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Information, Nonexcludability, and Financial Market Structure*

I. Introduction

The vast literature on financial intermediation and contracting written over the last 25 years presents a seeming contradiction. On the one hand, many authors stress that information is costly to produce and becomes a public good when agents use it to trade. On the other hand, the literature often emphasizes that financiers incur these costs because they gather private information that endows them with an informational monopoly.¹

Is information a public or a private good? The answer to this question has important positive and normative implications. For example, most of what we know about financial contracting comes from models in which it is assumed that

We study the determinants of market structure in financial intermediation markets when property rights over information are weak. We show that incentives to gather information to screen firms can be preserved in decentralized markets with more than one intermediary. Local monopoly power is sustained by an aggregate oligopolistic market structure, where intermediaries voluntarily refrain from free riding. We find that this market structure is robust to entry and does not change with market size. We apply our theory to two markets—investment banking and venture capital—and use it to organize and interpret the evidence.

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1. On information as a public good, see, e.g., Grossman and Stiglitz (1980). On informational monopolies, see, e.g., Fischer (1989), Rajan (1992), and Besanko and Thakor (1993).

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firms deal with only one financier who is somehow granted monopoly power. This assumption seems warranted if information is a private good but seems questionable if information is public. On the normative side, some authors suggest that financiers with market power may be desirable, in that they reduce the inefficiencies arising from free riding in information gathering (see, e.g., Fischer 1989; Petersen and Rajan 1995). Yet this seems to run contrary to the dominant wisdom among policy makers, who often stress that price competition should be fostered and barriers to entry lowered.

In this article we argue that in many settings the information needed to intermediate is not necessarily a public good, but it is nonexcludable, so that property rights over the relevant information are difficult to define and enforce. A central problem that intermediaries must then solve is how to prevent others from free riding on their costly information-gathering efforts.

The free-riding problem has received considerable attention in the literature.² Several solutions have been proposed, among them sequential trades, contracts with employees to prevent information disclosure, and contracts with prospective borrowers to prevent them from approaching rivals after being screened. In each of these cases, an intermediary employs some mechanism that prevents the disclosure of information to its rivals and allows it to appropriate most of the returns from information gathering. The fact that many mechanisms are used by intermediaries to solve the free-riding problem suggests, however, that no single one is perfect.³ For example, labor contracts may be incomplete, leaving room for competitors to hire away employees. Similarly, firms may be unwilling to bond themselves to a particular intermediary, fearing an *ex post* holdup. And while the assumption of sequential trades may be natural in some settings (such as stock market trading activity), it may be inadequate when applied to many others.

While many papers have studied the effects of free riding on the design of financial contracts and securities, few have considered its effects on the structure of intermediation markets. The purpose of this article is to show that the incentives to gather information can be preserved simply by the endogenous adjustment of the intermediary market structure. We show how an oligopoly of long-lived intermediaries may be able credibly to commit not to free ride on rivals even when contracts are incomplete or ineffective, and when competitors can enter

2. See Grossman and Stiglitz (1980) and subsequent articles examining capital market microstructure. Numerous other studies have also recognized the importance of free riding in financial markets; see, e.g., Millon and Thakor (1985) and Thakor (1996).

3. See the working paper version of this article (Anand and Gatetovic 1997) for a detailed discussion on the limits to the effectiveness of contracts in solving the free-riding problem. There, we also discuss why signals by the firm may not suffice in revealing the necessary information to the intermediary.

in response to excess profits. In equilibrium, the short-run gains of free riding on other intermediaries' information-gathering efforts are less than the long-run profits of cooperation. To study the implications of such self-enforcing behavior by intermediaries, we present a model in which market structure, intermediary sizes, and prices are endogenously determined.

There are many channels through which information may leak to rival intermediaries. In this article we study two of these channels. In the first, an intermediary must screen many entrepreneurs to find one profitable project. For example, in venture capital markets almost 99 entrepreneurs are screened and rejected for every one that is financed.⁴ Thus, the decision to finance a particular entrepreneur reveals much information to competing intermediaries, who need not incur the costs of screening rejected firms. In this case, information is akin to a pure public good. The second channel considers the case when the information, experience, and skills necessary to structure financing deals become embodied in a few employees of the intermediary. For example, most of the relationships and knowledge necessary for investment banks to acquire clients and implement deals reside in a few employees.⁵ Here, the costs of information gathering are the expenditures incurred by the intermediary in establishing and maintaining relationships with clients. It may be difficult, however, to prevent other intermediaries from hiring away these employees. Thus, intermediaries cannot establish property rights over the relevant information, which is, therefore, nonexcludable.⁶

A central consequence of nonexcludability is that market structure needs to be analyzed at two levels: first, at the local level (i.e., at the level of each deal) and, second, at the aggregate or market level. We find that *ex post* local monopoly (i.e., after intermediaries pay the expenses needed to gather information) is necessary to preserve the incentives to gather information. Thus prices are determined by bilateral bargaining rather than by competition between intermediaries. But local monopoly power is all that intermediaries need, because the nonconvexity introduced here by nonexcludability is a feature only of the production set of each individual deal, not of the aggregate production set of intermediation services. However, since information is nonexclud-

4. Fenn, Liang, and Prowse (1995, p. 28), e.g., summarize this viewpoint in their recent survey of the venture capital market. They suggest that one reason why "pre-investment due diligence and post-investment monitoring [is] not efficiently performed by large numbers of investors [is] the tendency of investors to free-ride on the efforts of others. Thus, delegating these activities to a single intermediary is potentially efficient."

5. Petersen and Rajan (1994) study the formation and effects of lending relationships.

6. Public finance economists distinguish between nonexcludability and nonrivalness. A good is nonrival if, once produced, its marginal cost of provision is equal to zero. A good is nonexcludable if the owner cannot prevent others from using it. See Cornes and Sandler (1996) for a discussion.

able, local monopoly power is not a technological feature of the market. Rather, it is preserved by an aggregate market structure that is required to make the commitment not to free ride self-enforcing. This has implications both for the distribution of market shares among intermediaries and for entry. First, intermediaries must have similar market shares; if any one becomes too large, market shares of other intermediaries will become too small and the gains of free riding will outweigh the long-run gains from cooperation. Second, when too many intermediaries enter, the market share of each becomes too small to make cooperation attractive. Thus, entry will be limited by the need to make cooperation self-enforcing rather than being solely determined by a zero-profit condition. Conversely, the concentrated aggregate market structures that emerge are robust to both free riding and such entry; in contrast, an aggregate monopolist is not robust to either. Both implications suggest that one should expect intermediation markets to be natural oligopolies.

Nonexcludability implies the following additional results. First, even without entry costs intermediaries may make profits in equilibrium. Second, increases in the size of the market have no effect on entry and market concentration. Third, prices charged by intermediaries are lower in more concentrated markets. Fourth, wages are higher in more concentrated markets. While these results run counter to the intuition that one would obtain from standard models (e.g., Cournot), in all cases the explanation lies in the fact that when inputs are nonexcludable, both local and aggregate market structures matter.⁷ Since in equilibrium prices are determined at the local level by bilateral bargaining and the number of intermediaries in the market is limited by the need to make cooperation self-enforcing, entry does not affect prices and may stop before profits are competed away. Moreover, we show below that lower prices (or higher wages) make cooperation harder to sustain unless the number of intermediaries falls. And when markets become larger, both the gains from long-run cooperation and the temptation from short-run free riding increase, leaving the incentives to enter unaffected. Thus the negative relation between prices and concentration and the independence of market concentration from market size follow directly from nonexcludability.

Our article is related to a growing literature on financial intermediation pioneered by Diamond (1984) and recently surveyed by Bhattacharya and Thakor (1993). Like Petersen and Rajan (1995), we study the role of market power in solving the problems caused by the inability

7. In standard models where inputs are excludable, local market structure is irrelevant. Thus, cooperation is not necessary for the existence of the market, entry is limited only by a standard zero-profit condition, and prices are lower in less concentrated markets. Moreover, increases in market size attract new firms into the market because market rents increase and diseconomies of scale are present at the firm level.

of borrowers to bond themselves contractually to lenders. We go beyond their analysis by endogenizing market structure and showing how incentives to gather information can be preserved in a decentralized market. Like Millon and Thakor (1985), we study the effects of free riding on information gathering. However, while they examine the effects of free riding within each intermediary and show that it introduces diseconomies of scale in intermediation, we analyze free riding across intermediaries. We thus provide an alternative explanation for the existence of multiple intermediaries. Yanelle (1997) also examines price competition among intermediaries. In her model, banks compete both for deposits and for borrowers by setting prices. She shows that as a consequence of nonconvexities in the monitoring technology, price competition need not lead to Bertrand outcomes. We differ from her in that in our model nonconvexities only occur at the level of individual deals and stem from nonexcludable inputs. This leads to the distinction between aggregate and local market structure and provides several predictions that follow from nonexcludability.

Our article is also related to the literature that examines the structure of financial contracts that provide optimal postcontract monitoring incentives. In these settings, intermediaries are assumed, *a priori*, to possess informational monopolies over borrowers.⁸ At first, this assumption may seem inconsistent with settings where information may be acquired by rivals and free riding is of concern. However, by providing an equilibrium-based explanation of local monopoly power, our models suggest that such optimal contracts can be studied within a one entrepreneur—one financier framework without loss of generality. In addition, by deriving local monopoly power from aggregate market structure, we show why intermediaries that possess informational monopolies often have aggregate market power as well.

The rest of the article proceeds as follows. In Section II we present two models that differ in the channels through which information is disclosed to rivals. In Section III we study the multiperiod interactions between intermediaries and show how endogenous cooperation may emerge to solve the free-riding problem, even when allowing for entry. In Section IV we apply our theory to the U.S. investment banking and venture capital markets. Section V concludes.

II. The Models

The models presented in this section illustrate two sources of nonexcludability. In the first, contract offers are publicly observable and convey all relevant information in equilibrium. In the second, information

8. See, e.g., Ramakrishnan and Thakor (1984), Diamond (1991), Aghion and Bolton (1992), Hart and Moore (1994), and von Thadden (1995).

becomes embodied in the employee who gathers it. Information is thus rival but can be transferred to another intermediary if the employee moves. We show that there are no incentives to gather information in equilibrium in either model when the market lasts only for one period.

A. *Public Information Model*

There is a measure cn of entrepreneurs (with $c > 1$ and large), and there are m identical intermediaries (e.g., venture capitalists). Each entrepreneur is endowed with one project but no wealth to finance it. Only a measure n of these projects can generate a net surplus $S > 0$; the rest are useless and generate a loss L . We assume that $S - (c - 1)L < 0$, so that lending randomly without screening is not profitable. Neither intermediaries nor entrepreneurs know which projects are worth funding, but by spending E in an evaluation (with $cE < S$), an intermediary can determine with certainty the quality of the project.⁹ Both the decision to screen and the result of the evaluation are private information.¹⁰ The timing is as follows.

1. Each entrepreneur randomly approaches each intermediary with probability $1/m$. Intermediary i screens a fraction σ_i of those entrepreneurs that approach her.

2. In first-stage contract offers (in this stage intermediary i makes offers only to entrepreneurs who approach her), each intermediary i makes an offer to a fraction $\pi_i(ds)$ of unscreened entrepreneurs, to a fraction $\pi_i(g)$ of those who were screened and are good, and to a fraction $\pi_i(b)$ of those who were screened and are bad.¹¹ An offer specifies the fraction $\lambda_i^1 \in [0, \lambda^m]$ of the project's surplus S that will be kept by the intermediary if the project succeeds; λ^m , which we take as exogenously given, denotes the fraction that the intermediary would keep if it would have local monopoly power over the entrepreneur and $\lambda_i^1 = \infty$ denotes a rejection. Expression λS denotes the profits per deal net of financing costs, but gross of screening costs; therefore, we refer to λ as the "gross margin" hereafter. We assume that intermediary i offers the same $\lambda_i^1 \in [0, \lambda^m]$ to all entrepreneurs whom it does not reject. Contract offers are observable and commit the intermediary to finance the project.

3. In second-stage contract offers (in this stage intermediary i can make offers only to entrepreneurs who did not approach it in the first

9. This assumption implies that information is symmetric, which is not crucial to derive the results that follow. The assumption that the screening technology is perfect is made for simplification; thus, we do not consider ex post monitoring activities by intermediaries.

10. The information, however, is revealed to entrepreneurs. One reason why intermediaries may not be able to lie to entrepreneurs and undertake projects on their own stems from the inalienability of entrepreneurial human capital (see Hart and Moore 1994).

11. Note that we allow intermediaries to offer first-stage dummy contracts to unscreened and bad entrepreneurs. In principle, they could use these contract offers to mislead other intermediaries about the quality of their pool of entrepreneurs.

stage),¹² after observing first-stage offers, intermediaries simultaneously bid for entrepreneurs not in their pool. We denote an offer by intermediary i to entrepreneurs who received an offer λ_j^1 from intermediary j in the first stage by $\lambda_i^2(\lambda_j^1) \in [0, 1] \cup \{\infty\}$; $\lambda_i^2 = \infty$ denotes that no offer was made.

4. Next, entrepreneurs choose to contract with the intermediary with the lowest offer. The tie-breaking conditions are (i) if there is a tie among intermediaries, each gets the deal with equal probability, and (ii) if an intermediary expects zero profits from a deal, she is better-off doing it. After contracting, projects are undertaken, surpluses are shared, and the game ends.

A strategy by intermediary i is a tuple $(\sigma_i, \Pi_i, \lambda_i^1, \Lambda_i^2)$, where $\Pi_i \equiv [\pi_i(ds), \pi_i(g), \pi_i(b)]$; $\lambda_i^1 \in [0, \lambda^m]$ is the offer made to entrepreneurs who were not rejected; and Λ_i^2 is an $(m-1)$ -dimensional vector function $[\lambda_i^2(\lambda_j^1)]_{j \neq i}$, with $\lambda_i^2(\lambda_j^1) : [0, 1] \cup \{\infty\} \rightarrow [0, 1] \cup \{\infty\}$. Since only contract offers are observable, beliefs in the second stage are given by the vector function $\mu(\lambda_i^1) \equiv [\mu(ds|\lambda_i^1), \mu(g|\lambda_i^1), \mu(b|\lambda_i^1)]$, where $\mu(ds|\lambda_i^1)$ is the conditional probability that an entrepreneur was not screened, given that he received an offer λ_i^1 in the first stage. Similarly, $\mu(g|\lambda_i^1)$ and $\mu(b|\lambda_i^1)$ denote the beliefs that an entrepreneur is good or bad, respectively, given that he received an offer λ_i^1 .¹³ Proposition 1 characterizes the set of sequential equilibria of this game.

PROPOSITION 1. In any sequential equilibrium no intermediary screens and no projects are financed.

Proof. Suppose not—that is, suppose a sequential equilibrium exists where $\sigma_i \in [0, 1]$ for some i , and some entrepreneurs receive an offer $\lambda_i^1 \in [0, \lambda^m]$, which maximizes i 's profits. We first show that then $\pi_i(g) = 1$ and $\pi_i(ds) = \pi_i(b) = 0$.

Fix equilibrium beliefs $\mu(\lambda_i^1)$. Then there exists an offer $\underline{\lambda} \in [0, 1] \cup \{\infty\}$ such that rival intermediaries break even if they contract with an entrepreneur who received a first-stage offer. Clearly, entrepreneurs will contract at not more than $\underline{\lambda}$, so that in equilibrium $\lambda_i^1 \leq \underline{\lambda}$. But then, intermediary i maximizes her profits by rejecting bad and un-

12. If intermediaries were allowed to respond to second-stage offers to entrepreneurs in their pool, they could prevent undercutting by (a) screening all of them, (b) not making any first-stage offers (so that no information is revealed to other intermediaries), and then (c) making final offers only to their good entrepreneurs. Such a game, however, would arbitrarily introduce a final period of contracting in which intermediaries would be endowed with an informational monopoly with respect to the entrepreneurs they screened. This would make screening excludable by assumption and go against the very spirit of our argument. Note further that the results when all intermediaries can make simultaneous second-stage offers after observing first-stage offers are identical to those obtained in the simpler game we analyze.

13. As is standard in the literature, we require agents with the same information to share the same beliefs.

screened entrepreneurs [$\pi_i(ds) = \pi_i(b) = 0$], sets $\pi_i(g) = 1$, and offers one if $\lambda = \infty$, a shade below λ if $\lambda \in (0, 1]$, or zero if $\lambda = 0$.

Now along the equilibrium path, beliefs must be consistent with strategies. If $\sigma_i > 0$, then $\mu(g|\lambda_i^1) = 1$ and $\mu(g|\infty) = 0$, hence, $\lambda = 0$. Given these equilibrium second-stage offers, intermediary i always loses money if she evaluates. Thus, in any sequential equilibrium, $\sigma_i = 0$. This proves the first part of the proposition.

To prove the second part we need to show that $\pi_i(ds) = 0$. Suppose not—that is, suppose $\pi_i(ds) > 0$ and $\lambda_i^1 \in [0, \lambda^m]$ for some intermediary i . Since $\sigma_i = 0$ in any sequential equilibrium, beliefs along the equilibrium path must be such that $\mu(ds|\lambda_i^1) = 1$. Since lending to entrepreneurs who received an offer $\lambda_i^1 \in [0, \lambda^m]$ leaves losses given beliefs, no intermediary makes a second-stage offer [$\lambda_j^2(\lambda_i^1) = \infty$ for all j]. But then intermediary i can increase her payoff by setting $\pi_i(ds) = 0$. Thus, since $\sigma_i = 0$, no projects are financed in equilibrium. Q.E.D.

An important component of this result is that along any equilibrium path with screening, intermediaries cannot credibly commit to offer dummy contracts. The reason is that whenever dummy offers are believed by rivals, it is optimal not to make them and to lend only to good entrepreneurs. In equilibrium, any offer will thus unambiguously signal that the project is good. This prompts undercutting, drives λ to zero, and leaves no rents to pay for the evaluation cost E .

Proposition 1 does not depend on rival intermediaries observing λ^1 . At the cost of additional notation it can be shown that nonexcludability obtains even when rival intermediaries do not observe λ_i^1 at all but only observe whether an offer has been made. The intuition hinges again on the fact that whenever dummy offers are believed by rivals, it is optimal not to make them. Since an offer unambiguously signals that the entrepreneur is good, Bertrand competition in the second stage must force margins down to zero. For similar reasons, it is not restrictive to force intermediaries to make the same offer to all entrepreneurs. The point is that in this model the relevant information is not what offer the entrepreneur received, but whether the entrepreneur received an offer.

Last, our analysis would not change if a free rider must do some due diligence on its own before contracting with an entrepreneur that it did not screen. The reason is that the cost of sorting out a good entrepreneur after first-stage contract offers have been made is much smaller than the cost of screening entrepreneurs out of the pool of all entrepreneurs.¹⁴

14. That is, c is large. As we mentioned before, in Sec. IV we cite evidence suggesting that $c \approx 100$ in the venture capital industry. One may argue that, fearing Bertrand competition, a small screening cost would dissuade free riders. However, if the screening cost is small, entrepreneurs who have received an offer would be willing to pay a free rider to receive a competing offer.

B. Human Capital Model

There is a measure n of firms, and there are m intermediaries (e.g., investment banks). Each firm needs to structure one deal that generates net surplus S . Neither intermediaries nor firms know what the structure of the deal should be, but the intermediary can find out by hiring an employee who performs an evaluation that costs E . This information becomes embodied in the employee who did the evaluation. Thus, the employee has private information about the optimal structure of the deal and the details of its implementation. (One can interpret the “information” that is embodied in the employee more broadly to include, e.g., the relationships that the employee has built by working with particular clients or his knowledge about the markets and products the firm targets; these may afford him an advantage in competing for deals with such firms.) The timing of the game is as follows.

1. In screening and first-stage wage offers, firms randomly approach each intermediary with probability $1/m$. Intermediary i decides to gather information on none or all firms that approach it, denoted, respectively, by $\sigma_i = 0$ and $\sigma_i = 1$.¹⁵ This decision is publicly observable.¹⁶ If intermediary i decides to gather information, it hires employees and offers them a wage $w_i^1 \geq w^m$, where w^m is the wage that the employee would get in bilateral bargaining with the intermediary.

2. In second-stage wage offers, after observing first-stage offers w_i^1 but before deals are structured, intermediaries simultaneously bid for all employees of other intermediaries. We denote an offer by intermediary i to an employee employed by intermediary j by $w_i^2(w_j^1) \geq 0$. Tie-breaking conditions are as in the public-information model.

3. Each firm does the deal with the intermediary that succeeded in hiring its employee. The contract allocates a share λ^m of the firm's surplus S to the intermediary, with $\lambda^m S - E > 0$, λ^m being determined in bilateral bargaining. Then the game ends.

A strategy by intermediary i in this 1-period game is a tuple $(\sigma_i, w_i^1, \Omega_i^2)$, where Ω_i^2 is an $(m - 1)$ -dimensional vector function $[w_i^2(w_j^1)]_{j \neq i}$, with j th element $w_i^2(w_j^1) : [0, \infty) \rightarrow [0, \infty)$. Proposition 2 characterizes the set of subgame perfect equilibria of this game.

PROPOSITION 2. In any subgame perfect equilibrium, no intermediary gathers information and no deals are implemented.

Proof. Suppose not—that is, suppose $\sigma_i = 1$ for some intermediary i . Then Bertrand competition for employees drives wages w^2 up to $\lambda^m S$ in the second stage, and intermediary i loses E per deal. Hence, $\sigma_i = 0$ for all i , and no deals are implemented. Q.E.D.

15. Allowing an investment bank to gather information on only a fraction of those firms that approach it would not change our results in any substantive way.

16. The idea is that firms will not accept deals made by intermediaries that have not gathered information. Since firms' decisions are publicly observable, screening decisions are also publicly observable.

The intuition is almost the same as in the previous model: free riding on each other's information gathering drives up wages until profits gross of screening costs are zero and nothing remains to pay the sunk evaluation cost E . In this model, information becomes embodied in employees; thus, it is rival. But it is nonexcludable in equilibrium: labor contracts are incomplete; hence, a competing intermediary can acquire the information by hiring the employee.

III. Implicit Contracts with Endogenous Entry

When information is nonexcludable, intermediaries will screen only if they anticipate that they will not be undercut by a rival. The incentives to cooperate will be stronger when they repeatedly compete against each other, since then the threat of retaliation is more powerful. In this section, we characterize the aggregate market structure and intermediary sizes that emerge when implicit contracts are used to deter free riding. In contrast to the standard treatment of such repeated games, we endogenize entry. The determination of prices, market structure, and firm sizes in equilibrium are then studied.

We consider a repeated game where intermediaries are infinitely lived with discount factor $\delta \in (1/2, 1)$ and play the 1-period game an infinite number of times. Each generation of firms or entrepreneurs lives only for 1 period. Entry can occur each period before first-stage offers are made; intermediary i can enter and become "active" by paying a one-time entry cost $E < n(S - cE)/(1 - \delta)$.

In what follows we characterize sequential equilibria where it is profitable to screen because first-stage offers are not matched. As is well known from the literature on repeated games, there are many equilibria with these features (see Fudenberg and Maskin 1986), so that one cannot hope to obtain sharp predictions on the outcomes that will emerge. But, as Sutton (1991, 1997) has shown in a different context, it can still be very useful to characterize the bounds on the key variables under study that obtain in these models. Thus, we focus our attention on the bounds on prices, market shares, and concentration that define the intervals over which cooperative equilibria exist. Our plan is as follows. We first characterize stationary equilibria where any deviation by an active intermediary destroys cooperation forever; that is, we consider equilibria with the strongest feasible punishment (since any active intermediary can guarantee itself an average payoff of at least zero by doing nothing in the 1-period game, the minmax and Nash payoffs coincide). We then show that the outcome of these equilibria determine the bounds on prices, market shares, and concentration. Since specifying assessments that yield such equilibrium paths and proving that they are a sequential equilibrium is tedious, this is relegated to appendices A and B. Here we only characterize the equilibrium path.

For the discussion that follows it will be useful to define “undercutting” and “outbidding.”

DEFINITION 1. *a)* There is undercutting in period t if for any pair of active intermediaries i, j , $\lambda_j^2 \{\lambda_i^1(t) \in [0, \lambda^m]\} \leq \lambda_i^1(t)$;

b) there is outbidding in period t if for any active intermediaries i, j , $w_j^2[w_i^1(t)] \geq w_i^1(t)$.

That is, j undercuts or outbids i if it matches or improves i 's first-stage offer.

A. Market Structure

In this subsection we answer the following questions: What does a market look like when inputs are nonexcludable? We study the determination of bounds on prices, market shares, and entry.

Prices. A central feature of the implicit contract is that intermediaries will not free ride on each other's information-gathering efforts. It follows that in the public information model, intermediaries have local monopoly power over each entrepreneur; similarly, in the human capital model, each intermediary is granted a local monopsony in the market for employees. In those circumstances, margins λ and wages w will be determined in bilateral bargaining and will equal, respectively, λ^m and w^m in equilibrium. It follows that the continuation payoff of an active intermediary from continued cooperation is

$$\frac{1}{(1 - \delta)} \eta_i n (\lambda^m S - w^m - cE),$$

where η_i is i 's market share and $\lambda^m S - w^m - cE$ is the net profit made from a deal. In the public information model, $w^m = 0$ and $c > 1$; in the human capital model, $w^m \geq 0$ and $c = 1$. If intermediary i free rides, it captures the $(1 - \eta_i)n$ deals that were screened by other intermediaries and earns $\lambda^m S - w^m$ per deal, since it does not have to incur the screening cost cE . Thus, optimally undercutting or outbidding by an active intermediary yields additional short-run profits slightly below

$$(1 - \eta_i)n(\lambda^m S - w^m)$$

and no long-run profits thereafter since cheating destroys the market.

The particular level of prices will depend on the details of the bargaining game, but the feasible ranges are given by the following proposition.

PROPOSITION 3. *a)* In the public information model $cE/S + [(1 - \delta)/nS]E \leq \lambda^m \leq 1$ in equilibrium.

b) In the human capital model $0 \leq w^m \leq (\lambda^m S - E) - [(1 - \delta)/n]E$ in equilibrium.

Proof. *(a)* The lowest feasible value of λ^m that can be charged by an intermediary in any equilibrium obtains when there is only one active intermediary that captures all market profits and covers exactly the en-

try cost E . (Note that if λ^m equals that value and one additional intermediary enters, then both lose money net of the entry cost, so that the lowest feasible λ^m must be higher when there are more intermediaries in the market.) Then, profits will be equal to

$$\frac{1}{(1 - \delta)} n(\lambda^m S - cE) = E.$$

Solving for λ^m yields the lower bound. To show that the upper bound is equal to one, assume, by way of contradiction, that the highest feasible λ^m that is sustainable in equilibrium—call this $\bar{\lambda}^m$ —is less than one. Then, for any active intermediary, its profits must cover the costs of becoming active,

$$\frac{1}{(1 - \delta)} \eta_i n(\bar{\lambda}^m S - cE) = E, \quad (1)$$

and cooperation must be sustainable, that is,

$$\frac{\delta}{1 - \delta} \eta_i n(\bar{\lambda}^m S - cE) \geq (1 - \eta_i) n \bar{\lambda}^m S. \quad (2)$$

Now, substitute one for $\bar{\lambda}^m$ into equations (1) and (2). It is clear that equation (1) would still hold, with strict inequality; moreover, since $\lambda S - cE$ increases proportionately faster than λS as λ increases,

$$\frac{\delta}{1 - \delta} \eta_i n(S - cE) > (1 - \eta_i) nS,$$

which contradicts the assumption that $\bar{\lambda}^m$ is the highest feasible gross margin that is sustainable in equilibrium.

(b) The proof for the human capital model b is almost identical, so we omit it. Q.E.D.

Note that according to proposition 3, the upper bound of λ^m is equal to one, in which case all the surplus of the project is appropriated by the intermediary. Since the gains from cheating increase with the gross margin λ , one may wonder why the upper bound on λ^m is not smaller than one—the idea being that a high enough gross margin might prompt intermediaries to undercut each other. The reason is that, somewhat counterintuitively, cooperation becomes easier to sustain when the gross margin λ is higher. To see the logic behind this, note that in the public information model, cooperation is sustainable only if the continuation payoff from period $t + 1$ on exceeds the gains from undercutting and destroying cooperation, that is,

$$\frac{\delta}{1 - \delta} \eta_i n(\lambda S - cE) \geq (1 - \eta_i) n \lambda S. \quad (3)$$

(Recall that $w = 0$ in the public information model.) Now, an intermediary that free rides does not have to incur any additional screening cost. Thus, net profits per deal are higher when undercutting; this follows directly from nonexcludability of information. Hence, although both the right-hand side and the left-hand side of equation (3) are increasing in λ , the gains from cooperation increase faster than the gains from cheating as the gross margin λ increases. A similar reasoning explains why the lower bound on w^m in the human capital model is equal to zero.

The upper bound on margins and the lower bound on wages simply characterize what is feasible in a cooperative equilibrium. Intermediaries need not capture all the deal surplus, however, since at best this division is determined in bilateral bargaining with the entrepreneur or employee. We elaborate on this distinction in Section III C.

Relatedly, it is easy to show that cooperative equilibria exist in which margins are lower than λ^m (but no smaller than the lower bound established in proposition 2: call this lower bound λ_0). In other words, while λ^m reflects the gross margins resulting from bilateral bargaining, any gross margin in $[\lambda_0, \lambda^m]$ is supportable in a sequential equilibrium. Nevertheless, none of the results concerning bounds on prices, market shares, and concentration that we present are affected by this consideration.

Market shares. The need to make implicit contracts self-enforcing will impose constraints on aggregate market structure. Proposition 4 establishes lower and upper bounds for the market share of intermediaries, and corollary 1 an upper bound on the number of intermediaries in the market.

PROPOSITION 4. Fix the equilibrium number of active intermediaries, m . Then

$$\frac{(1 - \delta)(\lambda^m S - w^m)}{\lambda^m S - w^m - \delta c E} \leq \eta_i \leq 1 - (m - 1) \frac{(1 - \delta)(\lambda^m S - w^m)}{\lambda^m S - w^m - \delta c E}.$$

Proof. Along the equilibrium path, and as of period t , the continuation payoff from period $t + 1$ on must exceed the gains from undercutting and destroying cooperation, that is,

$$\frac{\delta}{1 - \delta} \eta_i n (\lambda^m S - w^m - c E) \geq (1 - \eta_i) n (\lambda^m S - w^m). \quad (4)$$

Straightforward manipulation of equation (4) yields the first inequality. Thus, the market share of the $(m - 1)$ competitors of any active intermediary i cannot be less than $(m - 1) [(1 - \delta)(\lambda^m S - w^m)/(\lambda^m S - w^m - \delta c E)]$, from which the second inequality follows. Q.E.D.

COROLLARY 1. The upper bound on the number of intermediaries in the market is $(\lambda^m S - w^m - \delta cE)/[(1 - \delta)(\lambda^m S - w^m)]$ and obtains when all intermediaries have the same market share.

Proof. When all intermediaries have a market share equal to the lower bound in proposition 4, then $m = (\lambda^m S - w^m - \delta cE)/[(1 - \delta)(\lambda^m S - w^m)]$ and both the upper and lower bound coincide. Q.E.D.

In standard oligopoly models where inputs are excludable, cooperation is just a mechanism for firms to obtain excess rents. By contrast, when inputs are nonexcludable, an implicit contract is necessary for the existence of the market. Proposition 4 is a direct consequence of the implicit-contract condition in equation (4). Proposition 4 implies, on the one hand, that intermediaries cannot be too small, because the incentives to free ride would become too large. On the other hand, there cannot be a very large intermediary either, for it would reduce others' market shares to the point that cooperation would no longer be sustainable. Therefore, a distinct prediction of this model is that intermediaries will tend to be of similar sizes. Corollary 1 implies that there is a maximum number of intermediaries beyond which cooperation is no longer sustainable. This number is independent of market size n and entry costs E , and it does not require differentiation among intermediaries either. Thus, when inputs are nonexcludable, there is a lower bound on concentration and markets can be viewed as "natural oligopolies."

Note that proposition 4 assumes that intermediaries face no capacity constraints when they cheat. This seems natural in settings where inputs are nonexcludable, because limits on the capacity to screen are not important when intermediaries can free ride on the efforts of rivals—thus avoiding screening altogether.

Entry. In standard models with excludable inputs, entry is typically determined by a zero-profit condition: excess profits attract new firms and drive prices down. By contrast, when inputs are nonexcludable, there need be no link between entry and prices because prices are determined in bilateral bargaining. Moreover, entry need not drive profits down to zero because the implicit-contract condition may become binding before the zero-profit condition does. The next proposition studies entry. Although the multiplicity of sequential equilibria in the repeated game admit many different levels of market concentration, one can determine an upper bound on the number of intermediaries and, thus, a lower bound on concentration. This bound obtains for an equilibrium where (i) all intermediaries have the same market shares (see corollary 1), (ii) entry is accommodated as long as it is profitable, and (iii) the punishment is the strongest possible (weaker punishments lead to more concentrated markets; see Sec. IIIC).

PROPOSITION 5. Let $\delta \geq \{(\lambda^m S - w^m)/[2(\lambda^m S - w^m) - cE]\} > 1/2$. In a sequential equilibrium with symmetric market shares where

entry is accommodated as long as it is profitable, the number of active intermediaries is at most equal to $\min[m^{\mathcal{P}}, m^c]$, where $m^{\mathcal{P}}$ is given by

$$\frac{1}{(1 - \delta)} \times \frac{n}{m^{\mathcal{P}}} (\lambda^m S - w^m - cE) = E. \quad (5)$$

and m^c by

$$\frac{\delta}{(1 - \delta)} \times \frac{n}{m^c} (\lambda^m S - w^m - cE) = \left(1 - \frac{1}{m^c}\right) n (\lambda^m S - w^m). \quad (6)$$

Proof. (To simplify the notation, assume that both m^c and $m^{\mathcal{P}}$ are integers.) The assumption that $\delta \geq \{(\lambda^m S - w^m)/[2(\lambda^m S - w^m) - cE]\} > 1/2$ ensures that cooperation is sustainable when there are two active intermediaries. Then a necessary condition for entry to occur is that it is profitable. The discounted stream of profits in an equilibrium with equal market shares is $[1/(1 - \delta)](n/m)(\lambda^m S - w^m - cE)$. If entry is accommodated as long as it is profitable, it will occur as long as profits are at least as large as the costs of becoming active, E ; that is, $[1/(1 - \delta)](n/m^{\mathcal{P}})(\lambda^m S - w^m - cE) \geq E$, from which equation (5) follows. A second necessary condition for entry to be profitable is that cooperation is sustainable, that is, $[\delta/(1 - \delta)](n/m)(\lambda^m S - w^m - cE) \geq [1 - (1/m)]n(\lambda^m S - w^m)$; this follows directly from equation (4), substituting $1/m$ for η_i . The condition in equation (6) then follows. Finally, entry will stop whichever condition binds first. Q.E.D.

Note that m^c equals the lower bound on m obtained in proposition 4. Equation (5) is a standard zero-profit condition, but it does not necessarily determine the number of active intermediaries. Proposition 5 says that if $m^c < m^{\mathcal{P}}$, equilibria exist where active intermediaries make profits net of entry costs, and yet there can be no further entry. The reason is that when inputs are nonexcludable, entry has no effect on prices but simply serves to reduce market shares of active intermediaries. When market shares fall, the gains from free riding increase, which undermines cooperation. Thus, with too much entry, cooperation is no longer sustainable, and the operating profits made by an intermediary are zero, since no intermediary screens in equilibrium. As a consequence, no additional firm will incur the sunk cost to enter, and incumbents will make positive profits.

The assumption that entry is accommodated as long as it is profitable serves to establish an upper bound on the number of intermediaries in the market. It is clear that there always exist sequential equilibria where incumbents discourage entry by threatening to destroy cooperation (which leads to a more concentrated market). However, one may argue that it is unlikely that such equilibria will be observed in practice since, if confronted with entry (and $m < m^c$), the incumbent will have incen-

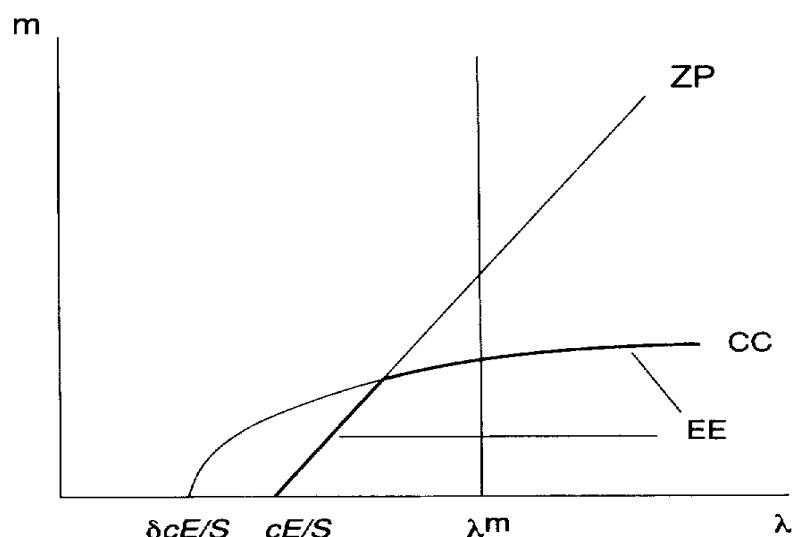


FIG. 1.—Equilibrium in the public information model. λ^m = the gross margin in the (λ, m) space; ZP = the zero-profit locus; CC = the cooperation locus; EE = the lower envelope of ZP and CC ; $\delta cE/S$ = the x-intercept of CC locus; cE/S = the x-intercept of ZP locus.

tives to renegotiate with the entrant rather than follow through on its threat of a price war that destroys the market.

B. Comparative Equilibria

In this subsection we examine how equilibria differ across intermediation markets with different exogenous characteristics. For each model we study the relation between concentration and prices, between entry costs and prices, and between market size and market structure. Again, the fact that the model admits multiple equilibria means that these relations describe how the bounds of feasible equilibrium values vary with exogenous characteristics.

The public information model. Figure 1 graphs the zero-profit condition in equation (5), the implicit-contract condition in equation (6), and the gross margin λ^m in the (λ, m) space. The equilibrium gross margin and number of intermediaries are determined by the intersection of λ^m with either the zero-profit locus (ZP) or the cooperation locus (CC). Since both the zero-profit and cooperation conditions are satisfied only for points on or below the respective loci, we can restrict attention to the EE curve, the lower envelope of ZP and CC . The following is apparent from EE .

Result 1. In more concentrated markets gross margins are lower.

In standard models with excludable inputs there is typically a negative relation between prices and the number of firms. This relation obtains because the existence of more firms leads to tougher competition and lower prices. Thus, the price-concentration relation obtains from

asking: If m firms are in the market, what will the price be? In contrast, in this model, prices are not affected by the number of firms in the market as long as cooperation is sustainable and change exogenously only when the bargaining game changes. Lower prices lead to smaller net profits per deal, and the equilibrium number of firms must be consistent with either the zero-profit condition or the implicit-contract condition. Thus, the price-concentration relation obtains from asking: As gross margins vary, how will the maximum sustainable number m of firms in the market change?

To see the intuition behind result 1, consider first the zero-profit condition in equation (5). At high prices, profits per intermediary increase; therefore, additional intermediaries can enter the market while still ensuring nonnegative profits to each. Hence, ZP slopes upward. Consider next the implicit contract condition in equation (6), which, after straightforward manipulation, yields

$$\frac{\lambda^m S - cE}{\lambda^m S} = \frac{1 - \delta}{\delta} (m^c - 1). \quad (7)$$

(Recall that in the public information model $w^m = 0$.) As noted in the proof of proposition 3, lower gross margins λ^m reduce the profits from cooperating, $\lambda^m S - cE$, proportionately more than the profits from undercutting, $\lambda^m S$. To preserve the incentives to cooperate, the number of intermediaries must therefore be smaller as well—thereby increasing the gains from cooperating and reducing the gains from undercutting. Again, therefore, the lower the gross margins are, the fewer intermediaries can be sustained in equilibrium.¹⁷

Next we discuss the relation between entry costs, concentration, and prices. Result 2 follows from the fact that margins are determined in bilateral bargaining.

Result 2. (a) Gross margins are not affected by entry costs E . (b) If the implicit-contract condition from equation (6) binds, entry costs do not affect market structure.

In standard models, lower entry costs will increase the number of firms in the market and reduce prices because of fiercer competition. By contrast, as we have seen, nonexcludability implies that changes in entry costs will not affect prices. Finally, when the implicit-contract condition is binding, changes in entry costs will have no effect on mar-

17. This result is reminiscent of the well-known finding in the literature that tougher price competition implies fewer firms in equilibrium (see Sutton 1991, 1997). However, it differs because of two reasons. First, in standard models it is typically the consequence of scale economies; in this model it holds even when scale economies are unimportant but the cooperation condition is binding. Second, in this model prices are not affected by competition, as they are determined in bilateral bargaining.

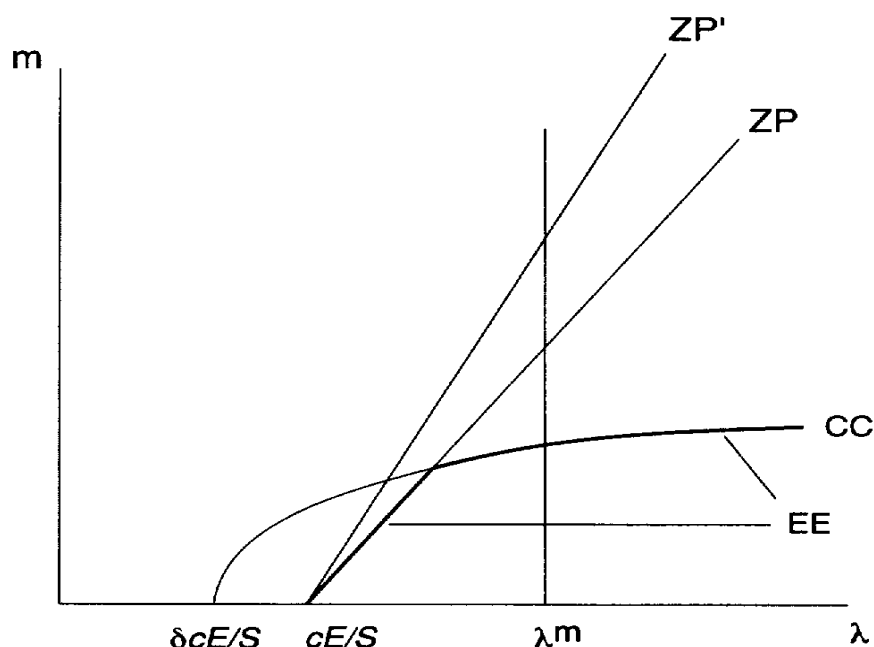


FIG. 2.—Smaller entry costs in the public information model. ZP' = the zero-profit locus with smaller entry costs. For definition of all other terms and variables, see figure 1.

ket concentration either, since aggregate market structure is determined by equation (4) (see fig. 2).

The human capital model. Figure 3 is the mirror image of figure 1 and traces the locus of m^z and m^c against first-stage wage offers w^m . Both these loci are downward sloping. To see why, consider first the zero-profit condition from equation (5). Lower equilibrium wage offers w^m imply larger per-deal profits; in order for equation (5) to hold, the number of active intermediaries must fall; hence, ZP slopes downward. Consider next the implicit-contract condition in equation (6); after straightforward manipulation it yields

$$\frac{\lambda^m S - w^m - E}{\lambda^m S - w^m} = \frac{1 - \delta}{\delta} (m^c - 1).$$

(Recall that in the human capital model $c = 1$.) Lower equilibrium wage offers increase the profits from cooperation proportionately more than the profits from defection for exactly the same reasons as in the public information model. This implies that when wages are high, the number of active intermediaries must be smaller. Thus, CC is negatively sloped, and so is the lower envelope EE . We can now state three results that are the analogues to results 1 and 2 (see figs. 3 and 4).

Result 3. In more concentrated markets, wages w^m are higher.

Result 4. (a) Wages are not affected by entry costs E . (b) If the

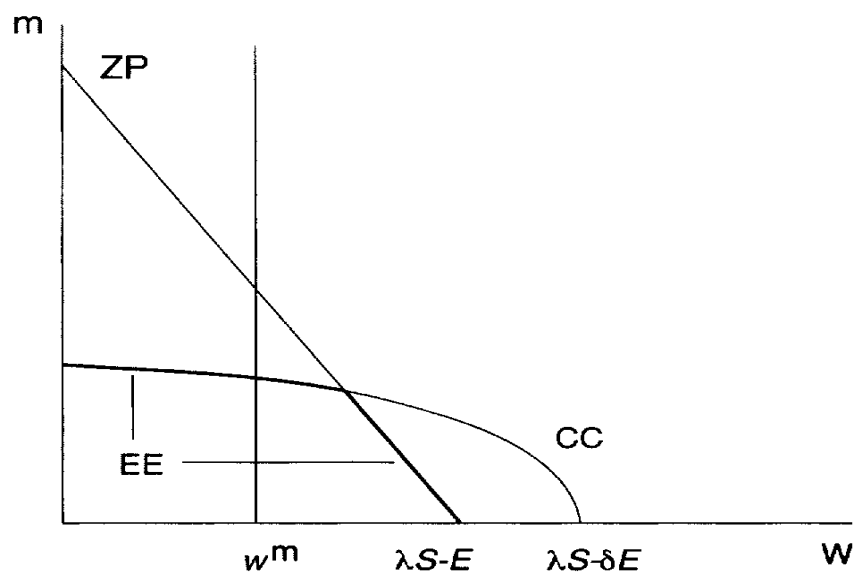


FIG. 3.—Equilibrium in the human capital model. w^m = the wage in (w, m) space; $\lambda S - E$ = the x-intercept of ZP locus; $\lambda S - \delta E$ = the x-intercept of CC locus; see figure 1 for all other definitions.

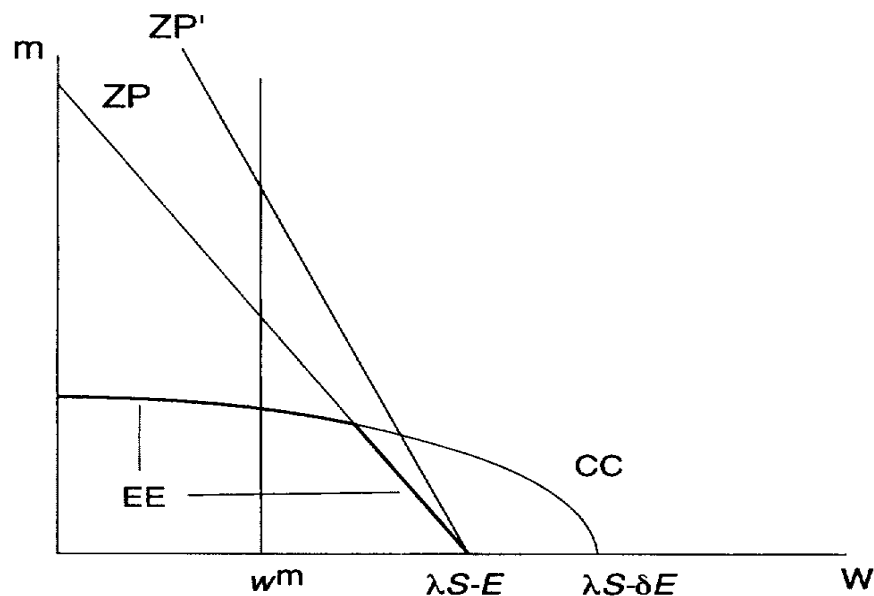


FIG. 4.—Smaller entry costs in the human capital model. ZP' = the zero-profit locus with smaller entry costs. See figures 1 and 3 for all other definitions.

implicit-contract condition from equation (6) binds, entry costs do not affect market structure.

The intuition behind these results is the same as in the public information model, so we proceed without further comment.

Market size and concentration. We now examine the relation between market size, concentration, and prices. The intuition from several models in industrial organization is that concentration falls as the market becomes larger because entry costs and scale economies become less important. Moreover, in larger markets prices are closer to minimum average cost (see Mas-Collel, Whinston, and Green [1995, ch. 12] for a rigorous proof of this assertion). In this model, concentration falls when the market grows if the zero-profit condition is binding; this can be seen from figures 2 and 4. However, prices are not affected by market size as local monopoly must hold independently of market size. Further, if the implicit-contract condition is binding, the following distinct prediction obtains.

Result 5. *Ceteris paribus*, concentration does not depend on market size n when the implicit-contract condition from equation (6) binds.

For a given m , a larger market makes cooperation more attractive, as profits per intermediary increase. At the same time, it also makes cheating more attractive since free riding is more attractive the larger the market. Both effects cancel out exactly, leading to the result.

C. Weaker Punishments

To derive our results, we have used the strongest feasible punishment. Here we show that the bounds on market shares and concentration that we derived above do not change with weaker punishments. Moreover, we show that the comparative equilibria results do not change qualitatively.

Consider a punishment that yields $n\eta_i v_p > 0$ in present value to each active intermediary (i.e., we assume that the payoff of each intermediary during a punishment increases linearly with market size; thus, in larger markets intermediaries earn more during a punishment phase). The implicit-contract condition then reads

$$\frac{\delta}{(1 - \delta)} \eta_i n (\lambda^m S - cE) \geq (1 - \eta_i) n \lambda^m S + \delta \eta_i n v_p.$$

Clearly, proposition 4, which gives lower and upper bounds on market shares, still holds. In particular, when punishments are weaker, the maximum number of intermediaries that is consistent with cooperation (call this m'') is smaller than m^c , the upper bound on the number of intermediaries established in proposition 5. Therefore, weaker punishments lead to more concentrated markets. This is not surprising: weaker punishments make cheating more attractive, so that cooperation must

be made more attractive as well. This is obtained by having fewer intermediaries. Expression m^w is obtained by substituting $1/m^w$ for η_i :

$$\frac{\delta}{(1 - \delta)} \times \frac{n}{m^w} (\lambda^m S - cE) = \left(1 - \frac{1}{m^w}\right) n\lambda^m S + \delta \frac{n}{m^w} v_p. \quad (8)$$

The comparative equilibria results (results 1–4) are strengthened with weaker punishments. This can be seen by rearranging equation (8) to read

$$\frac{\lambda^m S - cE - (1 - \delta)v_p}{\lambda^m S} = \frac{1 - \delta}{\delta} (m^w - 1),$$

which is equivalent to equation (7), except for the fact that there is an additional term in the numerator of the left-hand side of the equation subtracting from the net margin per deal. This implies that the increase in the gains from cooperating relative to undercutting when gross margins increase is even faster than before. Finally, result 5, which relates market size with concentration, continues to hold as long as payoffs in the punishment phase increase linearly with market size.

The following property is also apparent from the implicit-contract condition in equation (8): suppose that a punishment $(n/m^c)v_p > 0$ sustains cooperation with gross margins $\lambda^1 < \lambda^m$. Then, the same punishment $(n/m^c)v_p$ can also sustain the best feasible equilibrium, where the gross margin equals λ^m . Thus, it is easier to sustain an equilibrium that Pareto-dominates another. Consequently, there is no loss of generality in restricting attention to equilibria sustained by the worst feasible punishment.

D. Extensions

Ex post local monopoly versus surplus sharing. A link that deserves elaboration is that between ex post local monopoly power and surplus sharing. Earlier, we established that the upper bound on margins ($\bar{\lambda}^m$) equals one and that the lower bound on wages (w^m) equals zero. Moreover, since intermediaries do not compete with each other ex post, should they not capture all the rents? The answer is no because ex post local monopoly power need not destroy the bargaining power of the entrepreneur or employee, which depends on the outside options available to them. For example, bargaining with entrepreneurs who possess unique ideas or bankers in whom considerable expertise, knowledge, or relationships are embodied may be better described as a situation of bilateral monopoly; many authors study this contracting situation and suggest reasons why the financier may not capture all the project surplus.¹⁸ By contrast, entrepreneurs and employees should not

18. Hart and Moore (1994), e.g., examine the role of inalienable human capital in a model of debt financing, and Anand and Galetovic (2000) consider entrepreneurial holdup in research and development.

be able to derive additional rents ex post simply because information is nonexcludable, and they could switch, since intermediaries will not free ride in equilibrium. Put simply, rents derive from outside options, not from nonexcludability.

It might also appear that there is an apparent tension between ex post local monopoly power and the potential costs of such power on the entrepreneur or employee. However, ex post local monopoly need not imply that intermediaries will be able to exploit entrepreneurs or employees in significant ways. After all, an intermediary that attempts to do so may cause entrepreneurs or employees to switch to other intermediaries that offer superior service on nonprice dimensions. Moreover, such switching should be feasible as long as such ex post nonprice competition among intermediaries does not trigger a price war. This would also provide a different explanation for switching by entrepreneurs or employees among intermediaries than that suggested by a literal interpretation of the model—after all, these need not all be interpreted as off-equilibrium phenomena or imply a breakdown in cooperation but, rather, may be a result of nonprice competition between intermediaries.

Partial excludability and contracts. Our assumption that information is completely nonexcludable is extreme. For example, in some settings, contracts may be effective in binding firms or employees to intermediaries. In our 1997 paper, we model the degree of nonexcludability (call it p) as a continuous variable. We show that market structure does not vary continuously with the degree of nonexcludability. Rather, there are only two distinct regions of interest in the parameter space: if nonexcludability exceeds some critical value (call this p^*), then contracts will not be effective in preventing free riding, and the model behaves qualitatively in exactly the same manner as when information is completely nonexcludable. Even in this region, however, intermediaries' profits increase with the degree of excludability or with the effectiveness of contracts. Thus, contracts and market structure are complements in providing incentives to gather information.

IV. Applications

In this section, we apply our theory to interpret evidence on the U.S. investment banking and venture capital markets. For each market we look at aggregate market structure, local monopoly, and the sources of nonexcludability.

A. The Investment Banking Market

Aggregate market structure. Aggregate market structure and practices in the U.S. investment banking market have been remarkably stable since the early 1800s. Hayes, Spence, and Marks (1983, p. 5) note

TABLE 1 Underwriting Volumes 1950–86 (in Millions of Dollars)

	1950	1955	1960	1965	1970	1975	1980	1986
Top 1	724	1,019	1,340	2,362	7,023	14,066	21,298	50,867
Top 4	2,264	3,529	4,017	6,959	23,111	49,374	62,880	158,466
Top 6	2,818	4,494	5,229	9,110	31,224	65,017	84,184	219,001
Top 8	3,261	5,393	6,181	10,859	37,206	77,668	102,528	246,546

SOURCES.—Hayes, Spence, and Marks (1983, table 1); and Eccles and Crane (1988, table 5.4). Full credit given to lead manager.

TABLE 2 Market Shares in Underwriting: 1950–86 (%)

	1950	1955	1960	1965	1970	1975	1980	1986
Top 1	17	13	15	14	13	12	15	18
Top 4	52	44	46	42	41	43	43	55
Top 6	64	56	60	55	55	57	57	76
Top 8	75	68	71	65	66	68	70	86

SOURCES.—Our calculations using information from Hayes, Spence, and Marks (1983) and Eccles and Crane (1988).

that investment banks have consistently used syndicates to underwrite securities. At any point in time most have been managed by a handful of banks responsible for the origination of most deals. For example, according to Carosso (1970, p. 95), in the late nineteenth century only six banks were able to handle security flotations of more than \$20 million. The volume of securities underwritten between 1950 and 1986 by syndicates managed by each of the top one, four, six, and eight underwriters is shown in table 1, and their market shares are presented in table 2.¹⁹ Three facts are apparent. First, market shares are quite stable (though concentration has increased somewhat in recent years). Second, as predicted by the theory, no bank is dominant; in every period, the industry leader has a market share of less than 20%, and the top banks are of similar size. Third, although the top firms hold stable market shares, their identities vary over time. As table 3 indicates, almost invariably one new bank makes it into the top group every 5 years. Thus, as Bloch (1989, p. 7) notes, more than half of the top investment banks in the 1950s were no longer major players in the late 1980s (see also Matthews 1994, p. 160). An implication of the latter fact is that, as many industry observers note, entry barriers cannot be high (see, e.g., Smith 1986, n. 7; Bloch 1989, p. 36); if they were, the identities of the top investment banks would probably not change over time.²⁰

19. Actual market shares are slightly lower, since market shares are calculated only among the top 20 investment banks. In 1986 the top 19 investment banks led 96.3% of all corporate security flotations.

20. However, cooperation can still be sustained with a positive probability of losing the franchise, if the probability of surviving one more period is not too small.

TABLE 3 Top Six Underwriters, 1950-86

Rank	1950	1955	1960	1965	1970	1975	1980	1986
1	Halsey, Stuart	Morgan Stanley	First Boston	First Boston	First Boston	Merrill Lynch	Merrill Lynch	Salomon Brothers
2	Morgan Stanley	First Boston	Halsey, Stuart	Lehman Brothers	Merrill Lynch	First Boston	Salomon Brothers	First Boston
3	First Boston	Halsey, Stuart	Morgan Stanley	Blyth Eastman	Lehman Brothers	Salomon Brothers	First Boston	Morgan Stanley
4	Merrill Lynch	Blyth Eastman	Lehman Brothers	Merrill Lynch	Salomon Brothers	Morgan Stanley	Morgan Stanley	Merrill Lynch
5	Kidder Peabody	Glore Forgan	Merrill Lynch	Morgan Stanley	Morgan Stanley	Goldman Sachs	Goldman Sachs	Drexel Burnham
6	Blyth Eastman	Kuhn Loeb	Blyth Eastman	White Weld	Blyth Eastman	Blyth Eastman	Lehman Brothers	Goldman Sachs

SOURCES.—Hayes, Spence, and Marks (1983); and Eccles and Crane (1988).

Nevertheless, the industry is quite profitable. Matthews (1994, p. 228) reports that the pretax return on equity for large investment banks was on average close to 30% between 1981 and 1991.

Regulation cannot explain the persistence in market structure. On the contrary, aggregate market structure has been remarkably unresponsive to drastic regulatory changes. The industry was virtually unregulated until the Great Depression, but during the 1930s the enactment of the Securities and Glass-Steagall Acts of 1933, the Securities Exchange Act of 1934, and several other pieces of legislation transformed investment banking into one of the most regulated industries.²¹ Carosso (1970) stresses that only one of the major investment banks survived these changes, and the industry was drastically restructured.²² Yet little changed in the way business was conducted, and new banks were quickly organized by the partners of those that disappeared. By the late 1930s, the industry had recovered its traditional structure.

Regulatory changes provide natural experiments to test a theory's implications. One such change was the introduction of Rule 415 under the Securities Act of 1933 (better known as "shelf registration") in the early 1980s. It allows firms to eschew the mandatory 20-day waiting period between the registration of the issue with the Securities and Exchange Commission and the moment that the issue can be brought to market.²³ In exchange, eligible firms file a blanket registration document describing their financing plans over the subsequent 2 years. The primary motivation behind Rule 415 was to increase competition. It was reasoned that making firms' financing plans widely available would increase the ability of banks, particularly those that did not have relationships with firms, to bid for such issues, thus weakening bank-firm relationships and decreasing concentration. Rule 415 can be viewed as a fall in intermediaries' bargaining power.²⁴ Our model suggests that margins would then fall but that concentration will increase. Indeed, there is evidence suggesting that spreads charged in bond flotations have fallen.²⁵ Moreover, table 4 shows that the shelf registration market is even more concentrated than the overall underwriting market: the top four and six investment banks lead, respectively, almost 70% and 90% of all debt flotations (see also Hayes and Regan 1993, pp. 154–58; Matthews 1994, p. 160). According to Hayes and Regan

21. See Carosso (1970, chs. 18 and 19) for a detailed description of the regulations introduced during that period and their effects on the industry.

22. Kuhn and Loeb was the only major bank that remained. J. P. Morgan turned into a commercial bank, and the partners who remained in investment banking founded Morgan Stanley.

23. Waiting periods were introduced in the 1930s to protect investors from fraud.

24. See Foster (1989) for evidence on this.

25. See Kidwell, Marr, and Thompson (1987); Foster (1989); and Hayes and Regan (1993). The *Economist* (1995, p. 9) argues that the fall in spreads is a general trend that began in the early 1980s.

TABLE 4 Rule 415 Debt Underwritings (%)

	1982	1985	1988	1991
Top 1	23	26	23	23
Top 4	63	78	71	69
Top 6	80	91	91	88

Sources.—Hayes and Regan (1993, table 6.2).

(1993), most shelf flotations are bond flotations; only 15% of all equity flotations are put on the shelf.

Local monopoly. Next, we discuss evidence on cooperation at the deal level. Firms seldom choose underwriters through competitive bidding. Smith (1986) reports that, between 1980 and 1984, underwriting contracts were negotiated in 95% of all security flotations; competitive bidding was used in the remaining 5%. According to Carosso (1970, ch. 20), competitive bidding has been used only when required by law; even in these cases, syndicates were carefully organized to reproduce the conditions of a negotiated offer.²⁶ Moreover, Matthews (1994, p. 161) suggests that spreads on high-quality, long-term corporate bonds have been $\frac{7}{8}$ % of capital raised for several decades. Similar practices are observed in Britain, where, for decades, underwriting fees have been equal to 1.25% of capital raised.²⁷ Recent evidence by Chen and Ritter (1998) also shows that, in the United States, 90% of initial-public-offering deals raising between \$20 and \$80 million have gross spreads of exactly 7.0%.

Banks also extensively participate in each other's underwriting syndicates. Historically, such ties have been very strong. According to Carosso (1970, p. 59), the same group of banks regularly participated in buying and selling the securities of the same corporations. The structure of syndicates has remained similar until the present. Table 5 shows comanagers chosen by the top six investment banks between 1984 and 1986. In the majority of security flotations, major investment banks select another major investment bank as comanager. Eccles and Crane (1988, p. 94) report that of the 6,327 domestic securities issues led by one of the top six banks in that 3-year period, 60.4% were comanaged by another top-six bank.²⁸

Further, long-term relationships between firms and underwriters have traditionally been important. Until about 25 years ago, the rule

26. On this, see Carosso (1970, ch. 20). It is interesting to note that the open opposition to competitive bidding was one of the reasons that the Justice Department decided to sue the industry in the late 1940s (see Carosso 1970, ch. 21).

27. See "Some old peculiar practices in the City of London," *Economist*, February 18, 1995.

28. Issues of tax-exempt bonds (mainly municipal bonds) are not included in this count.

TABLE 5 Lead and Colead Banks: 1984–86 (%)

Lead	Colead						
	GS	SB	FB	MS	SL	ML	Other
Goldman Sachs	...	19	12	9	9	11	40
Salomon Brothers	12	...	16	7	8	24	34
First Boston	19	14	...	15	12	13	28
Morgan Stanley	10	17	12	...	4	10	47
Shearson Lehman	12	13	15	4	...	9	48
Merrill Lynch	7	18	14	5	9	...	47
Other	3	5	4	1	5	5	77

SOURCE.—Eccles and Crane (1988, table 5.1).

NOTE.—GS = Goldman Sachs, SB = Salomon Brothers, FB = First Boston, MS = Morgan Stanley, SL = Shearson Lehman, ML = Merrill Lynch.

was that a firm would maintain a relationship with only one bank. This has changed in the recent past, but firms still typically maintain relationships with only a handful of banks.²⁹ Baker (1990) recently examined ties between investment banks and corporations with market values of \$50 million or more between 1981 and 1985. He reports that for the 1,091 corporations that made two or more deals during this period, the average number of lead banks used per firm is three (these firms made eight deals on average). All but nine firms granted more than 50% of their business to their top three banks and, on average, 59% of the business was allocated to the top bank. Eccles and Crane (1988, ch. 4) similarly report that among the 500 most active corporations in the market during 1984–86, 55.6% predominantly used one bank to float their securities, with the rest maintaining relationships with only a few banks. They did not find any corporation selecting underwriters on a deal-by-deal basis.

Sources of nonexcludability. According to Eccles and Crane (1988, p. 76), corporations maintain relationships with only a few investment banks because of time constraints. Since most of the exchange of information takes place through direct interaction between the firm's officers and the bank's staff person, it is costly to deal with many banks. This is also costly for banks, for a considerable fraction of the time of an investment banker is spent interacting with the firm and exchanging information, not doing deals. These relationships are, however, characterized by what Eccles and Crane (1988) call "loose linkages"; that is, the firm and the bank interact constantly, but banks are paid only when a deal takes place.

But how important are individuals? It used to be that personalities

29. What seems to have changed is that today's investment banks actively solicit business; it used to be the case that banks would not approach firms that had an ongoing relationship with another bank.

such as J. P. Morgan or Jacob Schiff were of tremendous importance to their businesses. As we have mentioned, during the major restructuring of the 1930s new investment banks were quickly organized, most of them by the partners of the major banks that disappeared following the passage of the Glass-Steagall Act. Carosso (1970, p. 400) notes that bankers respected previous personal relationships so that most firms followed partners to their new investment banks.³⁰ More recently, the importance of employees has been underscored by the attempt of Deutsche Bank (DB) to build a global investment bank by hiring away staff en masse from other major banks. In just over a year, DB lured more than 200 employees of other investment banks, including many senior managers.³¹ This mass hiring by DB is also said to have caused other major banks, such as J. P. Morgan and Goldman Sachs, to compete for Morgan Stanley's high-tech clients.³² It has been said that one additional fallout of DB's rally is it has significantly increased salaries in the industry.³³ The importance of individuals in making (or breaking) an investment bank's business may also explain why employees receive a considerable premium.

B. The Venture Capital Market

Sources of nonexcludability. Venture capitalists screen, monitor, and finance high-risk, start-up ventures. Their costs of information gathering include the general partners' compensation for running the venture capital fund and administrative, travel, and other operating costs, a significant fraction of which is the time and money spent on evaluating "dud projects." Typically, a venture capital firm performs due diligence on over 1,000 entrepreneurs every year and funds only about a dozen projects—a rejection rate of almost 99%.³⁴ Clearly, the return on funded projects must be high enough to cover the costs of screening unworthy projects. Entrepreneurs who are offered funding by a particular venture capitalist have strong incentives to shop around for better terms.

The high rejection rate of projects suggests that considerable infor-

30. This was subsequently used in the late 1940s by the Justice Department to support its claim that the major investment banks had conspired to restrain competition.

31. These included Maurice Thompson, who had built a successful international equity business at S. G. Warburg; Jonathan Beatson-Hird, managing director of the Latin American Equity Group at ING-Barings; and Carter McClelland, who brought with him an entire team of bankers specializing in high-technology from Morgan Stanley. According to the *Economist* ("Herr Dobson's fishing trip," May 11, 1996), DB's chairman said he wanted 200 more investment bankers. For details, see also "Deutsche Morgan windfall," *Economist*, June 8, 1996; and "The brain drain at ING-Barings," *Business Week*, July 8, 1996.

32. See "Silicon Valley's hottest startup is . . . a bank," *Business Week*, April 29, 1996.

33. See "Deutsche Morgan windfall," *Economist*, June 8, 1996.

34. See Perez (1986) and Sahlman (1990). Fenn et al. (1995) provide a detailed description of the due diligence process. Note that a rejection rate of 99% implies $c = 100$.

mation is revealed when an entrepreneur is offered a contract. According to the *Economist*: "When [venture capitalists] back a start-up, they confer on it a stamp of approval. Suddenly a lot of other services become available. 'Venture lawyers' will offer to work for little or nothing, betting that when a start-up company gets big enough it will stick with whom it knows. Accounting firms handle a venture-blessed start-up for a few thousand dollars; they charge their *Fortune 500* clients millions. 'Venture landlords' lease at a discount.'" ³⁵ Free riding has often been observed in practice. For example, according to Bygrave and Timmons's (1992, p. 51) characterization of the industry,

In the 1980s, the normal investing cycle was compressed. Time and time again, extensive due diligence began to have a perverse consequence; the more dedicated you were to doing careful screening, the more likely you would be outbid at the twelfth hour by an impulsive competitor from a new fund. In the great frenzy of mid-1983, a venture capitalist of our acquaintance had this experience. After spending months of effort in evaluating a deal, he proposed an offer to the company founders. They told him that they also planned to talk with other venture capital firms. Just a few days later, he was told that they had decided to accept money from a competing firm. It would have been impossible to conduct reasonable due diligence in that very short time period. The other investor's explanation was simple: if he did the due diligence and made the company an offer, that's good enough for me!

Aggregate market structure. Next, we consider the evidence on market concentration. Casual observation might suggest that the venture capital market is competitive: in 1990, there were more than 95 megafunds in the United States (each managing more than \$200 million in capital), more than 375 smaller funds, 50 "niche" funds, and almost 100 corporate financial and corporate industrial funds. Further, in 1988, two-thirds of the total pool of venture capital in the United States was concentrated in just three states: California, Massachusetts, and New York. Similar figures are observed for 1995.³⁶ Nevertheless, since venture capital funds tend to specialize by industry (e.g., telecommunications, biotechnology), concentration must be examined at the industry level. We employ a nationwide dataset from Venture Economics for telecommunications firms, with information on venture capitalists' participation in each financing round between 1969 and 1993.³⁷ Measured by either the number of deals or the amount of financing disbursed, this was the most active industry over this period.³⁸ The data represent

35. See "A really big adventure," *Economist*, January 25, 1997.

36. See "Industry resources edge down," *Venture Capital Journal*, July 1995.

37. Venture Economics dataset, Thompson Financial, Securities Data Company, Newark, N.J. Lerner (1994) has used similar data for biotechnology financings.

38. See Gompers (1995).

a unique panel on ownership structure at the firm level for the venture capital market.

Table 6 shows descriptive statistics. We have aggregated venture capital activity occurring in each of three time periods, 1969–83, 1984–87, and 1988–93.³⁹ Thus, the market is defined by the industry, the region where entrepreneurs were located, and the period in which the investment occurred. It can be seen that ventures in California (mostly in Silicon Valley and San Francisco), Massachusetts (near U.S. Route 128), and Texas received more than 50% of all disbursements over the sample period. On average, there were 113 venture capitalists competing in any single region and time period, with almost 250 in California, the most active market. Moreover, nonlocal financing is important, in many cases reaching more than 60% for each region and time period considered.

Table 7 reports the market share of the top eight venture capital firms for each region and time period considered. Since a venture capitalist usually disburses funds in several stages and coinvests with other venture capitalists in each round, there are many ways to define a firm's market share. We use three definitions. The first ("top-8 share [i]") is the share of the total financing in a given region and time period: nonlocal venture capitalists investing in California, for example, are considered as competitors to locally based venture capitalists there. The second measure ("top-8 share [ii]") is similar to the one used in the investment banking market: it gives all the credit for financing a given firm (or round, as the case may be) to the lead venture capitalist. Since we do not know the actual lead investor, we assume it to be the one with the largest disbursements to the firm in question (in a given round, or aggregated across rounds, as the case may be). Finally, we calculate the fraction of all deals in a given region and time period in which at least one of the top eight venture capitalists participates ("top-8 participation").

While there is some variation, all the measures tell a similar story. The market share of the top eight venture capitalists is, on average, well above 40%; in most regions it is greater than 50% for any time period under consideration, sometimes as high as 70%. While aggregate concentration in Massachusetts and California appears lower than in other regions, in Massachusetts the share of the top eight venture capitalists is still over 50% when full credit is granted to the lead investor. And Bygrave and Timmons (1992, p. 192) report that in California, the most active region, the "top 9 firms managed a whopping 71% of

39. The years 1978–83, 1983–87, and post-1987 roughly represent three distinct time periods of venture capital activity (see Bygrave and Timmons 1992, ch. 2). Since comprehensive data are available only after around 1977, virtually all activity reported between 1969 and 1983 occurred after this year.

TABLE 6 **Venture Capital (VC) Industry: Summary Statistics**

Region and Variable	1969-83	1984-87	1988-93	Total
Northeast:				
Regional share (%)	15.21	13.62	21.74	16.67
Timepd share (%)	22.19	34.80	43.01	100.00
Number of VCs	104	128	66	99
Local VCs (%)	57.59	48.04	48.52	50.88
South:				
Regional share (%)	10.51	15.89	13.05	13.64
Timepd share (%)	18.84	49.60	31.55	100.00
Number of VCs	100	115	101	105
Local VCs (%)	13.55	10.45	13.49	12.35
North-Central:				
Regional share (%)	7.01	9.00	6.79	7.79
Timepd share (%)	22.03	49.23	28.74	100.00
Number of VCs	65	93	63	74
Local VCs (%)	37.95	10.43	21.25	21.99
West:				
Regional share (%)	6.96	9.87	7.53	8.39
Timepd share (%)	20.29	50.12	29.60	100.00
Number of VCs	53	86	75	71
Local VCs (%)	16.51	13.85	14.31	14.50
Massachusetts:				
Regional share (%)	15.45	12.05	6.78	11.15
Timepd share (%)	33.89	46.06	20.04	100.00
Number of VCs	103	164	88	118
Local VCs (%)	33.60	34.70	37.95	35.37
California:				
Regional share (%)	36.51	28.02	34.78	32.32
Timepd share (%)	27.62	36.92	35.46	100.00
Number of VCs	217	296	227	247
Local VCs (%)	31.29	36.80	47.39	39.86
Texas:				
Regional share (%)	8.43	11.55	9.32	10.05
Timepd share (%)	20.50	48.93	30.56	100.00
Number of VCs	53	109	75	79
Local VCs (%)	21.64	29.72	20.96	25.41
Total:				
Regional share (%)	100.00	100.00	100.00	100.00
Timepd share (%)	24.45	42.59	32.96	100.00
Number of VCs	99	142	99	113
Local VCs (%)	31.89	30.43	35.16	32.47

NOTE.—“Regional share” indicates fraction of total disbursements in a given time period (column) that are in a given region (row). Row total indicates fraction of total disbursements over the entire sample period that accrues to companies in given regions. “Timepd share” indicates fraction of total disbursements in a given region (row) that are in a given time period (column). “Number of VCs” indicates number of venture capital companies investing in a given region and time period. “Local VCs” indicates fraction of total disbursements in a given region and time period that accrue from investors in same region. Row total indicates the fraction of local investments in a given region (for the entire sample period).

TABLE 7 **Venture Capital Industry: Market Concentration and Investor Participation (%)**

Region and Measure	1969-83	1984-87	1988-93	Total
Northeast:				
Top-8 share (i)	43.70	46.57	63.76	49.38
Top-8 share (ii)	34.48	46.00	56.67	43.48
Top-8 participation	20.45	50.00	56.89	42.45
Top-8 coinvesting	33.33	60.61	48.48	47.47
South:				
Top-8 share (i)	42.31	53.31	42.93	46.51
Top-8 share (ii)	38.18	46.03	50.00	44.17
Top-8 participation	26.19	36.36	36.55	33.04
Top-8 coinvesting	72.73	50.00	64.71	62.48
North-Central:				
Top-8 share (i)	44.90	73.37	49.97	58.33
Top-8 share (ii)	57.69	60.00	51.72	56.32
Top-8 participation	47.37	58.54	48.94	51.61
Top-8 coinvesting	44.45	66.67	39.13	50.08
West:				
Top-8 share (i)	63.46	56.02	57.92	58.53
Top-8 share (ii)	48.57	57.58	53.85	53.11
Top-8 participation	48.00	61.54	67.50	59.01
Top-8 coinvesting	16.67	62.50	62.96	47.38
Massachusetts:				
Top-8 share (i)	37.64	26.55	41.44	33.46
Top-8 share (ii)	48.65	54.84	48.15	50.42
Top-8 participation	42.86	47.50	46.81	45.72
Top-8 coinvesting	50.00	73.68	77.28	66.90
California:				
Top-8 share (i)	22.79	26.55	38.00	28.96
Top-8 share (ii)	29.63	37.18	37.33	34.46
Top-8 participation	27.66	41.02	62.76	43.81
Top-8 coinvesting	76.92	62.50	76.94	72.11
Texas:				
Top-8 share (i)	63.18	40.98	61.66	52.49
Top-8 share (ii)	59.26	53.33	73.33	59.98
Top-8 participation	36.36	67.86	60.71	54.98
Top-8 coinvesting	50.00	57.89	70.59	59.49
Total:				
Top-8 share (i)	39.18	40.78	47.39	42.24
Top-8 share (ii)	41.18	48.17	49.16	45.82
Top-8 participation	35.56	51.83	54.31	47.23
Top-8 coinvesting	49.16	61.98	62.87	58.00

NOTE.—“Top-8 share (i)” calculates market shares of an investor as its share of total venture capitalist (VC) disbursements to companies in given region. “Top-8 share (ii)” allocates full credit for each deal to lead investor, which, for a given company, is defined to be the VC with the maximum disbursements to that company. “Top-8 participation” is defined to be the fraction of all deals in the given region and time period in which at least one of the top eight VCs participated. “Top-8 coinvesting” indicates the fraction of deals in which there is participation by more than one of the top eight VCs, conditional on participation by at least one such investor. Row and column totals indicate simple averages of row and column measures.

the total pool of venture capital under management by California firms of all types.” An alternative measure of market concentration is also provided by Bygrave and Timmons (1992, p. 199), who report that in 1979, 20 venture capital firms (out of more than 400 in the United States) had board seats on two-thirds of those high-tech companies that went public and were backed by venture capital.

Local monopoly. Raw measures of market concentration may mask vigorous price competition at the deal level. However, Fenn, Liang, and Prowse (1995, p. 30) report that “though partnerships compete intensely to *locate* potential investment opportunities, they also cooperate with one another [once they do so], mostly through syndication.” We now present additional evidence on cooperation.

Table 7 (last row for each region) shows the probability of a top-eight venture capitalist participating in a given financing round, conditional on the participation of another top-eight venture capitalist.⁴⁰ On average, this probability is 58%, and it is highest in Massachusetts (66.9%) and California (72.11%). This is confirmed by Bygrave and Timmons (1992, p. 189), who studied ties among 464 venture capital firms. They find that the probability of finding one of the top 21 U.S. high-tech funds in any given financing, conditional on another top-21 fund being present, is 37%. The figure is 69% for California’s top nine funds. Moreover, it seems to be common that if two venture capitalists are approached by an entrepreneur, they will likely participate in a syndicate rather than compete away fees by undercutting.⁴¹

A second source of evidence about the extent of cooperation is the pervasiveness of information sharing among them. As two observers report,

A venture capitalist can have a lunch with a friendly competitor and pick up useful information about a particular entrepreneur whose business plan he is considering. . . . Venture capitalists commonly invest in groups of two to five (“pack investing”). There is a great deal of cronyism among venture capital firms and one venture capitalist would be considered greedy to hog an especially attractive investment. The venture capital community in Silicon Valley is like a country club. Everyone knows everyone else, news and gossip travel quickly within the group, and most of the activities of club members remain hidden from most of the public.⁴²

Conversely, Bruno and Tyebjee (1983) report that companies denied follow-on financing have their chances of obtaining financing from outsiders reduced by 74%.

40. Lerner (1995) examines changes in syndication patterns across different financing rounds.

41. Personal communication with an industry insider.

42. Rogers and Larsen (1984), cited by Bygrave and Timmons (1992, p. 187).

TABLE 8 **Venture Capital (VC) Industry: Measures of Local Monopoly (%)**

Round No.	Init-VC (a)	Init-VC (b)	Avge Init-VC	Prev-VC (a)	Prev-VC (b)	N
2	81.88	63.98	58.45	81.88	63.74	552
3	78.93	56.39	62.38	83.47	61.67	375
4	71.31	46.74	57.75	83.67	58.94	251
5	64.61	39.77	55.49	78.65	54.09	178
6	62.62	38.05	45.94	76.42	54.66	123
7	58.54	33.83	44.04	76.83	50.61	82
>7	51.08	28.29	41.71	80.01	54.21	139
Mean	68.68	50.98	55.93	81.37	59.49	

NOTE.—Init-VC (a) = probability of finding at least one member of first-round syndicate in round k . Init-VC (b) = fraction of first-round syndicate members who participate in k th-round, averaged over such rounds. Avge Init VC = mean probability of participation of first-round investors in subsequent rounds of a firm with a total of k financing rounds. Prev-VC (a) = probability of finding at least one member of $(k - 1)$ th round syndicate in round k . Prev-VC (b) = fraction of members in $(k - 1)$ th financing round who participate in k th round, averaged over such rounds.

Information sharing appears to be facilitated by the fact that venture capitalists usually cluster and locate near to each other.⁴³ According to Bygrave and Timmons (1992, p. 186), 30 venture capitalists controlling more than 10% of the entire U.S. venture capital pool are located in four buildings at 3000 Sand Hill Road in Menlo Park, California. Clustering appears to be more important in California, where the top five local venture capitalists over the period 1987–93 were all located on the same street.⁴⁴

Table 8 presents several measures of the participation of initial-round financiers in subsequent rounds, a proxy for the degree of local monopoly.⁴⁵ Column 1 reports the probability of finding at least one member of the original syndicate in each subsequent financing round. It is .8188 in the second round and greater than .5 for those firms that make it into an eleventh financing round (not shown in the table).⁴⁶ Column 2 shows the fraction of members of the original syndicate that participates in each subsequent round of financing. On average, almost two-thirds (63.98%) of the members of the original syndicate participate in

43. Note that in addition to risk sharing, syndication also facilitates information sharing by allowing venture capitalists to pool their imperfect signals on the quality of a project. Moreover, as Lerner (1995) reports, the decision to syndicate does not vary according to the size of the investors that participate, which suggests that the simple risk-sharing explanation is incomplete.

44. The addresses of venture capitalists were obtained from Silver (1996).

45. These measures distinguish between separate funds that may be managed by a single venture capital management company. The results for the cases in which we analyze the participation of the management company, or when we examine the persistence in the identity only of the lead investor in any given round, are even stronger.

46. Some attrition in investor financing across firm rounds is likely for reasons such as the investor's limited portfolio size or the need to attract new investors to signal the quality of the firm to external capital markets as the initial public offering approaches.

the second round, and 50.98% in any subsequent round. Column 3 shows the mean probability of participation of an initial investor in each subsequent round of financing for a firm that had a total of k financing rounds. Thus, the probability of finding a first-round investor in any subsequent round of a firm is, on average, .6238 for firms with three financing rounds and .4171 for firms with more than seven financing rounds.

Next, we examine persistence from one round to the next. For each round of financing, column 4 (the equivalent of col. 1) shows the probability of finding at least one financier who participated in the previous financing round. On average for any given round, this probability is .8137. Moreover, as column 5 indicates, almost 60% (.5949) of all investors in any given round also participate in the subsequent round.

An alternative explanation for this observed persistence is that it may be costly to search for and develop a working relationship with outside financiers. If so, one should observe more switching in early rounds, not in later ones in which the incremental benefits of transacting with a new venture capitalist for just one or two additional rounds may not cover these transaction or search costs. The data, however, indicate exactly the opposite: column 5 in table 8 shows that persistence is higher in earlier rounds. Note that the observed pattern is plausible if information-gathering costs are incurred early on, in which case the threat of switching is likely to render ex ante screening unprofitable.⁴⁷ Moreover, it is unlikely that the costs of switching financiers conditional on having received a follow-on financing offer are high.

C. Alternative Explanations

We close this section by examining two alternative explanations for the evidence we have presented—scale economies and product differentiation.

Scale economies. The simplest explanation for market concentration is that there are scale economies in the provision of financial services. If the market is not too small, many intermediaries will operate in equilibrium at their minimum efficient scale. One implication of this explanation, however, is that an increase in market size should attract entry, leave the size of the average intermediary unchanged, and decrease market concentration. This implication is not consistent with the evidence from the investment banking market, however. As can be seen from table 1, the volume of underwritten securities increased considerably during the past 40 years, yet market structure remained stable; if anything, concentration has increased since the early 1980s. Similarly,

47. Note that the ubiquitous "rights of first refusal," which give extant venture capitalists the option to match any offer made by an outside financier, do not prevent ex post competition and, hence, will not preserve screening incentives ex ante.

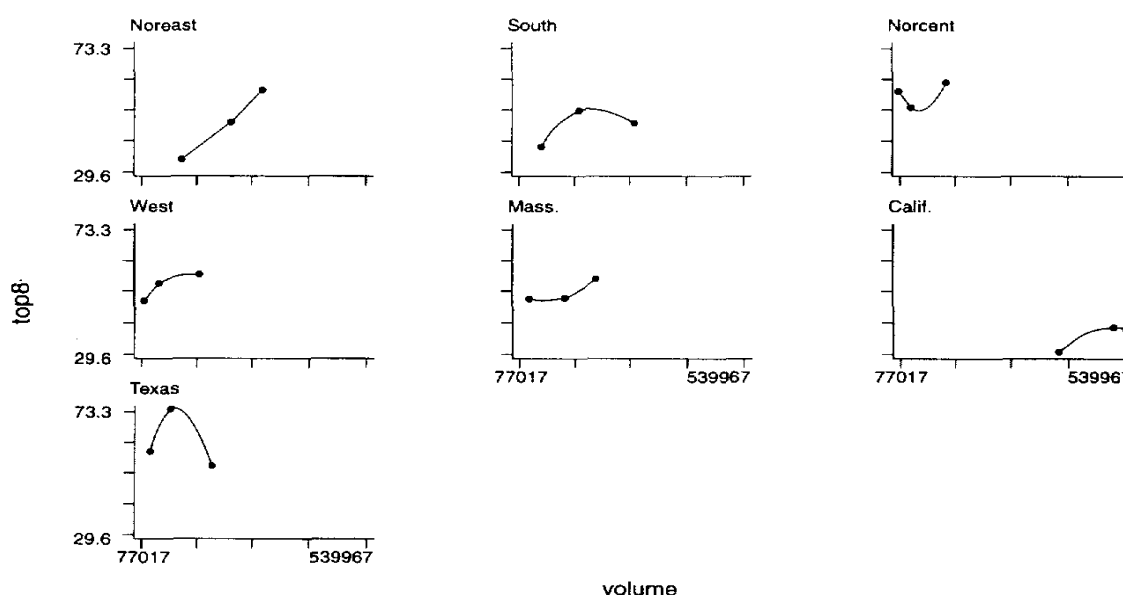


FIG. 5.—Volume and concentration in the U.S. venture capital market

concentration does not fall in the venture capital market when volume increases. Figure 5 plots the market share of the top eight venture capital funds against volume for each of the seven regions considered in table 7. (The market share measure we use in the plots allocates all credit for a given financing round to the lead venture capitalist; see the "top-8 share (ii)" measure in table 7). If anything, concentration tends to increase with volume. This is confirmed in a simple regression of market concentration on volume, presented in table 9. The results plainly reject the hypothesis of a negative relation between market size and concentration. Indeed, after controlling for region-specific differences (these fixed effects are not shown in the table), there is a weak positive relationship: increases in deal volume of \$100,000 result in an increased share for the top eight venture capitalists of about 1% on average. This relationship is not statistically significant at the 10% level after controlling for other time trends. In conclusion, a binding implicit-contract condition is consistent with the evidence.

Product differentiation. A second explanation for market concentration posits that intermediaries specialize and offer differentiated services because information-gathering or deal-structuring costs increase with the "distance" between the intermediary and the firm.⁴⁸ Specialization can be based on location, on the types of deals offered, or on the type of industry or firm financed. For example, one investment bank

48. See Salop (1979) for the theory and Aleem (1990) and Susman (1993) for applications to credit markets.

TABLE 9 Volume and Market Concentration in the Venture Capital Market

Variable	Concentration (a)		Concentration (b)		Concentration (c)	
	(i)	(ii)	(i)	(ii)	(i)	(ii)
Volume	.268 (.377)	.737 (.676)	.512** (.232)	.645 (.384)	1.260** (.358)	1.050* (.488)
1984–87	...	-.078 (.096)	...	-.021 (.054)039 (.069)
1988–93012 (.065)042 (.037)130** (.047)
Constant	.417** (.084)	.338** (.113)	.386** (.052)**	.350** (.064)	.202** (.080)	.189** (.082)
Number of observations	21	21	21	21	21	21
R ²	.46	.49	.64	.69	.51	.71

NOTE.—Concentration (a) measures the share of total VC disbursements to companies in given region-time period accruing from top-eight investors. Concentration (b) measures market share of total VC disbursements to companies in given region-time period, where full credit for each deal is allocated to lead investor. Concentration (c) measures the fraction of all deals in given region-time period in which there is participation by at least one top-eight venture capitalist. Regional fixed effects are not shown. For the two regressions, (i) does not include time dummies for 1984–87 and 1988–93, and (ii) does. Numbers in parentheses are standard errors.

* Significant at the 10% level.

** Significant at the 5% level.

may specialize in doing merger and acquisition deals, another in doing leveraged buyouts; one venture capitalist may specialize in financing projects in telecommunications, another financing projects in biotechnology.

One piece of evidence against models that assume differentiated intermediaries stems from the fact that specialization can occur only if fixed or sunk costs are important; otherwise, one would observe a continuum of intermediaries along the product or location space. Thus, the implications concerning the effects of volume on entry and market concentration in the standard scale economies case above also apply here. The strongest evidence against theories built on the assumption of differentiation, however, is the pervasiveness of clustering among intermediaries. First, most major investment banks are located in New York, and, as we have already mentioned, most venture capital firms are located in California's Silicon Valley, near U.S. Route 128 and Boston in Massachusetts, or in New York City. Similar clustering is also commonly observed among other intermediaries dealing with small-business lending and rural credit markets (see, e.g., Aleem 1990; Chang, Chaudhuri, and Jayaratne 1997). Second, Hayes et al. (1983) find that while investment banks can be grouped into four major clusters according to the types of firms with which they make deals, each cluster contains at least two of the major investment banks. Further, according to Eccles and Crane (1988, p. 104), all major investment banks are multiproduct firms. And while some banks specialize some-

what according to industry, major investment banks have an important presence in all industries.⁴⁹ Finally, while venture capitalists tend to specialize in particular industries, we have seen from the telecommunications data that a large number of them compete for projects in any given industry. Moreover, the significant extent of out-of-region financing (on average, more than 60%; see table 6) suggests that regional segmentation is not as strong as might appear.

V. Conclusion

This article has developed a theory of financial market structure built on the premise that intermediaries find it difficult to control the flow of the information that they gather. We presented two different models of information gathering that differ in the channels through which information gets revealed to rivals—hence, in the source of nonexcludability of information—and have shown that the implications for market structure and prices are similar in both. Our basic conclusion is that when information is nonexcludable, various institutional mechanisms are likely to evolve in order to ensure that intermediaries can appropriate the gains from information gathering. We have studied one such mechanism that may be necessary for market existence, namely, cooperation between intermediaries. In equilibrium, the market will be an oligopoly in which each intermediary is granted a local monopoly over its clients. Thus, prices are determined in bilateral bargaining, and entry will determine market shares.

We do not explore any policy implications but can make two observations. First, because nonexcludability changes the direction of many comparative equilibria results, antitrust recommendations based on standard models of product markets with excludable inputs may lead to misleading policy conclusions. Second, we have shown how intermediation markets can be organized to overcome the free-riding problem. Recognizing this may be useful when answering the question of how intermediation markets should be designed and regulated.

There has been significant interest recently in the design of an anti-trust policy for intellectual property in product markets. While information has become an important input in product markets only in the recent past—especially with the birth of the biotechnology and computer industries—its importance in financial markets is as old as these markets. Thus, understanding how financial markets solve the incentive problems arising from incomplete property rights may contribute to

49. See Hayes et al. (1983, table 25). Matthews (1994, p. 41) similarly observes that although “the securities industry has multiple lines of business, with different firms holding leadership positions in various lines . . . the national full-line firms compete against one another in virtually all securities lines of business.”

our understanding of the structure and conduct of firms facing similar problems in high-technology product markets and may shed light on how antitrust should be conducted in them.

Finally, this framework may be useful in understanding the differences between types of intermediaries and financial systems. When thinking about cross-country differences, one usually makes a sharp distinction between indirect and direct finance, or "bank" and "market-based" systems (see, e.g., Allen and Gale 1995; Shleifer and Vishny 1997). Our theory suggests that these markets may have important similarities. These stem from the fact that all financial intermediation markets must solve the same problem, namely, how to gather information and use it to trade. To the extent that the characteristics of the production technology are the same, similar market structures should be observed across these intermediation markets. In a related issue, although concentrated ownership is usually thought of as a prerequisite for effective screening and monitoring, our analysis suggests that such incentives may also be preserved by concentrated intermediaries serving a market in which ownership claims are small and diffuse.

Appendix A

A Cooperative Sequential Equilibrium in the Public Information Model

In this appendix we construct an assessment that is a cooperative sequential equilibrium in the public information model. Our strategy is to construct a sequential equilibrium of the 1-period game, which we then use as a punishment of defection in the repeated game.

DEFINITION A1. Call assessment D (for "defection"):

$$\begin{aligned}\sigma_i &= 0, \\ \Pi_i &= [0, 1, 0], \\ \lambda_i^1 &= 0, \\ \lambda_i^2(\lambda_j^1 \in [0, \lambda^m]) &= 0; \lambda_i^2(\infty) = \infty \text{ for all } i \text{ and } j \neq i; \\ \mu(\lambda_j^1 \in [0, \lambda^m]) &= [0, 1, 0], \mu(\infty) = [1, 0, 0] \text{ for all } j.\end{aligned}$$

We now prove that assessment D is a sequential equilibrium of the 1-period game.

LEMMA A1. Assessment D is a sequential equilibrium in the 1-period game.

Proof. In view of proposition 1, it remains to be shown that

a) $\pi_i(g) = 1$, $\pi_i(b) = 0$, and $\lambda_i^1 = 0$ is sequentially rational.

b) $\lambda_i^2(\lambda_j^1 \in [0, \lambda^m]) = 0$ is sequentially rational.

c) $\mu(\lambda_j^1 \in [0, \lambda^m]) = [0, 1, 0]$ and $\mu(\infty) = [1, 0, 0]$ are part of a consistent assessment.

Part *a* is obvious, as financing bad entrepreneurs always leaves losses and financing good ones never does, even if $\lambda_j^1 = 0$. Part *b* follows from the fact that

any entrepreneur who receives an offer $\lambda_j^1 \in [0, \lambda^m]$ in the first stage is believed to be good with probability one, in which case it is optimal to make him an offer.

To prove part *c* it is sufficient to show that there exists a sequence $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ with Δ_i^ϵ a mixed strategy in λ_i^1 over $[0, \lambda^m]$ such that as $\epsilon \rightarrow 0$, (a) $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon) \rightarrow \{0, [0, 1, 0], \text{prob}(\lambda_i^1 = 0) = 1\}$; (b) $\mu^\epsilon(\lambda_j^1 \in [0, \lambda^m]) \rightarrow [0, 1, 0]$; and (c) $\mu^\epsilon(\infty) \rightarrow [1, 0, 0]$, with $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ completely mixed and μ^ϵ deduced from $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ using Bayes rule.

Now consider assessment $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon, \mu^\epsilon)$, with $\sigma_i^\epsilon = \epsilon$, $\Pi_i^\epsilon = [\epsilon^2, 1 - \epsilon, \epsilon]$,

$$\Delta_i^\epsilon = \begin{cases} 1 - \epsilon & \text{for } \lambda_i^1 = 0 \\ \frac{\epsilon}{\lambda^m} & \text{for } \lambda_i^1 \in (0, \lambda^m] \end{cases}$$

(i.e., $\Delta_i^\epsilon(\lambda_i^1 \in (0, \lambda^m]) = \epsilon/\lambda^m$ is a uniform density function over $(0, \lambda^m]$, and $\Delta_i^\epsilon(\lambda_i^1 = 0)$ is an atom of mass $1 - \epsilon$), and

$$\mu^\epsilon(\lambda_i^1 \in [0, \lambda^m]) = \frac{1}{a} [(1 - \epsilon)\epsilon^2, \epsilon p(1 - \epsilon), (1 - p)\epsilon^2],$$

$$\mu^\epsilon(\infty) = \frac{1}{b} [(1 - \epsilon)(1 - \epsilon^2), p\epsilon^2, \epsilon(1 - p)(1 - \epsilon)],$$

with $p \equiv 1/c$, the probability that an entrepreneur is good; $a \equiv (1 - \epsilon)\epsilon^2 + \epsilon[p(1 - \epsilon) + (1 - p)\epsilon]$; and $b \equiv (1 - \epsilon)(1 - \epsilon^2) + \epsilon[p\epsilon + (1 - p)(1 - \epsilon)]$. Clearly $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon) \rightarrow \{0, [0, 1, 0], \text{prob}(\lambda_i^1 = 0) = 1\}$; and μ^ϵ is derived from $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ using Bayes rule. Now simple algebra shows that $\lim_{\epsilon \rightarrow 0} \mu^\epsilon(\lambda_j^1 \in [0, \lambda^m]) = [0, 1, 0]$, and $\lim_{\epsilon \rightarrow 0} \mu^\epsilon(\infty) = [1, 0, 0]$, which completes the proof. Q.E.D.

Next we define “cooperative” and “noncooperative” states in the repeated game.

DEFINITION A2. We say that the state of the game at time t is cooperative if

- a) $m \leq m^c(\lambda^m)$;
- b) No undercutting has occurred so far. That is, for all $\tau \leq t$, $\lambda_j^2(\lambda_i^1(\tau) \in [0, \lambda^m]) > \lambda_i^1(\tau)$ for all i and j who were active at time τ .

We denote a cooperative state by ϕ^c . Any other state of the game is noncooperative and is denoted by ϕ^{nc} . Note that according to this definition, the initial state of the game (after history ϕ) is cooperative. Moreover, part *b* of the definition implies that if cooperation breaks once, then the state of the game is noncooperative forever after, that is, if $\phi(t) = \phi^{nc}$ for any t , then $\phi(t + k) = \phi^{nc}$ for all $k \in N$.

We now define strategies and beliefs in an assessment C (for cooperation). To ease the notation, we assume that m^c and m^p are integers.

DEFINITION A3. Call assessment C the following strategy and belief combination:

a) Strategies

1. Entry. Only outside intermediaries move.

1a. If $\phi = \phi^c$.

i) enter if $i = m + 1, \dots, \min[m^c, m^p]$;

ii) stay inactive if $i > \min[m^c, m^p]$.

1b. Otherwise stay inactive.

2. First-stage offers. Only active intermediaries $i = 1, 2, \dots, m$ move.
 - 2a. If $\phi = \phi^c$, play $\sigma_i = 1$, $\Pi_i = [0, 1, 0]$, and $\lambda_i^1 = \lambda^m$.
 - 2b. Otherwise play according to assessment D .
3. Second-stage offers by active intermediaries $i = 1, 2, \dots, m$.
 - 3a. If $\phi = \phi^c$ and

$$\delta \frac{n}{m} (\lambda^m S - CE) \geq (1 - \delta) \max_k \sum_{j \neq k} \beta_j \lambda_j^1 S \quad (A1)$$

holds for $\lambda_j^1 \in [0, \lambda^m]$, then play

- i) $\lambda_i^2(\lambda_j^1) \geq \lambda_j^1$ for $\lambda_j^1 \in [0, \lambda^m]$;
- ii) $\lambda_i^2(\infty) = \infty$.

3b. Otherwise play according to assessment D .

b) Beliefs

1. Beliefs in a cooperative state.
 - 1a. $\mu(\phi^c, \lambda_i^1 \in [0, \lambda^m]) = [0, 1, 0]$;
 - 1b. $\mu(\phi^c, \infty) = [0, 0, 1]$.
2. Beliefs in a noncooperative state.
 - 2a. $\mu(\phi^{nc}, \lambda_i^1 \in [0, \lambda^m]) = [0, 1, 0]$;
 - 2b. $\mu(\phi^{nc}, \infty) = [1, 0, 0]$.

Proposition A1 characterizes the outcome induced by assessment C .

PROPOSITION A1. Along the path induced by assessment C :

- a) all entry occurs at $t = 0$,
- b) intermediaries cooperate and charge $\lambda^1 = \lambda^m$,
- c) all intermediaries have the same market share, and
- d) $m = \min[m^c, m^p]$.

Proof. The proof is straightforward, and we leave it to the reader. Q.E.D.

Next, we state and prove the main proposition in this appendix.

PROPOSITION A2. Assessment C is a sequential equilibrium.

Proof. We first show that assessment C is sequentially rational. Because this is a repeated game with bounded payoffs, we only have to check that one-step deviations from strategies are not profitable in any information set (Hendon, Jacobsen, and Sloth 1996).

Consider first information sets in which the state of the game is noncooperative ($\phi = \phi^{nc}$).

i) At the beginning of the period it is optimal for any outside intermediary to remain inactive because according to strategies all active intermediaries will play according to assessment D forever after, and entry would yield losses equal to the entry cost E .

ii) We know from lemma A1 that when all other active intermediaries are playing according to assessment D in the 1-period game, it is optimal for intermediary i to do the same. Since all active intermediaries will play according to assessment D forever after, it is also optimal for active intermediary i to play according to D in any period of the repeated game.

Next consider information sets where the state of the game is cooperative ($\phi = \phi^c$).

i) It is optimal for intermediaries $m + 1, m + 2, \dots, \min[m^c, m^p]$ to enter, since according to specified strategies there will be cooperation in the future. For intermediaries $\min[m^c, m^p] + 1, \dots, M$ it is optimal to remain inactive, since

further entry would either switch the game to a noncooperative state, in which case long-run profits gross of entry cost E are zero; or else raise m above m^p .

ii) Now consider decisions by active intermediary i after being approached by entrepreneurs. Given strategies, she cannot gain by choosing $\sigma_i < 1$, because she would overlook some good entrepreneurs who pay more than what it costs to screen them. Moreover, as we have shown in the proofs of proposition 1 and lemma A1, it is always profitable to make an offer to a good entrepreneur and to reject both unscreened and bad ones. Last, given strategies and beliefs, setting λ_i^1 below λ^m would leave money on the table.

iii) We now show that second-stage offers by active intermediaries are sequentially rational. If the condition in equation (A1) does not hold, then intermediary i plays according to assessment D , which is optimal given that $\mu(\phi^c, \lambda_j^1 \in [0, \lambda^m]) = [0, 1, 0]$ and $\mu(\phi^c, \infty) = [0, 0, 1]$ and that all other active intermediaries play according to assessment D . Next suppose that condition in equation A1 does hold. Given that all other active intermediaries do not undercut, entry will occur next period until $m_{t+1} = m^* \equiv \min\{m^c, \max\{m^p, m_t\}\}$ (if intermediary i sticks to her strategy in period t) and there will not be any further entry. Furthermore, the net present value of cooperating from period $t + 1$ on is given by the left-hand side of equation (A1) divided by $(1 - \delta)$. Undercutting optimally yields at most a shade below $\sum_{j \neq i} \beta_j \lambda_j^1 S \leq \max_k \sum_{j \neq k} \beta_j \lambda_j^1 S$, for $\lambda_j^1 \in [0, \lambda^m]$; thus, it is optimal to cooperate.

To prove that beliefs are consistent, note first that in a noncooperative state all agents play according to assessment D and, furthermore, recall that we have shown in the proof of lemma A1 that beliefs $\mu(\phi^{nc}, \lambda_j^1 \in [0, \lambda^m]) = [0, 1, 0]$ and $\mu(\phi^{nc}, \infty) = [1, 0, 0]$ are consistent with strategies as specified in assessment D . We now show that when the state is cooperative, beliefs as specified in assessment C are consistent.

It is sufficient to show that there exists a sequence $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ with Δ_i^ϵ a mixed strategy in λ_i^1 over $[0, \lambda^m]$ such that as $\epsilon \rightarrow 0$, (a) $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon) \rightarrow \{1, [0, 1, 0], \text{prob}(\lambda_i^1 = \lambda^m) = 1\}$; (b) $\mu^\epsilon(\phi^c, \lambda_j^1 \in [0, \lambda^m]) \rightarrow [0, 1, 0]$; and (c) $\mu^\epsilon(\phi^c, \infty) \rightarrow [0, 0, 1]$, with $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ completely mixed and $\mu^\epsilon(\phi^c)$ deduced from $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ using Bayes rule. (To ease notation henceforth, we drop ϕ^c from the specification of beliefs.)

Consider assessment $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon, \mu^\epsilon)$ with $\sigma_i^\epsilon = 1 - \epsilon$, $\Pi_i^\epsilon = [\epsilon, 1 - \epsilon, \epsilon]$,

$$\Delta_i^\epsilon = \begin{cases} 1 - \epsilon & \text{for } \lambda_i^1 = \lambda^m \\ \epsilon & \text{for } \lambda_i^1 \in (0, 1], \lambda_i^1 \neq \lambda^m, \end{cases}$$

and

$$\mu^\epsilon(\lambda_j^1 \in [0, 1]) = \frac{1}{a'} [\epsilon^2, p(1 - \epsilon)^2, (1 - \epsilon)(1 - p)\epsilon],$$

$$\mu^\epsilon(\infty) = \frac{1}{b'} [(1 - \epsilon)\epsilon, (1 - \epsilon)p\epsilon, (1 - p)(1 - \epsilon)^2],$$

with $a' \equiv \epsilon^2 + (1 - \epsilon)[p(1 - \epsilon) + (1 - p)\epsilon]$ and $b' \equiv \epsilon(1 - \epsilon) + (1 - \epsilon)[p\epsilon + (1 - p)(1 - \epsilon)]$. Clearly, $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon) \rightarrow \{1, [0, 1, 0], \text{prob}(\lambda_i^1 = \lambda^m) = 1\}$; and μ^ϵ is derived from $(\sigma_i^\epsilon, \Pi_i^\epsilon, \Delta_i^\epsilon)$ using Bayes rule. Now some simple algebra

shows that $\lim_{\epsilon \rightarrow 0} \mu^\epsilon(\lambda_j^1 \in [0, \lambda^m]) = [0, 1, 0]$ and that $\lim_{\epsilon \rightarrow 0} \mu^\epsilon(\infty) = [0, 0, 1]$, which completes the proof. Q.E.D.

Appendix B

A Cooperative Subgame Perfect Equilibrium in the Human Capital Model

In this appendix we construct a strategy combination that is a subgame perfect equilibrium in the human capital model. We start by defining a strategy combination that is a subgame perfect equilibrium of the 1-period game.

DEFINITION B1. Call strategy combination D :

$$\begin{aligned}\sigma_i &= 0; \\ w_i^1 &= \lambda^m S; \\ w_i^2(w_j^1) &= \lambda^m S \text{ for all } w_j^1 \geq 0, \text{ all } j.\end{aligned}$$

Clearly, strategy combination D is a subgame perfect equilibrium in the 1-period game. Next we define cooperative and noncooperative states.

DEFINITION B2. We say that the history of the game at time t is cooperative if

- a) $m \leq m^c(w^m)$;
- b) no outbidding has occurred so far. That is, for all $\tau \leq t$, $w_i^2(w_j^1) \leq w_j^1$ for all i and j who were active at time τ .

As before, we denote a cooperative history by ϕ^c . Any other state of the game is noncooperative and is denoted by ϕ^nc . Note that the initial state of the game is cooperative. We now define the symmetric strategy combination C .

DEFINITION B3. Call strategy combination C the following:

1. Entry. Only outside intermediaries move.
 - 1a. If $\phi = \phi^c$,
 - i) enter if $i = m + 1, \dots, \min[m^c, m^w]$;
 - ii) stay inactive if $i > \min[m^c, m^w]$.
 - 1b. Otherwise stay inactive.
2. Screening and first stage wage offers. Only active intermediaries $i = 1, 2, \dots, m$ move
 - 2a. If $\phi = \phi^c$, then play $\sigma_i = 1$, $w_i^1 = w^m$.
 - 2b. Otherwise stay inactive.
3. Second-stage wage offers by active intermediaries $i = 1, \dots, m$.
 - 3a. If $\phi = \phi^c$ and

$$\delta \frac{n}{m^*} (\lambda^m S - w^m - E) \geq (1 - \delta) \max_k \sum_{j \neq k} \gamma_j (\lambda^m S - w_j^1) \quad (\text{B1})$$

holds, where γ_j is the measure of employees who received wage offer $w_j^1 < \lambda^m S$ in the first stage and $m^* = \min\{m^c, \max\{m^w, m_i\}\}$, then play $w_i^2(w_j^1) < w_j^1$ for all j .

3b. Otherwise play according to D .

It is easy to check that along the outcome path induced by strategy combination C all entry occurs at the beginning of the game and all active intermediaries pay wages equal to w^m . We now state and prove proposition B1.

PROPOSITION B1. Strategy combination C is a subgame perfect equilibrium in the infinitely repeated game.

Proof. To prove this proposition, we show that the players' strategies for the repeated game are optimal after any history. Since this is a repeated game with bounded payoffs, it suffices to show that one-step deviations from strategies are not profitable after any history.

Consider histories after which the state of the game is noncooperative ($\phi = \phi^{nc}$).

i) At the beginning of the period it is optimal for any outside intermediary to remain inactive because according to strategies all active intermediaries will play according to D forever after, and entry would yield losses equal to entry cost E .

ii) We know that when all other active intermediaries are playing according to D in the 1-period game, it is optimal for intermediary i to do the same. Since all active intermediaries will play according to D forever after, it is also optimal for active intermediary i to play according to D in any period of the repeated game.

Next consider histories after which the state of the game is cooperative ($\phi = \phi^c$).

i) It is optimal for intermediaries $m + 1, m + 2, \dots, \min[m^c, m^p]$ to enter, since according to strategies, there will be cooperation in the future. For intermediaries $\min[m^c, m^p], \dots, M$ it is optimal to remain inactive, since further entry would either switch the game to a noncooperative state, in which case long-run profits gross of entry cost E are zero; or else raise m above m^p .

ii) Now consider decisions by active intermediary i after being approached by firms. Given strategies, she cannot gain by choosing $\sigma_i = 0$. Moreover, given strategies and beliefs, setting w_i^l above w^m would leave money on the table.

iii) We now show that second-stage offers by active intermediaries are optimal. If the condition in equation (B1) does not hold, then intermediary i plays according to assessment D , which is optimal given that all other active intermediaries play according to D . Next suppose that the condition in equation (B1) does hold. Given that all other active intermediaries do not outbid, entry will occur next period until $m_{t+1} = m^* = \min\{m^c, \max\{m^p, m_t\}\}$ (if intermediary i sticks to her strategy in period t), and there will not be any further entry. Furthermore, the net present value of cooperating from period $t + 1$ on is given by the left-hand side of equation (B1) divided by $(1 - \delta)$. Undercutting optimally yields at most a shade below $\sum_{j \neq i} \gamma_j (\lambda^m S - w_j^l) \leq \max_k \sum_{j \neq k} \gamma_j (\lambda^m S - w_j^l)$; thus, it is optimal to cooperate. This completes the proof that C is a subgame perfect equilibrium. Q.E.D.

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