Available online at www.sciencedirect.com

SCIENCE DIRECT®

Economics Letters 91 (2006) 131–137

economics letters

www.elsevier.com/locate/econbase

Patents, trade secrets and the correlation among R&D projects

Harun Bulut, GianCarlo Moschini *

Department of Economics, Iowa State University, Ames, IA, 50011-1070, United States

Received 18 July 2005; received in revised form 27 October 2005; accepted 11 November 2005

Abstract

In patent race models, firms' noncooperatively chosen research projects typically display too much correlation. But when there are multiple intellectual property rights protection instruments, we find that the paths chosen in an R&D race can move towards the social optimum.

Keywords: Intellectual property rights; Parallel R&D; Patent races

JEL classification: O3; L0

1. Introduction

By endowing inventors with exclusive property rights over their discoveries, patents can be a powerful incentive for undertaking new research and development (R&D) projects in a market economy, but they provide only a second-best solution to market failures that affect the provision of innovations (Scotchmer, 2004). The economic issues raised by patent races are a case in point. The competition for the economic rents secured by a patent provides incentive for parallel research (Dasgupta, 1990). Given that R&D projects have uncertain outcomes, some parallel research may be socially desirable. But, because of the winner-takes-all nature of the contest, too much parallel research is also possible. In addition to providing a possibly inefficient amount of R&D investment, parallel research also may fail to provide the correct type of R&D efforts. Competitors in a patent race may choose strategies that are too risky from society's

* Corresponding author. Tel.: +1 515 294 5761; fax: +1 515 294 6336.
E-mail address: moschini@iastate.edu (G.C. Moschini).

0165-1765/$ - see front matter
doi:10.1016/j.econlet.2005.11.010

viewpoint (Klette and de Meza, 1986). More subtly, R&D competitors may choose projects that are excessively correlated relative to what is socially desirable (Dasgupta and Maskin, 1987).

A feature of the real world that is not explicitly modeled in the foregoing studies is that firms use a variety of instruments (trade secrets, lead time, and manufacturing capabilities) that not only complement patents in helping firms appropriate returns from R&D activities but are often considered more important (Cohen et al., 2000). Studies that have analyzed the economics of alternative modes of intellectual property rights (IPR) have focused on the decision of whether or not to patent and on the choice of research intensity (e.g., Anton and Yao, 2004; Denicolò and Franzoni, 2004). In this paper, by contrast, we study whether the availability of alternative modes of protection affects the research paths chosen by R&D competitors. We do so by extending the model of Dasgupta and Maskin (1987) to include the strategic interaction between firms at the stage of IPR choice (in addition to the stage of project selection). We find that the availability of additional modes of protection (trade secrets in our model) may in fact lead R&D competitors to choose less correlated projects.

2. The modeling framework

As in the two-point distribution approach of Dasgupta and Maskin (1987), the R&D contest here is represented as a one-shot game in which two firms (firm 1 and firm 2) simultaneously pursue a research project, the outcome of which is either success (S) or failure (F). Let $X_i \in \{\mathrm{S}, \mathrm{F}\}$ denote the random outcome for the ith firm ($i=1,2$), such that four events (X_1, X_2) are possible: (S, S), (S, F), (F, S), and (F, F). If p_i denotes the ith firm's unconditional probability of success, and ρ represents the coefficient of correlation of the dichotomous variables X_i, the events' probabilities are:

$$\mathrm{prob}(\mathrm{S},\mathrm{S}) = p_1 p_2 + \rho\sqrt{p_1(1-p_1)p_2(1-p_2)} \tag{1.a}$$

$$\mathrm{prob}(\mathrm{S},\mathrm{F}) = p_1(1-p_2) - \rho\sqrt{p_1(1-p_1)p_2(1-p_2)} \tag{1.b}$$

$$\mathrm{prob}(\mathrm{F},\mathrm{S}) = (1-p_1)p_2 - \rho\sqrt{p_1(1-p_1)p_2(1-p_2)} \tag{1.c}$$

$$\mathrm{prob}(\mathrm{F},\mathrm{F}) = (1-p_1)(1-p_2) + \rho\sqrt{p_1(1-p_1)p_2(1-p_2)} \tag{1.d}$$

where $\rho\sqrt{p_1(1-p_1)p_2(1-p_2)} = \mathrm{Cov}(X_1, X_2)$ is the covariance term.

We assume that each firm can choose an action $a_i \in [0,1]$ that affects both the unconditional probability of success p_i as well as the correlation/covariance of outcomes, where $a_i=0$ represents no diversification effort and $a_i=1$ represents maximum diversification.[1] Specifically, we write $p_i=p(a_i)$, $i=1$, 2, and $\mathrm{Cov}(X_1, X_2)=C(a_1, a_2)$. As in Dasgupta and Maskin (1987), we restrict attention to the case of nonnegative covariance, and further assume:

Assumption 1. (i) The unconditional probability function $p(a_i)$ is strictly decreasing and strictly concave in its domain, with maximum at $a_i=0$ and minimum at $a_i=1$. (ii) The covariance function $C(a_1, a_2)$ is

[1] Our specification differs slightly from that of Dasgupta and Maskin (1987), who consider the project space to be [1/2,1] for firm 1 and [0,1/2] for firm 2. Also, their parameterization of the covariance structure differs from the canonical form given above.

strictly decreasing in a_i ($i=1, 2$). (iii) The probability of event (F, F) that is $[1-p(a_1)][1-p(a_2)]+C(a_1, a_2)$ is strictly convex in a_i ($i=1, 2$).

2.1. Social optimum

Following Dasgupta and Maskin (1987) we assume that the payoff to society of at least one project being successful is $B>0$, and we abstract from cost considerations. Thus, the expected welfare maximization problem effectively entails maximizing the total probability of success:

$$\max_{a_1,a_2} \; B\cdot[1-\text{prob}(F,F)]. \tag{2}$$

The objective function in Eq. (2) is strictly concave by Assumption 1, and thus there is a unique solution to the welfare maximization problem. This solution is symmetric and it is labeled (a^*, a^*). Note that, because prob(F, F)$=1-$prob(S, F)$-p(a_2)=1-$prob(F, S)$-p(a_1)$, from Eqs. (1.a)–(1.d) the optimality conditions for an interior solution are equivalent to

$$\frac{\partial \text{prob}(\text{S},\text{F})}{\partial a_1} = \frac{\partial p(a_1)}{\partial a_1}[1-p(a_2)] - \frac{\partial C(a_1,a_2)}{\partial a_1} = 0, \tag{3.a}$$

$$\frac{\partial \text{prob}(\text{F},\text{S})}{\partial a_2} = \frac{\partial p(a_2)}{\partial a_2}[1-p(a_1)] - \frac{\partial C(a_1,a_2)}{\partial a_2} = 0. \tag{3.b}$$

That is, the social planner effectively maximizes the probabilities that each firm is the single winner.

2.2. Noncooperative solution

In a competitive R&D setting, firms simultaneously choose research projects in a noncooperative fashion. Let U_{SS} denote the expected payoff to each firm when both firms are successful, let U_{S} denote the payoff to a single successful firm, and let U_{F} be the payoff to the firm that fails (whether alone or jointly with the other firm). It is assumed that $U_{\text{S}} \geq 2U_{\text{SS}} > U_{\text{F}} = 0$.[2] Then, the firms' optimization problems (conditional on the other firm choice) are

$$\max_{a_1} \; V_1(a_1,a_2) \equiv U_{\text{SS}}\cdot \text{prob}(\text{S},\text{S}) + U_{\text{S}}\cdot \text{prob}(\text{S},\text{F}), \tag{4.a}$$

$$\max_{a_2} \; V_2(a_1,a_2) \equiv U_{\text{SS}}\cdot \text{prob}(\text{S},\text{S}) + U_{\text{S}}\cdot \text{prob}(\text{F},\text{S}), \tag{4.b}$$

with first-order conditions (FOCs) for an interior solution being

$$U_{\text{SS}}\frac{\partial \text{prob}(\text{S},\text{S})}{\partial a_1} + U_{\text{S}}\frac{\partial \text{prob}(\text{S},\text{F})}{\partial a_1} = 0, \tag{5.a}$$

$$U_{\text{SS}}\frac{\partial \text{prob}(\text{S},\text{S})}{\partial a_2} + U_{\text{S}}\frac{\partial \text{prob}(\text{F},\text{S})}{\partial a_2} = 0, \tag{5.b}$$

[2] The condition $U_{\text{SS}}>0$ presumes that competition between successful innovators does not dissipate the rent created by the innovation, an outcome that is likely under a variety of market conditions. The condition $U_{\text{S}} \geq 2U_{\text{SS}}$ simply means that a monopoly is at least as profitable as a duopoly.

which yield the firms' best response functions. It can be shown that, because of Assumption 1, $V_1(a_1, a_2)$ and $V_2(a_1, a_2)$ are concave in the decision variables. Hence, the FOCs in Eqs. (5.a) and (5.b) are both necessary and sufficient for a maximum. The (symmetric) competitive market portfolio—the Nash equilibrium, denoted with (a^c, a^c)—satisfies the best response functions of both firms, i.e., it solves Eqs. (5.a) and (5.b). In what follows, we further assume that the problems in Eqs. (4.a) and (4.b admit solutions in the interior of $[0,1]\times[0,1]$.

The following result (Proposition 3 in Dasgupta and Maskin, 1987) then follows (an explicit proof of this result for our model, omitted here, can be found in Bulut and Moschini, 2005).

Proposition 1. *The noncooperative solution consists of projects that are too highly correlated, relative to the social optimum. That is,* $a^c < a^*$.

2.3. Comparative statics

To extend the analysis of Dasgupta and Maskin (1987) with the aim of considering multiple modes of protection, we first note that the competitive (Nash equilibrium) solution depends on the relative magnitude of the payoffs U_{SS} and U_S. More specifically, the following preliminary result will be useful (see Bulut and Moschini, 2005 for details on these standard comparative statics effects).

Lemma 1. *Let* (a^c, a^c) *denote the symmetric Nash equilibrium of the noncooperative (interior) solution. Then* a^c *is increasing in* U_S *(the payoff to a single successful firm) and it is decreasing in* U_{SS} *(the payoff when both firms are successful). Furthermore, if* $R \equiv U_{SS}/U_S$, *then* a^c *is decreasing in* R.

3. The model with patents and trade secrets

We continue to assume that research outcomes are common knowledge, but now extend the one-shot game discussed earlier by the addition of an IPR subgame. What were exogenous payoffs in Dasgupta and Maskin (1987) are made a function of IPR choices along the lines of Denicolò and Franzoni (2004). Specifically, the winner of the research stage chooses between a patent and trade secret protection. The patent provides $T<\infty$ periods of absolute monopoly. If we interpret the social payoff B as the present value of a perpetual flow of benefits, then $B = \int_0^\infty be^{-rt}dt = \frac{b}{r}$, where b is the per-period benefit and r is the discount rate. Assuming, for simplicity, that the patentee can capture the entire social surplus while the patent is valid, a patent lasting T periods provides a return of $\int_0^T be^{-rt}dt \equiv \delta(T)B$, where $\delta(T) \equiv (1-e^{-rT})$.

Unlike the case of patents, the temporary monopoly offered by trade secrets is of random duration and ends whenever other firms independently invent or reverse engineer the invention. Assuming an exponential distribution for the duration of the trade secret, the payoff in this case can be written as $\int_0^\infty be^{-(z+r)t}dt$, where the hazard rate z indexes the difficulty of concealing the invention. Thus, the reward from trade secret protection can be written as $y(z)B$, where $y(z) \equiv r/(r+z)$. The loser of the R&D race gets zero payoff from its research activity. Furthermore, without loss of generality, in what follows we normalize the social benefit of success to $B=1$.

3.1. Equilibria in the IPR subgame

To find the subgame perfect Nash equilibrium of our extended R&D game, we begin with the subgames that start when R&D outcomes become known. For the event (F, F), where both firms fail to

Table 1
Parametric domain, equilibrium IPR strategies and outcomes with both patents and trade secrets

Parametric domain	Event (S, S): both firms are successful			Events (S, S) or (F, S)
	Equilibrium profile(s)	Type of equilibrium	Equilibrium payoff(s)	Winner's payoff
$\delta(T) \geq \gamma(z)$	(Patent, Patent)	UNE-1	$\frac{1}{2}\delta(T)$	$\delta(T)$
$\gamma(z) > \delta(T) \geq \mu\gamma(z)$	(Patent, Patent)	UNE-1	$\frac{1}{2}\delta(T)$	$\gamma(z)$
$\mu\gamma(z) > \delta(T) > \mu\gamma(z)/2$	(Patent, Patent)	UNE-2	$\frac{1}{2}\delta(T)$	$\gamma(z)$
$\mu\gamma(z)/2 \geq \delta(T)$	(Patent, Patent)	MNE	$\frac{1}{2}\delta(T)$	$\gamma(z)$
	(Secret, Secret)		$\frac{\mu}{2}\gamma(z)$	
	(σ^*, σ^*)		$\frac{\mu\gamma(z)\delta(T)}{2(\mu\gamma(z)-\delta(T))}$	

UNE-1 = Unique Nash equilibrium (Pareto efficient); UNE-2 = Unique Nash equilibrium (prisoner's dilemma); MNE = Multiple Nash equilibria, where (σ^*, σ^*) denotes the mixed strategy equilibrium.

innovate, the game ends with both firms obtaining a zero payoff. For the events (S, F) and (F, S), on the other hand, only one firm succeeds. The successful firm can obtain payoff $\delta(T)$ with patenting and payoff $y(z)$ with trade secrecy, and thus the IPR choice depends on $\max\{y(z), \delta(T)\}$. The unsuccessful firm gets zero payoff. For event (S, S), when both firms are successful with the invention, we have a simultaneous-move game for the firms' choice of IPR protection mode. We assume that if both firms try to patent, each has an equal chance of getting priority (but, in the spirit of a winner-takes-all contest, the successful patentee can exclude the other firm). If both choose trade secret protection, they will engage in a duopoly competition as long as the secret does not leak out. If one of the firms decides to keep secret, we assume that it will be excluded whenever the other inventor decides to patent (the patenting firm gets the full reward).[3] Finally, the parameter $\mu \in (0, 1)$ captures the profit dissipation of competition that arises when both firms use trade secrets (e.g., the joint profit of duopolists is lower than that of a monopolist). The equilibrium for this case is characterized by the following:

Lemma 2. *In the IPR subgame that follows the event (S, S): (i) For $\delta(T) \geq \mu\gamma(z)$ there is a unique Nash equilibrium where both firms patent, and this equilibrium is Pareto efficient. (ii) For $\mu\gamma(z) > \delta(T) > \mu\gamma(z)/2$ there is a unique Nash equilibrium where both firms patent, and this equilibrium is of the prisoner's dilemma type. (iii) For $\mu\gamma(z)/2 \geq \delta(T)$ there are two pure-strategy equilibria—(Patent, Patent) and (Secret, Secret)—and a mixed-strategy equilibrium (σ^*, σ^*), where $\sigma^* = [\delta(T)/(\mu\gamma(z) - \delta(T))]$ denotes the probability assigned to the pure strategy "Secret".*

Table 1 summarizes the equilibrium outcomes of the IPR subgame. Note that, as μ decreases towards 0 (that is, the market competition between firms when both hold the trade secret dissipates profits more and more), the range of the parameter where (Patent, Patent) is the unique Nash equilibrium increases (in

[3] As pointed out by a reviewer, this simplification may neglect the possible implications of prior user rights doctrines of patent law (see, e.g., Denicolò and Franzoni, 2004).

particular, the range for UNE-1 increases and that for UNE-2 decreases). Furthermore, the range of parameters where multiple equilibria arise also shrinks.

3.2. Impact on firms' research paths

By introducing alternative modes of protection, we have made otherwise exogenous payoffs a function of IPR choices. Once the payoffs associated with the equilibria discussed in Lemma 2 are obtained, the reduced game has the same structure as the one in Dasgupta and Maskin (1987). We can then exploit the comparative statics analysis that we discussed in Lemma 1 to obtain comparisons of alternative IPR environments. Specifically, we can conclude the following.

Proposition 2. *Whenever $\mu \in (0, 1)$ and $\delta(T) < \gamma(z)$, the availability of trade secret protection, in addition to patents, leads firms to select actions that decrease the correlation of R&D outcomes, as compared with the patent-only environment.*

Proof. The equilibrium payoffs of the IPR subgame, under the patents-plus-trade-secret environment, are summarized in the last two columns of Table 1. In contrast, recall that, in the patents-only environment, the expected payoff to the firms for the event (S, S) is $U_{\mathrm{SS}}^{\mathrm{P}} = \frac{1}{2}\delta(T)$ and the payoff to the successful firm for events (S, F) and (F, S) is $U_{\mathrm{S}}^{\mathrm{P}} = \delta(T)$. Hence, for the parameter range $\gamma(z) > \delta(T) > \mu\gamma(z)/2$, the availability of trade secret protection (in addition to patents) increases the winner's payoff for the events with only one successful firm while it leaves unchanged the payoff for the event when both firms succeed. By Lemma 1, therefore, the equilibrium correlation level must decline (i.e., the Nash equilibrium action a^{c} increases. For the parameter range $\mu\gamma(z)/2 \geq \delta(T)$ the payoff associated with the event (S, S) depends on which particular equilibrium one considers. For the (Patent, Patent) equilibrium the outcome is exactly as for the $\gamma(z) > \delta(T) > \mu\gamma(z)/2$ parameter range. For the (Secret, Secret) equilibrium, the equilibrium payoffs under patent-plus-trade-secret environment is $U_{\mathrm{SS}}^{\mathrm{P+S}} = \frac{\mu}{2}\gamma(z)$ for event (S, S) and $U_{\mathrm{S}}^{\mathrm{P+S}} = \gamma(z)$ for the events with a single successful firm. Then, $\left(U_{\mathrm{SS}}^{\mathrm{P+S}}/U_{\mathrm{S}}^{\mathrm{P+S}}\right) = \frac{\mu}{2} < \left(U_{\mathrm{SS}}^{\mathrm{P}}/U_{\mathrm{S}}^{\mathrm{P}}\right) = \frac{1}{2}$ because $\mu \in (0, 1)$, and hence the results of Lemma 1 apply to this domain as well. Finally, the mixed-strategy equilibrium payoff under event (S, S) cannot exceed that of the equilibrium (Secret, Secret), and therefore we again conclude that $\left(U_{\mathrm{SS}}^{\mathrm{P+S}}/U_{\mathrm{S}}^{\mathrm{P+S}}\right) < \left(U_{\mathrm{SS}}^{\mathrm{P}}/U_{\mathrm{S}}^{\mathrm{P}}\right)$. By Lemma 1, therefore, the equilibrium correlation level must decline. □

4. Conclusion

We have shown that the availability of multiple modes of IPR protection—specifically trade secrets and patents—can affect the equilibrium outcome of competitively chosen diversification efforts in a parallel research contest and it can push the correlation among R&D projects towards the social optimum. The root of our finding is that the presence of trade secrets in addition to patents provides an additional incentive to be the sole winner, thereby driving firms' R&D choices closer to the social optimum for a range of parameter values. Therefore, considering a generic winner-takes-all contest (with an implicit single mode of protection) in studying the correlation level of firms' R&D activities may miss an important institutional feature and may overestimate the bias inherent in competitive parallel research contests. Furthermore, the strength of trade secret protection may vary across technology fields because it depends crucially on the feasibility of reverse engineering (admissible under trade secret protection).

Hence, in some fields at least, the availability of trade secret protection may be critical for the nature of competitively chosen R&D activities and may beneficially affect firms' R&D diversification efforts.

References

Anton, J.J., Yao, D.A., 2004. Little patents and big secrets: managing intellectual property. RAND Journal of Economics 35 (1), 1–22.

Bulut, H., Moschini, G., 2005. Parallel research, multiple intellectual property right protection instruments, and the correlation among R&D projects. CARD Working Paper 05-WP 404. Iowa State University. September.

Cohen, M.W., Nelson, R.R., Walsh, J.P., 2000. Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or Not). NBER Working Paper, vol. 7552.

Dasgupta, P., 1990. The Economics of Parallel Research. In: Hahn, Frank (Ed.), The Economics of Missing Markets, Information and Games. Oxford University Press, New York, NY.

Dasgupta, P., Maskin, E., 1987. The simple economics of research portfolios. Economic Journal 97, 581–595.

Denicolò, V., Franzoni, L.A., 2004. Patents, secrets and the first inventor defense. Journal of Economics and Management Strategy 13 (3), 517–538.

Klette, T., de Meza, D., 1986. Is the market biased against Risky R&D? RAND Journal of Economics 17 (1), 133–139.

Scotchmer, S., 2004. Innovation and Incentives. The MIT Press, Cambridge, MA.