disclosure equilibria, the equilibrium with disclosure φ is Pareto dominant with respect to the payoff of the seller in that $\Pi^S(\theta) = [\theta - \varphi(\theta)]\Pi$, for all $\theta > \underline{\theta}$, is strictly greater than the equilibrium payoff in any equilibrium with a disclosure strategy other than φ.*

The proof of Proposition 2 provides a characterization of the set of separating PBE for our model. Here, we focus our discussion on the economic structure of φ and the reasoning behind the results in Proposition 2.

As a general property, a disclosure equilibrium only requires that the R_0 component of a contract offer be (weakly) decreasing as disclosure increases. Then, different specifications for how R_0 declines can support different disclosure equilibria. When BC holds, the contract offer at every disclosure must have $R_0 = -L$. To understand why φ is the minimum possible equilibrium disclosure, recall the trade-off between disclosure incentives and the contract payment spread of $R_M - R_0$. When BC is relaxed the buyer's contract offer softens, as it has a smaller spread, and sellers with little IP find an upward disclosure deviation more attractive. As a result, higher seller types are forced to disclose more IP in equilibrium.

3.4. *Market structure, exclusivity, and disclosure incentives*

The argument that a "softening" of the spread makes IC more difficult to meet and forces increased disclosure has implications for extensions of our model that relax assumptions on market structure and contracting contingencies. For example, in a four-state reduced-form payoff structure that is consistent with a Cournot market structure, a positive payment for the nonunique success state (duopoly) softens the incentive structure governing separation, increases equilibrium disclosure, and leads to lower seller payoffs. The impact is analogous to that found in Proposition 2 where we characterized the set of separating PBE for the basic model: a smaller contract payment spread induces the seller to disclose more IP initially. (Details available from the authors.)

Incentive softening also arises with nonexclusive contracting. Under our assumption of independent innovation draws, exclusive contracts are efficient when the seller has large amounts of IP.[17] When the seller has a relatively small amount of IP, however, maximizing joint surplus requires full revelation of the seller's IP to both buyers.[18] In the latter case, can the seller benefit by contracting with both buyers?

Suppose we allow each buyer to offer a pair of contracts to the seller, $\{\Re^{iE}, \Re^{iN}\}$, where $\Re^{iE}$ is an exclusive offer and $\Re^{iN}$ is a nonexclusive offer. The seller has the option of accepting either exclusive offer, accepting either or both nonexclusive offers (provided the wealth constraint is satisfied), or declining all offers.[19] Then, the contracting stage can support an outcome

17. If innovation draws are positively correlated, then joint surplus can be maximized globally at asymmetric IP allocations across the buyers and exclusive contracts are fully consistent with efficiency. We have extended the model to allow for parametrically correlated draws where asymmetric IP allocations are globally efficient. Our basic equilibrium conclusions are robust to this extension as contracts are based on the incremental value of IP to buyers and the seller follows a partial disclosure strategy. Positive correlation makes disclosure more costly for the seller and, in equilibrium, strictly less IP is disclosed than under independence.

18. Expected joint surplus is $[r_i(1 - r_j) + (1 - r_i)r_j]\Pi$ when buyers have IP of r_i and r_j. Given a disclosure $r \geq \alpha$, this is maximized at $(r_i, r_j) = (\theta, \theta)$ when $\theta < 1/2$; for $\theta > 1/2$, a choice of (θ, r) is maximizing when $r < 1/2$ while (r, r) is maximizing when $r > 1/2$.

19. The simpler game where each buyer makes a single nonexclusive offer has a strong "free-rider" flavor and has no nonexclusive outcome: contract payments must induce revelation to both buyers but each buyer has an incentive to let the other one provide the payment incentive to the seller. At the same time, each buyer has an individual incentive to obtain exclusive revelation. If contracts create a strict incentive for the seller to reveal θ to both buyers, then either buyer can reduce some contract payment without changing the revelation outcome; if the incentive is weak, then an

(whenever full revelation maximizes joint surplus) where the seller accepts a nonexclusive offer from each buyer and then reveals θ to both. Supporting this outcome requires that each buyer also makes an exclusive offer, to which the seller is indifferent. This contracting outcome, however, unravels once we consider the disclosure incentives of the seller. Equilibrium disclosure is necessarily determined by IC as the seller compares payoffs available at the nonexclusive offers corresponding to different feasible disclosures. However, IC cannot be maintained across the supporting exclusive offers at the same time. Intuitively, nonexclusive contracting involves softer incentives and a smaller payment wedge because the seller ends up in a positive payment state with higher probability when IP is revealed to both buyers rather than one. (Details are available from the authors.) Maintaining IC across the nonexclusive offers creates the profitable deviation to under-disclose and accept a supporting exclusive offer. In contrast, the equilibrium from Proposition 1 survives in this contract menu game by simply augmenting the buyer offers with an unattractive nonexclusive offer.

3.5. *Contracting under seller bargaining power*

The sale of ideas frequently occurs in markets characterized by asymmetric information, limited property rights, and nonverifiability of amounts of disclosure. In such environments our analysis shows that sellers with weak bargaining power can use unprotected disclosure followed by competitive contracting to generate substantial rents. Relative to the full monopoly surplus, $(\theta - \alpha)\Pi$ (which would obtain if one of the above characteristics were missing), the seller appropriates the fraction $\Pi^S(\theta)/[(\theta - \alpha)\Pi] = L/(\alpha\Pi)$. Thus, the extent of appropriation depends on the relative size of the seller's bond.

To assess the seller's ability to appropriate rents, we compare the outcome to that when the seller is endowed with a strong bargaining position. Suppose that there is only one buyer and that the seller can make a take-it-or-leave-it contract offer in conjunction with an initial disclosure. It follows directly that the seller can capture a payoff of at least $\left(\frac{\theta-\alpha}{\alpha}\right)L$: the seller offer can be designed to have an attractive expected value for the buyer (for any belief) at the chosen disclosure while also making the payment spread as large as possible.[20]

The set of disclosure equilibria for this single-buyer seller-offer model consists of: (i) a disclosure strategy ϕ that is any one-one function with $\alpha \leq \phi(\theta) \leq \varphi(\theta)$; (ii) the contract offer of $R_0 = -L$, and $R_M = \left(\frac{1-\alpha}{\alpha}\right)L$, which is accepted by the buyer; and (iii) subsequent full revelation by the seller. All equilibria are payoff equivalent and the unique seller payoff of $\left(\frac{\theta-\alpha}{\alpha}\right)L$ coincides with that in Proposition 1.[21] By this measure, public disclosure and the induced competition in contract offers among buyers allows the seller to capture rents as effectively as when the seller makes the contract offer. In both cases, IC constrains the bargaining power of the seller in equilibrium, with wealth L and the contract payment spread emerging as pivotal features.

arbitrarily small increase in the monopoly state payment will tip the revelation to full and exclusive for the deviating buyer and generate a payoff increase of $\theta(1 - r)\Pi - \theta(1 - \theta)\Pi$. It is straightforward to verify, however, that the exclusive contracting equilibrium survives in this nonexclusive game.

20. Let the seller disclose r and offer $R_0 = -L$, $R_M = \left(\frac{1-r}{r}\right)L - \epsilon$ where $\epsilon > 0$ is arbitrarily small. The buyer strictly prefers to accept this offer since it has an expected value greater than $r\Pi$ for any beliefs (including the point belief that the seller is type r). The seller then earns $\left(\frac{\theta}{r} - 1\right)L - \theta\epsilon$ by revealing fully. This holds for any $\epsilon > 0$ and $r \geq \alpha$.

21. The unique buyer payoff is $\varphi(\theta)\Pi$ and the buyer benefits relative to Proposition 1. Note, however, that total surplus is different with only one buyer; the effect of a second (passive) firm who also innovates with α is to reduce the surplus by $(1-\alpha)$. Another alternative is a model in which two independent buyers (with distinct output markets) seek to purchase the innovation. In such a setting disclosures do not involve an economic cost for the seller and we expect that, as in the single-buyer model, a similar set of IC constraints will determine the seller payoff.

Disclosure has a very limited role in the single-buyer model and this contrast is useful for understanding the economics of disclosure in the competitive model. Neither the payoffs nor the contract offer depend on the extent of disclosure in equilibria of the single buyer model. The reason is that disclosure has no economic cost for the seller: the buyer and seller always contract with each other in equilibrium and full revelation of the IP ultimately renders the initial disclosure, which only impacts the buyer's refusal or "walk away" value of $\phi(\theta)\Pi$, payoff irrelevant. IC requires that all seller types offer the same contract. The only incentive restriction on equilibrium disclosure is that it not be so large that the interim joint surplus of $(\theta - r)\Pi$ falls below $\frac{(\theta-\alpha)}{\alpha}L$, as this would create a downward deviation incentive for the seller.

In contrast, disclosure plays an integral role in the competitive model. A larger disclosure is costly for the seller because it reduces the amount a winning buyer is willing to pay: when the losing bidder utilizes more disclosed IP in its own efforts, the chance for a unique success by the winning bidder is reduced. In the contract offer competition, disclosure impacts the buyer offers and, as we have seen, the inference of a higher type based on a larger observed disclosure leads to a larger payment spread in the contract. Consequently, the variation in the extent of disclosure across equilibria (Proposition 2) is payoff relevant and a trade-off between disclosure and wealth emerges.

4. PRIVATE VERSUS PUBLIC DISCLOSURE

With a public disclosure, the seller attracts contract offers by initially disclosing know-how to both potential buyers. In contrast, a private disclosure involves disclosing know-how to only one buyer. From the seller's perspective private disclosure avoids the rent dissipation of a public signal but reduces direct competitive pressure. We explore this trade-off by extending the model of Section 2 and find that an underlying threat of public disclosure and competition with a second buyer can support an attractive offer even from a buyer with extreme bargaining power.

Consider a sequential private/public disclosure game in which the seller may make an initial private disclosure to one of the buyers, say B^i. Upon receiving disclosed IP, B^i can offer the seller a contract; the seller can accept and reveal any remaining IP to B^i (and, if desired, to B^j); then payoffs are realized. Otherwise (no seller private disclosure, no offer from B^i, or seller rejects offer), the game proceeds to the public disclosure stage, which remains as in Section 2 with the exception that B^i may be endowed with IP from the private disclosure stage.

Because the seller can potentially make two disclosures, a problem of consistent beliefs for B^i across the private and public disclosure stages arises. To avoid a problem associated with out-of-equilibrium-event updating, we model B^i as receiving "garbled" IP of s_0 when the seller privately discloses r_0 and assume that $s_0 \leq r_0$, $s_0 \sim H$ with support $[\alpha, r_0]$, and $H(s_0 \mid r_0)$ is the conditional probability of B^i observing s_0 or less when the seller disclosed r_0.[22] For simplicity, we assume the seller observes s_0. We then have the following proposition.

Proposition 3. *Let* $\underline{\theta} = \alpha$*, suppose* $\alpha\Pi > L$*, and take* $\varphi(\theta)$ *and* $\Pi^S(\theta)$ *as in Proposition* 1*. Then an equilibrium with partial disclosure exists for the sequential private/public disclosure game. On the equilibrium path,* (*i*) *the seller privately discloses* $\varphi(\theta)$ *to one of the buyers;* (*ii*) *the selected buyer, say* B^i*, offers the contract* $(S_M, -L)$ *such that* $\Pi^S(\theta) = \theta(1-\alpha)(S_M + L) - L$*;* (*iii*) *the seller accepts the offer and reveals fully and exclusively to* B^i*. The equilibrium is supported by a public disclosure of* $\max\{\varphi(\theta), s_0\}$ *by the seller.*

22. If r_0 were observed directly by B^i, then the extensive form would not allow for a consistent assignment of beliefs for some events. For instance, if B^i infers type θ_0 upon receiving r_0 and subsequently, a public disclosure of $r > \theta_0$ occurs (which is a feasible action for a type $\theta > \theta_0$), then the point belief of θ_0 is contradicted since such an r is not feasible for θ_0. Note that H may put arbitrarily large mass on r_0 without impacting the equilibrium.

Corollary 3. *In equilibrium, the payoff to the seller is* $\Pi^S(\theta)$, *the payoff* (*pointwise in* θ) *to* B^i *is* $\theta(1-\alpha)\Pi - \Pi^S(\theta)$ *and the other buyer earns* $\alpha(1-\theta)\Pi$.

In essence, the public disclosure equilibrium has been converted into a closely related private disclosure equilibrium in which the seller still discloses $\varphi(\theta)$ and receives the same payoff.[23] Our goal with this model is to demonstrate that there is such an analog to the public disclosure game. The model does, however, highlight some interesting aspects of private disclosure. Because r_0 and, hence s_0, are superseded by the later revelation of θ, any initial monotonic disclosure function that lies at or below $\varphi(\theta)$ can also support a private disclosure (separating) equilibrium. In equilibrium, the seller reveals θ fully and exclusively to B^i and, if the game were to proceed to public disclosure, the seller would disclose $\varphi(\theta)$. In either event, there is no direct payoff impact of the initial disclosure r_0.[24] Rather, the basis for seller profits rests with the underlying threat of public disclosure and induced competition with a second buyer. The equilibrium requires that the initial private disclosure not interfere with the credibility and value of the public disclosure threat and, hence, r_0 must not exceed φ. Finally, we note that a public disclosure threat is superior to a threat to disclose privately to B^j because, if the seller proceeds sequentially to seek an offer via private disclosure with B^j after rejecting an offer from B^i, the prior disclosure to B^i reduces the value of an offer from B^j. Recognizing this, B^i can make a less aggressive offer (*e.g.* even if B^j were to offer $(S_M, -L)$ from Proposition 3, prior disclosure makes the offer worth less than $\Pi^S(\theta)$ to the seller).

Anton and Yao (1994) explore a different setting for private disclosure where the seller discloses all know-how to the buyer prior to contracting and then receives a contract based on a "blackmail" threat to destroy monopoly rents through disclosure to the other buyer. That approach also solves an underlying adverse selection problem by substituting an expropriation problem. The approaches, however, involve quite different economic forces as partial disclosure—impossible in the earlier binary ($\theta \in \{0,1\}$) model—is used in the current model to signal the extent of yet undisclosed know-how which is then bid for by competing buyers. As noted earlier, part of the seller payoff in Lemma 1 involves a variation on the blackmail threat. In this case, however, the threat has a strong "*ex-ante*" flavor since the buyers are symmetric at that point and each is seeking to acquire the remaining IP from the seller and, hence, prevent it from going to the opposing buyer. By contrast, the blackmail threat in the earlier model has an "*ex-post*" dimension since one buyer is already in full possession of the seller's IP and seeks to prevent the second buyer from acquiring it. That blackmail threat leads to a contract designed to eliminate duopoly gains to trade between the seller and the second buyer, whereas it is the lure of monopoly profit that drives contracting incentives in the current model.

Across the two disclosure approaches, the roles of system profits and seller wealth are worth noting. Duopoly profits are important for the strength of the blackmail threat. In fact, when duopoly profits are zero, as in the current model, the high-type seller ($\theta = 1$) in the earlier model has no credible blackmail threat. Further, the blackmail threat is weakened and the seller

23. As discussed for Proposition 1 in footnote 11, IC for the seller is pushed to weak equality in the public disclosure stage when $R_0 = -L$ and this carries over to the private disclosure stage in Proposition 3. As before, letting R_0 follow a negative and decreasing $\rho(\theta)$ yields strict IC for public disclosure and $\Pi^S(\theta)$ is strictly convex. Setting aside the garbling issue, the private disclosure offer that yields $\Pi^S(\theta)$ has $S_0 = \rho(\theta)$ and S_M such that $(1-\alpha)[S_M - \rho(\theta)] = \frac{d}{d\theta}\Pi^S(\theta)$, and strict IC holds for private disclosures. As $\rho(\theta)$ approaches $-L$, the private offer converges to $S_0 = -L$ and $S_M = \left[\frac{1}{\alpha(1-\alpha)} - 1\right]L$, which is independent of θ.

24. Under less extreme bilateral bargaining assumptions, one expects the seller to share in the added surplus although some (perhaps all) might be dissipated if larger equilibrium disclosures are necessary for maintaining incentives across seller types. Less extreme bargaining assumptions might also force more structure on the initial disclosure functions.

payoff decreases as seller wealth increases because greater L makes it easier to design a contract that neutralizes that threat. By contrast, for partial disclosure larger L relaxes the incentive constraints and the seller's payoff increases. This comparison suggests that private disclosure employing an *ex-post* blackmail threat may have advantages when seller wealth is small. A fully integrated treatment of these disclosure approaches is needed to resolve this issue and is a topic for future research.

5. CONCLUSION

In this paper we examined how signaling through partial disclosure can overcome exchange problems plaguing the sale of ideas. The implementation takes place in an environment where disclosure signals are limited by feasibility and transfer valuable know-how to the receivers. Partial disclosure signaling solves the adverse selection problem by creating an extreme moral hazard problem—allowing potential buyers to expropriate the know-how contained in the signal—that impacts each seller type differently and is used to support separation.

This paper focused on the sale of ideas and not on the incentives for creative activity, but the market for ideas is relevant for such incentives. If important ideas for many industries originate outside the industry, then understanding the market for ideas is an important, and perhaps somewhat overlooked, component of the assessment of how industry structure encourages innovative activity.

APPENDIX

Proof of Lemma 1. Define the value of $\Re = (R_M, R_0)$ to a seller of type θ at disclosure r by $v(\Re) = \max_{t,s}[t(1-s)(R_M - R_0) + R_0]$ for t and s in $[r, \theta]$, where t is the revelation to the buyer offering $\Re$ and s is the revelation to the other buyer. Clearly, $t = \theta$ and $s = r$ if $R_M > R_0$, while $t = r$ and $s = \theta$ if $R_M < R_0$; the seller is indifferent across t and s when $R_M = R_0$. It follows directly that S is choosing optimally in (ii) of Lemma 1. In turn, each B^i is making an optimal offer in (i). Any offer less than $(\theta - r)\Pi$ will be rejected in favor of $\Re^j$ while a higher-value offer attracts S but earns a payoff less than $(1-\theta)r\Pi$.

The following claims (details omitted) show that (i)–(iii) of Lemma 1 are necessary properties of the contracting stage. First, each B^i must offer $\Re^i$ such that $v^i \equiv v(\Re^i) > 0$ and $R^i_M \geq R^i_0$; otherwise, B^j can capture the full surplus of $\theta(1-r)\Pi$. Given this, we must have $v^i = v^j$ with full and exclusive revelation by the seller; otherwise, a small reduction in the state M or 0 contract payment will be profitable. Finally, the option for each B^i to make no offer implies $\theta(1-r)\Pi - v^i \geq r(1-\theta)\Pi$ and, if this were strict, a small payment increase would be profitable for at least one buyer. This establishes Lemma 1. ‖

Proof of Lemma 2. Suppose, instead, that $\varphi(\theta) \leq \alpha$ for some $\theta > \underline{\theta}$. The contracting outcome is found by applying Lemma 1 at the inferred type θ and a disclosure of $r = \alpha$, as $\varphi(\theta)$ has no direct payoff impact on the buyers when $\varphi(\theta) \leq \alpha$. Now, consider type $\underline{\theta}$. Since $\underline{\theta} \geq \alpha \geq \varphi(\theta)$, type $\underline{\theta}$ can feasibly disclose $\varphi(\theta)$ and accept an ensuing (R_M, R_0) offer from a buyer. Employing Lemma 1, the resulting payoff reduces to $\underline{\theta}(1-\alpha/\theta)\Pi + R_0(1-\underline{\theta}/\theta) \equiv v$, as $\underline{\theta}$ optimally reveals fully and exclusively to the offering buyer ($t = \underline{\theta}, s = \alpha$ for $R_M \geq R_0$). Since $R_0 \geq -L$, we have $v \geq \underline{\theta}(1-\alpha/\theta)\Pi - L(1-\underline{\theta}/\theta)$. As we now show, however, v necessarily exceeds the equilibrium payoff for $\underline{\theta}$.

In equilibrium, $\underline{\theta}$ discloses $\varphi(\underline{\theta})$ and has a payoff of either $(\underline{\theta} - \varphi(\underline{\theta}))\Pi$ if $\varphi(\underline{\theta}) > \alpha$ or $(\underline{\theta} - \alpha)\Pi$ if $\varphi(\underline{\theta}) \leq \alpha$. In either case, this payoff is no larger than $(\underline{\theta}-\alpha)\Pi$. We then have $\underline{\theta}(1-\alpha/\theta)\Pi - L(1-\underline{\theta}/\theta) > (\underline{\theta}-\alpha)\Pi \Leftrightarrow \alpha\Pi > L$, which holds by assumption on L. Hence, type $\underline{\theta}$ has a profitable deviation and, therefore, no equilibrium can have $\varphi(\theta) \leq \alpha$ for $\theta > \underline{\theta}$.

Now consider the equilibrium disclosure and payoff for type $\underline{\theta}$. In the case of $\underline{\theta} = \alpha$, feasibility implies $\varphi(\underline{\theta}) \leq \alpha$. Trivially, Lemma 1 with $\theta = r = \alpha$ implies that buyers offer contracts with an expected value of zero. Hence, $\Pi^S(\underline{\theta}) = 0$ for $\underline{\theta} = \alpha$. Now consider the case of $\underline{\theta} > \alpha$. Suppose that $\varphi(\underline{\theta}) > \alpha$. Then, the equilibrium payoff to $\underline{\theta}$ is $\Pi^S(\underline{\theta}) = (\underline{\theta} - \varphi(\underline{\theta}))\Pi$, which is less than $(\underline{\theta} - \alpha)\Pi$.

Consider a disclosure of α. Since $\underline{\theta}$ and all other types disclose more than α, this is not an equilibrium event and we must consider buyer beliefs. If buyers hold a point belief, say $\hat{\theta} \in [\underline{\theta}, \overline{\theta}]$, when α is observed, then, by Lemma 1, the type $\hat{\theta}$ will clearly benefit by deviating from $\varphi(\hat{\theta})$ to α since $\varphi(\hat{\theta}) > \alpha$. If beliefs are given by a c.d.f., say G with support $\subseteq [\underline{\theta}, \overline{\theta}]$, we can prove an analogous version of Lemma 1, the result being that each buyer offers a contract $(R_M, -L)$

where $(\mu-\alpha)\Pi+L=\mu(1-\alpha)(R_M+L)$, and $\mu\equiv\int_{\underline{\theta}}^{\bar{\theta}}\theta dG(\theta)$ is the mean of G. Suppose $\underline{\theta}$ deviates to disclose α and accept the contract. The resulting payoff of $\underline{\theta}(1-\alpha)\bar{R}_M-[1-\underline{\theta}(1-\alpha)]L=\underline{\theta}(1-\alpha/\mu)\Pi-(1-\underline{\theta}/\mu)L$ is strictly increasing in μ and equals $(\underline{\theta}-\alpha)\Pi$ at $\mu=\underline{\theta}$. From above, this exceeds the equilibrium payoff to $\underline{\theta}$ if $\varphi(\underline{\theta})>\alpha$ and the deviation is profitable. Hence, $\varphi(\underline{\theta})\leq\alpha$ in any equilibrium. It follows directly that $\Pi^S(\underline{\theta})=(\underline{\theta}-\alpha)\Pi$. ‖

Proof of Proposition 1 *and Corollary* 1. Clearly, φ is $1-1$. Partial disclosure holds as $\theta-\varphi(\theta)=\left(\frac{\theta}{\alpha}-1\right)\frac{L}{\Pi}>0$ for all $\theta>\alpha$, with equality at $\theta=\underline{\theta}=\alpha$. To verify the conditions for a PBE, note that Lemma 1 applies by construction. Thus, the buyer contract offers and the seller acceptance and revelation choices are optimal at each disclosure r in the range of φ for the inference $\varphi^{-1}(r)$. For the disclosure choice $\varphi(\theta)$ by a type θ seller, we calculate equilibrium profits to be $\Pi^S(\theta)=[\theta-\varphi(\theta)]\Pi=\left(\frac{\theta}{\alpha}-1\right)L$. Feasible disclosures for θ are $\hat{r}\in[\alpha,\theta]$. If θ discloses $\hat{r}=\varphi(\hat{\theta})$, then the contract $(\hat{R}_M,\hat{R}_0)$ at $\varphi(\hat{\theta})$, from Proposition 1, can be accepted. Revelation choices of $t=\theta$ and $s=\varphi(\hat{\theta})$ are strictly optimal and the deviation payoff for θ reduces to $U(\theta,\hat{\theta},\varphi(\hat{\theta}),-L)=(\theta-\hat{\theta})[1-\varphi(\hat{\theta})](\hat{R}_M-\hat{R}_0)+\Pi^S(\hat{\theta})=\Pi^S(\theta)$ and there is no gain. With beliefs for disclosures $r>\varphi(\bar{\theta})$ that the seller is type $\bar{\theta}$ with probability one and for $r<\alpha$ that the seller is type $\underline{\theta}$ with probability one, the equilibrium is supported. Corollary 1 follows directly. ‖

Proof of Proposition 2 *and Corollary* 2. We develop a set of claims that characterize separating PBE and then prove Proposition 2 and Corollary 2.

The equilibrium payoff $\Pi^S(\theta)$ for a seller in any PBE must be weakly increasing in θ because a higher type can always mimic the strategy of a lower type. Also, $\Pi^S(\theta)\geq 0$ for all θ since contracts may be refused. Thus, if $\Pi^S(\theta)=0$ for some $\theta>\underline{\theta}$, then $\Pi^S(\hat{\theta})=0$ for all $\hat{\theta}<\theta$. Also, if $\Pi^S(\theta)>0$ for some $\theta<\bar{\theta}$, then $\Pi^S(\hat{\theta})>0$ for all $\hat{\theta}>\theta$. Thus, for each PBE we can define a value $\theta^c\in[\underline{\theta},\bar{\theta}]$ by $\theta^c\equiv\inf\{\theta\mid\Pi^S(\theta)>0,\underline{\theta}\leq\theta\leq\bar{\theta}\}$; take $\theta^c=\bar{\theta}$ if the set is null. We then have

Claim 1. *Each separating PBE has a unique θ^c such that (i) $\Pi^S(\theta)=0$ and $\varphi(\theta)=\theta$ for $\theta\leq\theta^c$ and (ii) $\Pi^S(\theta)=[\theta-\varphi(\theta)]\Pi>0$ and $\varphi(\theta)<\theta$ for $\theta>\theta^c$.*

From Lemma 2, $\varphi(\theta)>\alpha$ holds for all $\theta>\alpha$. By Lemma 1, $\Pi^S(\theta)=[\theta-\varphi(\theta)]\Pi$ in equilibrium. Then, (i) and (ii) follow by definition of θ^c, except at types $\theta=\underline{\theta}$ and $\theta=\theta^c$. By Lemma 2, $\Pi^S(\underline{\theta})=0$ and we set $\varphi(\underline{\theta})=\alpha$ as a convention. To show $\Pi^S(\theta^c)=0$, we need the following result.

Claim 2. *Suppose $\Pi^S(\theta)>0$ in a separating PBE. Then $\varphi(\theta)<\theta$ and $\Pi^S(\hat{\theta})>0$ and $\varphi(\hat{\theta})<\hat{\theta}$ for all $\hat{\theta}$ such that $\varphi(\theta)\leq\hat{\theta}$.*

From above, $\Pi^S(\theta)>0$ implies $\varphi(\theta)<\theta$. Thus, $\varphi(\theta)$ is feasible for any $\hat{\theta}$ between $\varphi(\theta)$ and θ. If $\hat{\theta}$ discloses $r=\varphi(\theta)$, accepts an ensuing contract offer and then reveals optimally, the deviation payoff (as in the text) is $\hat{u}\equiv U(\hat{\theta},\theta,r,R_0)=\frac{\hat{\theta}}{\theta}\Pi^S(\theta)-R_0(\frac{\hat{\theta}}{\theta}-1)$. As $\Pi^S(\theta)=(\theta-r)\Pi$, we have $\hat{u}>0\Leftrightarrow\hat{\theta}>-\theta R_0/[(\theta-r)\Pi-R_0]$, assuming $(\theta-r)\Pi>R_0$. [If $(\theta-r)\Pi=R_0$, then $\hat{u}=\Pi^S(\theta)>0$, as this is the case of $R_M=R_0$.] We know $\hat{\theta}\geq r$. Clearly, $r>-\frac{\theta R_0}{(\theta-r)\Pi-R_0}\Leftrightarrow(\theta-r)[r\Pi-R_0]>0$. By hypothesis $\theta>r$, so we need only show $r\Pi>R_0$. $r\Pi\geq\alpha\Pi>L\geq -R_0$, as $r\geq\alpha$ by Lemma 2, $\alpha\Pi>L$ by the limited wealth assumption, and $R_0\geq -L$ by the contracting liability constraint. Thus, $r\Pi>R_0$ and $\hat{u}>0$ for any $\hat{\theta}\geq r=\varphi(\theta)$. In a separating PBE, $\hat{\theta}$ must prefer the disclosure $\varphi(\hat{\theta})$ to $\varphi(\theta)$ and, hence, $\Pi^S(\hat{\theta})\geq\hat{u}>0$. Then $\hat{\theta}>\varphi(\hat{\theta})$ holds and Claim 2 is established.

Return to Claim 1 and suppose $\Pi^S(\theta^c)>0$. Then $\varphi(\theta^c)<\theta^c$ and, by Claim 2, $\Pi^S(\theta)>0$ for types below θ^c. This contradicts the definition of θ^c and, hence, $\Pi^S(\theta^c)=0$, establishing Claim 1. Thus, a separating PBE has (at most) two regions: a set of low types who disclose fully and earn zero, and a set of high types who reveal partially and earn a positive payoff. We now show the following.

Claim 3. *In any separating PBE, φ is continuous and strictly increasing over $[\underline{\theta},\bar{\theta}]$, and $\Pi^S(\theta)$ is continuous over $[\underline{\theta},\bar{\theta}]$ and strictly increasing over $[\theta^c,\bar{\theta}]$.*

This is trivial over $[\underline{\theta},\theta^c]$, as $\varphi(\theta)=\theta$ and $\Pi^S(\theta)=0$. Consider $[\theta^c,\bar{\theta}]$ and assume it is non-degenerate. To prove Claim 3, we first derive the IC conditions. Let $\theta>\theta^c$ and take $\hat{\theta}$ such that $\varphi(\theta)\leq\hat{\theta}<\theta$, as in Claim 2. Then $r=\varphi(\theta)$ is feasible for $\hat{\theta}$ and, clearly, $\hat{r}=\varphi(\hat{\theta})$ is feasible for θ. Any separating PBE must satisfy the pair of IC conditions given by $\Pi^S(\theta)\geq U(\theta,\hat{\theta},\hat{r},\hat{R}_0)$ and $\Pi^S(\hat{\theta})\geq U(\hat{\theta},\theta,r,R_0)$, where U is the payoff calculated, as above, at a deviation disclosure when the seller accepts a contract offer and then reveals optimally. These can be combined and simplified to yield

$$(\theta-\hat{\theta})(1-r)(R_M-R_0) \geq \Pi^S(\theta)-\Pi^S(\hat{\theta}) \geq (\theta-\hat{\theta})(1-\hat{r})(\hat{R}_M-\hat{R}_0). \tag{IC-A}$$

Substituting for R_M and $\hat{R}_M$ via Lemma 1, (IC-A) can be written as

$$\hat{R}_0(\theta-\hat{\theta}) \geq \theta\Pi^S(\hat{\theta})-\hat{\theta}\Pi^S(\theta) \geq R_0(\theta-\hat{\theta}). \tag{IC-B}$$

(IC-A) and (IC-B) only apply to θ and $\hat{\theta}$ pairs where $\varphi(\theta) \leq \hat{\theta} < \theta$. To show $\Pi^S(\theta)$ is continuous over $[\theta^c, \bar{\theta}]$, let $\theta > \theta^c$ and apply (IC-A) as $\hat{\theta} \uparrow \theta$. Since $\hat{R}_M - \hat{R}_0 \geq 0$ and $1-\hat{r} \geq 0$, we see $(\theta-\hat{\theta})(1-\hat{r})(\hat{R}_M-\hat{R}_0) \geq 0$ holds; the LHS of the inequality goes to 0 as $\hat{\theta} \uparrow \theta$, so $\Pi^S(\theta)$ is continuous from the left. Now, let $\hat{\theta} \downarrow \theta$ and apply (IC-A), noting that the roles of θ and $\hat{\theta}$ are reversed as $\theta < \hat{\theta}$: $(\hat{\theta}-\theta)(1-\hat{r})(\hat{R}_M-\hat{R}_0) \geq \Pi^S(\hat{\theta})-\Pi^S(\theta) \geq (\hat{\theta}-\theta)(1-r)(R_M-R_0)$. Clearly, $(\hat{\theta}-\theta)(1-r)(R_M-R_0) \geq 0$ and goes to zero from above as $\hat{\theta} \downarrow \theta$. On the other side, $(1-\hat{r})(\hat{R}_M-\hat{R}_0) = \frac{\Pi^S(\hat{\theta})-\hat{R}_0}{\hat{\theta}} \leq \frac{(\hat{\theta}-\hat{r})\Pi+L}{\hat{\theta}} < \frac{1}{\underline{\theta}}(\Pi+L)$ is bounded above and so $(\hat{\theta}-\theta)(1-\hat{r})(\hat{R}_M-\hat{R}_0)$ goes to zero from above as $\hat{\theta} \downarrow \theta$. Thus, $\Pi^S(\theta)$ is continuous at $\theta > \theta^c$. For continuity at $\theta = \theta^c$, we must show $\Pi^S(\theta)$ converges to zero as $\theta \downarrow \theta^c$, since $\Pi^S(\theta^c) = 0$. Since $\theta > \varphi(\theta) \geq \theta^c$, we have $(\theta-\theta^c)\Pi > [\theta-\varphi(\theta)]\Pi = \Pi^S(\theta) \geq 0$ and $\Pi^S(\theta)$ goes to zero as $\theta \downarrow \theta^c$.

Continuity of $\varphi(\theta)$ on $[\theta^c, \bar{\theta}]$ follows directly since $\Pi^S(\theta) = [\theta-\varphi(\theta)]\Pi$. Then, $\varphi(\theta)$ is strictly increasing on $[\theta^c, \bar{\theta}]$ by the following argument. For $\theta > \theta^c$, $\varphi(\theta) = \theta^c$ implies $\varphi(\theta) = \varphi(\theta^c)$ and then φ is not $1-1$, while $\varphi(\theta) < \theta^c$ implies, by Claim 2, that $\Pi^S(\theta^c) > 0$ but we know $\Pi^S(\theta^c) = 0$. Thus, $\varphi(\theta) > \theta^c$. Consider $\hat{\theta}$ where $\theta^c < \hat{\theta} < \theta$. If $\varphi(\hat{\theta}) = \varphi(\theta)$ then φ would not be $1-1$. If $\varphi(\hat{\theta}) > \varphi(\theta)$, then by continuity φ crosses the value $\varphi(\theta)$ at some type between θ^c and $\hat{\theta}$, again violating $1-1$. Thus, $\varphi(\hat{\theta}) < \varphi(\theta)$ for $\hat{\theta} < \theta$.

To show $\Pi^S(\theta)$ is strictly increasing, we need the following result. At disclosure $\varphi(\theta)$, let (R_M^i, R_0^i) denote the equilibrium contract offer from B^i, $i = 1, 2$. Then, define the correspondence $\rho(\theta) = \{R_0^i, R_0^j\}$ to be the set of state-0 contract payments offered at disclosure $\varphi(\theta)$. We then have

Claim 4. *Let $\hat{R}_0 \in \rho(\hat{\theta})$ and $R_0 \in \rho(\theta)$, where $\theta^c < \hat{\theta} < \theta$. Then* $0 \geq \hat{R}_0 \geq R_0$.

(IC-B) directly implies Claim 4 when $\varphi(\theta) \leq \hat{\theta} < \theta$. We extend to any $\hat{\theta}$ and θ pair as follows. Fix any $\hat{\theta} > \theta^c$. As $\varphi(\hat{\theta}) < \hat{\theta}$, define $\hat{\Delta} = \hat{\theta}-\varphi(\hat{\theta}) > 0$. Let $\hat{R}_0 \in \rho(\hat{\theta})$. By (IC-B), we know $\hat{R}_0 \geq R_0 \in \rho(\theta)$ for any θ s.t. $\varphi(\theta) \leq \hat{\theta} < \theta$. Define $\theta_1 = \hat{\theta}+\hat{\Delta}$. Then, as $\Pi^S(\theta_1) \geq \Pi^S(\hat{\theta})$, $\theta_1-\varphi(\theta_1) \geq \hat{\theta}-\varphi(\hat{\theta}) \Rightarrow \hat{\theta}+\hat{\Delta}-\varphi(\theta_1) \geq \hat{\theta}-\varphi(\hat{\theta}) \Rightarrow \varphi(\hat{\theta})+\hat{\Delta} \geq \varphi(\theta_1) \Rightarrow \hat{\theta} \geq \varphi(\theta_1)$. Thus, $\hat{R}_0 \geq R_0 \in \rho(\theta)$ for any $\theta \in (\hat{\theta}, \theta_1]$. Define $\theta_2 = \theta_1+\hat{\Delta}$. Note $\theta_2-\varphi(\theta_2) \geq \theta_1-\varphi(\theta_1)$ implies, by the same argument, $R_0^1 \geq R_0^2$ for $R_0^1 \in \rho(\theta_1)$ and $R_0^2 \in \rho(\theta_2)$. Since $\hat{\Delta} > 0$, then $\theta_N \geq \bar{\theta}$ for some finite integer N.

It remains to show $0 \geq \hat{R}_0 \in \rho(\hat{\theta})$ for any $\hat{\theta} > \theta^c$. Suppose, instead, that $\hat{R}_0 > 0$ for some $\hat{\theta} > \theta^c$. Then, $R_0 \geq \hat{R}_0 > 0$ for any θ where $\theta^c < \theta < \hat{\theta}$. From $R_M - R_0 \geq 0$, however, $\Pi^S(\theta) = \theta[1-\varphi(\theta)](R_M-R_0)+R_0 \geq R_0 \geq \hat{R}_0 > 0$, and $\Pi^S(\theta)$ remains bounded away from 0 as $\theta \downarrow \theta^c$. This implies a discontinuity at $\Pi^S(\theta^c)$. Hence, $0 \geq \hat{R}_0$. This establishes Claim 4.

We now show $\Pi^S(\theta)$ is strictly increasing over $[\theta^c, \bar{\theta}]$. Let $\theta > \theta^c$ and take $\hat{\theta}$ such that $\varphi(\theta) \leq \hat{\theta} < \theta$. Consider (IC-B) and suppose that $\Pi^S(\hat{\theta}) = \Pi^S(\theta)$. Then $\hat{R}_0(\theta-\hat{\theta}) \geq \theta\Pi^S(\hat{\theta})-\hat{\theta}\Pi^S(\theta) = (\theta-\hat{\theta})\Pi^S(\theta) > 0$, which is not possible since $\hat{R}_0 \leq 0$ by Claim 4. Thus, $\Pi^S(\hat{\theta}) < \Pi^S(\theta)$ for $\varphi(\theta) \leq \hat{\theta} < \theta$. Following the logic in the Claim 4 proof extends this to any $\theta < \hat{\theta}$ pair in $[\theta^c, \bar{\theta}]$. This establishes the final part of Claim 3. An immediate consequence of Claim 4 is given by

Claim 5. *$\rho(\theta)$ is single-valued and continuous a.e. on* $[\theta^c, \bar{\theta}]$.

Define $\rho^U(\theta) = \max\{R_0 \mid R_0 \in \rho(\theta)\}$ and $\rho^L(\theta) = \min\{R_0 \mid R_0 \in \rho(\theta)\}$. By Claim 4, each of ρ^U and ρ^L is non-increasing, $\rho^U(\theta) \geq \rho^L(\theta)$, and $\rho^L(\hat{\theta}) \geq \rho^U(\theta)$ for $\hat{\theta} < \theta$. Then, each of ρ^U and ρ^L is continuous except on a set of measure zero, say A^U and A^L, respectively. Further, $\rho^U = \rho^L$ except on a set of measure zero. To see this, let $\theta \in [\theta^c, \bar{\theta}]\backslash(A^U \cup A^L)$ and suppose $\rho^U(\theta) > \rho^L(\theta)$. By continuity at θ, we have $\lim_{\hat{\theta}\uparrow\theta} \rho^L(\hat{\theta}) = \rho^L(\theta)$, but then $\rho^L(\hat{\theta}) < \rho^U(\theta)$ for $\hat{\theta}$ close to θ and so $\rho(\theta)$ fails to satisfy Claim 4. Thus, Claim 5 is established.

Claim 6. *$\Pi^S(\theta)$ is differentiable and $\frac{d}{d\theta}\Pi^S(\theta) = \frac{\Pi^S(\theta)-\rho(\theta)}{\theta}$, a.e. on* $[\theta^c, \bar{\theta}]$.

Let $\theta > \theta^c$ and take $\hat{\theta}$ such that $\varphi(\theta) \leq \hat{\theta} < \theta$. By (IC-A), $\frac{\Pi^S(\theta)-\rho(\theta)}{\theta} \geq \frac{\Pi^S(\theta)-\Pi^S(\hat{\theta})}{\theta-\hat{\theta}} \geq \frac{\Pi^S(\hat{\theta})-\rho(\hat{\theta})}{\hat{\theta}}$. Letting $\hat{\theta} \uparrow \theta$, continuity of Π^S and ρ a.e. implies the LH derivative exists (a.e.). On the RHS, take $\hat{\theta} > \theta$ close enough that $\varphi(\hat{\theta}) < \theta < \hat{\theta}$ and apply (IC-A) again (reversing θ and $\hat{\theta}$).

Claim 7. *For $\theta \in [\theta^c, \bar{\theta}]$, a separating PBE satisfies (i) $\varphi(\theta) = \theta + \frac{1}{\Pi}\int_{\theta^c}^{\theta} \frac{\rho(t)}{t^2}dt$ and (ii) $\Pi^S(\theta) = -\theta\int_{\theta^c}^{\theta} \frac{\rho(t)}{t^2}dt$.*

Since $0 \le \Pi^S(\theta) \le (\bar{\theta} - \alpha)\Pi$ and $-L \le \rho(\theta) \le 0$, applying (IC-A) as in Claim 6 reveals that $\left|\frac{\Pi^S(\theta)-\Pi^S(\hat{\theta})}{\theta-\hat{\theta}}\right| \le \frac{(\bar{\theta}-\alpha)\Pi+L}{\underline{\theta}}$. Thus, $\Pi^S(\theta)$ is Lipschitz on $[\underline{\theta}, \bar{\theta}]$ and, hence, absolutely continuous. Integrate directly the implied differential equation of $\frac{d}{d\theta}\left(\frac{\Pi^S(\theta)}{\theta}\right) = -\frac{\rho(\theta)}{\theta^2}$ from Claim 6 over $[\theta^c, \theta]$ with $\Pi^S(\theta^c) = 0$. This yields (ii). Then $\Pi^S(\theta) = [\theta - \varphi(\theta)]\Pi$ yields (i). These necessary properties lead to the following sufficient conditions.

Claim 8. *Suppose $\theta^c \in [\underline{\theta}, \bar{\theta}]$ and $\rho(\theta)$ is non-increasing on $[\theta^c, \bar{\theta}]$ with $\rho(\theta^c) \le 0$. Then, there exists a separating PBE with $\varphi(\theta)$ given by (i) of Claim 7.*

Verification is straightforward with $\varphi(\theta)$ from (i) of Claim 7, (R_M, R_0) at θ via Lemma 1 with $R_0 = \rho(\theta)$, and the implied seller acceptance and revelation choices. In particular, (IC-A) and (IC-B) are satisfied with $\Pi^S(\theta) = [\theta - \varphi(\theta)]\Pi$ and $\rho(\theta)$ non-increasing. For (any) downward jumps in $\rho(\theta)$, we can set R_0 anywhere between the LH and RH limits of ρ. Finally, offers at $\theta \le \theta^c$ must not create a profitable deviation; $R_0 \equiv 0$ is sufficient.

We now prove Proposition 2. First, suppose BC holds at $\underline{\theta} = \alpha$. Then, $U(\theta, \underline{\theta}, \underline{\theta}, -L) > 0$ for $\theta > \underline{\theta}$ holds and so $\Pi^S(\theta) > 0$ for all $\theta > \underline{\theta}$. Thus, $\theta^c = \underline{\theta}$. We have $\rho(\theta) = -L$ for all θ since $\rho(\underline{\theta}) = -L$ under BC and, by Claim 4, $\rho(\theta)$ is non-increasing. Claim 7 (i) then implies $\varphi(\theta)$ and, upon integrating, we see that this is equal to the disclosure strategy of Proposition 1. If ϕ is part of a separating PBE in which BC does not hold, let $\rho(\theta)$ denote the state-0 payment offered at $\phi(\theta)$. Ignoring the trivial case in which BC fails but $\lim_{\theta\downarrow\underline{\theta}} \rho(\theta) = -L$, suppose $\underline{\rho} \equiv \lim_{\theta\downarrow\underline{\theta}} \rho(\theta) > -L$. Then, for any $\theta > \underline{\theta}$, $\phi(\theta) - \varphi(\theta) = \int_{\underline{\theta}}^{\theta}\left(\frac{\rho(t)+L}{\Pi t^2}\right)dt > 0$, as $\rho(t) + L \ge 0$ for all $t \in [\underline{\theta}, \bar{\theta}]$ and $\rho(t) + L > 0$ over (at least) some interval $[\underline{\theta}, \theta']$, where $\theta' > \underline{\theta}$ as $\underline{\rho} > -L$. This proves Corollary 2. ‖

Proof of Proposition 3. Supporting beliefs are as follows. Observing s_0, B^i updates the prior F on types using φ and H to obtain the posterior $G(\theta \mid s_0) = P(\varphi(\theta) \mid s_0)$ where $P(r_0 \mid s_0) = \int_{\alpha}^{r_0} h(s_0 \mid x)q(x)dx \big/ \int_{\alpha}^{\varphi(\bar{\theta})} h(s_0 \mid x)q(x)dx$ and $Q(x) = F(\varphi^{-1}(x))$. $G(\theta \mid s_0)$ has support $[\varphi^{-1}(s_0), \bar{\theta}]$. For a public disclosure r, we specify a point belief for B^i of $\max\{r, s_0\}$, where s_0 is the private disclosure (set $s_0 = \underline{\theta}$ if no disclosure); B^j infers type $\varphi^{-1}(r)$ for the seller and r for the IP of B^i (from the disclosure strategies) as B^j does not observe s_0. When $s_0 \le r$, Lemma 1 applies directly to contract offers. When $s_0 > r$, Lemma 1 still applies to the B^j offer but B^i optimally offers $(R^i_M, -L)$ s.t. $(1 - r)(R^i_M + L) = (1 - s_0)(R^j_M + L)$ to attract type $\varphi^{-1}(s_0)$ by matching B^j's offer. Consider the optimal public disclosure for θ, given s_0. Feasibility implies $\theta \ge s_0$. Disclosing $r < s_0$ is strictly dominated. Since $r \in [s_0, \theta]$ induces buyer inferences of $\varphi^{-1}(r)$, the proof of Proposition 1 implies any such r will yield a payoff of $\Pi^S(\theta)$. As $r = \max\{\varphi(\theta), s_0\} \in [s_0, \theta]$, this is an optimal choice.

Consider the private disclosure stage. For B^i, offers with $S_M < S_0$ are either equivalent to or strictly dominated by no offer. Consider $S_M \ge S_0$. Given s_0, a type-θ seller accepts (S_M, S_0) from B^i iff $\theta(1 - \alpha)(S_M - S_0) + S_0 \ge \Pi^S(\theta)$. If S rejects, B^i expects each $\theta \in [\varphi^{-1}(s_0), \bar{\theta}]$ to disclose publicly $r = \varphi(\theta)$, as $\theta \ge s_0$, with resulting B^i payoff $\varphi(\theta)(1 - \theta)\Pi$. It is easy to verify that $\theta(1 - \alpha)\Pi - \Pi^S(\theta) > \varphi(\theta)(1 - \theta)\Pi$ for all $\theta > \alpha$. Then the offer $S_M = \left[\frac{1}{\alpha(1-\alpha)} - 1\right]L$, $S_0 = -L$ uniquely maximizes B^i's expected payoff. Verification that no agent has a profitable deviation is straightforward. Corollary 3 follows directly. ‖

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