APPROPRIABILITY, PREEMPTION, AND FIRM PERFORMANCE

MARCO CECCAGNOLI*

College of Management, Georgia Institute of Technology, Atlanta, Georgia, U.S.A.

The impact of strategies used to appropriate innovation rents on firm performance is analyzed using a sample of U.S. public manufacturing firms. Stronger appropriability at the firm level, achieved through patent protection or the ownership of specialized complementary assets, leads to superior economic performance, as measured by the stock market valuation of a firm's R&D assets. Among commonly used 'nonconventional' patent strategies, preemptive patenting allows incumbents to strengthen their market power. Consistent with theory, such effect is higher for incumbents with higher ex ante market power and facing a higher threat of entry, and lower when R&D competition is characterized by the discovery of drastic innovations. Copyright © 2008 John Wiley & Sons, Ltd.

INTRODUCTION

The quintessential goal of strategy research is to understand what accounts for differences in profitability across firms. Introducing new or improved products and processes is widely believed to be a central determinant of a firm's competitive advantage. Yet it is also well-known that such competitive advantage is transitory due to the ease with which such new knowledge can spill over to rivals, eroding rents quickly—either because other firms imitate the innovative firm, or because other firms introduce substitute products and processes. The strength of strategies used to appropriate innovation rents, such as patenting, secrecy, exploitation of first-mover advantages, and ownership of specialized complementary assets, is therefore a

key determinant of profitability differences across firms.

The extent to which appropriability and patenting strategies affect firm performance has, however, received relatively little scrutiny. Recent work in the economic literature has focused on assessing the value of patents at the firm level by estimating the impact of a firm's stock of patents on its market value, after controlling for the stock of tangible capital (Bloom and Van Reenen, 2002; Hall *et al.*, 2005). The literature has consistently estimated a positive and significant marginal value of the patent stock. Bloom and Van Reenen (2002) find that doubling the citation-weighted patent stock increases the value of U.K. public firms, per unit of capital, by about 35 percent. Hall, Jaffe, and Trajtenberg (2005) report that an extra citation per patent, controlling for a firm's research and development (R&D) stock and the patent/R&D ratio, boosts market value by three percent in the U.S. manufacturing sector. These effects reflect the change in market value for a given change in the quality—or value—of patented innovations.

Most studies suffer from an inability to disentangle the impact of innovation on performance from the benefits of patenting over and above the profits derived from alternative appropriation strategies.[1] However, Cockburn and Griliches (1988) show that returns to innovation, as measured by the market valuation of a firm's intangible assets, is critically affected by appropriability conditions, measured by survey-based scores of the effectiveness of patent protection at the industry level, available from the Yale survey on the appropriability of R&D (Levin *et al.*, 1987). Among the Yale appropriability measures, only patent protection to prevent duplication had a significant impact on the market valuation of innovation.

This study shows that greater appropriability, achieved through patent protection, as well as the ownership of specialized complementary assets, has a large, positive, and significant impact on a firm's economic performance. As a second, and more important contribution, the study delves deeper into the black box of patenting, by analyzing the impact of a widely diffused technology strategy, patent preemption, that is, the patenting of substitutes of existing technologies before potential competitors, a topic that has received considerable theoretical attention, but scant empirical work.

Consistent with theory (Gilbert and Newbery, 1982; Reinganum, 1983), I find that such strategy tends to remarkably improve the appropriability of the returns to R&D for incumbents with greater market power, those facing a threat of entry, and when R&D competition is characterized by incremental technical change.

The data used in this study are derived by matching the Carnegie Mellon survey (CMS) on the appropriability of R&D (Cohen, Nelson, and Walsh, 2000) with Standard & Poor's Compustat at the firm level to analyze the impact of appropriability and patenting on a commonly used measure of a firm's performance, such as Tobin's q—that is, the market value of the financial claims on a firm divided by the replacement value of the firm's assets.

As a forward-looking measure of firm performance, Tobin's q captures two fundamental components of innovation and appropriability: the contribution of a firm's intangible assets to its market value and the firm's ability to earn supranormal rents from its tangible and intangible assets (Hall, 1993a). By merging Compustat and the CMS survey data, I can separately identify the impact of innovation and the strategies used to appropriate rents due to an innovation on a firm's performance at the firm level.

The CMS is a unique data source in that it measures the strategies used to appropriate rents at the firm level, as opposed to the industry-level scores available from the previous Yale survey.[2] This is important because the effectiveness of patent protection depends not only on the characteristics of the legal system, the nature of the technology to be protected, and the extent and nature of competition in the industry, but also on the firm's strategy for using and enforcing its patents.

THEORY AND HYPOTHESES DEVELOPMENT

Appropriability refers to the degree to which a firm captures the value created when it introduces innovations. This standard definition of appropriability is influenced by the work of Kenneth Arrow and Joseph Schumpeter, among others (see Winter, 2006 for a recent overview of the appropriability literature). Strategies typically used to increase appropriability include secrecy, patent protection, being first to market, and the ownership of specialized complementary marketing and manufacturing assets (Arundel, van de Paal, and Soete, 1995; Cohen *et al.*, 2000, 2002; Levin *et al.*, 1987).[3]

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[1] This is also the case for Lerner (1994), who finds that an increase of one standard deviation in the average patent scope—one dimension of the strength of patent-related appropriability, but also a measure of the value of an innovation itself—is associated with a 21 percent increase in the firm's value.

[2] More specifically, and in regard to patenting, the Yale survey (Levin *et al.*, 1987: 794) asked respondents about the effectiveness of 'patents to prevent competitors from duplicating a new or improved product and process' in the main line of business of the firm. A separate and similar question was asked to rate the effectiveness of patents 'to secure royalty income.' The CMS asked a broader question related to the percentage of a firm's product and process innovations for which patent protection effectively protected the competitive advantage from an innovation (with reference to the main business unit of the firm). In addition to the appropriability questions, the CMS asked about how patents are used, information that was not available in the Yale survey.

[3] For the management literature on first-mover advantages, see Lieberman (2005), Lieberman and Montgomery (1988, 1998), Makadok (1998), and Mitchell (1991). On the relationship between appropriability and the concept of specialized complementary assets, see the seminal article by Teece (1986).

The industrial organization literature typically models appropriability as the extent to which firms can limit other firms from imitating its innovations. The majority of previous work has considered symmetric industry-level appropriability, focusing on its impact on the incentives to innovate (see, e.g., Cohen and Levinthal, 1989; Levin and Reiss, 1988; Spence, 1984). Only more recently have researchers begun to consider the impact of asymmetric, firm-specific appropriability and analyze its implications for firm and industry innovation incentives and performance (Amir and Wooders, 1999; Cassiman and Veugelers, 2002; Ceccagnoli, 2005).

Greater appropriability, modeled as lower spillover from high-quality, low-cost firms to less efficient competitors, is associated with greater market power for the innovator. For product innovations, using a simple vertical (quality) differentiation model (Shaked and Sutton, 1982), greater appropriability translates into greater quality differences, thus increasing the innovator's profits and market power. Similarly, in a standard Cournot model, in which heterogeneous firms compete in a homogeneous product market, the profits of the innovator (low-cost firm) are a positive function of the difference between the marginal costs of non-innovating (high-cost) and innovating (low-cost) firms (Amir and Wooders, 1999; Ceccagnoli, 2005; Tirole, 1988). In such a setting, greater appropriability for the innovator translates into larger cost differentials, enhancing an innovator's ability to obtain higher price-cost margins and profits for the final product.

I therefore test the following hypothesis focusing on the appropriability strategy used and the empirical magnitude of its impact on firm performance:

Hypothesis 1: Stronger appropriability of profits due to a firm's innovations strengthens a firm's economic performance.

Patenting is one mechanism to protect competitive advantage due to an innovation. A patent may be commonly used to commercialize an innovation (vertical integration), defend an incumbent against potential lawsuits, license a technology to other firms, or block another firm's patent. Cohen *et al.* (2000, 2002) show that such unconventional patenting strategies are pervasive in both the United States and Japan. Bunch and Smiley

(1992) found earlier empirical evidence on using patents to deter entry; more recently, Cockburn and MacGarvie (2006) concluded that, at least in the software industry, 'patents have an entry-deterring effect above and beyond the degree to which they reflect the technological capabilities of the firms that generate them' (Cockburn and MacGarvie, 2006: 33). Ziedonis (2004) analyzes the conditions under which firms expand their own portfolios of patents to avoid being 'fenced in' by owners of patented technologies.

A patent on an invention generally acts as a deterrent to entry by making entry into the market by 'close' substitutes costly (Waterson, 1990). Firms wishing to protect some valuable invention may 'invent around' it, by introducing substitutes that may—or may not—represent improvements upon the original product. The incumbent may well have no intention of commercializing those inventions, and by building what is sometimes called a 'patent fence,' it can preempt R&D rivals by foreclosing their ability to introduce substitutes and compete with its 'core' innovations (Cohen *et al.*, 2000).

In particular, the theoretical logic underlying preemptive patenting—defined as the patenting of a substitute technology before rivals to deter entry—is based on two basic elements related to the existence of a threat of entry and the presence of *ex ante* market power (Bresnahan, 1985; Gilbert and Newbery, 1982; Vickers, 1985).[4] Indeed, incentives for preemptive patenting from the point of view of the incumbent depend on the difference between profits with and without preemption. An R&D incumbent, earning above-normal returns from its innovative products, will preempt rivals if such difference, net of the costs of inventing and patenting the substitutes, is positive. A positive and larger difference is also associated with higher overall profits for the incumbent relative to the case without preemption.

Without a threat of entry, as when the probability of entry by R&D competitors is null, the expected profits from preemption (gross of patenting and R&D costs) would be null, and the incumbent would have no incentive to introduce a substitute before potential rivals.

Notice that without the threat of entry by technology rivals, a firm that patents around its own

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[4] See also Tirole (1988) and Gilbert (2006), for a review of the literature.

inventions may still increase its technological capabilities, or generative appropriability—that is, a firm's ability to develop subsequent or second-generation inventions that build on the previous inventions (Ahuja, 2003)—but the incentives for preemptive patenting would be absent. To summarize, I formulate the following hypothesis:

> *Hypothesis 2: A necessary condition for the impact of preemptive patenting on innovating incumbent's economic performance to be positive is that the incumbent be threatened by the potential entry of R&D competitors.*

If the threat of entry exists, and the incumbent is a monopolist, as in the model of Gilbert and Newbery (1982), invention of the substitute technology is always valuable to the incumbent (gross of R&D and patenting costs), because it would preserve monopoly profits, which typically exceed both the duopoly profits that the incumbent would obtain with entry and the duopoly profits that the entrant would obtain by introducing the substitute—that is, the *potential entrant*'s incentive to preempt. By the same token, in the absence of *ex ante* market power the incentive to preempt for incumbents would be absent because profits with preemption, net of R&D and patenting costs, would always be negative. In general, incentives for and performance with preemptive patenting by the incumbents are expected to increase as market power increases, because the *ex ante* profits to preserve increase and the drop in profits due to entry if preemption does not occur is larger. I therefore formulate the following hypothesis:

> *Hypothesis 3: The impact of preemptive patenting on a firm's economic performance is higher for incumbents with greater market power.*

A last basic result from the preemptive patenting models is that the more drastic the underlying innovation on which the R&D competition is based, the lower the incentives for and the profits with preemptive patenting (Gilbert and Newbery, 1982). In this context, an innovation is defined as drastic if it makes the incumbent's technology obsolete (Arrow, 1962).

The intuition can be summarized as follows:[5] If the incumbent introduces a drastic invention

first, its benefits from preemption would be the monopoly profits associated with the drastic invention, which would 'replace' its monopoly profits associated with its current product. However, such potential payoffs would be offset by the larger costs needed to introduce a drastic innovation. Without preemption, the incumbent would obtain zero profits due to the entrant's introduction of the drastic innovation. In summary, with drastic innovations the difference between net benefits with and without preemptive patenting would tend to zero, and the incumbent would have no incentives to preempt. As a consequence, we would not expect any effect of preemptive patenting on the incumbent's profits.[6]

Notice that if the incumbent's *ex ante* market power was obtained through the introduction of drastic innovations, which arguably are more difficult to be displaced by subsequent innovations, the cost of inventing a substitute would increase, and, therefore, the incentives to preempt would decrease. As a consequence, the drastic nature of innovation that leads to lower incentives to preempt could refer to either the incumbent's R&D or the nature of the innovative process underlying the R&D competition between incumbent and potential entrants, or both. Indeed, in the empirical analysis I have experimented with both incumbent-level and industry-level measures of drastic innovation, and obtained similar results. However, in Hypothesis 4 I focus on the 'industry-level effect,' which was directly addressed by Gilbert and Newbery (1982). I therefore formulate the following hypothesis:

> *Hypothesis 4: The impact of preemptive patenting on incumbent's economic performance is lower when the underlying innovation on which R&D competition is based is drastic.*

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[5] The intuition is based on equations (4) and (5) of Gilbert and Newbery (1982).

[6] Subsequent work has focused on the differential incentives to invest in R&D between incumbent and entrants. In particular, Reinganum (1983) shows that when innovation is drastic and uncertain, the R&D competitor has actually greater incentive to invent and patent the drastic innovation before the incumbent. In this study I only focus on the incentives to preempt by the incumbents, given direct data availability on patent preemption strategies and firm performance. From this perspective, Hypothesis 4 suggests that the performance impact of incumbent's patent preemption is reduced when R&D competition is based on drastic innovations.

SPECIFICATION AND ESTIMATION

To test the theoretical hypotheses, I estimate the market's valuation of a firm's R&D stock relative to physical assets. Following Griliches (1981) and others (e.g., Jaffe, 1986; Hall, 1993a,1993b), I analyze the market valuation of a firm's R&D assets starting from the following equation:

$$V = q(A + \gamma \overline{R}), \qquad (1)$$

where V is the current market value of the firm as of the end of the year, A is the current book value of the capital stock, $\overline{R}$ is the current value of the firm's R&D capital and γ represents the marginal contribution of R&D to the firm's market value. q represents the current market valuation coefficient of the firm's total assets, that is, the bundle of capital and R&D assets (assumed to be additive in value), reflecting a firm's differential risk and market power (Griliches, 1981).[7]

Equation (1) can actually be derived from a dynamic optimization model of the determinants of a firm's value, in which the deviation of the market value of the firm from its book value depends on three factors: the present value of returns to physical assets above and beyond those that cover their costs; the relative magnitude of intangible assets; and the present value of the supra- or subnormal returns to intangible assets (Hall, 1993a).

Dividing both sides of Equation (1) by A and taking logs, I obtain the following nonlinear equation:

$$\log \frac{V}{A} = \log q + \log \left(1 + \gamma \frac{\overline{R}}{A} \right). \qquad (2)$$

To estimate Equation (2), and following Griliches (1981), I set

$$q = \exp(\mathbf{X}\beta + \varepsilon), \qquad (3)$$

with X and ε representing factors affecting a firm's market power and other unobserved firm attributes,

and β a vector of parameters to be estimated. To test the hypotheses outlined in the previous section, I set

$$\gamma = \mathbf{S}\theta, \qquad (4)$$

where $\mathbf{S}$ represents observed firm characteristics associated with a firm's appropriability strategy, including its preemptive patent strategy, and θ a vector of parameters to be estimated. The variables included in $\mathbf{S}$, given the specification used in Equation (2), do not enter the equation independently, but interacted with the R&D stock variable. The specification used is supported by additional unreported sensitivity estimation results suggesting that the variables included in $\mathbf{S}$ do not have an independent and significant effect on Tobin's q.

$\overline{R}$ represents the stock of R&D assets, and it is measured using a distributed lag of current and past flows of R&D expenditures, as further explained in the next section. Previous studies have included other measures in addition to R&D to proxy for the firm's intangible capital stock, including advertising expenditures[8] and patents (see Hall 1999 for a review). In particular, Hall *et al.* (2005) have recently shown that the ratio of the patent stock to R&D stock (patent yield), and the ratio of cumulated forward citations stock divided by the patent stock, have an independent and significant impact on a firm's market value. Bessen (2006) similarly finds a positive effect of the patent yield on a modified version of Tobin's q. Using a broader set of industries that includes the nonmanufacturing sector, McGahan and Silverman (2006) confirm the positive effect of citations, but find a slightly negative and insignificant effect of the patent yield on Tobin's q.

In this study I exclude those variables from the analysis, because theory does not provide much guidance for their inclusion as determinants of intangible assets (Hall *et al.* 2005). Moreover, from an empirical point of view, the firm's patent stock and related stock of forward citations do not allow us to disentangle the impact on firm performance of the value of an innovation from the impact of a firm's appropriability strategy. In this

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[7] Equation (1) assumes that the value function exhibits constant returns to scale. Such assumption is typically met in cross-section empirical studies (Hall 1999). As a further robustness check, I have also estimated a modified—and more general—version of Equation (1), where $V = q(A + \gamma \overline{R})^{\sigma}$, using the method of nonlinear least squares. I estimated $\sigma = 0.97$, which supports the constant returns to scale hypothesis when the model is estimated with cross-section data.

[8] For recent studies estimating market value equations that include both R&D and advertising expenditures for the U.S. and Japanese cases see Lenox, Rockart, and Lewin (2007), and Nagaoka (2006), respectively. I do not include advertising expenditures in the analysis because of the excessive (>50%) number of missing values for this variable in Compustat for the CMS sample firms.

study, I will therefore focus the analysis on the role of firm-level appropriability and patent strategy in conditioning the market valuation of R&D.

DATA AND MEASURES

The data come from matching two datasets: the CMS data on industrial R&D, described more fully by Cohen *et al.* (2000)[9] and Compustat.[10] The resulting cross-sectional dataset related to the 1991–1993 period consists of a subset of 330 firms, for which I have firm-level R&D and financial information from Compustat and firm-level appropriability data relating to the primary business segment of each firm from the CMS. For part of the empirical analysis the sample is restricted to 266 observations, due to missing data for some

[9] The population sampled is that of all R&D labs located in the United States conducting R&D in manufacturing industries as a part of a manufacturing firm. R&D lab managers were asked to answer questions about the 'focus industry'—defined as the principal industry for which the unit was conducting its R&D. Valid responses were received from 1,478 R&D units, a response rate of 54 percent. For the present analysis, I only used responses from labs belonging to public companies.

[10] I have matched the CMS and Compustat data by the R&D lab's parent firm's CUSIP (Committee on Uniform Security Identification Procedures, National Securities Identification Number).

of the survey information used, including instrumental variables. Tables 1 and 2 contain summary statistics and basic correlations, respectively.

Dependent variable

The Compustat files contain data to approximate Tobin's q, as in Chung and Pruitt (1994), that is, as the ratio of a firm's *market value*, defined as the sum of a firm equity value, the book value of long-term debt, and net current liabilities, and the firm book value of its *total assets*. Use of the more computationally complex measure of Tobin's q proposed by Lindenberg and Ross (1981) does not change the qualitative conclusions of this study.[11] Tobin's q, by combining capital market data with accounting data, is especially suitable to capture the impact of R&D investment. Relative to accounting-based measures, market-based measures are forward-looking, thus better reflecting the discounted future profits due to innovative investments. I use the log of the 1991–1993 average of

[11] The measure used in this study, a simple 'market-to-book ratio,' differs from the more accurate measure used by Lindenberg and Ross (1981), mainly because: 1) it implicitly assumes that the replacement values of a firm's plant, equipment, and inventories are equal to their book values; 2) the way in which the market value of the firm's long-term debt is developed (Chung and Pruitt 1994). Chung and Pruitt (1994) show that the approximate q explains over 96 percent of the variability of the more accurate measure.

Table 1. Descriptive statistics

	Mean	Std dev	Median	Min.	Max.
Dependent variable					
Market-to-book value (Tobin's q)	1.74	1.73	1.15	0.13	16.40
Independent variables					
R&D stock/assets	0.31	0.48	0.19	0.01	4.54
Effectiveness of secrecy	0.49	0.29	0.5	0.05	0.95
Effectiveness of patent protection	0.40	0.30	0.375	0.05	0.95
Effectiveness of first-mover advantages	0.46	0.29	0.475	0.05	0.95
Ownership of specialized complementary assets	0.56	0.50	1	0	1
Preemptive patenting (dummy variable)	0.34	0.47	0	0	1
Concentration ratio (weighted)	0.39	0.18	0.35	0.00	0.84
Market share (weighted)	0.12	0.17	0.04	7.4E-07	0.97
Variables for subsample estimation					
Market share (primary business segment)	0.05	0.10	0.02	5.5E-07	0.81
% R&D projects initiated to respond to rivals' R&D	0.27	0.22	0.25	0.05	0.95
Drastic inn. (dummy, factor based)	0.49	0.50	0	0	1
% R&D to create new products	0.48	0.09	0.47	0.274	0.66
Industry rate of introd. prod. inn. (Likert scale)	3.02	0.41	2.93	2.33	4.25
% Basic R&D	0.04	0.02	0.03	0.008	0.10
N = 330					

Table 2. Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Market-to-book value (Tobin's *q*)	1.00															
2 R&D stock/assets	**0.44**	1.00														
3 Effectiveness of secrecy	0.06	0.01	1.00													
4 Effectiveness of patent protection	**0.27**	**0.18**	**0.14**	1.00												
5 Effectiveness of first-mover advantages	0.08	0.02	**0.32**	**0.14**	1.00											
6 Specialized compl. assets (dummy)	0.09	0.00	0.09	−0.03	**0.20**	1.00										
7 Patent propensity	**0.18**	0.08	0.04	**0.60**	0.05	−0.04	1.00									
8 Preemptive patenting (dummy variable)	−0.01	−0.06	−0.03	**0.12**	0.01	**0.13**	**0.17**	1.00								
9 Concentration ratio (weighted)	**−0.14**	−0.07	0.02	−0.12	0.01	−0.10	−0.10	**−0.13**	1.00							
10 Market share (weighted)	**−0.13**	−0.01	−0.01	−0.02	−0.04	**−0.11**	0.05	0.01	**0.27**	1.00						
11 Market share (primary bus. segment)	**−0.14**	**−0.12**	0.05	0.02	−0.02	−0.10	0.06	0.01	**0.23**	**0.61**	1.00					
12 % R&D as response to rivals' R&D	−0.02	0.04	−0.01	−0.05	0.07	0.10	−0.06	−0.02	−0.05	−0.04	−0.04	1.00				
13 Drastic inn. (dummy, factor based)	**0.34**	**0.28**	0.07	**0.12**	**0.16**	**0.17**	**0.13**	0.03	**−0.23**	**−0.15**	**−0.12**	0.10	1.00			
14 % R&D to create new products	**0.38**	**0.29**	0.01	**0.12**	**0.14**	**0.12**	0.11	0.05	**−0.15**	**−0.16**	**−0.20**	**0.14**	**0.76**	1.00		
15 Ind. rate of intr. prod. inn. (Likert s.)	**0.25**	**0.33**	0.02	0.01	**0.17**	**0.15**	0.00	−0.03	**−0.13**	**−0.11**	**−0.12**	**0.22**	**0.72**	**0.60**	1.00	
16 % Basic R&D	**0.33**	**0.11**	0.09	**0.21**	−0.10	−0.06	**0.20**	0.00	−0.03	−0.05	0.03	−0.06	**0.24**	**0.31**	0.09	1.00

Note: Values in bold denote at least 5% significance level.

Tobin's q as the main dependent variable in the market-value equation (Equation 2).[12]

Explanatory variables

The *R&D stock* variable in Equation (2) is computed as the cumulated stock of past deflated R&D expenditures, available from Compustat, using a 15 percent depreciation rate.[13] I use the end of 1992 stock measures in the analysis to match the CMS period. This is divided by the book value of *total assets*, also available from Compustat.

To evaluate the impact of appropriability and patent strategy on the market valuation of R&D, I use a new source of data, the CMS appropriability variables and a variable related to the strategic use of patents, all for the period 1991–1993 and at the firm level, referring to a firm's primary line of business. In particular, the CMS asked respondents to indicate the percentage of their product and process innovations for which patent protection, secrecy, or being first to market effectively protected their firm's competitive advantage during the 1991–1993 period. I build variables from these data related to the *effectiveness of patent protection, secrecy*, and *first-mover advantages*.[14] Such broad effectiveness measures summarize the various costs and benefits of using the different strategies. In particular, patent effectiveness includes costs such as the need to disclose enabling technical information in the patent application or the benefit derived from delayed imitation.

The CMS also provides a measure of specialized complementary assets using information related to the frequency of face-to-face interaction between personnel from R&D and production, and R&D and sales/marketing measured in a four-point Likert scale.[15] I constructed a binary variable, *ownership of specialized complementary assets*, which takes a value of 1 if R&D and manufacturing or R&D and sales/marketing personnel interact daily (the median value is weekly interaction).

When testing the hypotheses related to preemptive patenting, I control for appropriability using a more parsimonious and easier to interpret measure represented by a firm's *propensity to patent*, that is the percentage of product and process innovations for which a firm applied for patents in the period 1991–1993 in the United States, available from the CMS (but unavailable in the previous Yale survey).[16] This variable directly reflects a firm's strategy, by broadly summarizing its appropriability choice (patenting versus not), without specifying, but including all, the potential ways patents can be used to appropriate innovation rents. However, since this is a choice variable for the firm, I use the measure of patent effectiveness previously described, both at the firm and industry level, to instrument for it. Indeed, the patenting choice depends on the net benefits from patenting, which are in turn empirically captured by the measure of patent effectiveness (Arora, Ceccagnoli, and Cohen, 2008; Arora and Ceccagnoli, 2006). More details in support of the power and validity of this instrument, in the specifications where patent propensity is used in the main market value equation, are provided in the next section.

To measure whether the firm adopts a *preemptive patenting* strategy, I follow the Cohen *et al.* (2000) definition of 'fence patenting.' In particular, I constructed a dummy variable equal to one if a respondent indicated 'the prevention of rivals from patenting related inventions'—sometimes defined

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[12] Notice from Table 1 that the maximum value of the market-to-book ratio of 16.4 is within commonly used upper limits for this variable (cf. Hall *et al.*, 2005). A more conservative trimming procedure of excluding observations with values of q less than 10 (e.g., excluding the upper 1% of the distribution) resulted in estimates very similar to those reported here.

[13] The deflated R&D stock in year t equals the firm-level real R&D expenditures in year t plus 85 percent of the previous year deflated R&D stock. The yearly consumer price index was used to deflate past R&D investments. The initial stock variable is the real R&D expenditures of the earliest year for which the firm has a non-null R&D value in Compustat, noting that R&D data in Compustat could go as far back as 1950. The deflated R&D stock in year t was then reflated to current (1992) dollars.

[14] For all such variables, there were five mutually exclusive response categories for both product and process innovations separately: <10 percent, 10–40 percent, 41–60 percent, 61–90 percent, and >90 percent. I computed a weighted average of the product and process scores (using midpoints) with the percentage of R&D effort devoted to product and process innovations as weights.

[15] Respondents were asked: 'How frequently do your R&D personnel talk face-to-face with personnel from the Production, Marketing or Sales, and Other R&D units?'. In general, measuring the degree of specialization is difficult but, as Teece (1992) suggests, complementary assets often arise from the interaction and learning over time of people from different parts of a firm's organization. This is especially relevant for the interaction with R&D, which typically requires organizationally embedded interpersonal and interfunctional activities (Zhao, Anand, and Mitchell, 2005). A similar measure has been used by Arora and Ceccagnoli (2006).

[16] I computed a weighted average of product and process patent propensities using the percentage of R&D effort devoted to product and process innovations, respectively, as weights, as reported by the CMS respondents.

as 'blocking'—*and not* licensing, *nor* cross-licensing, as reasons to apply for their most recent application for a product or process patent. The exclusion of licensing and cross-licensing is motivated by the desire to focus on the entry deterrence effect of patent blocking, thus avoiding the possibility of cases where incumbents patent and license to competitors (e.g., Fosfuri, 2006) or patent to gain the 'freedom to compete' in a technology domain by negotiating with rivals' complementary technologies (Cohen *et al.*, 2000).

This measure is of course subject to limitations. In particular, patenting a related invention without intending to license or cross-license may not necessarily fit the adopted definition of preemption. For example, a pharmaceutical company may patent a molecule to block rivals (but not its close substitutes) without intending to license or cross-license. The preemptive patenting proxy is, therefore, subject to measurement error, which leads to attenuation bias. I will adopt an instrumental variable approach to correct for potential biases originating from both measurement error and unobserved heterogeneity across firms, as explained in the next section.[17]

The presence of a *threat of entry* by potential R&D competitors, thought to condition the returns to preemptive patenting according to Hypothesis 2, is measured using the CMS survey question related to the percentage of R&D projects that the R&D unit initiated 'to respond to specific R&D projects of competitors.' This variable is used to estimate Equation (2) within samples constructed according to whether the *threat of entry* is present or not.[18]

To test the hypothesis that the returns from preemptive patenting are higher for firms with greater market power (Hypothesis 3), I estimate the market value equation (Equation 2) within the sample of low and high market-share firms.[19] A

firm's *market share* is computed as the fraction of total industry sales captured by the firm in its primary business segment.[20] Indeed, in order to test Hypothesis 3, I need to measure market power at the same product-level as that used to measure preemptive patenting.

To measure whether the R&D competition is based on *drastic innovations*, I use multiple variables available from the CMS. The first two measures capture the resources—and their effectiveness—devoted to new product introductions, both measured as averages across firms within the incumbent's primary business segment: the percentage of R&D projects with the 'key goal of creating new products' and the industry rate of introduction of product innovations in a firm's primary business segment.[21] The basic rationale underlying the selected variable is that a drastic technological innovation involves methods and materials that are completely novel to both the firm and the industry, as opposed to the outcome of activities that incrementally improve existing products and processes. I therefore expect that in industries where firms devote greater effort to introducing new products, as opposed to improving the quality and performance of existing products, and achieve greater rate of introduction of new products, are more likely to introduce more drastic innovations.

A third variable used to measure the extent to which innovative activity is drastic is the average percentage of R&D effort that firms devote to basic research in the incumbent's primary business segment.[22] Indeed, basic research is more likely to result in significant advances in knowledge (Nelson, 1959). According to Nelson (1959), the more basic the research is, the less clearly defined its

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[17] Non-patenting firms in the CMS were not required to respond to questions related to reasons to patent. I therefore substituted the resulting missing value for the preemptive patenting dummy with zero. Any systematic bias that may arise from such substitution is attenuated by the inclusion in the analysis of a variable controlling for whether the firm patented (patent propensity) and the correction for the endogeneity of the preemptive patenting dummy, as explained later in the text.

[18] This variable was coded in the survey using five mutually exclusive response categories: <10 percent, 10–40 percent, 41–60 percent, 61–90 percent, >90 percent. To test Hypothesis 2, I construct a dummy variable equal to 1 if the respondent indicated a category greater than the lowest (<10%).

[19] A standard industrial organization result is that in asymmetric oligopolies characterized by firms competing on output and

linear demand, the Lerner index of market power is a positive function of a firm's market share and the degree of collusion in the industry, as conjectured by the firm, and a negative function of the elasticity of demand.

[20] I use Compustat to measure 1992 sales in the primary business segment of the firm (defined at the four-digit SIC [Standard Industrial Classification] level) and the *1992 Census of Manufacturers* (U.S. Department of Commerce, Bureau of the Census), to measure the *total industry sales* in the same year and at the same four-digit SIC level.

[21] The first variable was coded using five mutually exclusive response categories (<10%, 10–40%, 41–60%, 61–90%, >90%), the second using a five-point Likert scale (indicating an introduction rate of product innovations in the firm's primary business segment in the previous 10 years from 'very slowly' to 'very rapidly').

[22] This variable is measured as the percentage of an R&D unit's effort defined as 'scientific research with no specific commercial objectives.'

goals are, the greater is the risk of the underlying investment, and the more likely it is to lead to significant breakthroughs.[23] A classic example of the impact of basic research on radical innovation is Charles Stine's fundamental research program that led to Du Pont's discovery and commercialization of nylon (Hounshell and Smith, 1988).[24]

I summarized the three variables described above using common factor analysis, which indicated that the three measures can be reduced to one factor. The first factor has a dominant and positive eigenvalue of 0.593, and it therefore explains about 60 percent of the variance of the three observed variables.[25] To test Hypothesis 4, I therefore divide the observations into two subsamples using the median value of the *drastic innovation* variable, which reflects the common variance underlying the three variables described above. Industries included in the drastic innovation group include most R&D-intensive industries, such as biotechnology and pharmaceutical, computers, and electronic components and instruments. This is consistent with the idea that industries with more drastic innovations are also characterized by higher technological opportunities, one of the main industry-level drivers of R&D incentives (Dosi, 1988; Klevorick *et al.*, 1995; Nelson, 1959).

Other control variables

Consistent with previous work (see Hall, 1999 for a review of the literature), I include industry concentration and a firm's market share as controls for

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[23] Arora and Ceccagnoli (2006) find that firms with higher investments in basic research also have a greater propensity to out-license their innovations. Basic scientific research is also more likely to result in useful knowledge that a firm is itself unable or unwilling to commercialize in-house (due to the lack of complementary assets) or the use of which may be much broader than the firm's domain of operation (Nelson, 1959).

[24] The concept of radical innovation is closely related to that of technological opportunity, that is, the set of possibilities for technological advance (Klevorick *et al.*, 1995, among others). Shane (2001) considers the 'radicalness' of a technology to be itself an attribute of technological opportunity. Advances in scientific knowledge, one of sources of variation exploited in this study, seems to be the most exogenous factor affecting both the introduction of breakthroughs and the expansion of technological opportunities (Dosi, 1988; Klevorick *et al.*, 1995; Nelson, 1959).

[25] The correlations between the retained factor and the variables, derived from the factor-pattern matrix, are 0.48 (% new products from R&D), 0.56 (industry-rate introduction of new products), 0.21 (% basic research). The correlations among the three variables after the retained factor is accounted for (partialled out) are all <0.1, indicating that the retained factor can accurately account for the observed correlations among them.

q, the current market valuation coefficient of the firm's total assets in Equation (2). Both variables are weighted averages for each firm, constructed using their 1991–1993 four-digit SIC sales distributions as weights, available from Compustat. The *overall weighted market share* of the firm is measured as 1991–1993 average sales in each business segment of the firm, defined at the four-digit level and available from Compustat, divided by total industry sales, available from the 1992 U.S. Census of Manufacturers. The *weighted four-firm concentration ratio* is the percentage of total industry sales accounted for by the four leading firms in each business segment of the firm, defined at the four-digit SIC level and available from the 1992 U.S. Census of Manufacturers.

Finally, I include a full set of 18 industry dummies in all specifications, mostly defined at the two- and three-digit SIC level of the primary business segment of the firm.[26]

RESULTS AND DISCUSSION

Appropriability

Table 3 shows the results of estimating the market value equation obtained substituting Equations (3) and (4) into Equation (2), using the method of nonlinear least squares (first two columns), and nonlinear GMM (third column). Hypothesis 1 is tested by adding the CMS appropriability variables or patent propensity (instrumented using appropriability variables) as main drivers of the marginal shadow value of the stock of R&D assets relative to ordinary assets of the firm in Equation (4).

The main elasticity of interest, labeled η, represents the percentage change in Tobin's q (i.e., the market-to-book ratio) for one percentage point increase in R&D intensity (i.e., the ratio R&D/assets):

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[26] Eighteen industry dummies constructed using the SIC code of the focus industry: Food and Tobacco (SIC 20,21), Industrial Chemicals (SIC 281–82,286), Drugs (SIC 283 excl. biotech), Biotech (various SIC), Other Chemicals (SIC 284–85,287–89), Petroleum (SIC 13,29), Rubber (SIC 30), Metals (SIC 33–34), Computers (SIC 357), Machinery (SIC 35, exc.357), Communication Equipment (SIC 366), Electronic Components (SIC 367 excl. 3674), Semiconductors (SIC 3674), Transportation (SIC 37 excl. 372,376), Aircraft and Missiles (SIC 372,376), Instruments (SIC 38 excl. 384), Medical Instruments (SIC 384), Other Manufacturing (SIC 22–27,31–32,361–65,369,39). Other Manufacturing is the excluded dummy.

Table 3. The impact of appropriability. Dependent variable: Log of Tobin's q (log V/A)

	OLS	OLS	GMM
R&D stock/assets ($\overline{R}/A$)	−0.578**	−0.029	−0.181**
	0.215	*0.214*	*0.017*
Effectiveness of patent protection × R&D stock/assets	1.402**		
	0.279		
Effectiveness of secrecy × R&D stock/assets	−0.418		
	0.575		
Effectiveness of being first to market × R&D stock/assets	0.391		
	0.398		
Ownership of specialized compl. assets × R&D stock/assets	0.421[a]		
	0.237		
Patent propensity × R&D stock/assets		1.034**	2.119**
		0.394	*0.514*
Market share	0.050	0.035	−0.029
	0.152	*0.133*	*0.126*
Concentration ratio	−0.277[a]	−0.288[a]	−0.229
	0.159	*0.172*	*0.168*
% change in Tobin's q for 10% change in R&D intensity (η):			
-Sample average	0.183	0.291[a]	0.459**
	0.233	*0.173*	*0.129*
-Firms with patent effectiveness at one st. dev. above mean	0.512**		
	0.177		
-Firms with secrecy effectiveness at one st. dev. above mean	0.069		
	0.340		
-Firms with lead times effectiveness at one st. dev. above mean	0.281		
	0.302		
-Firms with specialized complementary assets	0.338		
	0.282		
-Firms with patent propensity 10% above mean		0.375*	0.607**
		0.174	*0.149*
Industry fixed effects (18)	Yes	Yes	Yes
R^2	0.50	0.44	0.41
N	330	330	330

- The table shows results of estimation of the nonlinear market value Equation (2). The nonlinear instrumental variable (IV) estimates shown in column 3, obtained using the generalized method of moments, use the appropriability measures as instruments for patent propensity. Their use as instruments is supported by standard validity test discussed in the main text.
**, *, [a]: Significantly different than 0 at the 0.01, 0.05, and 0.10 confidence levels.
- Heteroscedasticity consistent standard errors are shown in italics.

$$\eta \equiv \frac{\partial(\log q)}{\partial(\overline{R}/A)} = \frac{\gamma}{(1 + \gamma\,\overline{R}/A)}, \qquad (5)$$

with γ being a function of variables used to measure appropriability and preemptive patenting and a set of estimated parameters (see Equation 4). Such effect represents the impact of R&D on market value, and any mediating effect of appropriability or preemptive patenting is assessed by evaluating the elasticity at above-average levels of the corresponding explanatory variables. Estimates of η are reported at the bottom of Tables 3 and 4.

Overall, the results support Hypothesis 1, showing that stronger appropriability tends to increase the market valuation of R&D assets. In

particular, stronger patent protection is found to increase substantially and significantly the market valuation of R&D. As shown in the first column of Table 3, an increase of one standard deviation above the mean in the *effectiveness of patent protection* is associated with an increase from 0.18 to 0.51 in the R&D elasticity. Firms with *specialized complementary assets*, with an R&D elasticity of 0.34, are also characterized by a significantly higher market valuation of R&D assets, almost twice that of the average firm in the sample. One standard deviation increase in the *effectiveness of first-mover advantages* leads to an increase in η (from 0.18 to 0.28), although this is not significant at conventional levels.

Table 4.   The impact of preemptive patenting. Dependent Variable: log Tobin's q (V/A)

	Full sample		Threat of entry		Market share		Drastic innovation	
			Low	*High*	*Low*	*High*	*Low*	*High*
	OLS	GMM	GMM		GMM		GMM	
R&D stock/assets	−0.197**	−0.200**	−0.444	−0.191**	−0.192**	−1.142**	−0.796**	−0.192**
	0.015	*0.010*	*0.455*	*0.007*	*0.008*	*0.118*	*0.084*	*0.006*
Patent propensity × R&D stock/assets	1.049**	1.334**	5.366**	0.890**	1.291**	3.730**	1.259*	1.381**
	0.347	*0.311*	*1.701*	*0.318*	*0.265*	*0.744*	*0.590*	*0.220*
Preemptive patenting × R&D stock/assets	0.188	0.544	−0.502	0.633[a]	0.106	0.846*	0.994**	−0.245
	0.356	*0.687*	*0.453*	*0.343*	*0.474*	*0.335*	*0.303*	*0.169*
Market share	−0.043	−0.026	−0.018	−0.040	0.174	−0.172	−0.375**	0.260
	0.166	*0.159*	*0.444*	*0.135*	*0.327*	*0.152*	*0.117*	*0.247*
Concentration ratio	−0.318[a]	−0.238	0.305	−0.524**	0.349	−0.403**	−0.226	0.317
	0.179	*0.166*	*0.300*	*0.170*	*0.474*	*0.140*	*0.142*	*0.382*
% change in Tobin's q for 10% change in R&D intensity (η):								
-Sample average	0.199	0.377*	0.951**	0.266*	0.228[a]	0.397*	−0.093	0.199**
	0.146	*0.191*	*0.323*	*0.110*	*0.121*	*0.183*	*0.102*	*0.067*
-Firms with preemptive patenting = 1	0.305	0.636	0.763*	0.589**	0.287	0.823**	0.526*	0.058
	0.304	*0.450*	*0.351*	*0.223*	*0.354*	*0.276*	*0.205*	*0.151*
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.46	0.44	0.48	0.41	0.50	0.40	0.24	0.45
N	266	266	89	177	132	134	139	127

- Table shows results of estimation of nonlinear market value Equation (2). The nonlinear instrumental variable (IV) estimations are obtained using the generalized method of moments, with log q, patent propensity, and preemptive patenting as endogenous variables. Instrumental variables for patent propensity are the following: The effectiveness of patent patent protection (both at the firm and industry levels), effectiveness of secrecy, effectiveness of lead times, and the ownership of specialized complementary assets. Instrumental variables for the preemptive patenting dummy variable are the following: The % of rivals in the firm's primary industry adopting a preemptive patenting strategy, the number of technological rivals, and imitation lags. The validity of the instrumentation strategy is discussed in section 5.
- All specifications include an intercept and a full set of 18 industry dummies. Industry dummies without non missing values are dropped from the sub-sample estimations.
**, *, [a]: Significantly different than 0 at the 0.01, 0.05, and 0.10 confidence levels.
- Heteroscedasticity consistent standard errors are shown in italics.

Finally, *secrecy* is associated with an insignificant decrease in the R&D elasticity (from 0.18 to 0.07). The lack of expected impact may be attributed to a combination of poor measurement or the inability of financial markets to observe and value such strategy.[27]

A comparison to the results of Cockburn and Griliches (1988), who analyzed the market valuation of R&D assets using the industry-level appropriability measures available from the 1983 Yale survey, yields important differences. First, results presented here suggest that *intra-industry* variation

in appropriability, as opposed to the *interindustry* variation captured by the earlier Yale responses, is substantial and systematically related to firm performance. The proportion of the variance of log q explained by the present model is more than twice the variance explained by Cockburn and Griliches (1988) earlier model. Second, other measures, such as the ownership of specialized complementary assets or the effectiveness of being first to market, in addition to patent effectiveness, have a substantial impact on the appropriability of innovation rents.

Table 3 shows the estimation of the market value Equation (2) measuring **S** in Equation (3) with a constant and patent propensity. The first specification considers patent propensity exogenous (second column), estimated with the method

[27] Heeley, Matusik, and Jain (2007) provide evidence for the role of the transparency of the link between internal innovative activities and the ability to appropriate returns from them as determinants of information asymmetries in the financial market and the underpricing of initial public offerings.

of nonlinear OLS; the second specification (shown in third column), is estimated by nonlinear GMM, using patent effectiveness at the firm and industry level, as well the other appropriability measures as instrumental variables. Patent propensity is indeed a choice variable, and the Hausman test of endogeneity rejects its exogeneity when included on the right-hand side of the Tobin's q equation.

Further tests of instruments validity support the identification strategy. The first-stage F-statistic related to the joint null that the set of instruments have no effect on the endogenous patent propensity is 75.14, suggesting a strong correlation with the instruments. A test of the overidentifying restrictions also suggests that instruments are exogenous.[28]

Results (shown in the third column of Table 3) indicate that a 10 percent increase in a firm's patent propensity is associated with an increase from 0.46 to 0.61 in the R&D elasticity η, i.e. almost a 35 percent increase in the market valuation of R&D. Since patent propensity is a direct, albeit survey-based, measure of a firm patent strategy, these results strongly support the idea that appropriability is endogenous, and that firms' choices about the use and enforcement of its patents have a remarkable impact on firm performance.

Preemptive patenting

To test Hypotheses 2–4, I use Equation (3) to control for the market valuation of the total assets of the firm, as above, and include in Equation (4) both *patent propensity* and *preemptive patenting*. By broadly controlling for the appropriability strategy of the firm for each of its innovations, the preemptive patenting variable will then capture the contribution of such strategy to the market valuation of R&D assets, in addition to the full set of potential uses of patenting, implicitly captured by patent propensity.

Since both patent propensity and the adoption of preemptive patenting are choice variables for the firm, testing of Hypotheses 2–4 requires the use of an instrumental variable approach. Instruments

for patent propensity have been explained above. I use three additional variables to instrument for the adoption of preemptive patenting: 1) The percentage of firms within a respondent's primary business segment adopting preemptive patenting, computed excluding the focal firm's response, which is thought to broadly capture the underlying exogenous industry-level conditions affecting the incentives for preemptive patenting; 2) The number of a focal firm's technological rivals;[29] and 3) Imitation lags for unpatented innovations.[30] The latter two variables reflect the ease and risk of rivals inventing around the focal firm's innovations, and therefore its expected returns with and without preemptive patenting.

The proposed instruments do suffer from limitations. In particular, the extent to which rivals use preemptive patenting will be correlated with unobserved industry-level factors that are only imperfectly controlled for using industry dummies. Similarly, imitation lags are partly an outcome of firm-level strategies that may be correlated with unobserved heterogeneity. I will present tests of instrument validity that will partly address such concerns in what follows below.

Results of this specification are shown in Table 4. The first two columns present estimates of the market value equation for the full sample, using both nonlinear ordinary least squares (OLS) and the general method of moments (GMM). Such full sample estimations are reported for two reasons. The first is to simply show the benchmark results for the average firm in the sample. The second, and more important reason, is to check the validity of the instruments.

In particular, I complement the GMM estimation results by estimating two auxiliary regressions,

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[28] The J-statistic is equal to 11.65. This is distributed as a chi-square with eight degrees of freedom (31 unique instruments minus 23 estimated parameters). The p-value is equal to 0.1677, implying that the null hypothesis of instruments validity—that is, that the instruments are uncorrelated with the error term in the market value equation—cannot be rejected at conventional significance levels.

[29] This is measured in the CMS as the number of U.S. competitors capable of introducing competing innovations in time that can effectively diminish the respondent's profits from an innovation in the primary business segment of the firm. I used the midpoints of the chosen interval: 0, 1–2, 3–5, 6–10, 11–20, or >20 competitors.

[30] In the CMS, each respondent was asked 'how long was it until another firm introduced a competing alternative' for its most significant product or process innovation introduced in the previous 10 years. The response categories for this question were less than six months, six months to one and one-half years, one and one-half to three years, three to five years and more than five years. I used the midpoints of the intervals and computed a weighted average of the product and process scores, with the percentage of R&D effort devoted to product and process innovations as weights (available from the CMS), to construct imitation lags.

corresponding to the projection of the two endogenous variables against all the exogenous variables and the instruments and compute the F-statistic, corresponding to the test of the joint null hypothesis that the instruments have no effect on the endogenous variables. The instrumental projection yields a joint F value related to the instruments equal to 131 for patent propensity and 12 for preemptive patenting, suggesting a strong correlation.

To check instruments exogeneity, a test of the null hypothesis that the overidentifying restrictions fit the model is conducted. The J statistic is equal to 12.13 and the p-value is 0.52, so that I fail to reject the null of instruments exogeneity.[31] I also performed C tests to verify that subsets of instruments are exogenous, assuming that the industry-level instruments are exogenous, and cannot reject the null hypothesis that the appropriability measures or the imitation lags and technological rivals instruments are exogenous.

Given the results of the above tests, I will therefore discuss below only the instrumental variable estimation results. The estimates shown in the second column of Table 4 suggest that in the full sample, the adoption of preemptive patenting is characterized by a higher valuation of R&D. The estimates suggest that for firms adopting preemptive patenting, a one percentage increase in R&D intensity (R&D stock over total assets) has a 50 percent greater impact on Tobin's q then the average firm in the sample. The elasticity is not, however, significantly different than zero at conventional levels. The lack of significance is not surprising, since preemptive patenting is expected to be always profitable *only* for monopolists threatened by entry, a condition that is almost certainly not met for most of the firms in the sample.

By estimating Equation (2) within subsamples built using the *market share, threat of entry*, and *drastic innovation* variables, I obtain the results presented in Table 4, used to test Hypotheses 2–4. In all three cases, a Wald test of the null hypothesis that the parameters are equal across subsamples produces p values of 0.0001, rejecting the null at the one percent confidence level.

First, consistent with Hypothesis 2, the third and fourth columns of Table 4 suggest that for the sample of firms facing a higher threat of entry by R&D competitors, the impact of preemptive patenting on the market valuation of R&D increases. Indeed, for firms adopting preemptive patenting within the *low threat-of-entry* sample, a one percentage point increase in R&D intensity leads to a 0.8 percentage increase in Tobin's q, that is, a *lower* increase relative to the average firm in the subsample, for which the semi-elasticity is 0.95. In the *high threat-of-entry* subsample, the analogous semi-elasticity doubles from 0.3 to 0.6, a *positive* and much greater and significant increase in the impact of preemptive patenting on the rate of return to R&D and firm performance.

Notice, however, how firms benefiting from a low threat of entry are characterized, on average, by a higher market valuation of R&D, with an almost unitary semi-elasticity of R&D, which drops to 0.3 in the case of firms threatened by entry. This is to be expected, since without an entry threat, firms will achieve, on average, greater market power arising from its process and product innovations generated by their stock of R&D capital.

The fifth and sixth columns of Table 4 suggest that the positive impact of *preemptive patenting* on the market valuation of R&D doubles for firms characterized by greater market power, in support of Hypothesis 3. Indeed, a one percentage point increase in R&D intensity for the typical firm within the low market-share sample leads to a 0.2 increase in Tobin's q, an effect that increases to 0.3 for preemptive patenting firms. Within the high market-share sample, the typical firm is characterized by a semi-elasticity of 0.4, which jumps to 0.8 for preemptive patenting firms. In the latter case the conditioning effect of preemption is significant at the one percent significance level, whereas it is not significantly different than zero within the low market share sample.

The evidence, in particular the corollary finding that the R&D semi-elasticity is about twice as large for firms with larger market shares, is consistent with previous findings suggesting that the market places greater value on R&D assets of firms with high market shares (cf. Hall and Vopel, 1997; Blundell, Griffith, and Van Reenen, 1999). As previously pointed out (Hall and Vopel, 1997), this effect reflects an R&D cost spreading advantage of larger firms (Cohen and Klepper, 1996). There

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[31] The J statistic is computed as the minimized value of the GMM objective function (0.046) times the number of observations (266), which is asymptotically distributed with a chi-square distribution with 56 degrees of freedom, obtained as the number of unique instruments (81) minus the number of estimated parameters (24).

is some controversy in the literature on the underlying reasons leading to such advantage. Blundell *et al.* (1999) interpret the result as supporting the strategic preemption effect of R&D advanced by Gilbert and Newbery (1982), analyzed in this study, whereas Hall and Vopel (1997) suggest that a higher rate of returns for larger firms is the result of lower R&D financing costs benefiting larger firms. Relative to these previous studies, this study marks an advance, in that the data provide direct support for the strategic preemption effect of R&D, in particular in relationship to market power as summarized by Hypothesis 3.

Finally, estimates shown in the last two columns of Table 4 provide support for Hypothesis 4. Indeed, firms with preemptive patenting competing in industries characterized by *incremental innovations* are characterized by a substantially higher valuation of R&D assets ($\eta = 0.53$), whereas it is not significantly different than zero in the *drastic innovation* case.

As a corollary and meaningful result, note that the market valuation of R&D is clearly lower for the sample of firms competing in industries with incremental innovations, where η is not significantly different from zero, as opposed to a positive and significant elasticity of 0.2 for the typical firm in the drastic innovation case. In such setting, therefore, preemptive patenting appears to be a key driver of firm performance, pushing the impact of R&D intensity on Tobin's q to well above average levels.

CONCLUSION

Scholars in the past two decades have increasingly considered the strategies used to capture the value created by innovative investment to be fundamental drivers of a firm's competitive advantage. To date, however, the empirical evidence on the impact of such strategies on performance has been limited. The CMS survey data, matched to Compustat, is an important and novel source for innovative empirical work on this topic.

The results show that appropriability at the firm level has a greater impact on firm performance than previously thought. In particular, the strength of patent protection and the ownership of specialized complementary assets appear to significantly increase the returns captured from R&D and, therefore, the market power associated with innovative

investments. A broad and more interpretable measure of appropriability, such as a firm's propensity to patent (not previously available), is also shown to have a positive and robust effect on the market valuation of R&D.

The CMS has shown that nonconventional reasons to patent, such as patent preemption, are more common than previously thought (Cohen *et al.*, 2000). I show that such a strategy tends to remarkably improve the appropriability of returns to R&D, especially for incumbents with stronger market power, suggesting that entry deterrence is a key driver of higher profits obtained through broad-based patent-portfolio strategies. I also show that such preemptive patenting behavior is 'strategic,' because its value is higher for firms conducting a larger fraction of R&D in response to rivals' R&D investments.

To my knowledge, the results related to the patent-preemption hypotheses (Hypotheses 2–4) are the first systematic and direct test of the strategic patent-preemption hypothesis advanced by Gilbert and Newbery (1982) across a broad variety of industries. Blundell *et al.* (1999) perform a less direct test with results consistent with theory: they find that for a broad panel of British manufacturing firms, those with higher market share are characterized by higher market valuation of their intangible assets, suggesting that dominant firms, by achieving higher rates of returns on their R&D investments, have greater incentives to innovate. Industry-specific studies, such as Henderson (1993) and Lerner (1997), have found support for the Reinganum (1983) subsequent technology-race behavior model.[32] The results of this study accord with both theories, in particular the finding that with drastic innovations the impact of preemptive patenting on the returns to R&D is reduced.

This study points to the need for a deeper understanding of the conditions under which it is optimal to follow specific appropriation strategies—in particular by endogenizing the decision to adopt different appropriability strategies. Each choice should entail a variety of costs and benefits, including the potential benefit of using broad-based patent portfolio strategies in the context of strategic R&D competition.

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[32] More recently, Gilbert (2006) himself highlights the paucity of empirical evidence in this area, with the important exception of the industry-specific studies cited above.

Finally, I have not addressed the question of whether preemptive patenting is socially wasteful or limits the overall rate of technical change. In particular, it would be important to understand if the impact of preemptive patenting on firm performance highlighted above is due not only to complete entry deterrence, but also, as Waterson (1990) argues, to the effect of patenting on the choices of product variety that actual and potential rivals make. Indeed, although patent-based entry barriers may exist, if potential entrants redirect their efforts toward less duplicative research, ownership of valid patents on the resulting innovations may actually favor entry and overall industry profits.[33] This appears to be a key business and policy issue that goes beyond the scope of the present research but merits further investigation.

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[33] This conjecture is consistent with Cockburn and MacGarvie (2006), whose findings suggest that although patent-based entry barriers may exist in the software industry, they are offset by the benefits provided by the patents on innovations that entrants hold.

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