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When does start-up innovation spur the gale of creative destruction?

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This article studies the determinants of commercialization strategy for start-up innovators. We examine whether the returns on innovation are earned through product market competition or through cooperation with established firms (through licensing, alliances, or acquisition). Our hypotheses are that the relative returns to cooperation are increasing in (i) control over intellectual property rights, (ii) low transaction costs, and (iii) sunk costs associated with product market entry. Using a novel dataset of the commercialization strategies of start-up innovators, our results suggest that the procompetitive impact of start-up innovation—the gale of creative destruction—depends on imperfections in the market for ideas.

1. Introduction

■ Over the past decade, there has been a rapid increase in investment funding provided to technology-oriented start-up firms. Venture capital investments increased by an order of magnitude between 1991 and 1999 (VentureOne, 2000), and venture-backed firms currently account for more than 8% of all domestic industrial innovation (Kortum and Lerner, 2000). Not surprisingly, there is considerable interest in the economic implications of this R&D investment surge in start-up firms (Gompers and Lerner, 1999).

Many analysts suggest that start-up innovation affects existing sources of market power by spurring the "gale of creative destruction" (Schumpeter, 1943). However, industry studies suggest a more nuanced relationship (Gans and Stern, forthcoming(b)). For example, in the biotechnology industry, cooperation between start-up innovators and more established firms is

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the norm (whether through licensing, strategic alliances, or outright acquisition) (Orsenegio, 1989; Lerner and Merges, 1998). On the other hand, start-up innovators in the electronics industry often engage in creative destruction, earning their innovation rents through product market entry and competition with more established firms (Christensen, 1997). We attempt to understand these different patterns by evaluating how economic factors such as the strength of intellectual property protection shape the *relative* returns to cooperation versus competition.

Consider a cooperation strategy. Start-up innovators and more established firms share (at least) two distinct gains from trade in the "market for ideas": (1) preserving current market power and (2) avoiding duplicative commercialization investments, such as those associated with distribution, manufacturing, or a branded reputation. If a market for ideas functions efficiently, incumbents can contract for start-up innovations and so foreclose on a potentially important form of competition. Imperfections in the market for ideas, conversely, can spur a competitive strategy by start-up innovators.

We identify three factors that shape start-up commercialization strategy. First, the strength of intellectual property rights (IPR) not only affects the absolute returns to innovation (regardless of commercialization strategy) by reducing the threat of expropriation, but also the relative returns to competition versus cooperation. While expropriation may occur under competition or cooperation, the returns negotiated by the start-up with an established firm reflect their ability to threaten competitive entry and the transaction costs of bargaining. These two factors ensure that the returns to cooperation are more sensitive to the strength of IPR than the returns to competition, and so an increase in the strength of IPR increases the relative returns to cooperation. Second, the relative returns to cooperation are increasing in the presence of intermediaries, such as venture capitalists or specialized legal counsel, that reduce search and transaction costs associated with identifying and contracting with incumbents. Third, the returns to competitive entry are decreasing in the (sunk) costs of market entry. To the extent that incumbent-owned "complementary assets" (such as distribution channels, brand names, or manufacturing expertise) are costly to duplicate, the relative profitability of competitive entry will decrease in these costs.

This article empirically evaluates whether commercialization strategy differs with measures capturing variation along these three dimensions—the strength of IPR, the cost of contracting, and the importance and effectiveness of complementary-asset ownership. Perhaps surprisingly, little empirical work has been devoted to this topic. Most prior analyses of the relationship between start-up and established firms have focused on the relative incentives to innovate in the first place, under the assumption that innovation by a start-up is followed by product market competition.[1] Several analyses examine the *form* of cooperation between smaller research-oriented firms and larger established firms without considering the potential for product market entry (Salant, 1984; Katz and Shapiro, 1987; Lerner and Merges, 1998). By relating the *choice* between cooperation and competition to the firm's economic environment, our analysis suggests that the industrial organization consequences of start-up innovation are endogenous to the commercialization environment, as determined by factors such as the strength of IPR and the availability of venture capital. These commercialization environment parameters depend, at least in part, on various aspects of public policy.

We study a novel dataset composed of the commercialization strategies of 118 start-up projects. We evaluate whether cooperation is associated with (i) innovations that receive formal IPR protection (e.g., a patent), (ii) firms with access to a network of contacts (e.g., through a venture capital relationship), and (iii) environments where complementary-asset ownership by the start-up is perceived as ineffective in earning profits from innovation. Each factor has a quantitatively significant effect on the probability of cooperation. For example, firms with IPR are estimated to be 23 percentage points more likely than nonpatentholders to pursue a cooperative strategy. Although the impact of IPR is estimated relatively precisely, estimates of the effects of venture capitalists and the costs of complementary assets are noisier (occasionally significant

[1] The literature on R&D and product market competition between incumbents and start-up firms is too large to be summarized here. See Cohen and Levin (1989) or Gans and Stern (2000) for a review.

only at the 10% level). These core findings are robust to the inclusion of a variety of controls, varying the definitions of each empirical concept, and relying exclusively on within-industry or cross-industry variation. We interpret this evidence cautiously, given the small sample size and imperfect measurement of key concepts. However, our results do accord with the presence of strategic interaction between start-up innovators and incumbents in high-technology industries.

The article is organized as follows. Section 2 develops predictions of how the commercialization environment affects optimal commercialization strategy. Section 3 provides a data review, and Section 4 presents the key empirical results. Section 5 concludes.

2. The determinants of start-up commercialization strategy

■ Consider a start-up innovator who has successfully developed a commercializable innovation and now faces a choice between entering the product market—a *competition* strategy—or "selling" the innovation to an incumbent—a *cooperation* strategy.[2] Cooperation may be achieved through several mechanisms (e.g., a licensing agreement, a strategic alliance, or acquisition of the entrant by the incumbent). Although each mechanism differs in its impact on *future* incentives to innovate and the locus of decision authority, they share a common feature: if an agreement is reached, the incumbent forecloses product market competition and monopoly profits are maintained. Most prior research focuses on how changes in key parameters such as the strength of IPR affect the absolute returns to innovation, but commercialization strategy depends on the relative returns to competition versus cooperation.

Consider the impact of IPR (the Appendix presents a brief formal model). In general, start-up innovation incentives and commercialization strategy depend on the "expropriation" threat (Arrow, 1962; Anton and Yao, 1994). This threat is present whether a start-up competes or cooperates. Under competition, incumbent firms will attempt to reverse engineer the innovation and commercialize an imitation. Under cooperation, negotiating over the sale of an idea inevitably involves a disclosure risk, eroding the bargaining position of the start-up and reducing the incumbent's willingness to pay. Increasing the strength of IPR reduces the expropriation threat for either strategy, and thus it increases the absolute expected returns to start-up innovators.

Two factors affect the impact of IPR on the relative returns to cooperation. First, bargaining between a start-up and incumbent takes place in the "shadow" of potential product market competition. The return to cooperation reflects both the intrinsic value of the start-up's proprietary knowledge and the start-up's ability to threaten competitive entry. As such, increasing the strength of IPR reduces the threat of expropriation during bargaining and increases the start-up's outside option (breaking off negotiations and entering the product market). Since the (negotiated) returns to cooperation reflect the improved competitive prospects of the start-up, an increase in the strength of IPR increases the relative returns to cooperation. Also, certain types of IPR, such as patents, reduce the transaction costs associated with cooperation. A well-defined technology specification and clear legal ownership reduce the costs of reaching an agreement, particularly for licensing. Together, these effects make the relative payoffs to cooperation more sensitive, and we expect the probability of cooperation to be increasing in the strength of IPR.

A second factor determining start-up commercialization strategy is the level of search and bargaining costs associated with cooperation. Even when IPR are well defined, there may be uncertainty about the value (or other characteristics) of the start-up technology; this uncertainty may necessitate detailed bargaining between the parties about royalty rates and other contingent contracting provisions (Arora, Fosfuri, and Gambardella, 2001). Bargaining intermediaries that reduce the cost of forging an agreement may increase the relative likelihood of cooperation (Burt, 1992; Lamoreaux and Sokoloff, 2002). Specifically, we evaluate whether these costs of trade may be lower in the presence of third-party "brokers" (such as venture capitalists), who have long-term reputations with incumbents and can therefore credibly certify the expected value of specific innovations.

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[2] A commercializable innovation is one in which all technological uncertainty has been resolved (e.g., a prototype exists) and so, with (known) investments, could be introduced into the market.

Finally, cooperation allows start-up innovators to exploit "complementary assets" controlled by incumbents, including distribution channels, regulatory or manufacturing expertise, and brand-name recognition (Teece, 1986). While avoiding duplication of sunk assets is important in some environments (such as when biotechnology firms exploit the regulatory expertise and distribution channels of established pharmaceutical companies), incumbent-owned assets confer minimal value in other settings (e.g., when start-ups develop incompatible technology). As the sunk costs of product market entry increase, the gains from trade between start-up innovators and incumbents also increase, so start-ups will be more likely to forgo competition.

3. Data

■ The remainder of the article evaluates the empirical salience of the above predictions. Our approach is straightforward (as in the spirit of Mansfield, Schwartz, and Wagner, 1981). Using a novel dataset, we evaluate how the cooperation probability of a sample of start-up innovators varies with observable characteristics of the commercialization environment.

□ **The commercialization strategies survey.** Our empirical approach requires measuring commercialization environment and strategy, data that are unavailable from either public or commercial databases (Gompers and Lerner, 1999; Hellmann and Puri, 2000). We therefore developed and administered a start-up commercialization strategy survey during the first half of 1999.[3] The survey population is composed of start-ups receiving external R&D financing from one of two sources: private venture capital (VC) or the Small Business Innovation Research program (SBIR). Dividing the sample between SBIR- and VC-funded firms incorporates variation in the costs of identifying and contracting with partners while maintaining the ability to evaluate the impact of IPR strength and sunk costs in a cross-section of firms.

The sample consists of 63 SBIR-backed and 55 VC-backed firms (for a total of 118 observations).[4] Following Lerner (1999), we use a "matching" process to identify the sample population in an effort to preserve within-sample consistency. First, we collected the sample of SBIR-funded projects (drawn from the top 200 SBIR award winners between 1990 and 1993) and then matched each SBIR project with a single VC-backed project. The matching criterion is based on each firms' four-digit SIC code, initial sales, and geographic location.[5] The key requirement for inclusion in the sample is that the firm successfully commercialized an externally funded technology, either independently or through a cooperative agreement. Our evaluation of commercialization strategy thus conditions on innovations that have in fact been commercialized.

The projects are distributed across five SIC codes: biotechnology (2836), computer software (7372), industrial machinery and equipment (35), electronic equipment (36), and scientific instruments (38). We collected data on each firm's employees, promotion policies, and corporate ownership and governance, as well as financial information including expenditures and revenues. For each project, we collected information about commercialization and financing history, revenue information including sales and licensing, the importance of the technology in achieving firm objectives, and the key personnel associated with the firm's commercialization strategy.[6]

It is useful to compare the two sources of innovation financing. Administered by all federal agencies with an R&D budget, the SBIR program provides R&D grants to U.S. firms with fewer

[3] The survey is available at http://www.mbs.edu/home/jgans/research.htm. It was first pretested with a small sample of potential respondents, then administered by phone, fax, and mail.

[4] The survey response rate was approximately 50%. Nonresponders seemed randomly mixed between firms not having a commercial product and those declining for other reasons. The respondent was typically the CEO or the director of R&D, sales, or marketing.

[5] Specifically, we searched the *Venture Economics* database (www.ventureeconomics.com) for candidate companies whose primary business matched the 4-digit SIC codes for a given SBIR-backed company. We then eliminated those that received SBIR funding. Using the *Corptech Directory of Technology Companies* (Corporate Technology Information Services, 1998), we then selected firms that matched most closely in initial sales revenues and geographic location (Lerner, 1999).

[6] Public data were used to verify survey responses (e.g., patents and venture capital financing).

than 500 employees (USGAO, 1995).[7] Grant applications are peer reviewed and awarded through a competitive process (fewer than 15% of applications are granted).[8] Once awarded, the SBIR grant is a "hands-off" subsidy; the government has neither managerial control nor an equity stake. Because it is administered through all R&D-performing federal agencies, the SBIR program funds a diverse array of firms and technologies relative to the concentrated distribution of private VC financing (Gans and Stern, forthcoming(a)). We ensure comparability by limiting the sample to five industrial segments heavily funded by both VCs and the SBIR program.

In contrast to the SBIR program, VCs provide capital to start-ups in exchange for equity and managerial control. In addition, VCs aid start-up firms by offering a network of contacts and potential partners as well as providing experience in corporate governance (Gompers and Lerner, 1999; Stuart, Hoang, and Hybels, 1999; Hellmann and Puri, 2000). Although SBIR- and VC-funded projects differ, since VC funding directly affects the operation and decision rights of the firm, projects from either source are comparable in several key respects: (i) firms tend to be young, (ii) the projects are R&D-intensive, (iii) project selection is competitive, and (iv) the size of financing is comparable.

□ **Variable definitions and summary statistics.** *Cooperation measures.* Table 1 reports variable definitions and summary statistics. Our principal dependent variable is a combination of two distinct measures associated with a cooperative commercialization strategy. *LICENSED* is a dummy variable indicating whether the firm earned licensing revenues from its innovation, a practice undertaken by 22% of the firms in the sample.[9] Similarly, *ACQUIRED* is a dummy variable indicating whether the firm was acquired since the project was funded (mean = .14). Together, *LICENSED* and *ACQUIRED* form a meaningful concept of cooperative behavior for firms within our sample. The percentage of overall revenues derived from cooperation (either through licensing or acquisition) is bimodal. For 68% of the sample, revenues are derived solely from independent commercialization; for 21%, revenues are derived solely from licensing/acquisition. Accordingly, our principal measure of cooperation is *COOP*(*LIC* + *ACQ*), a dummy equal to one if either *LICENSED* or *ACQUIRED* is equal to one. It is interesting to note that there is substantial heterogeneity of *COOP*(*LIC* + *ACQ*) across industrial sectors. For example, while the probability of cooperation is above 50% in biotechnology, less than 25% of industrial equipment firms cooperate in commercialization.

We also investigate alternative measures of cooperation. First, we evaluate differences between the determinants of *LICENSED* and *ACQUIRED*. Also, drawing on a descriptive literature highlighting the impact of strategic alliances on cooperative activity (Gomes-Casseres, 1996), we define *HI ALLIANCES* as a dummy equal to one for firms with a level of strategic alliance activity in the top quintile. We also group *HI ALLIANCES* with *COOP*(*LIC* + *ACQ*) to calculate *COOP*(*ALL*) (mean = .41).

Commercialization environment measures. Our analysis relates these cooperation measures to variables associated with the strength of IPR, the costs of transacting with potential partners, and the role of sunk-cost asymmetries.

We measure IPR strength in several distinct ways. For most of our analysis, we focus on whether the start-up innovator has received at least one patent associated with the technology (*PATENT THRESHOLD* = 1). While the mean number of project-specific patents across firms is just over six, fewer than two-thirds of the sample firms' projects possess at least one patent. To ensure that these measures reflect the commercialization environment at the time of the commercialization strategy choice, the patents included in the sample are granted prior to the cooperation event (either acquisition or the receipt of licensing revenues). In addition, we also collected

[7] The SBIR budget for each agency is equal to a fixed percentage of its total R&D budget.

[8] Our sample received "Phase II" awards (see USGAO (1995) for further details of the program). The rationale for the SBIR is that entrepreneurial firms are highly productive, associated with spillovers, and subject to underinvestment (Lerner, 1999). However, SBIR administrators may have incentives to select inframarginal projects, which would have been funded in the absence of subsidies (Wallsten, 2000).

[9] Over 95% of the technology licenses are assigned on an exclusive basis.

TABLE 1 Variables and Definitions

Variable	Definition	Mean	Standard Deviation	Source
Cooperation dummies				
LICENSED	Dummy = 1 if licensing revenues > 0	.220	.416	MIT Survey
ACQUIRED	Dummy = 1 if firm acquired since project initiation	.144	.353	MIT Survey
HI ALLIANCES	Dummy = 1 if firm's strategic alliance activity is in the top 10%	.110	.314	MIT Survey
COOP(LIC + ACQ)	Dummy = 1 if *LICENSED* = 1 or *ACQUIRED* = 1	.339	.475	Authors Calc.
COOP(ALL)	Dummy = 1 if *LICENSED* = 1 or *ACQUIRED* = 1 or *HI ALLIANCES* = 1	.407	.493	Authors Calc.
Appropriability measures				
PROJECT PATENTS	Number of patents associated with project	6.678	14.189	MIT Survey, USPTO
PATENT THRESHOLD	Dummy = 1 if *PROJECT PATENTS* > 0	.653	.478	MIT Survey, USPTO
IPR PROTECTION LIKERT	5-point Likert scale rating of importance of patent or copyright protection for appropriating returns	3.475	2.139	MIT Survey
IPR LITIGATION LIKERT	5-point Likert scale rating of importance of patent or copyright litigation for appropriating returns	2.441	1.405	MIT Survey
SECRECY LIKERT	5-point Likert scale rating of importance of trade secrecy for appropriating returns	3.678	1.371	MIT Survey
STRONG FORMAL IPR	Dummy = 1 if *IPR PROTECTION LIKERT* > 3 or *IPR LITIGATION LIKERT* > 3	.576	.496	Authors Calc.
Funding source measures				
VC-FUNDED	Dummy = 1 if project is initially VC-funded	.466	.501	MIT Survey, Venture Econ
EVER VENTURE-FUNDED	Dummy = 1 if firm received any VC financing by January, 1999	.504	.502	MIT Survey, Venture Econ
Complementary-asset measures				
CA LIKERT MAX	Max over 5-point Likert scales measuring the importance and effectiveness of ownership of complementary assets (branding, manufacturing, distribution, and service).	4.627	.596	MIT Survey
EXPENSIVE COMP ASSET OWNERSHIP	Dummy = 1 if *CA LIKERT MAX* < 5	.322	.469	MIT Survey
Firm-level controls				
INITIAL EMPLOYEE SIZE	Number of employees at project initiation	25.481	43.662	MIT Survey
CEO FOUNDER	Dummy = 1 if current CEO is firm founder	.598	.492	MIT Survey
PHD EMP SHARE	Share of employees with Ph.D. education	.142	.177	MIT Survey
INDUSTRY SEGMENTS	Dummy variable for primary SIC industrial segment: biotechnology, industrial equipment, instruments, and software			Corptech Directory
Project-level controls				
TIME TO MARKET	Time in months from idea conception to first sale	44.925	49.068	MIT Survey
YEAR OF PRODUCT INTRODUCTION	First year in which product is sold commercially	92.492	4.644	MIT Survey
PRODUCT INNOVATION	Dummy = 1 if project results in product innovation	.678	.469	MIT Survey
NOVEL SYSTEM	Dummy = 1 if project results in novel overall system	.373	.486	MIT Survey
MASS-PRODUCED	Dummy = 1 if project requires mass production	.636	.483	MIT Survey

several qualitative measures of the level of appropriability (in the spirit of Levin et al. (1987)). Specifically, we asked each firm to rank several appropriability strategies on a five-point Likert scale, including the importance of patent and copyright protection (*IPR PROTECTION LIKERT*), patent and copyright litigation (*IPR LITIGATION LIKERT*), and trade secrecy (*SECRECY LIKERT*). We define a combination dummy, *STRONG FORMAL IPR*, which is equal to one if either *IPR PROTECTION LIKERT* or *IPR LITIGATION LIKERT* is greater than three.

By construction, the sample is (approximately) equally divided between exclusively VC-backed firms ($VC = 1$) and SBIR-funded firms ($VC = 0$). This feature allows us to compare the commercialization strategies of firms differing in relative costs of negotiating cooperative agreements with established firms. While we use the *VC* dummy in most of the analysis, we also employ an alternative dummy measure, *EVER VENTURE FUNDED*, which groups together firms for which $VC = 1$ and firms initially funded by the SBIR that received some form of venture financing by the end of 1999.

Measuring the investment costs that entrants face in acquiring complementary assets necessary for effective competitive commercialization (relative to the costs associated with a cooperative strategy) is extremely difficult, especially in a cross-industry study. Because "objective" measures of relative investment costs are elusive (a problem not confined to this study), we developed a set of five-point Likert scales. Respondents rated the "importance and effectiveness of control" over key assets in earning returns from their innovation: manufacturing, distribution channels, brand development, and servicing. Based on our field interviews, we believe that respondents rated the importance of each complementary-asset element by their perception of the relative attractiveness and cost-effectiveness of *ownership* (i.e., control) of that element.

The empirical analysis uses two measures summarizing these survey responses. First, we defined *CA LIKERT MAX* as the maximum Likert score over the set of questions. The highest level of *CA LIKERT MAX* (i.e., *CA LIKERT MAX* = 5) suggests that the respondent perceived that ownership of at least *one* of the complementary-assets elements was cost-effective for earning profits from the innovation. As such, we define *EXPENSIVE COMP ASSET OWNERSHIP* as a dummy variable equal to one if *CA LIKERT MAX* is less than five. *EXPENSIVE COMP ASSET OWNERSHIP* = 1 reflects a perception by the respondent that ownership of relevant complementary assets would not be cost-effective relative to cooperation with preexisting owners of those assets (mean = .32).

Firm-level control variables. A benefit of our survey-based method of data collection is our ability to collect detailed firm- and project-level controls. We measure the preinnovation size of firms with categorical variables related to *INITIAL EMPLOYEE SIZE*. We group these data into four size categories, as the impact of size may vary across the distribution. Two additional variables measure differences in overall commercialization orientation and strategy. *PHD EMP SHARE* is the share of firm employees with Ph.D.-level training, and *CEO FOUNDER* is a dummy variable indicating whether the founder of the firm has remained the CEO. Firms with a high *PHD EMP SHARE* might avoid direct entry into product markets, perhaps to maintain a "scientific" firm culture (Stern, 2000), while the presence of a CEO-founder may be associated with the presence of "empire-building" motives (Roberts, 1991).

Project-level control variables. We also define project-level controls to capture the timing and technological type of different innovations. *TIME TO MARKET* is the time in months from idea conception to first sale of the product. Projects requiring long development times, for example, might be commercialized more frequently via cooperation due to firm resource constraints. Furthermore, *YEAR OF PRODUCT INTRODUCTION* (the year in which a product is initially commercialized) may also affect commercialization strategy, perhaps because of time-varying market effects.

Finally, the *nature* of the technological innovation may also influence the firm's cooperative behavior. For example, radical innovations may result in more competitive behavior (Reinganum, 1983; Henderson, 1993). We employ *NOVEL SYSTEM* and *PRODUCT INNOVATION* dummies to control for the degree to which the innovation might be incompatible with the incumbent's current

TABLE 2 **Probability of Cooperation by Commercialization Environment**

	PATENT THRESHOLD			*VC-FUNDED*			*EXPENSIVE COMP ASSET OWNERSHIP*		
	0		1	0		1	0		1
COOP(LIC + ACQ) = 1	.20		.42	.25		.44	.28		.47
t-stat: equality of means		2.45			2.15			2.11	
N = 118 observations									

technology (for example, almost 40% of the innovations were recorded as "novel systems"). We now turn to the analysis of start-up commercialization strategy.

4. Empirical results

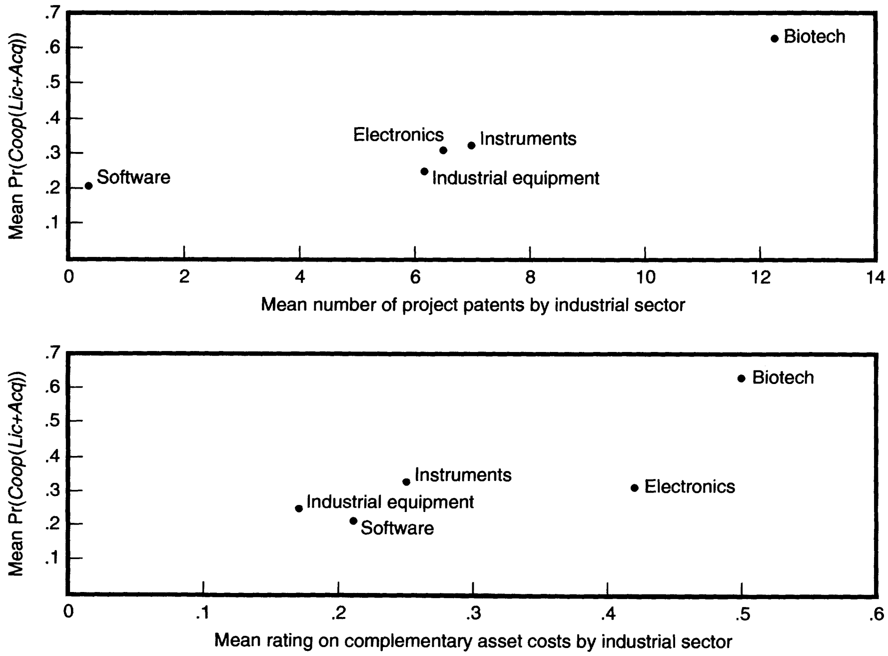
■ Our analysis proceeds in three steps. First, we review pairwise and cross-industry correlations to highlight some facets of the data. Second, we present regression estimates relating commercialization strategy to the commercialization environment, exploring various controls, and alternative measures of key variables. Finally, we disaggregate the form of cooperation by separating the determinants of licensing and acquisition.

Table 2 reports the pairwise conditional means of the probability that *COOP(LIC* + *ACQ)* = 1 and each of the three principal variables. The results are striking. Changes in each of the (binary) commercialization environment measures are associated with over a 70% increase in the probability of cooperation, in the direction predicted (each difference is significant at the 5% level). For example, firms with at least one project-related patent are more than twice as likely to cooperate relative to those with no patents.

In addition, commercialization strategy varies across industrial sectors. The first panel of Figure 1 displays a scatter plot of the mean of project-level patenting for each industrial sector

FIGURE 1

PROBABILITY OF COOPERATION BY INDUSTRY AND KEY VARIABLES



and the industry-specific probability of cooperation. Consistent with qualitative assessments of cross-industry differences (Gans and Stern, forthcoming(b)), industries with higher average project-level patenting are more likely to pursue a cooperative commercialization strategy. Figure 1 reports an analogous result for the industry-specific mean of *EXPENSIVE COMP ASSET OWNERSHIP*. The probability of cooperation is highest in biotechnology, where the relative costs of acquiring complementary assets are high.[10] While suggestive, these results do not control for project- and firm-level factors, and so we turn to the regression analysis.

Table 3 presents the binary probit results. For each specification, the dependent variable is *COOP(LIC + ACQ)*. Inclusion of all three commercialization environment measures shows that each is associated with cooperation (including any two of the three yields similar results). In addition to their statistical significance (about 5% for all three), the estimates in column 1 suggest strong quantitative effects. Changing one of the three (indicator) variables, at the means of the other variables, is associated with a predicted change in the cooperation probability of 23% (*PATENT THRESHOLD*), 17% (*VC*), and 18% (*EXPENSIVE COMP ASSET OWNERSHIP*).

So far, we have assumed that the commercialization environment variables are exogenous. However, the observed level of IPR and VC funding might be related to the firm's commercialization strategy. We therefore paid close attention to the sequence of commercialization events. Specifically, we checked that patent awards and external financing by VCs and the SBIR program preceded cooperation events. Of course, the sequencing of events does not make these variables predetermined, so the rest of Table 3 exploits our detailed survey data to provide industry-, firm-, and project-level controls for omitted factors potentially correlated with commercialization strategy and the commercialization environment.

We first include industry segment dummies in column 2. Evidence for our key hypotheses is present even relying only on within-industry variation. As well, the positive coefficient on *BIOTECHNOLOGY* suggests a favorable environment for cooperation, above and beyond the commercialization environment measures. The remainder of the empirical work includes these industry controls, highlighting how the firm's commercialization environment (rather than simply "average industry practice") shapes commercialization strategy.

We now consider the chief "candidate" for potential bias: our exclusion of controls for project quality, firm resources, or the overall strategic orientation of the firm. In column 3, we report a specification including detailed controls for each of these factors as well as industry dummies. To control for project quality (which may be correlated with *PATENT THRESHOLD* and *VC-FUNDED*), we include dummy variables for the type of technology and additional controls for the timing of product introduction. We control for initial firm size (using four distinct firm size categories) to account for precommercialization resource differences among firms. Also, to capture differences in the overall strategic orientation of firms, we include *CEO FOUNDER* and *PHD EMP SHARE*.

Two types of findings stand out. First, the coefficients on the commercialization environment measures are effectively unchanged (all remain above the 10% significance level). Because the size of the coefficients remains similar to column 1, each continues to have a large predicted impact on the cooperation probability. Second, the coefficients on the control variables are insignificant (and tend to be small in magnitude).[11] For example, neither the time from project conception to product introduction nor the technology type has an effect on commercialization strategy. Similarly, there is little evidence that the initial size of the firm, continued control by the initial entrepreneur, or the composition of employees affects the probability of cooperation. While these results stand in contrast to the prior literature highlighting the importance of the procompetitive effects of "radical" technologies and entrepreneurial preferences, we do not emphasize these findings, as the innovation type and firm organization is self-reported. Instead, our main point is the robustness of

[10] By construction of matched pairs, the mean of *VC* will be constant across industrial segments.

[11] Even if we exclude industry controls and/or the firm-level controls, the project-level controls remain insignificant. Similarly, excluding project-level controls, the firm-level controls remain insignificant.

TABLE 3 **Cooperation Probits. Dependent Variable:** *COOP(LIC + ACQ)*

	(1) Baseline	(2) (1) with Industrial Segments	(3) (1) with All Segment, Project and Firm Controls
PATENT THRESHOLD	**.684**	**.674**	**.647**
	(.273)	**(.292)**	**(.317)**
VC-FUNDED	*.481*	**.553**	**.730**
	(.250)	**(.261)**	**(.309)**
EXPENSIVE COMP ASSET OWNERSHIP	*.497*	*.458*	*.499*
	(.262)	*(.273)*	*(.303)*
Industry segments (default = electronic equipment)			
BIOTECHNOLOGY		**.862**	*.895*
		(.405)	*(.537)*
INDUSTRIAL EQUIPMENT		−.179	−.108
		(.492)	(.545)
INSTRUMENTS		.209	.015
		(.323)	(.356)
SOFTWARE		.141	−.054
		(.468)	(.556)
Firm-level controls			
CEO FOUNDER			−.194
			(.275)
INITIAL EMPLOYEES (1–2)			−.195
			(.641)
INITIAL EMPLOYEES (3–10)			−.543
			(.573)
INITIAL EMPLOYEES (11–74)			−.075
			(.560)
PHD EMP SHARE			.014
			(.010)
Product-level controls			
TIME TO MARKET			−.001
			(.003)
YEAR OF PRODUCT INTRODUCTION			−.051
			(.036)
PRODUCT INNOVATION			.203
			(.334)
NOVEL SYSTEM INNOVATION			−.157
			(.302)
MASS-PRODUCED PRODUCT			−.127
			(.321)
CONSTANT	**−1.288**	**−1.503**	3.523
	(.280)	**(.377)**	(3.294)
Log-likelihood (*N* = 118)	−68.338	−65.511	−61.760

the core results to project-level measures of "radicalness" and firm-level measures of resources and strategic orientation.

Simultaneously including industry-, firm-, and project-level variables controls for many potential sources of unobserved heterogeneity. We ran an extensive number of alternative specifications to check robustness. For example, as an additional project quality measure, we ran specifications including project-level performance, measured as project revenues (cumulatively or in specific years), as an explanatory variable. Of course, project-level performance is endogenous to the chosen commercialization strategy (and so we do not report these results). However, it is interesting to note that (i) measures of project-level performance are positively correlated with *COOP(LIC + ACQ)* and (ii) inclusion of project-level performance measures substantially *strengthens* each of the commercialization environment estimates.

We also experimented with an instrumental-variables procedure where, for firm j, we instrument for *PATENT THRESHOLD* with the average, excluding firm j, of *PATENTS* and *PATENT LIKERT* in firm j's industry segment. While the complementary-asset variables tend to fall in significance, our results on the role of IPR and *VC-FUNDED* are robust.[12]

Finally, conflating strong IPR or association with VCs with "high-quality" projects probably reduces the power of our empirical work to detect the impact of the commercialization environment. Suppose that control of IPR (or association with VCs) is simply proxying for "high-quality" or "radical" projects. Earlier research suggests that high-quality innovations would be associated with higher rates of independent product market entry (Foster, 1986; Christensen, 1997), implying that our empirical work provides a *lower* bound on the impact of the commercialization environment measures.

These results provide support for a model in which start-up innovators earn their returns on innovation through the market for ideas when the environment offers a strong intellectual property regime, and, at the same time, the start-up faces high relative costs in acquiring and controlling complementary assets necessary for commercialization success. As imperfections arise in the market for ideas (e.g., through increases in the expropriation hazard), start-up innovators are more likely to pursue competitive strategies, which in turn contribute to the gale of creative destruction.

□ **Alternative measures.** In Table 4, we document the robustness of our results to alternative measures of the key variables. This is important given the novelty of the dataset and our latitude in defining the variables. First, in column 1 we employ *STRONG FORMAL IPR*, a dummy based on the Likert scale measures of the effectiveness of patent protection and litigation, as our measure of IPR strength; we then include *SECRECY LIKERT* in combination with *PATENT THRESHOLD* in column 2. While there is a significant relationship between *STRONG FORMAL IPR* and cooperation, *SECRECY LIKERT* has no impact on either the probability of cooperation or the size or significance of *PATENT THRESHOLD*. This is consistent with the role of formal IPR in reducing the transaction costs associated with cooperation. While *PATENT THRESHOLD* and *STRONG FORMAL IPR* do have interpretational problems,[13] the robust relationship between these measures and *COOP(LIC + ACQ)* supports one of our hypotheses: stronger IPR is positively associated with cooperation between start-up innovators and incumbents.

Next, we vary the measure of external project funding to include projects *ever* funded by venture capital. *EVER VENTURE-FUNDED* captures the idea that entrants associated at any time with VCs may face lower transaction costs in transacting with established firms. The key coefficients are robust to the inclusion of this measure.

We also evaluated alternative definitions of the complementary-asset regime. For example, *CA LIKERT MAX* is the maximum value of the Likert complementary-asset measures. While this measure is not quite statistically significant (it is just below the 10% level), its predicted quantitative impact remains large (similar to *EXPENSIVE COMP ASSET OWNERSHIP*).[14] Given the modest sample size and measurement issues that arise in estimating the impact of sunk assets, it is not surprising that the precision of the findings is reduced for some of the measures we explored.

Finally, recognizing that the definition of cooperation itself is subject to interpretation, column 5 includes a broader definition (*COOP(ALL)*), which adds firms with *HIALLIANCES* = 1

[12] We do not separately report these results, since the essential empirical relationship is highlighted in Figure 1 (which suggests that the substantial cross-industry variation in the rate of cooperation is related to the variation in the commercialization environment across sectors).

[13] For example, *PATENT THRESHOLD* might be proxying for quality, while it is difficult to ensure comparability from Likert-based survey responses.

[14] By construction, the coefficient on *CA LIKERT MAX* has a sign opposite to *EXPENSIVE COMP ASSET OWNERSHIP*.

TABLE 4 **Alternative Measures: Cooperation Probits**
Dependent Variable: *COOP(LIC + ACQ)*

	(1) *STRONG FORMAL IPR* as IPR Measure	(2) (3-1) Including *SECRECY LIKERT*	(3) *EVER VENTURE-FUNDED* as VC Measure	(4) *CA LIKERT MAX* as Asset Ownership Importance Measure	(5) *COOP(ALL)* as Dependent Variable
PATENT THRESHOLD		**.704**	**.592**	**.638**	**.824**
		(.296)	**(.292)**	**(.290)**	**(.299)**
STRONG FORMAL IPR	*.563*				
	(.339)				
SECRECY LIKERT		.084			
		(.098)			
VC-FUNDED	**.555**	**.565**		**.567**	**.573**
	(.260)	**(.262)**		**(.260)**	**(.262)**
EVER VENTURE-FUNDED			*.516*		
			(.273)		
EXPENSIVE COMP ASSET OWNERSHIP	*.912*	*.485*	*.486*		**.547**
	(.512)	*(.276)*	*(.271)*		**(.276)**
CA LIKERT MAX				−.326	
				(.215)	
*EXPENSIVE COMP ASSET OWNERSHIP * STRONG FORMAL IPR*	−.788				
	(.614)				
Industry dummies	Significant	Significant	Significant	Significant	Significant
CONSTANT	**−1.311**	**−1.844**	**−.979**	.151	**−1.575**
	(.362)	**(.554)**	**(.357)**	(1.006)	**(.386)**
Log-likelihood ($N = 118$)	−66.831	−65.135	−65.970	−65.780	−65.710

to the set of cooperators in the sample. As in the other checks, the key coefficients are robust to the use of this alternative measure.

□ **Form of cooperation.** We conclude by "unbundling" the *COOP(LIC + ACQ)* measure. We divide commercialization strategy into three distinct choices, *LICENSED*, *ACQUIRED*, and *COMPETE*. Taking *COMPETE* as the default, we can estimate the impact of each of the commercialization environment measures (along with industry dummies) on the probability of *LICENSED* and *ACQUIRED*. Although we observe variation in the start-up commercialization environment, our data have no choice-specific variation (e.g., we do not observe different "prices" for *ACQUIRED* for different firms). In the absence of choice-specific variation, the distribution of idiosyncratic utility is not separately identified from the functional form for utility. For simplicity, then, we use a multinomial logit specification highlighting the overall influence of the commercialization environment on *ACQUIRED* or *LICENSED* (relative to *COMPETE*).

Table 5 offers additional insight into the nature of cooperation. While licensing behavior is associated with the IPR and complementary-asset regimes, acquisition is sensitive to the presence of VC funding. Since the parameters for each type of cooperation are not statistically different, these differences are only suggestive. However, the fact that licensing is more strongly associated with the presence of patents reinforces our hypothesis that IPR may be important for reducing the risk of expropriation and reducing the transactional costs of bargaining.

TABLE 5 **Cooperation Multinomial Logits**
Dependent Variable = *LICENSED* **or** *ACQUIRED* **(default** = *COMPLETE*)

	LICENSED = 1	*ACQUIRED* = 1
PATENT THRESHOLD	**1.667**	.603
	(.771)	(.629)
VC-FUNDED	.475	**1.684**
	(.538)	**(.647)**
EXPENSIVE COMP ASSET OWNERSHIP	.868	.724
	(.541)	(.625)
Industry effects	Significant	Significant
CONSTANT	**−3.019**	**−3.972**
	(.861)	**(.975)**
Log-likelihood (N = 118)	−86.543	

5. Discussion and conclusions

■ In economic environments like the biotechnology industry, where patents are relatively effective in protecting IPR, firms face high relative investment costs, and brokers are available to facilitate trade, start-up innovators tend to earn their returns from innovation through the market for ideas, acting as an upstream supplier of "technology" rather than as a horizontal innovation-oriented competitor. In contrast, when investment costs for the entrant are relatively low and the technological innovation is not protected by patents, as in the disk drive industry, the disclosure threat tends to foreclose the ideas market. Start-up innovators in this environment are more likely to commercialize their innovations through product market competition.

We find empirical support for these ideas. Perhaps most strikingly, firms that control IPR are more likely to pursue a cooperative strategy. These results suggest that the role of intellectual property on the competitiveness of product markets is subtle. While most prior work emphasizes how IPR increase the absolute returns to innovation, our evidence is consistent with the idea that IPR affects the *relative* returns to cooperation by facilitating the market for ideas.

Our study is not without limitations. First, the empirical measures may be imperfect in capturing the key theoretical concepts. The results are robust, however, to alternative measures of both cooperation and the start-up's commercialization environment. Second, our measures of the commercialization environment may be endogenous. We addressed this issue in two ways: (1) the sample was constructed to include only preexisting patent and external funding events relative to cooperation events; and (2) we include controls to limit the effect of omitted variables that may be correlated with both the start-up's commercialization strategy and its commercialization environment. Finally, the control of IPR or association with VCs may be correlated with underlying project quality. Our results are, however, robust to controls for both the type and size of innovation. Indeed, cooperation is positively associated with a revenue-based measure of the realized commercial returns from the project. Whereas most earlier research assumes or suggests that product market entry and competition would be associated with projects with higher quality (Christensen, 1997), our findings suggest that projects able to obtain IPR, funded by venture capitalists, and associated with higher revenues are all more likely to be commercialized through *cooperation*.

These findings suggest several directions for further research. First, we plan to investigate commercialization strategies for both entrants and incumbents in "mixed" economic environments. For example, in environments where IPR are weak and a dominant incumbent would prefer to take advantage of the R&D productivity of smaller firms, established firms may develop a reputation for "nonexpropriation" in order to provide incentives for innovation and cooperation by start-ups (Gawer and Cusumano, 2002). Second, our findings suggest that venture capitalists play a nonfinancial role in the strategy of start-up firms. Identifying the mechanisms by which VCs facilitate transactions, and whether they earn additional economic returns, remains an area for further investigation.

Appendix

■ **A model of commercialization strategy.** We present a simple model of commercialization strategy that formalizes our comparative statics. Consider a start-up innovator, E, that has successfully developed a commercializable innovation and faces a choice between a competition and a cooperation strategy. Monopoly profits are denoted π^m, while E and I both earn π^c under the competitive strategy. Sunk costs are incurred by the start-up under either strategy. To compete, E must invest K (to create the relevant complementary assets), while undertaking the cooperative strategy involves a transaction cost, c, associated with bargaining with I. Since these costs are irreversible, E compares expected profits associated with each path in choosing its commercialization strategy.

Figure A1 illustrates the model. Regardless of its strategy, E faces a risk that I imitates the innovation. If E competes, I may imitate E's innovation with probability $1 - p_r$, but, with probability θ, E successfully enforces its IPR. Therefore, with probability $(1 - p_r)(1 - \theta)$, I commercializes an imitative technology. For simplicity, we assume that successful commercial imitation by I raises I's profits by Δ and reduces E's by a similar amount, leaving industry profits unchanged.[15] By choosing to compete, E earns expected profits of $\pi^c - \Delta(1 - p_r)(1 - \theta) - K$, which are increasing in the strength of IPR (θ).

Under the cooperation strategy, E's return is determined through the outcome of a bargaining game with I, which involves a potential "expropriation" hazard. When E negotiates with I, I imitates the innovation with probability $1 - p_d$. As in the competition setting, E can enforce its IPR with probability θ. We assume that negotiations occur following the resolution of uncertainty as to whether E can enforce its IPR.[16] For simplicity, we assume that θ governs the strength of IPR under both the competition and cooperation strategies,[17] and that the impact of expropriation by I is to increase its potential product market profits by Δ and reduce E's by a similar amount. As such, E faces a risk, with probability $(1 - \theta)(1 - p_d)$, that I commercializes an imitative technology in the event negotiations break down.

The possibility of expropriation affects the expected outcome of negotiations between E and I. Allowing the bargaining outcome—that is, the transfer (τ) from I to E—to be determined by the Nash bargaining solution (as in Aghion and Tirole, 1994), each party "splits" the gains from trade. E's profits in the absence of expropriation are equal to

$$\underbrace{\tau - (\pi^c - \Delta(1 - p_r)(1 - \theta) - K)}_{E\text{'s Net Return}} = \underbrace{\pi^m - \tau - \pi^c - \Delta(1 - p_r)(1 - \theta)}_{I\text{'s Net Return}} \Rightarrow \tau = \frac{1}{2}(\pi^m - K) - \Delta(1 - p_r)(1 - \theta) \quad \text{(A1)}$$

On the other hand, expropriation by I reduces the share of the monopoly profits E expects to receive. Expropriation by I does not entirely eliminate E's rents because (i) E can still credibly threaten to reduce I's profits by competing in the product market (Anton and Yao, 1994, 1995) and (ii) E may be able to enforce its IPR with probability θ. However, relative to payoffs in the absence of expropriation, disclosure increases I's potential competitive position (and similarly decreases E's position). We further assume that following the successful enforcement of its IPR, I cannot reverse engineer and test E's IPR again. That is, imitation by I occurs only once over the course of the game. As such, using the same bargaining rule as above, E's share under expropriation will be

$$\begin{aligned} &\text{If IPR enforced, then} \quad \underline{\tau}_0 = \frac{1}{2}(\pi^m - K); \\ &\text{If IPR not enforced, then} \quad \underline{\tau}_1 = \frac{1}{2}(\pi^m - K) - \Delta. \end{aligned} \quad \text{(A2)}$$

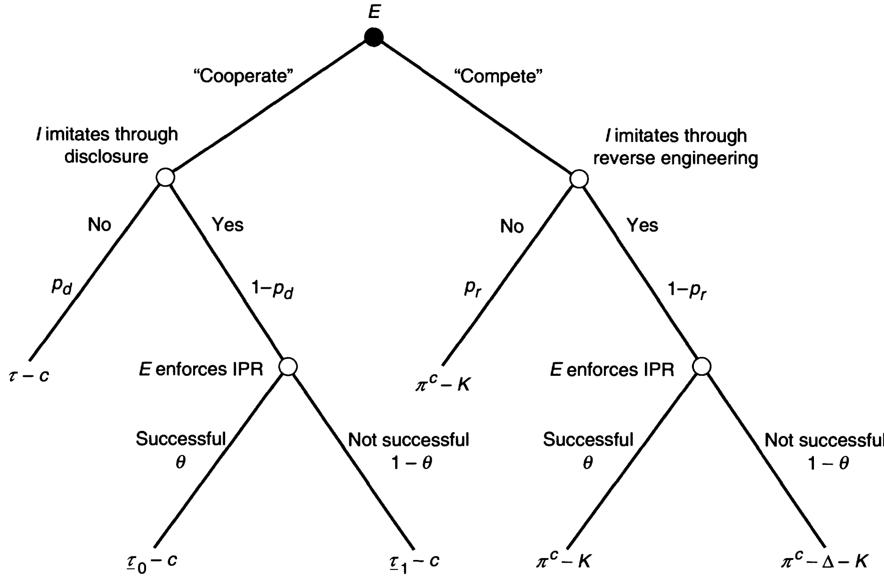
[15] Expropriation may also change the level of industry profits. However, as long as imitation does not decrease total industry profits too much, our comparative statics are unchanged. The bargaining game can be enriched considerably to incorporate the incumbent's ability to invest in expropriation during the bargaining process (Gans and Stern, 2000).

[16] The predictions of the model are unchanged if E and I negotiate before the resolution of uncertainty about IPR enforcement.

[17] Our comparative statics hold as long as the probability of enforcement under each regime is affected similarly by changes in factors such as the ease and scope of patent protection or the availability of legal remedies against IPR infringement.

FIGURE A1

START-UP CHOICES AND PAYOFFS



These can be found by solving

$$\underbrace{\underline{\tau} - (\pi^c - K - \Delta(1-\theta))}_{E\text{'s Net Return}} = \underbrace{\pi^m - \underline{\tau} - (\pi^c + \Delta(1-\theta))}_{I\text{'s Net Return}} \Rightarrow \underline{\tau} = \frac{1}{2}(\pi^m - K) - \Delta(1-\theta) \tag{A3}$$

for $\underline{\tau}$ and setting $\theta = 1$ (enforced) or $\theta = 0$ (not enforced).

Since E chooses to cooperate as long as

$$\begin{aligned} &p_d \tau + (1-p_d)\left((1-\theta)\underline{\tau}_1 + \theta \underline{\tau}_0\right) - c \geq \pi^c - \Delta(1-p_r)(1-\theta) - K \\ &\Rightarrow \frac{1}{2}\pi^m - \Delta p_r(1-p_d)(1-\theta) - c \geq \pi^c - \frac{1}{2}K, \end{aligned} \tag{A4}$$

E is more likely to choose cooperation as K rises, c falls, θ rises, or Δ falls. Cooperation is more likely when the sunk costs of product market entry are high relative to the costs of transacting with established firms. The start-up's bargaining outcome is equal to its *absolute* return under competition plus a fraction of the *surplus* associated with cooperation. As such, an increase in the strength of IPR (through an increase in θ or a decrease in Δ) increases the *relative* return to cooperation over competition. The relative returns to cooperation are increasing in θ because the bargaining process internalizes E's ability to threaten I with competitive entry.

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