Do the Costs of Cooperation Drive the Gale of Creative Destruction?
Commercialization Strategies in the Medical Device Industry

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ABSTRACT

Prior literature suggests that an inventor’s choice of commercialization strategy between entrepreneurship and cooperation with an incumbent firm is determined by the intellectual property environment, access to complementary assets, and transaction costs of collaborating with incumbents. We explore commercialization strategies from the perspective of the incumbent, and consider how the incumbents’ willingness to cooperate with the inventor influences patterns of entrepreneurship and collaboration. We argue that conditions exist under which inventors would prefer to commercialize their invention using cooperation, while incumbents find cooperation too costly, leading to entrepreneurship. Using data from the medical device industry, we empirically demonstrate that when the incumbents’ costs of cooperation are exogenously increased, a subset of inventors are more likely to pursue entrepreneurship and less likely to develop new technologies collaboratively. We also consider how these new entrants influence the competitive environment.

Keywords: entrepreneurship, commercialization strategies, corporate strategy
Introduction
An invention is only the first step in the path to technology commercialization. As the process unfolds, an inventor must often decide whether to develop, manufacture, and sell a new technology himself by launching a new entrepreneurial venture, or to cooperate with an incumbent firm to commercialize the technology (Audretsch 1995, Winter 1984). These choices by inventors have the potential to shape the competitive landscape of entire industries, powering the “gale of creative destruction” posited by Schumpeter (1950) or further concentrating the market power of incumbent firms. The drivers of this critical choice of commercialization mode have been studied both theoretically and empirically (Fosfuri 2006, Gans et al. 2002, Gans and Stern 2003, Teece 1986). In this study, we extend existing theory to consider how the incumbent firm’s costs of cooperating in the ‘market for ideas’ will influence the mode of commercialization selected. We argue that there are cases where the incumbent firm finds it prohibitively costly to cooperate, leading the inventor to pursue entrepreneurship as a second choice. Further, we provide supporting evidence using a quasi-natural experiment in the medical device industry, where a U.S. Department of Justice (DOJ) investigation increased the costs of cooperation for some incumbent firms and a subset of inventors.

The existing theory posits three key factors that influence commercialization mode: the strength of intellectual property protection, the availability and importance of complementary assets, and the costs borne by the inventor for cooperating with incumbent firms (Gans et al. 2002). Cooperation with an incumbent firm is favored when (1) intellectual property protection is strong enough to prevent expropriation; (2) there are significant complementary assets held by incumbent firms that are not widely available and would be costly to replicate; and (3) there are intermediaries that reduce the search and transaction costs inventors pay for cooperating with incumbent firms (Gans et al. 2002). However, even when these conditions hold, we argue that the likelihood of cooperation depends on the availability of incumbent firms that are willing and able to engage in transactions in the market for ideas. In this paper, we consider how changing the cost of cooperation for incumbent firms impacts inventors’ commercialization strategies. When incumbents’ costs of cooperation in this market increase, incumbent firms will be less willing to work with inventors to commercialize new technologies. Even when inventors might prefer cooperation to entrepreneurial entry, the costs of cooperation for the incumbent firm may preclude such a strategy, forcing inventors to pursue entrepreneurship. Our central prediction is that an increase in the cost of cooperation borne by incumbent firms leads to less collaboration between physician inventors and incumbent firms, and to more physician-founded entry.

We test this prediction using a robust empirical methodology that exploits an exogenous shock to the costs of cooperation for incumbent medical device companies in the orthopedics sector that were investigated by the U.S. Department of Justice (DOJ) in 2005. The purpose of the legal action was to
address potential conflicts of interest posed by physicians that receive consulting payments from orthopedic device firms while also being in a position to recommend their products to patients. However, the investigation had the practical impact of raising the costs of cooperation for medical device companies working with orthopedic surgeons. To test our theoretical prediction, we compare the temporal patterns in entrepreneurial entry and cooperative patenting (including physicians and companies) in the orthopedics segment with the rest of the medical device industry, which provides a natural and well-suited control group.

Our empirical results are consistent with the prediction that exogenously increasing incumbent firms’ costs of cooperation increases entrepreneurial entry by inventors. Following the DOJ investigation, there was an increase in new venture formation in the orthopedics area and an increase in the percentage of new orthopedics ventures founded by physicians. Further, evidence from patent assignment data suggests that physicians who invented new orthopedics technologies were significantly less likely to collaborate with U.S. medical device companies in the years following the DOJ investigation, relative to physicians in other areas and compared to the pre-DOJ investigation level of collaboration in the orthopedics segment. These findings provide support for our theoretical prediction that increases in the costs of cooperation for incumbent firms will influence inventors’ commercialization strategies, increasing the likelihood that inventors pursue entrepreneurship rather than cooperate with incumbent firms.

This paper makes both theoretical and empirical contributions to the academic literature on strategy and entrepreneurship. First, we extend existing theory on commercialization strategy by considering the incumbent’s strategic choice, based in part on the costs of cooperation that it bears, and demonstrate that this extension explains some cases of entrepreneurial entry. It is important to reiterate that, in these cases, entrepreneurship may not be the preferred outcome for the inventor but rather the only strategy available. Second, we provide an empirical test of our theoretical predictions using an exogenous shock to the costs of cooperation for a ‘treatment’ set of incumbent firms, an approach that has seldom been used to test theories in strategy and entrepreneurship. This paper represents one of the few empirical tests of an influential body of theoretical work on commercialization strategies (Gans et al. 2002, Gans and Stern 2003, Teece 1986). Third, we respond to the recent calls from leading strategy scholars to utilize theories from strategy to develop useful insights for public policy (e.g., Barney 2011, Mahoney et al. 2009). Taken together, our work builds a more complete theory of commercialization strategy and entrepreneurship, provides robust empirical evidence in support of these arguments, and demonstrates the influence, perhaps unintended, of public policy.

The next section briefly reviews the established theory regarding the inventor’s decision to either cooperate with established firms or pursue entrepreneurial entry to commercialize an invention. We build
on this theory to further develop the choice facing the incumbent firm—whether to cooperate with the inventor—and argue that the gap between the inventor’s preferred strategy and the willing participation of the incumbent increases with the incumbents’ cost of cooperating. We also explain the conceptual and methodological challenges associated with testing the effect of the availability of cooperative partners on the choice of commercialization mode and describe how we overcome these difficulties. The third section provides the details on our empirical context. The fourth section describes the empirical methodology used to test our prediction, including the data and variables. The fifth section reports the results of the empirical analysis, and the final section reviews implications for the academic literature.

Theory on Commercialization Strategies
Existing literature explores the decision by an inventor to either commercialize a technology in his own entrepreneurial venture or with an incumbent firm. Important work by Teece (1986), Gans and Stern (2003) and Gans et al. (2002) concluded that when incumbent firms hold specialized complementary assets that an entrant would find difficult or costly to replicate, and when the intellectual property environment provides strong protection against expropriation of new inventions, technological inventors can be expected to cooperate with incumbent firms rather than form new ventures to commercialize their inventions. Gans et al. (2002) provided a simple model of inventors’ commercialization strategy selection that incorporates a cost, borne by the inventor, for cooperating with incumbent firms. The comparative statics from the model suggested that, as the inventor’s costs of transacting with established firms fall, the inventor becomes more likely to choose cooperation (and vice versa).¹ We add to this model a cost of cooperating borne by the incumbent firm and find that there may be conditions under which the inventor would prefer to cooperate, but incumbent firms are not willing to do so.

We build our argument using the theoretical framework advanced by Gans et al. (2002). We consider the incumbent firm’s decision about whether or not to cooperate with the potential entrant by comparing the expected payoffs from cooperation and competing with the entrant if the incumbent elects not to cooperate. The model provided in the appendix demonstrates the condition under which the incumbent is willing to cooperate, incorporating of cost of cooperation borne by the incumbent. As in Gans et al. (2002), the incumbent and potential entrant bargain over the gains from trade, and the bargaining solution is impacted by the risk of imitation and expropriation. Where Gans et al. included a transaction cost borne by the entrant, we focus instead on a cost of cooperation borne by the incumbent.

¹ The authors did not test this prediction directly, although they did examine whether venture capital (VC) funded companies were more likely to cooperate with established firms than ventures funded by the Small Business Innovation Research (SBIR) program. They argued that VC funding reduces uncertainty, and therefore the costs of cooperating. However, it is likely that the allocation of inventions and inventors to venture capital funding and SBIR support is not random, so unobserved differences across these ventures may be driving commercialization strategies in this context.
In Figure 1 we represent the decision space of the incumbent and the entrant as a function of the incumbent’s cost of cooperating.

[Figure 1 Here]

It is evident from Figure 1 that there is a range of values (region C in the Figure) where an inventor would prefer cooperation with the incumbent, but the incumbent would prefer entry and competition to cooperation with the inventor. Each party would prefer cooperation when the payout from cooperation exceeds their respective gains from entry and competition. The shaded area between these lines is the range over which inventors would like to cooperate but incumbents are unwilling to do so. As the incumbents’ cost of cooperating increases, this wedge increases: there is an increasing range over which the inventor would prefer cooperation and the incumbent is not willing to cooperate. This shaded area represents instances where an inventor will pursue entrepreneurial entry when he would otherwise prefer to cooperate with the incumbent firm. Thus, our central prediction is that, as the incumbents’ cost of cooperating increases, cooperation between inventors and incumbents will become less likely and entrepreneurial entry by inventors will become more likely.

Related Literature and Conceptual Challenges

Existing research has considered inventors’ commercialization strategies in other industries, including Orsengio (1989), Shan (1990), Lerner and Merges (1998) and Arora and Gambardella (1990) in the biotechnology industry and Christensen (1997) in electronics. For example, Shan (1990) found evidence that the size of the firm, its internal capabilities, its competitive position in the industry, and whether it is competing in a foreign market all influence the likelihood of cooperation. Gans et al. (2002) used a survey of venture-backed and SBIR-backed start-ups across multiple industries to develop a cross-sectional test of the predictions that stronger intellectual property rights protection, greater importance of complementary assets, and lower transaction costs are associated with cooperation rather than with the independent development of innovations. Based on their sample of 118 start-ups, they found evidence consistent with these predictions.

Our work is distinct from its predecessors because we examine the effect of a change in the cost of cooperation borne by the incumbent firm. A related line of inquiry has considered the impact of the availability of venture capital on commercialization strategies (Hellmann and Puri 2002) and found that a greater availability and a lower cost of venture capital funding are associated with more entrepreneurial entry (Samila and Sorenson 2011). Our work is complementary to these papers, as we consider the impact of variation in the availability of the inventor’s alternative to entry: cooperating with an incumbent firm.

An important challenge faced by empirical studies in this area is that unobserved characteristics of the focal invention influence the mode of commercialization and are likely to be correlated with the
drivers of commercialization mode. For example, Shane (2001) found that the nature of technological opportunity has an impact on firm formation. However, the potential market value of a particular invention is usually unobserved. The market value is likely to be correlated with the strength of intellectual property protection for the focal invention (less potential for imitation by rivals means a greater opportunity to capture rents). When market value is unobserved, it is impossible to know whether a positive correlation between intellectual property rights and cooperation with incumbents reflects the effect of strong intellectual property rights or whether incumbent partners are simply more willing to cooperate when an innovation’s expected market value is greater.

As a second example, technologies in more established technological areas (i.e., further along the technology life-cycle trajectory) are likely to have two characteristics favoring cooperation with incumbents: a proven market and the need for more significant investment in complementary assets. If we observe only the need for complementary assets, and not the expected market size for the innovation, we cannot infer that the need for complementary capabilities favors cooperation with incumbents. Existing empirical work examining the drivers of commercialization mode has typically tried to control for at least some of the other relevant characteristics of the technology, or it has selected subsets of innovations that are argued to be similar across the critical dimensions. But, in the absence of an exogenous shock to the dimension under study, the problem of potential unobserved drivers of commercialization mode remains an issue.

In our study, we exploit an exogenous shock to the costs of cooperation in one segment of a market for technology. This approach allows us to overcome this common empirical challenge. The increase in the cost of collaborating was imposed exogenously, not correlated with any particular characteristics of the inventions. In addition, it was imposed on one segment of the medical device industry, providing a natural control group with the remainder of the industry. This control group allows us to account for other (unobserved) changes that might affect entry and cooperation in the medical device industry.

**Empirical Setting: Medical Devices and the Department of Justice Investigation**

The medical device industry is an ideal context to test theories about the market for technology and commercialization strategies. First, the two conditions that favor cooperation with incumbent firms to

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2 The examination of the transaction costs of cooperating by Gans, Hsu, and Stern (2002) did both, comparing venture backed and SBIR-backed ventures matched to be similar and also controlling for project-level characteristics. They proposed that the presence of venture capital backing reduced the costs of transacting by providing information that facilitates cooperation. They found that venture-backed inventors were more likely to cooperate, rather than start new ventures, to commercialize technology. This may reflect that venture capital backing is associated with higher quality inventions, and that incumbent firms are more willing to cooperate on higher quality inventions.
commercialize a new invention hold consistently across this industry. Patents on inventions provide very strong intellectual property protection in the medical device industry (Cohen et al. 2002), and complementary assets, including manufacturing expertise, knowledge of the regulatory approval process and reimbursement procedures, marketing, sales and distribution capabilities, and a network of relationships with doctors are all held by the established medical device firms and are costly to replicate. If previous theory is applicable, these conditions suggest that medical device inventors would elect to cooperate with established firms rather than form new companies to commercialize new inventions.

Previous studies have documented the important role of practicing physicians as inventors and entrepreneurs in the medical device industry (Chatterji et al. 2008, Chatterji and Fabrizio 2012, Smith 2008). Physicians contribute about 20% of the patented inventions in medical devices, and their inventions are, on average, more cited and more likely to be at the leading edge of new technologies (Chatterji and Fabrizio 2012). In many cases, physicians and medical device companies work together to identify unmet clinical needs and develop successful products. Physician often act as paid consultants for firms, an arrangement that has raised significant scrutiny in recent years (Chatterji et al. 2008). Company executives argue that these relationships are essential to successful product development since physicians are uniquely positioned to offer insights into product attributes. Critics suggest that the lucrative consulting arrangement can provide improper incentives for physicians to recommend a particular brand to hospital administrators and patients, irrespective of clinical evidence. A significant number of conflict-of-interest cases have involved orthopedic companies and surgeons, a market segment where products are largely produced by five leading incumbents and brand loyalty is a significant barrier to competition and entry.

In response to these concerns, the U.S. Department of Justice (DOJ) launched an investigation in March 2005 against the five largest U.S. orthopedic device makers, Biomet, the DePuy Orthopedics unit of Johnson and Johnson, Smith and Nephew, Stryker Orthopedics, and Zimmer. These companies comprised 93–95% of sales in the hip and knee implant market in the U.S. (Healy and Peterson 2009). The investigation alleged that the companies violated the anti-kickback statue, in essence paying physicians to favor their own products in orthopedic procedures.

In November 2007, a settlement was reached wherein four of the companies signed deferred prosecution agreements (Healy and Peterson 2009). Under these agreements, the companies agreed to increase transparency with substantial new disclosures, including prominently posting any payments to physicians on their websites. The companies also agreed to substantial oversight, including a monitor appointed by the Department of Justice and a compliance officer who would report to the Department of Health and Human Services Office of Inspector General. The settlement agreements also required the companies to develop prospective budgets and produce needs assessments that justified their
collaborations with physicians. If the companies succeeded in satisfying the conditions of the agreement, the Department of Justice stipulated that the conditions of the deferred prosecution agreements would expire in 18 months (March 2009), although the corporate integrity programs established with the Office of the Inspector General were to stay in place for five years, until September 2012 (Healy and Peterson 2009). According to media accounts, the deferred settlement agreements had a dramatic impact on the operations of the companies involved and on smaller firms in the orthopedic market (Healy and Peterson 2009).

While the companies reorganized their practices to satisfy the conditions of the settlement agreements, including posting payments to physicians, obtaining monitors, and fulfilling the other conditions of the agreements, “business as usual was suspended” (Healy and Peterson 2009: 1974). Payments to physicians, as well as funding for scholarships, grants, and research, were canceled or put on hold. Once practices had been aligned with the requirements, any companies desiring collaborations with physicians had to first pursue a needs assessment, precertify the work, and ascertain a fair market value for the work performed by the physicians (frequently resulting in rates much lower than the ones physicians were accustomed to, causing complaints).

A byproduct of the DOJ investigation was that cooperation between orthopedic physicians and medical device firms became much more costly and difficult for firms. This shift impacted physician inventors whose inventions had applications in the orthopedics sector. The investigation and settlement agreements did not prohibit licensing inventions from physicians, but they reduced companies’ willingness to cooperate with physicians and increased the costs of working with physicians on an ongoing basis. Ongoing interaction, consultation, and transfer of “tacit” inventor knowledge (Elfenbein 2007) are often necessary to effectively develop and commercialize new technological inventions, so the increased difficulty and costs involved in working closely with companies reduced the potential for physician inventors to license new technologies to orthopedic firms. As a direct result, we expected to find a decrease in collaborative physician–firm patenting and an increase in new venture activity in the orthopedics area following the initiation of the DOJ investigation, as more physicians developed and commercialized their inventions independently from incumbent firms.

**Empirical Methodology**

There are two aspects of this context that are critical for empirically identifying the impact of the cost of cooperation on entrepreneurial entry and collaborative patenting. First, the DOJ investigation provides an exogenous shock to the costs borne by incumbent orthopedics firms participating in the market for ideas from physicians. The increase in the costs of cooperation, and the resulting decrease in willing cooperative partners, is not endogenous to technology or market characteristics. Second, we have a
natural control group to which to compare the temporal pattern of entrepreneurship and collaborative patenting. The DOJ investigation involved only orthopedics companies. Physicians are active inventors in many other medical device segments (Chatterji and Fabrizio 2012). We can therefore compare the pattern of entrepreneurship and collaborative patenting in orthopedics to that in other medical device segments in order to isolate the effect of the lawsuit from other unobserved factors that affect commercialization strategies in the medical device industry as a whole, such as economy-wide fluctuations, the availability of venture capital, and the strength of intellectual property rights. If medical device companies outside of the orthopedics segment were impacted by the DOJ’s actions, it would bias our results toward non-significance.

We tested our prediction in two ways. First, we looked directly at new venture formation and explored whether there was an increase in entrepreneurial activity in the orthopedics segment after the DOJ investigation. Based on the set of new ventures founded between 2000 and 2009, we examined whether the likelihood of physician-founding was greater for orthopedics ventures founded during the settlement period, relative to outside of this period and relative to new medical device ventures in other segments. Examining the likelihood of physician-founding allowed us to control for the changes in the overall level of new venture founding (which affect both physician- and non-physician-founding) and examine how physician-founding, specifically, was affected by the lawsuit. In addition, by comparing orthopedics to other segments of the industry, we were able to control for factors that might influence physician entrepreneurship generally, such as changes in opportunity costs owing to health sector regulations and reforms. One limitation of the data on new ventures is that the number of annual new ventures, especially within a limited segment like orthopedics, is quite small.

We therefore also pursued a second analysis, using patent data to explore the extent to which physicians working in the orthopedics area reduced collaborative innovation with U.S. companies following the DOJ investigation. We estimated a difference-in-differences model exploring the likelihood that a given physician-invented patent was assigned to a company (indicating collaborative invention) to explore whether the change in the likelihood of collaboration from pre-investigation/settlement to during the investigation/settlement was significantly different for patents in the orthopedics segment, relative to other medical device patents. The benefit of this analysis is that we were able to control for both persistent differences between the orthopedics segment and other medical devices and for changes over time that are common across orthopedics and other segments.

Data and measures
Table 1 summarizes the measures used in our analyses. To develop data on new ventures founded in the medical device industry, we used information from the Capital IQ database. Capital IQ is an online
A searchable database of information on private and public companies provided by Standard and Poor’s. We selected all companies classified with a primary designation in Healthcare Equipment; Medical Equipment; Medical Testing, Analyzing, and Diagnostic Equipment; or Healthcare Supplies that are located in the U.S. and founded from the year 2000. This yielded 1347 companies. We reviewed the company descriptions for each of these companies to identify medical device companies and identified 450 such companies. We also relied on company descriptions to identify 35 companies that are orthopedics companies. The descriptions are quite detailed and usually list the types of devices and markets that the company targets. Based on the founding year provided in the Capital IQ data, we identified the number of medical device ventures founded annually from 2000–2010 and how many of these firms were in the orthopedic segment.

We also utilized the biographical information provided in the Capital IQ database to research the founders and key executives. The biographical information typically included the relevant work history of the individual, his or her educational background, and his or her position (and history) within the focal firm. For each medical device venture, we coded whether or not the founding team included a physician and created an indicator variable DocFounded. For the cases where executive team data were not available from Capital IQ (approximately 20% of the ventures), we supplemented these data with web searches to identify the company founders and establish whether or not they are physicians. Based on this information, we identified 113 of the 450 (25%) medical device ventures as physician-founded. Among orthopedic firms, 13 of the 35 (37%) ventures were physician-founded.

Our second analysis relied on the evidence of collaboration between physicians and medical device firms available from the patent data. Because the DOJ investigation was fairly recent (beginning in 2005), and granted patents only emerge 2–3 years after a patent application, we used data on both granted and not-yet-granted applications. Using the Delphion patent database, we selected all granted patents and patent applications for application years 2001–2008 in the technology classes that the U.S. Patent and Trademark Office identified as medical device technologies (USPTO 2005). Our time period for analysis is necessarily truncated because the requirement to disclose applications only took effect in 2001 and

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3 We first identified any company for which the description included the term “medical device” and then reviewed each of these descriptions manually to eliminate companies that, for example, were suppliers to medical device companies or were purely incubators for medical device companies.

4 The database usually indicates which individual was the founder. When no founder is indicated, we coded the firm as having a physician founder if one of the top key executives is an MD and was with the firm at the time of founding. When the only MD on the executive team is the Medical Advisor, for example, and this person joined the firm after the founding year, this was not counted as a physician-founded firm.

5 After the web searches, we were still unable to identify whether the founders of 12 of the companies included a physician. We assumed that these were not physician-founded because it is our experience that companies with physician-founders are eager to advertise it. We report a sensitivity analysis below excluding these companies.
applications are disclosed with an 18 month lag, so that many from 2009 were not yet public when the data were downloaded. For each patent (or application), we collected information including the technology class and subclass, the application year, the assignee, and the name (first, middle, and last) and address (city, state, and country) of each inventor. Using the technology classifications provided by the USPTO office, we identified which of these patents were for orthopedic inventions and created an indicator variable, OrthoPat.

In order to identify physician-generated inventions, we relied on the American Medical Association (AMA) Masterfile data. The AMA Physician Masterfile contains the name, demographic information, address, history of prior locations, type of practice, and medical school information for all licensed US physicians. With this information, we were able to match the inventor data to the AMA list of physicians and identify which inventors listed on our sample of medical device patents were physicians.

We performed this match in several steps. First, we identified any physicians with the same last name, first name, and state location as an inventor listed on a medical device patent. We used the physicians’ historic and current locations listed in the AMA data and the inventors’ addresses provided in the patent data for this match. After identifying possible matches, we evaluated them more closely to assure a true match. For each record, if there was a middle name or initial available from both sources (the patent data and the AMA data), we verified that these records matched and eliminated any for which they did not match. When one or both of the middle initial observations was missing, we verified that the observations matched by city. Observations lacking sufficient middle name data that did not match exactly based on city were flagged for manual evaluation. Based on this match, we created an indicator variable equal to one for patents that included at least one physician inventor, DoctorPat.

In order to obtain more information about the patent assignees, we also merged this patent level data with the patent and assignee data available from the Patent Data Project, sponsored by the National Bureau of Economic Research. Through this merge, we identified which of the assignees are U.S. companies (as opposed to foreign companies or other organizations, such as government or academic institutions) and which of the assignees are public companies. We used this information to create an indicator equal to one for patents assigned to a U.S. company (CompanyPat), and an indicator equal to one for patents assigned to publicly traded U.S. companies (PublicCompanyPat).

[Table 2 Here]

Summary statistics

Summary statistics for the dataset of new medical device ventures is presented in Table 2. About one quarter (25%) of the ventures were founded by physicians, and 8% of the ventures were orthopedic device companies. Figure 2 provides the temporal pattern of new venture founding in medical devices, in
orthopedics specifically, and finally by physicians in the orthopedics sector. Note that there were no new orthopedic ventures founded while the DOJ investigation was in process, during 2005 and 2006, possibly as a result of uncertainty in the segment at the time. There was a marked rebound in new venture formation in the orthopedics sector in 2007, after the settlement agreement was in place and some uncertainty was resolved. Most interesting (for our purposes) is that we also see that a large proportion of the new orthopedics ventures in the settlement period included a physician founder.

Summary statistics for the dataset of medical device patents are reported in Table 3. Eighteen percent of the medical device patents in these years included a physician inventor. Five percent of medical device patents were in orthopedics technology classes. Figure 3 compares the percentage of physician inventions that were company-assigned in orthopedics to other medical device technologies over time. During much of this period the percentage of physician patents that were company-assigned was higher in orthopedics than in other medical device segments, and the two trends are roughly parallel. However, we see a substantial decrease in company-assignment of orthopedic physician patents in 2007 and 2008, during the settlement period of the DOJ investigation.

Regression Results

Evidence from New Venture Formation

Our first empirical analysis took a more robust approach to examine these patterns. Using the data on all identifiable new medical device ventures founded between 2000 and 2009, we tested whether there was a statistically significant increase in physician-founded new ventures in in 2007 and 2008 (during the settlement agreement) in the orthopedics segment relative to the rest of the medical device market.\(^6\) The dependent variable is an indicator equal to one for physician-founded companies (DocFounded) and zero otherwise. Using a probit model, we predicted the likelihood that a given venture was physician-founded as a function of the market segment (orthopedics or other) and the year of founding (in the settlement period or not). By comparing the likelihood of a physician founder instead of the number of physician-founded ventures, we controlled for the underlying changes in the number of new ventures. If the lawsuit had no effect of physicians’ commercialization strategies, we would expect to see the percentage of new

\(^6\) We explored models using separate year indicators for each year, and tested whether 2007 and 2008 were significantly different than other years, rather than the grouped dummy indicator reported here. The results were nearly identical in terms of magnitude and significance.
ventures including a physician founder (or the likelihood that a venture included a physician founder) remain roughly constant over time.

In order to control for common patterns of physician entrepreneurship over time, we included year indicators for each year 2001–2006 and for 2010. The year 2000 was the excluded year, and the years 2007, 2008, and 2009 were grouped in the “Settlement” indicator. Note that because there were no new orthopedics ventures founded during the investigation period (2005 and 2006), it is not possible to estimate an analogous regression for the investigation period.

[Table 4 Here]

The first column in Table 4 reports the results of this analysis. The insignificance of the estimated coefficient on the Orthopedics indicator suggests that ventures in orthopedics were, on average, equally likely to be founded by physicians as ventures in other segments. The insignificance of the estimated coefficient on the Settlement indicator suggests that the likelihood that a new, non-orthopedics medical device venture included a physician on the founding team was not significantly different during the Settlement period. However, the positive and significant coefficient on the interaction of the Settlement and Orthopedics indicators suggests that orthopedics ventures were more likely to be founded by a physician during the settlement period. This result is robust to excluding the 43 observations for which we were not able to satisfactorily confirm the lack of a physician founder (see results in column 2).

As with all non-linear models, the marginal effect of the coefficients cannot be read directly from the table, and depend on the values of the other variables at which the model is evaluated. We used the Clarify software (King et al. 2000; Tomz et al. 2003) to calculate the expected change in the likelihood that a new venture included a physician founder. Based on the results reported in column 1, new orthopedics ventures were 39% more likely to include a physician founder during the settlement period than orthopedics ventures founded in other years. Another way to think about these results is to compare orthopedics firms to other medical device firms. During the settlement period, new orthopedics ventures were 30% more likely to be founded by doctors, relative to new ventures in other segments. Recall that in other periods, there was no difference in the likelihood of a physician founder between orthopedics and other ventures. In both cases, the predicted difference is significantly different from zero at the 5% level. These results are consistent with the prediction that the settlement would be associated with an increased likelihood that physician inventors of orthopedic devices would commercialize their inventions through entrepreneurship rather than through collaboration with an incumbent firm.

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7 As noted above, the settlement period lasted through March, 2009, at which point the deferred prosecution agreements were allowed to expire. Due to the partial year included in the settlement period, and the lag between the decision to form a company and the founding date as recorded in venture capital records, we elected to include 2009 in the settlement period. Sensitivity analyses excluding 2009 from the settlement period yielded results very similar to those reported here.
Evidence from Collaboration on Inventions

Our second analysis examined the propensity for physician inventors to collaborate with an existing medical device firm by evaluating the likelihood that a physician-inventor’s patent was assigned to a firm. While assignment to a company may not be a perfect measure of cooperation to commercialize an invention, this empirical test is a reasonable proxy to estimate the choice of commercialization strategy for a given invention (independent or with an established company). Conceptually, this is a difference-in-differences estimation, wherein we compare the change in probability of company assignment from pre-settlement to post-settlement for two groups of patents: physician-invented orthopedics patents and physician-invented medical device patents in other segments. Our prediction was that company assignment would decrease more during the settlement period for physician-invented patents in the orthopedics segment than for other physician-invented patents.

Using patent-level data, we estimated a Probit model predicting the likelihood that a patent was assigned to a U.S. company (CompanyPat), including indicators for whether the patent is an orthopedic technology (OrthoPat) and this indicator interacted with the indicators for the years of the DOJ investigation (Investigation) and settlement (Settlement). We included year indicators for the years 2002–2004 (year 2001 is the excluded year) to account for any common time trends that affected the overall percentage of medical device patents that were assigned to U.S. companies, such as the rise (or fall) of foreign companies in this market. We also included a full set of technology class indicators, controlling for differences in the share of patents assigned to U.S. companies across technologies. We report robust standard errors in all regressions.

[Table 5 Here]

In the initial models, we used the sub-sample composed of only the physician-invented patents. This estimation answers the question: how much did the likelihood that a physician-invented patent was assigned to a U.S. company change during the settlement (or investigation) period? As results reported in column (1) of Table 5 demonstrate, the likelihood that a physician-invented patent was assigned to a U.S. company decreased significantly during both the investigation and settlement periods. As predicted, the decrease in company assignment during the settlement period was greater for physician-invented orthopedic patents than for other physician-invented patents (the interaction of the Orthopedics indicator and the Settlement indicator is negative and significant). For physician-invented patents in the orthopedics segment, there was a 21% decrease in the probability of company assignment during the settlement period, relative to other periods. This can be compared to the estimated 14% decrease in the probability of company assignment during the settlement period for physician-invented patents outside of the orthopedics segment. These two estimated decreases are statistically and economically significantly
different. Another way to think of the results is that during the settlement period, orthopedics patents were 8% less likely than other patents to be assigned to a company, while there was no difference in assignment outside of the settlement period. These results are consistent with the expectation that the increase in costs of collaborating associated with the settlement agreements reduced collaboration between physicians inventing orthopedic devices and the medical firms that could commercialize them.

The indicator, CompanyPat, used as the dependent variable in this estimation, included all U.S. companies, and therefore one might be concerned that it also reflects physician-invented patents assigned to their own start-up companies. In the second column, we used the same sample of physician-invented patents, but estimated instead the likelihood that a patent was assigned to a public U.S. company (PublicCompanyPat). Based on the results in column (2), the estimated decrease in the likelihood of public company assignment for physician-invented orthopedic technologies during the settlement was 8%. The corresponding decrease in company assignment for physician-invented non-orthopedic technologies was 2%.

One concern with this analysis is that it is possible that U.S. companies might have appeared as assignees on orthopedics patents less often (relative to other medical device patents) during the settlement period for reasons unrelated to the DOJ investigation, such as the entry of a major foreign competitor in the orthopedics segment. This could generate the observed negative coefficient on the interaction of the Orthopedics and Settlement indicators. In other words, the pattern presented here for physician inventions could be true of all inventions, which would undermine the interpretation that it was caused by an increase in the costs of firms collaborating with physicians. To address this, we estimated models using the full sample of all medical device patents (not only physician-invented patents), and examined the likelihood of a patent being assigned to a U.S. company. We included in the model a physician-inventor indicator (DoctorPat), and tested whether the negative coefficients on the interactions for OrthoPat and the settlement years indicator (Settlement) remained. Models (3) and (4) in Table 5 present this full estimation on the complete set of medical device patents.

A second possible concern is that there could be a third choice for inventors: to elect not to commercialize an invention, or to forgo inventing in the first place. If inventing physicians responded to the DOJ investigation by electing not to commercialize an invention at all, then the shift toward entrepreneurial entry that we observe understates the aggregate impact of the investigation on the choice of commercialization strategy. In addition, physicians may have responded to the DOJ investigation and settlement by inventing and commercializing either more inventions (e.g., to try to make up for lost consulting earning) or fewer inventions (in response to the decreased likelihood of collaboration with incumbents). Because our models estimate the likelihood that physician inventions were company-assigned, an increase (or decrease) in the number of physician inventions could influence the likelihood of
company assignment even if the number of company-assigned physician inventions did not change. To investigate this potential issue, we examined the annual number of orthopedic inventions with and without physician inventors. We found no evidence that the temporal pattern of physician inventorship deviated from the pattern for orthopedic inventions as a whole. In sum, we found no evidence that physicians changed their short-run inventive behavior in response to the suit or settlement.

The results demonstrate that the decrease in the likelihood that a U.S. company (and U.S. public company) became an assignee on an orthopedic patent in the settlement years was due entirely to patents that included a physician inventor. The estimated coefficients on the interaction of OrthoPat and Settlement are not significant, indicating that the assignment pattern for orthopedics patents that were not invented by physicians was not different during the settlement period than in other years. The estimated coefficient on the interactions of the physician-inventor indicator (DoctorPat) and the investigation and settlement indicators confirm that physician-invented patents were less likely to be company-assigned during these periods (though this does not hold for assignment to public companies). Further, the interaction of the physician-inventor indicator and settlement period indicator with the indicator for orthopedic technologies confirm that the reduction in company assignment was greater for physician inventions in orthopedics. Based on the results in column (3), patented physician-invented orthopedic technologies were 21% less likely to be assigned to U.S. companies during the settlement years, relative to physician-invented orthopedic technologies in other years. As above, this is relative to a 14% reduction in assignment for physician patents outside of orthopedics. Results in column (4) suggest that the decrease in assignment of physician-invented orthopedic patents to public companies was approximately 8%, while assignment of physician-invented patents outside of orthopedics was 3%. These results are consistent with those based on the sample of physician-invented patents, and confirms that the change in assignment likelihood during the settlement concentrated on physician inventors and did not impact medical device patents more broadly.

Some of the estimated coefficients on the control variables are also of interest. For example, physician-invented patents were less likely to be assigned to companies, especially public companies, relative to other patents. Also, physicians inventing orthopedic devices appear more likely to have assigned their patents to companies, especially public companies, relative to other physicians. This is consistent with the expectation that complementary assets are even more substantial in this market segment than in other medical device segments.

Additional Analyses
Our results demonstrate that, following the Department of Justice investigation, there was an increase in entrepreneurial entry by orthopedic physician-founded ventures and a decline in collaborative patenting
between physicians and orthopedic firms. These findings are consistent with prior theory on the market for ideas, whereby an increase in the costs of cooperation between incumbents and inventors increases the likelihood of commercialization through entrepreneurship. While not enough time has passed to rigorously assess the impact of these new entrants on competitive dynamics or the direction of technological change, we present descriptive statistics below to provide insights into the long-term impact of the DOJ settlement on the medical device industry.

Schumpeter’s (1950) “gale of creative destruction” posited that new entrants would identify entrepreneurial opportunities, commercialize new innovations, and challenge incumbent firms. Interestingly, the entrants created in the wake of the DOJ investigation may have resulted less from an abundance of opportunities and more from a foreclosure of another option to commercialize a new idea (working with an incumbent firm). In this case, the implications for Schumpeter’s predictions are not clear: Are the incremental ventures likely to out-compete incumbent firms or not? If the incremental ventures were formed based on technologies that were highly complementary to established products, or if they would depend heavily on complementary assets from incumbent firms, these new ventures will likely struggle to compete as independent organizations and incumbents will either acquire or outcompete the new firms over time. On the other hand, it is possible that the incremental ventures could commercialize disruptive technologies that would eventually displace the incumbent firms’ products, much as Schumpeter’s creative destruction thesis would suggest. A final possibility is that the DOJ investigation could have reduced the incentives for inventors to pursue marginal ideas, because incumbent firms would be less willing to collaborate, and only ideas with a higher (expected) value would warrant new venture formation. In this scenario, incumbent firms might continue to collaborate to acquire valuable ideas, and entrepreneurial entrants in orthopedics would look similar pre- and post-investigation.

We have limited data to explore these ideas, but offer preliminary evidence where we can. First, we collected data on FDA product approvals by orthopedic ventures. We considered the period between 2000–2004 and 2007–2010 to remain consistent with the main analysis, and compared orthopedic ventures with and without physician founders across the two time periods. Based on the FDA approval data, there was no apparent difference in the percentage of ventures with an FDA-approved product, or the number of FDA-approved products generated by physician-founded orthopedic ventures formed before and after the investigation, relative to other orthopedic ventures. Both before and after the settlement, physician-founded orthopedic ventures exhibited a roughly 30% higher likelihood of having an FDA-approved product, relative to other orthopedic ventures founded during the same respective time periods (see Table 6). Second, we created a record of acquisitions of orthopedic ventures, as of May 2012. In terms of exits, 38% of orthopedic startups founded without physician founders in 2000–2004 were acquired or went public, compared to 25% of physician-founded orthopedic ventures founded during this
period. Of the 18 orthopedic ventures founded between 2007–2010, only one, a physician-founded venture, has been acquired. However, a distinctive pattern could emerge over subsequent years as these firms develop further. Based on the preliminary data available, there is no evidence of a significant drop in the “quality” of the ventures, as measured by their ability to generate new products and the likelihood of exit.

**Discussion**

What factors shape the market for ideas? The theoretical and empirical literatures on commercialization strategy and entrepreneurship has focused on market characteristics, such as the strength of intellectual property rights and the availability of complementary assets, to explain the choice of inventors to work with incumbent firms or pursue entrepreneurial entry. However, this prior work has not considered how cooperation costs may differ across incumbent firms or over time, in some instances precluding collaboration and fostering entrepreneurship as a default choice, rather than as the preferred choice, for the inventor. To address this gap, we have extended the existing theory to consider the incumbent firm’s perspective, creating a theoretical framework that can more fully explain entrepreneurial entry as a chosen commercialization strategy.

We found empirical support for our prediction in the medical device industry using a novel empirical context that exploits a DOJ investigation and settlement that raised the costs of cooperation for a subset of incumbent firms and inventors. Unlike previous studies, our empirical approach provided a superior solution to the methodological challenges related to omitted variable bias, whereby the same forces driving commercialization choice would also drive the willingness of incumbent firms to cooperate with innovators. By comparing trends in orthopedics over time and comparing orthopedics to sub-sectors of the medical device industry that were not affected by the investigation and settlement, we have been able to identify the impact of an increase in the costs of collaboration more precisely than in previous work. We found a 39% increase in physician-founded new ventures in the orthopedic segment during the years covered by the DOJ settlement relative to other years, and physician-founding was 30% more likely in this period for orthopedics ventures than for other medical device ventures. Also during these years, inventions by physicians were 21% less likely to be developed collaboratively with orthopedic medical device firms, and were instead developed by the physicians independently. By promoting new entry instead of collaboration, the DOJ investigation shifted the competitive dynamics in the market, perhaps inadvertently powering the gale of creative destruction in the orthopedic industry.

The paper informs several related literatures exploring innovation and entrepreneurship. First, the work on open innovation (Chesbrough 2003) emphasizes the need for firms to identify and acquire knowledge from outside the organization, whether through new employees, alliances, corporate venture
capital investments, acquisitions, regional networks, or ties with universities. While much of this literature emphasizes the benefits of open innovation strategies, much less attention has been paid to the costs of implementing and executing these practices. The costs of managing an alliance or monitoring an investment in a startup company might outweigh the benefits under some conditions, and specifying those cases will provide a more complete portrait of how the market for ideas actually functions and when firms should pursue open innovation strategies. The cost of pursuing various open innovation strategies is likely an important factor driving heterogeneity in firm strategy. If these mechanisms are critical to accessing knowledge and developing capabilities, understanding differences in the costs of collaboration could lead to new insights into the sources of sustained competitive advantage.

The cooperation costs we discuss manifest themselves in the prior literature in a variety of ways. For example, one way to view the consequences of the DOJ investigation and settlement is as a shift in the institutional environment, that is, a change in “the political, social and legal ground rules that establish the basis for production, exchange, and distribution” (Davis and North 1971: 6-7). This institutional shift changes the hazards and costs of arms length transactions and, in turn, leads to a change in the governance of transactions (Williamson 1991). In more concrete terms, the DOJ investigation increased the cost of contracting, perhaps by changing monitoring costs (Dyer 1997), and made the customary hybrid form of governance less attractive to incumbent firms.

Another relevant stream of literature in strategy and organizations involves the exploration of how organizations and practices acquire legitimacy (DiMaggio and Powell 1983). In this setting, the DOJ investigation called into question the legitimacy of physician–industry interactions, and in particular the practice of firms paying doctors. There are other recent examples of certain business practices or entire models being questioned along these lines, including proprietary trading at investment banks or the marketing practices of for-profit universities. In the medical device industry, this rollback of regulative legitimacy (Scott 1995) could increase the firms’ costs of working with physicians, leading firms to be less likely to engage with physicians.

Whether the increased costs of cooperation are driven by transaction costs or a decline in legitimacy of the underlying transaction, future work could try to categorize these various costs more systematically and explain how each type affects cooperative relationships such as alliances, corporate venture capital, regional networks, and other open innovation strategies. For firms choosing between these various mechanisms to acquire external knowledge, a better understanding of the costs of cooperation underlying each strategy is especially important.

Our work is also relevant to a significant literature on “who” enters into entrepreneurship as a function of demographic characteristics, prior experience, and other considerations. We found evidence that changes in the institutional environment shift the incentives for entrepreneurship by making it more
difficult to work with incumbent firms. Physicians, armed with a deep knowledge of unmet needs and embedded in a social network of potential customers (their medical colleagues), are especially well placed to pursue these entrepreneurial opportunities. A more robust examination of the intersection between “who” becomes an entrepreneur and the market environment might be a fruitful path for future work.

Despite these contributions, there are some limitations to our study. We cannot directly evaluate the impact of raising the costs of collaborating on the rate and direction of innovation in the medical device industry. To do so, we would need several additional years of data past 2011 and would have to make several assumptions about how products would have been commercialized inside large firms. We can conclude that raising such costs shifts inventions that would have been developed via collaboration to be commercialized instead via entrepreneurial entry. Given that lower costs of collaboration would encourage inventors to choose to commercialize their inventions via collaboration, it is clear that, from the perspective of the inventor, entrepreneurship is sometimes a second-best alternative. New entrants may have to replicate the significant complementary assets already held by incumbent firms in these instances, an investment that may not be optimal from a social welfare perspective. However, entry and the subsequent increase in competition in the market may improve social welfare in the longer term. It is also possible that some inventions that would have been commercialized in cooperation with incumbent firms are not commercialized at all when the costs of cooperation increase. We do not have any direct empirical evidence on this point, but further research might identify technologies for which the necessary investments in complementary assets are too large to merit entrepreneurial entry.

Finally, despite our preliminary analysis, it is still an open question as to how the DOJ investigation will impact technological innovation and competitive dynamics in orthopedics in the long run. On one hand, the investigation may have shifted the timing of collaborations between inventors and incumbent firms. In cases where incumbent firms would have worked directly with inventors from the early stages of development, collaboration may instead occur after the inventor has founded a firm. It is also possible that these physician-founded ventures will eventually be acquired by larger firms who will further develop the innovations, gain FDA approval, and bring these products to markets. On the other hand, it could be that smaller, venture-capital-backed companies in orthopedics are more likely to develop products on their own, building their own complementary assets and eventually changing the competitive environment in the industry, a result that would take many more years to observe. These dynamics of industry evolution could have important implications for the pace and direction of innovation in health care more broadly, especially if doctor-founded ventures had to develop capabilities in sales, marketing, and regulatory processes rather than leveraging complementary assets from established firms.

Conclusion
Determining when inventors become entrepreneurs and when they collaborate with incumbent firms is a topic of great interest in the study of strategy and entrepreneurship and is also of interest to policy makers seeking to foster economic growth and development. The short-term and long-term implications of these decisions influence the trajectories of markets and firms, powering the gale of creative destruction as entrepreneurs enter and compete with incumbents, or consolidating the power of existing firms who own the crucial complementary assets. As we gain more insight into commercialization strategies, we will begin to understand more about the evolution of firms and markets themselves, building promising linkages between the study of strategy and entrepreneurship.

REFERENCES


Figure 1: The gap between inventor and incumbent preferences increases with incumbents’ costs of cooperating

$$\text{Payoff to Cooperation}$$

$$I: \frac{1}{2} (\pi^m + K) + X - T$$

$$E: \frac{1}{2} (\pi^m + K) - X$$

Incumbents’ cost of cooperation (T)

where $$X = \Delta \pi \cdot (1 - \theta)(1 - \pi^c)$$

In region A, the value of $$\pi^c$$ is less than the payoff from cooperation for both the incumbent and the entrant, and both the entrant and incumbent prefer cooperation. In region D, the value of $$\pi^c$$ is greater than the payoff from cooperation, and both prefer competition. In region B, the incumbent still prefers cooperation, but the entrant prefers competition. The shaded area between the lines (region D) indicates the range of values where the inventor would prefer to cooperate with the incumbent, but the incumbent is not willing to do so. Note that this range increases with an increase in T, the cost of cooperation.

When T, the cost of cooperation, increases, the incumbent is less willing to cooperate: He will cooperate only at lower and lower levels of profits available from competition.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Level of observation</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
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<tr>
<td>New Ventures</td>
<td>Annual</td>
<td>Number of new medical device ventures founded in a given year</td>
<td>Capital IQ</td>
</tr>
<tr>
<td>New Orthopedics</td>
<td>Annual</td>
<td>Number of new orthopedics medical device ventures founded in a given year</td>
<td>Capital IQ</td>
</tr>
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<td>Ventures</td>
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</tr>
<tr>
<td>Investigation Year</td>
<td>Annual</td>
<td>Equal to 1 in years of the DOJ investigation (2005 &amp; 2006), zero otherwise</td>
<td>Press releases</td>
</tr>
<tr>
<td>Settlement Year</td>
<td>Annual</td>
<td>Equal to 1 in years of the DOJ settlement (2007–2009), zero otherwise</td>
<td>Press releases</td>
</tr>
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<td>Doc Founded</td>
<td>Company</td>
<td>Equal to 1 if a given new venture was founded by a doctor, zero otherwise</td>
<td>Capital IQ and supplemental web searches</td>
</tr>
<tr>
<td>Ortho Company</td>
<td>Company</td>
<td>Equal to 1 if a given new venture is an orthopedic company, zero otherwise</td>
<td>Capital IQ and supplemental web searches</td>
</tr>
<tr>
<td>Ortho Pat</td>
<td>Patent</td>
<td>Equal to 1 for patents w/ orthopedics technology classifications</td>
<td>Delphion patent database and USPTO Technology Profile report.</td>
</tr>
<tr>
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<td>Patent</td>
<td>Equal to 1 for patents with at least one doctor inventor</td>
<td>Delphion patent database combined with AMA Physician masterfile</td>
</tr>
<tr>
<td>Company Pat</td>
<td>Patent</td>
<td>Equal to 1 for patents assigned to companies (rather than individuals, governments, or unassigned).</td>
<td>Delphion patent database and Patent Data Product</td>
</tr>
<tr>
<td>Public Company Pat</td>
<td>Patent</td>
<td>Equal to 1 for patents assigned to public companies (rather than private companies, individuals, governments, or unassigned).</td>
<td>Delphion patent database and Patent Data Product</td>
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### Table 2: Summary Statistics for New Ventures in Medical Devices, 2000-2010 (N=450)

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<tr>
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<th>Mean</th>
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<th>3</th>
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<td></td>
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<tr>
<td>2 Ortho Company (0/1)</td>
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<td>0.08</td>
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<td>0.09</td>
<td>0.11</td>
<td>-0.27</td>
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### Table 3: Summary Statistics for Patented Inventions in Medical Devices, 2000-2008 (N=111,117)

<table>
<thead>
<tr>
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<th>3</th>
<th>4</th>
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<td>1 CompanyPat (0/1)</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 PublicCompanyPat (0/1)</td>
<td>0.18</td>
<td>0.61</td>
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<td>3 DoctorPat (0/1)</td>
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<td>-0.09</td>
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<td>4 OrthoPat (0/1)</td>
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<td>-0.04</td>
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<td>5 DoctorPat X OrthoPat (0/1)</td>
<td>0.01</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.24</td>
<td>0.48</td>
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</table>
Figure 2: New Venture Formation by Founding Year (comparing orthopedics to all medical device sectors)

Figure 3: Company-assigned Physician Patents by Application Year (comparing physician-invented orthopedics inventions to other physician-invented medical device inventions)
Table 4: Physician-Founded Orthopedic Ventures Were More Likely When Collaboration was More Costly

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>Prob of Doc-Founded Venture</td>
<td>Prob of Doc-Founded Venture</td>
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<tr>
<td>Ortho Company X Settlement</td>
<td>0.998</td>
<td>1.003</td>
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<tr>
<td></td>
<td>(0.486)*</td>
<td>(0.522)*</td>
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<tr>
<td>Settlement</td>
<td>0.143</td>
<td>0.294</td>
</tr>
<tr>
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<td>(0.266)</td>
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<td>Ortho Company</td>
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<td>(0.357)</td>
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<tr>
<td>Constant</td>
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<td>-0.684</td>
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<tr>
<td></td>
<td>(0.226)**</td>
<td>(0.228)**</td>
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<td>Log Likelihood</td>
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<td>-230.61</td>
</tr>
<tr>
<td>Observations</td>
<td>450</td>
<td>407</td>
</tr>
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</table>

Robust standard errors in parentheses; * significant at 5%; ** significant at 1%
Probit regressions, all specifications include years 2002–2006 and 2010 indicator variables; years 2007, 2008, and 2009 are grouped in “Settlement” indicator.
DV equal to 1 for physician-founded ventures, zero for all others.
Table 5: Company–Physician collaborative patents were less likely when collaboration became more costly

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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<tr>
<td></td>
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<td>PubCompanyPat</td>
<td>CompanyPat</td>
<td>PubCompanyPat</td>
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<td>-0.029</td>
<td>0.102</td>
<td>-0.170</td>
<td>-0.414</td>
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<tr>
<td></td>
<td>(0.057)</td>
<td>(0.069)</td>
<td>(0.030)**</td>
<td>(0.038)**</td>
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<tr>
<td>OrthoPat X Investigation</td>
<td>0.123</td>
<td>0.157</td>
<td>0.183</td>
<td>0.116</td>
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<tr>
<td></td>
<td>(0.096)</td>
<td>(0.113)</td>
<td>(0.048)**</td>
<td>(0.063)</td>
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<tr>
<td>OrthoPat X Settlement</td>
<td>-0.284</td>
<td>-0.336</td>
<td>0.072</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>(0.094)**</td>
<td>(0.117)**</td>
<td>(0.051)</td>
<td>(0.066)</td>
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<tr>
<td>DoctorPat X OrthoPat X Investigation</td>
<td>-0.050</td>
<td></td>
<td></td>
<td>0.042</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(0.108)</td>
<td>(0.130)</td>
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<tr>
<td>DoctorPat X OrthoPat X Settlement</td>
<td>-0.346</td>
<td></td>
<td>0.072</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(0.107)**</td>
<td>(0.134)**</td>
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<tr>
<td>DoctorPat X OrthoPat</td>
<td>0.148</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(0.060)*</td>
<td>(0.074)**</td>
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<td></td>
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<td></td>
<td>(0.014)**</td>
<td>(0.018)**</td>
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<td>0.072</td>
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<td></td>
<td></td>
<td></td>
<td>(0.027)**</td>
<td>(0.035)*</td>
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<tr>
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<tr>
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<td></td>
<td></td>
<td>(0.029)**</td>
<td>(0.036)</td>
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<td>-0.179</td>
<td>-0.253</td>
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<td>(0.033)**</td>
<td>(0.042)**</td>
<td>(0.012)**</td>
<td>(0.016)**</td>
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<td>-0.181</td>
<td>-0.184</td>
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<td>(0.042)**</td>
<td>(0.013)**</td>
<td>(0.017)**</td>
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<td>-0.413</td>
<td>-0.992</td>
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<td>(0.047)**</td>
<td>(0.072)**</td>
<td>(0.019)**</td>
<td>(0.024)**</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>19,311</td>
<td>19,311</td>
<td>111,117</td>
<td>111,117</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses; * significant at 5%; ** significant at 1%


Sample in (1) and (2) is physician-invented medical device patents; Sample in (3) and (4) is all medical device patents.

DV in (1) and (3) equal to 1 for patents assigned to U.S. Companies; DV in (2) and (4) equal to 1 for patents assigned to public US companies.
Table 6: Comparison of FDA-approved Products for New Orthopedic Ventures

<table>
<thead>
<tr>
<th></th>
<th>% of Ventures with FDA-approved Product</th>
<th>Average # FDA-approved Products per Venture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w/ Physician Founder</td>
<td>w/o Physician Founder</td>
</tr>
<tr>
<td><strong>2000-04</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w/ Physician</td>
<td>75% (n=4)</td>
<td>58% (n=12)</td>
</tr>
<tr>
<td>Founder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>w/o Physician</td>
<td>44% (n=9)</td>
<td>33% (n=9)</td>
</tr>
<tr>
<td>Founder</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2007-10</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX

A model of commercialization strategy from the incumbent’s perspective

We draw on the simple model presented by Gans, Hsu, and Stern (2002) (henceforth GHS) to consider the incumbent’s willingness to cooperate with a potential entrant. We retained all of the key features of that model but, instead of the entrant’s payoffs, we considered the incumbent’s payoffs from cooperating or competing with the potential entrant. This allows us first to demonstrate that there is a non-zero range of values where the potential entrant (E) would prefer to cooperate, but the incumbent (I) prefers to compete. We added to the model a cost of cooperating with the entrant, borne by the incumbent firm (T), and showed that the range where the entrant prefers cooperation but the incumbent is unwilling to cooperate grows with this cost.

Figure A1 illustrates the choices and payoffs faced by the incumbent firm (I) in the model. We followed the notation used in GHS to ease the integration of the results. Monopoly profits are denoted $\pi^M$. The entrant (E) and incumbent (I) both earn competitive profits $\pi^C$ under the competitive strategy. Sunk costs of entry $K$ are incurred by the entrant in order to enter and compete. In either strategy, E faces the possibility that I will imitate his innovation.

If E competes with I, I may imitate E’s innovation with probability $1 - p_I$. With probability $\theta$, E successfully enforces its IPR. Therefore, I commercializes an imitative technology with probability $(1 - \theta)(1 - p_I)$. Assume that introduction of an imitative technology by I raises I’s profits by $\Delta$ and reduces E’s profits by the same amount.

Under the cooperative outcome, we follow GHS and allow the profit sharing between I and E to be determined by a Nash bargaining solution, where the bargaining involves the potential risk of
“expropriation” of E’s technology by I. I imitates E’s technology with probability $1 - p_d$ and E can enforce its intellectual property rights successfully with probability $\theta$. As in the competitive strategy, the impact of imitation is to raise I’s profits by $\Lambda$ and reduce E’s by the same amount. Thus, by negotiating to cooperate, E faces the risk that I will commercialize an imitative innovation with probability $(1 - \theta)(1 - p_d)$ if bargaining breaks down. As in GSH, the outcome of the bargaining game is that the two parties split the net gains from trade (Aghion and Tirole 1994). The transfer from I to E in the absence of expropriation is equal to $\tau = \frac{1}{2}(\pi^m - \Lambda) - \Delta(1 - p_r)(1 - \theta)$. The transfer from I to E under expropriation depend on whether E enforces his IPR, as follows:

With successful IPR enforcement ($\theta = 1$): $\tau_0 = \frac{1}{2}(\pi^m - \Lambda)$

Without successful IPR enforcement ($\theta = 0$): $\tau_1 = \frac{1}{2}(\pi^m - \Lambda) - \Delta$

Based on these payouts, the incumbent will cooperate if the benefit from doing so exceeds the payoff from competing. This occurs when the following condition is met:

$$\frac{1}{2}(\pi^m + \Lambda) + \Delta(1 - \theta)(1 - p_r p_d) > \pi^c + (1 - \theta)(1 - p_r)\Delta$$

I’s payoff from cooperating I’s payoff from competing

This reduces to the following condition that must be met for I to prefer cooperation to competition:

$$\frac{1}{2}\pi^m + \Delta p_r (1 - \theta)(1 - p_d) > \pi^c - \frac{1}{2}\Lambda$$

We can compare this to the following condition under which E prefers to cooperate, taken from GHS:

$$\frac{1}{2}\pi^m - \Delta p_r (1 - p_d)(1 - \theta) > \pi^e - \frac{1}{2}\Lambda$$

Comparing these two conditions, it is easy to see that there exists a range of potential values where I prefers to cooperate but E prefers to compete. The left hand side of the I’s condition to cooperate exceeds the left hand side of E’s condition to cooperate whenever $\theta$ (the probability of successful IPR enforcement by the entrant) is less than one and $p_r$ and $p_d$ (the probability of incumbent imitation and expropriation) are non-zero. Intuitively, this suggests that when there is some likelihood that I will imitate
or expropriate E’s technology, and E can not be certain of successfully enforcing his intellectual property rights, this risk favors E entering the market rather than cooperating with I.

More importantly for our study, it is intuitive that when I bears a cost to cooperation, T, this reduces I’s payoff to cooperation. I’s condition for cooperating when it must incur a cost to do so is:

\[
\frac{1}{2} \pi^m + \Delta p_r (1-\theta)(1-p_d) - T > \pi^c - \frac{1}{2} K
\]

As T increases, the range over which I prefers cooperation decreases while the relative payoffs to the entrant are unchanged. When T reaches the point at which

\[
T > 2\Delta p_r (1-\theta)(1-p_d)
\]

then it is possible that the entrant will prefer cooperation to competition, while the incumbent prefers competition to cooperation. Increases in the incumbent’s costs of cooperating with inventors force inventors, who would otherwise have elected cooperation, to enter and compete. This results in the costly duplication of complementary assets and changes the nature of competition in the industry.

**Figure A1: Model of Incumbent’s Choices and Payoffs**