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Patents, Inducement Prizes, and Contestant Strategy: Do Patents "Crowd Out" Prizes?

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PATENTS, INDUCEMENT PRIZES, AND CONTESTANT STRATEGY: DO PATENTS "CROWD OUT" PRIZES?

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Abstract

Debate over the merits of patents versus inducement prizes has tended to ignore the signaling roles of patents, and totally ignores the impact of patent signaling on prize contests. This paper asks: How does patent signaling affect the strategic choices of firms considering entering prize contests? First, we consider contests that do not allow patenting, then contests that do. If patenting is not allowed, we argue, patent-holders, both internal and external to the contest, can adversely impact prize contests by claiming prize winner violation of their patents, and suing for damages. The likelihood of such challenges being made can deter entry, particularly in contests requiring large sunk costs. Furthermore, the firm's decision-making process will discriminate against entering prize contests and favor R&D projects with patentable outcomes. Together, these problems may circumscribe any future wider role for prize contests, and limit their major putative welfare advantage: the ability to place prize winning solutions into the public domain. In contests where entrants may patent their inventions, entry is subject to basically the same problems as above (although such contests may carry some advantages as regards contest design). Our overall conclusion is that prize contests are liable to fail due to the lack of potential entrants, particularly as regards entry on the part of larger commercial firms.

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PATENTS, INDUCEMENT PRIZES, AND CONTESTANT STRATEGY: DO PATENTS "CROWD OUT" PRIZES?

1. Introduction

Inducement prizes are increasingly coming into the public eye. For example, over the past two years, three prizes in the United States have attracted wide attention. On October 8, 2005, the robot vehicle "Stanley" was the first to race across the Mohave Desert and cross the finish line, to the cheers of its Stanford University team. Stanley won the $2 million prize sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA), the result of a U.S. Congressional mandate to ensure that at least one-third of all future U.S. military vehicles should be unmanned. The winning entry had to navigate 131.6 miles through the desert on rough, winding roads and dry lake beds filled with overhanging brush and man-made obstacles. Then it had to traverse a narrow 1.3-mile mountain pass with a steep drop-off, and proceed through three tunnels designed to knock out its GPS signals. Another well publicized contest was also settled in the Mojave Desert. In late October 2004, Commander Brian Binnie landed *SpaceShipOne*, winning the $10 million Ansari-X Prize, awarded to the first private company to fly a vehicle with a payload equivalent to a pilot and two passengers 100 kilometers into space and back again, twice, within two weeks. The third prize was introduced the same year. The U.S. National Academy of Engineering and the Grainger Foundation announced an award of $1 million for an efficient low cost means of removing arsenic from drinking water, a source of thousands of deaths in the Third World.[3]

The reasons for this increasing interest in (*ex ante*) inducement prizes might be linked to a discontent with the use of existing intellectual property rights incentives. Boldrin and Levine

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[3] Other prizes claiming the spotlight at present: a Methuselah Mouse Prize, a prize to encourage research in the problem of aging. At issue in this contest is the ability to keep a laboratory mouse (*Mus musculus*) alive for longer than the mouse of any other contestant; the establishment of Eli Lilly's Innocentive, a company to elicit new ideas for solving problems in biology, chemistry, bio-chemistry, and materials science; GOOGLE®'s annual prize for a scalable computer program "that does something interesting;" a $100,000 Loebner prize for the invention of a computer whose responses to questions cannot be distinguished from a human's; the Foresight Institute's $250,000 prize to spur scientific and technical progress in nanotechnology; and proposals by the World Health Organisation and the World Bank to use prizes to induce the innovation of vaccines for the Third World. For lists of prominent earlier prize contests, see Masters, 2004, pp.37-39, and National Academy of Sciences, 2000, pp.

(2002, 2005), for example, critically analyze patents in terms of their social welfare and anti-competitive properties. Quah (2003, 2002a, 2002b) criticizes patents in terms of efficiency and in light of what he terms "the weightless economy." There has also been a renewed interest in open innovation systems (including open source software) and their potential to stimulate more efficient, less costly innovative efforts (e.g. Von Hippel, 1985). Moreover, there is also a growing realization that inducement prizes might possess some desirable properties (Davis, 2004, Davis and Davis, 2006).[4] A not atypical evaluation was made by the U.S. National Academy of Sciences in a report (1999) to the U.S. Congress. Here, prizes were seen to:

- Attract "a broader spectrum of ideas and participants" towards solving an idea, and [seen in contrast to procurement contracts] reduce "costs and other bureaucratic barriers to participation by individuals or firms";
- Shift risk from sponsors, who may know little about the problem to be solved to the prize contestants, who know more;
- Have a potential to leverage the financial resources of the sponsor; and
- Have a "capacity for educating, inspiring, and occasionally mobilizing the public with respect to particular scientific, technological and societal objectives (all quotes p. 1)"

To such a list can be added further advantages. Prizes can reward innovative work where no other incentives exist. This is particularly true for certain creative enterprises, such as original architectural solutions to building problems (prize competitions are widespread in architecture). Prizes also have a "knock on effect" for their sponsors' reputations, and can promote advertising objectives as well as stimulate innovation. In the words of Peter Diamandis, the original sponsor of the AnsariX prize, inducement prizes are a "fantastic, low risk, high-return mechanism. If no one succeeds, you do not have to shell out any money. And if someone does, you've automatically backed the winner (quoted in O'Reilly, 2003, p. 54)."

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[4] *Ex post* prizes where the size of the prize reward is decided *after* a winner is determined are not considered in this context.

A final economic argument for prizes is that they provide more efficient incentives for invention and innovation than patents. The patent system represents a market-based "bargain," providing limited monopoly rights for inventions in return for the publication of the patent document. Accordingly, the successful applicant can charge monopoly prices for consumer utilization of the innovation. "Pure" prize contests, which are administratively conferred awards for solutions to specifically identified commercial or social problems, confer no such monopoly rights. The winner earns no more than the prize itself. As a result, the deadweight welfare loss associated with the patent system no longer exists.[5]

Given these enthusiastic endorsements, why are inducement prizes still relatively infrequent? Existing work on patents and prizes does not address this issue. Beginning with Wright's (1983) classic article on patents, prizes and R&D contracts, studies have focused almost entirely on the properties by which one system is putatively superior or inferior to the other. In comparing the different incentive systems, many recent analyses view prizes sympathetically. In Gallini and Scotchmer's (2002) review of economic thought on R&D incentive schemes, prizes are found to have some appealing properties. Shavelle and Van Ypersele (2001) argue "that intellectual property rights [patents and copyrights] do not present a fundamental social advantage over reward systems, and that an optional award system in which innovators choose between rewards and intellectual property rights is superior to intellectual property rights." According to Maurer and Scotchmer (2003), "there is no single best mechanism for supporting research. Rather mechanisms can only be compared within single specific environments." De Laat (1996) contends that in cases where governments have asymmetric information about markets for innovation, they will systematically begin to prefer prizes to patents in their regulatory R&D roles.

Other scholars investigate how a patent system might be modified to take on some of the attributes of a prize contest. The most well-known example is Kremer's 1997 proposal for patent buy-outs, which has led to calls for the implementation of such schemes in the search

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[5] As can be seen, existing research on patents and prizes assumes (if often implicitly) that these incentives are geared to different markets. It is a key contention of this paper that due to the increasing proliferation of patents, and the use of broader and broader patents (e.g. Jaffe and Lerner, 2004), these incentive systems typically do not operate independently of each other in different markets, but jostle for space in the same markets. (See also footnote 10 on the use of technological trajectories.)

for new vaccines, and to encourage technical progress in tropical agriculture (Kremer and Zwane, 2002). But the possible negative effects of patents on prize contests remain unexplored.

In this paper, rather than comparatively examine the properties of patent incentives – and prize incentives – in isolation, we ask: How does the patent system affect inducement prize contests? We focus on one particular aspect of this broader question, namely: How does this interaction affect the innovating firm's strategic choices? Could it be that the patent system effectively "crowds out" inducement prizes? To our knowledge, this paper is the first to raise these questions.

The paper is structured as follows: In the following section, we review the empirical evidence on patent signaling underpinning our arguments. Of importance here is how patent-holders can use their patents to block firms from entering the market. Two patent blocking strategies are discussed: patent bargaining chips, and patent fences. While this survey evidence focuses on the effect of the patent blocking activities of one firm on other firms, we argue that such blocking can also have an impact on contestant behavior in prize contests.

In Sections 3 and 4, we discuss the impact of patenting on prize contests where contestants are not allowed to patent their entries. In Section 3, we examine the decision to participate in a prize contest from the point of view of the potential individual entrant. Firms with extensive patent portfolios, we argue, will affect the strategies of prize contestants, particularly the choice of whether or not to enter the contest.[6] Furthermore, in most industries, it is next to impossible to have full knowledge of all patents relative to one's innovative activity. Players must be aware of the possible existence of "submarine" or sleeper patents. This is because of the hold-up potential they present to other players both within and outside the contest, which might affect the firm's probabilities of either winning the prize, or collecting the full reward from its winning efforts. Our analysis builds on a game of imperfect information where a cash prize substitutes for patentable rights (i.e. the winning

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[6] In the approach outlined in this paper, whether firms with large relevant patent portfolios are within or outside a prize contest is only significant in the case of what are termed "closed prize contests," where potential contestants use their patent portfolios to signal competence to prize sponsors in order to enter the prize contest (See Section 3). In the game presented in Section 4, it is irrelevant whether firms with potentially blocking patents are in the contest concerned, or outside it.

prize becomes freely available to others). In this simple model, nature determines whether a prize contestant's innovative activity impinges on another player's patent rights or not. After presenting the model, we will examine the negative incentive effects of such a game on potential prize contestant incentives by using a simple numerical example of the logic involved.

In Section 4, we consider the role of prize contests where entrants, while not allowed to patent in this particular contest, are otherwise engaged in obtaining as wide and full patent protection as they can (such as participating in patent races, building patent fences, and the like). In contrast to Section 3, where the unit of analysis is the firm as player, in Section 4, the unit of analysis lies within the firm, at the level of the project management selection process. Given the competition for technical and R&D resources within the firm, it may be difficult for the firm to reorient its efforts towards prize contests. As a result, prize contests may be reserved for innovators not engaged in ongoing patenting activities. While patents may have a greater effect in contests impinging on the patent rights of players in "complex industries" (Cohen, Nelson, and Walsh, 2000) our logic arguably applies to players in "discrete industries" as well (for definitions of these industries, see Section 2). In the literature, a major putative advantage of prize contests is the avoidance of welfare losses imposed by the patent monopoly bargain. Our findings demonstrate that this advantage, in practice, may be difficult if not impossible to realize.

In Section 5, we look briefly at prize contests where patents are allowed, and attempt to identify the problems that can occur. Such contests may be superior in some respects to contests where patenting is disallowed, since a firm's extant patent-holdings can affect sponsor choices as regards the eligibility of would-be entrants, who must demonstrate their qualifications to compete. This can be interpreted as a classic signaling game where potential participant agents signal their competencies to the principal (prize contest sponsor) in order to enter the contest. Furthermore, if engaged in such a prize contest, a firm can supplement its income by patenting its inventions along the way and licensing out the rights, since the prize award per se may be insufficient to cover the firm's investment costs. Clearly, however, by definition, such contests do not avoid the deadweight welfare losses due to patenting that characterize the "pure" prize contests described above. Moreover, we demonstrate, entry is

subject to largely the same problems as for contests without patenting options. Section 6 concludes and further elaborates our findings.

2. Patent signaling: Empirical background

The conventional rationale for the patent system is that to give firms the incentive to invest in R&D, they must be able to legally exclude others from making, selling or using the invention for a limited period of time (now standardized to twenty years). In practice, particularly in recent years with the proliferation of patents, it has become clear that a firm's patenting choices are to a large degree influenced by the patenting activities of other market players. Existing patent-holders, by signaling the nature and strength of their patent portfolios, can force new (or would-be) patent-holders to enter into bargaining negotiations whereby the value and scope of their intellectual property rights may be redefined.

Of particular import is the *ex post* role of patents in firm licensing choices, a point made by Penin (2003), among others. In the words of Von Hippel, describing his industrial experiences with patents:

> Firm A's corporate patent department will wait to be notified by attorneys from firm B that it is suspected that A's activities are infringing B's patents. Because possibly germane patents and their associated claims are so numerous, it is in practice usually impossible for firm A – or firm B – to evaluate firm B's claims on their merits. Firm A therefore responds – and this is the true defensive value of patents in industry – by sending B copies of "a pound or two" of its possible germane patents with the suggestion that, although it is quite sure that it is not infringing B, its examination shows that B is in fact probably infringing A. The usual result is cross-licensing, with a modest fee being paid by one side or the other. Who pays, it is important to note, is determined at least as much be the contenders' relative willingness to pay to void the expenses and bother of a court fight as it is by the merits of the particular case (Von Hippel, 1988, p.53).

"Although patents still perform their traditional function of safeguarding against outright theft and infringement of these firms inventions," state Hall and Ham in their 1999 survey on patenting in the semiconductor industry, "the classical role of patents seems to be dominated by [a] broader use of patents that enable …firms to avoid being excluded in a particular field of use, to obtain more favorable terms to their licensing agreements, to safeguard against

costly patent litigation, or to gain access to external technologies on more favorable terms of trade (1999, p. 5)." Key here, again, is the use of patents and cross-licensing to enable firms to extend their technological reach beyond their fields of core technological competence into related domains of R&D and innovative activities.

Similarly, Cohen, Nelson, and Walsh (2000) find that this "legal bargaining chip" strategy applies across industries, although somewhat differently for what they call "complex" product industries, such as telecommunications and semi-conductors (industries that rely on multiple sources of innovation for product patents) than for "discrete" product industries (such as chemicals), where patent validity is easier to ascertain. Firms in the first category tend to use blocking patents in a "block to play" strategy where the ultimate intent is to leverage patents as bargaining chips in *ex post* licensing negotiations. Firms in discrete product industries leverage patents in a "block to fence" strategy, with the intent of creating an unassailable patent barrier around one or more core patented technology (Cohen, Nelson, and Walsh, 2000, pp. 21-23). Nor are these strategies confined to the United States. For example, a similar survey has found that patent bargaining chip leveraging is more common in Japan than in the U.S. (Cohen, Goto, Nelson and Walsh, 2002).

A major point in the Cohen, Nelson, and Walsh (2000) paper is that firms patent not so much because patents provide the necessary and sufficient protection needed, but because they provide protection on the margin when combined with other appropriability strategies, especially secrecy and lead-time. It is our contention that this area deserves further investigation. One potential side effect that patents may have, and the focus of this paper, is to contribute to prize contest failure.

Are prize contests exempt from the impingement of patent blocking strategies simply because these contests take place in a slightly different context? (This is the assumption underlying all existing studies on prizes, to our knowledge). Our paper takes issue with that assumption. While there is no survey evidence on this question, we feel that blocking patents can indeed influence the outcome of seemingly unrelated prizes.

An anecdotal example of the use of patent signaling to potential contestants is provided by the Granger Challenge, mentioned in the introduction to this paper. Its sponsor posted a $1 million prize for a low-cost, efficient method to remove arsenic from drinking water in Third World countries. No sooner had the prize been announced than a web blog declared that in searching for a solution to this problem, contestants could refer to a series of patents. These included US patent 6,821,434 on the use of magnesium oxide, magnesium hydroxide, calcium oxide, or calcium hydroxide, and US patent 6,706,195 the use of a highly efficient ion exchange system for removing arsenic from water. Other patent numbers mentioned were US patent 6,461,535, US patent 6,368,510, US patent 6,117,333, US patent 5,908,557, US patent 5,840,194 and US patent 5,182,023 (Gelsing, August 11, 2005). While this kind of information can be an aid to contestants, it can also serve as a signal as to what a successful winner might expect if his solution were deemed to infringe one of the above-mentioned patents.

3. Crowding out I: Prizes without patents: The individual contestant's entry decision

We start by utilizing a simple game with imperfect information. In the absence of a patent system, prize contestants compete for a cash prize, Π by investing I resources. For simplicity, we assume that the probabilities of winning Π are 100 percent. In keeping with games of imperfect information, we assume that moves by nature may reveal a blocking patent held by either a player or non-player, that may plausibly be infringed by an unknowing prize contestant. Should nature reveal a blocking patent, the contestant either exits the prize contest, or pursues one of the following strategic alternatives: enters a license agreement, invents around the patented technology, or invites the patent holder in question to join it in its pursuit of Π. Again for the sake of simplicity, we assume that the lowest cost alternative (of these three strategic options), and therefore the favored option, is represented by $C_{alternative\ strategy}$.[7]

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[7] By constructing our game in this manner, we assume that the costs of licensing are all incurred in the form of a lump sum at Point 3 on the time line. The reason for this is that the licensee is not guaranteed income from the prize-winning solution, since it may not lead to a marketable invention (if indeed it even wins the prize). Therefore it is in the interests of the owner of the blocking patent to negotiate for a lump sum payment.

The time line of our game (Figure 1) illustrates the sequence of events in decision time and real time: The prize contestant, C, enters/does not enter the contest at point 1. At point 2, nature, N, reveals whether or not a blocking patent exists, which C's choice of prize solution infringes. The probability that such a patent exists is expressed by μ. If nature reveals a blocking patent, the prize contestant has two alternatives. She can either alter her strategy ($C_{alternative\ strategy1)}$, or exit the contest. If nature does not reveal a blocking patent, the contestant need not change her strategy. These alternatives occur at point 3 on the time line. Should the contestant continue developing her innovation, at point 4, nature will reveal with a probability of ω whether or not there is an additional blocking patent. (Note that we assume, for the purposes of simplicity, that probability ω applies to all situations at point 4, irrespective of whether or not the contestant encountered a blocking patent at point 2). The decision-making process then repeats itself at point 5, which leads to the ultimate outcome of the game.

[Figure 1: Time Line – goes about here]

The rationale for two potential blocking patents is forthright. Given the alternatives chosen at point 3, for example, the contestant may choose to invent around the first patent (if this is the least costly alternative), only to discover later that her solution infringes another patent-holder's rights, of which she was unaware at point 3. Similarly, a firm could have taken out a blocking patent in the time span during which the contestant was working on her prize entry, between period 2 and period 4. Finally, a firm with a potential blocking patent at point 2 might decide not to bring suit at that point, preferring rather to wait, so as to be able to hold up the prize contestant at point 4, after the latter had sunk considerable costs into perfecting the innovation. The holder of the blocking patent, by timing his confrontation with the contestant, can hope to maximize the returns to his patent. (This is a point made, most forcibly, by Besen, 2004). Our game is presented in its extensive form, although without payoffs or probabilities, below:

Figure 2 presents the logic of our arguments as a game against nature, the nodes marked "N". The contestant, node "C_1", moves first, either entering or not entering the prize contest. Nature, node "N_1", then moves, revealing whether or not there is a blocking patent. Depending on nature's move, the contestant is confronted either with a blocking patent (node "C_2") or not (node "C_3"). The contestant then chooses her next move, either to implement an alternative strategy ($C_{\text{alternative strategy1}}$: inventing around, licensing, or cooperation, whichever costs less), or to exit. Thereupon nature moves again, revealing whether or not the contestant is confronted with yet another blocking patent (nodes "N_2" or "N_3"). If there is a blocking patent, the contestant, at both "C_4" and "C_7", may choose either to implement an alternative strategy ($C_{\text{alternative strategy2}}$), which enables her to submit her entry, or to exit. If there is no blocking patent, she can deliver her prize submission, unhindered, to the contest judges (nodes "C_5" or "C_6").

A simple numerical example can illustrate the logic of this game. Let us assume the following situation:

$$\Pi = 1000$$
$$I_{contestant} = -800$$
$$C_{\text{alternative strategy1}} = -400$$
$$C_{\text{alternative strategy2}} = -400$$
$$C_{exit} = -800$$
$$\mu = 0.3, \text{ and}$$
$$\omega = 0.25$$

where Π represents the prize, $I_{contestant}$, the investment costs of the prize winning entry, and $C_{\text{alternative strategy1}}$ and $C_{\text{alternative strategy2}}$, the costs of altering contestant prize strategy give a particular blocking patent (either blocking patent 1 or blocking patent 2). We assume that the cost of exit, C_{exit}, is uniformly -800, irrespective of the time line point where the contestant exits, and that probabilities ω and μ represent independent events.

The payoff to the contestant (assuming that she wins the prize) can be represented in the following equation:

$$\pi_{entry} = \Pi - (I_{contestant} + \mu * C_{alternative\ strategy1} + \omega * C_{alternative\ strategy\ 2})$$

The game in extensive form now has the following values:

[Figure 3: Patent-Prize Game II. Extensive Form – goes here]

Referring to the diagram Patent-Prize Game II (Figure 3), it can easily be demonstrated that a potential prize contestant, through the process of backwards induction, would not join the contest. At node C_4, the contestant would choose $C_{alternative\ strategy2}$, since this would yield the higher payoff. Likewise, at node C_7, the contestant would choose $C_{alternative\ strategy2}$. At node C_2, the contestant would prefer $C_{alternative\ strategy1}$, since this would lead to an expected payoff of $-300 = 0.25*(-600) + 0.75*(-200)$, which is higher than the alternative -800 payoff from exiting. Likewise, at node C_3, the contestant would choose to proceed, since this gives an expected payoff of 100 $(.75*200 + .25*(-200)$. At node C_1, the contestant would choose not to enter the contest, since this would lead to an expected payoff of $-20 = .3*(-300) + .7*(100)$. If all contestants made similar calculations, the prize contest would fail due to lack of interest.

Of course, this is not the only outcome of the generalized game. One can choose the nature of probabilities and the size of payoffs and potential losses. Critical here is the size of the required investment and whether it takes the form of a sunk cost. Reducing the values of exit, assuming only a 50 percent chance of contest success, changing the values of μ and ω, increasing or decreasing the value of the prize or the cost of prize submission, will all yield differing outcomes.[8]

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[8] Thus if the loss from exiting is reduced to 200, we get 200 → .3*(-200) + .7*(100) = 10 → risk neutral contestant will invest and enter the contest.

Another objection could be that it is unlikely that nature will move twice, as it does in this game. However, since blocking patents can appear anywhere along the time line and more than once, the contestant (and this paper) must take account of this possibility.

On the other hand, our assumption that the contestant has a 100 percent chance of winning the prize is also unrealistic. A more realistic assumption would be that nature moves only once (at node N_1), and that there is only a 50 percent chance of winning the prize. This will also result in the contestant not entering.[9]

Assuming that the contestant is capable of backward induction, and depending on the values of the various variables, it is likely that she will never enter the contest, which is exactly the point that this simplified example is intended to make.[10]

4. Crowding out II: Prizes without patents: Prizes in the context of the firm's R&D project choices

Let us assume that a firm is engaged in acquiring as many patents as possible in competition with a set of well known firms. Assume a three-division firm, where each division is headed by an R&D manager who must submit project proposals to an R&D/Innovations management committee for approval prior to undertaking the project. The R&D managers signal high competencies, but the quality of their judgment is not fully known to the committee. For simplicity's sake, we assume that two projects (projects A and B) aim at obtaining a series of patents in a given market. The third manager is weighing the merits of a

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[9] If probability of winning is 0.5 and nature moves only once → .3*(-700) + .7*(-300) = -420 → worse payoff.
[10] While we have chosen, in this paper, to focus on the impact of patent signalling on prize contests, the model introduced here could be developed in other directions where prizes are not involved. For example, with recent advances in methods of generating simulation models to predict technological developments, and in the science of patent "mining" and "mapping" (Rivette and Kline, 2000), companies are increasingly able to predict technological trajectories. Such techniques enable them to apply for patents in areas which can be expected to be important in the near future. There can be different ways in which to generate value from these patents, including commercializing the patented invention, but perhaps even more importantly as signals: to attract partners for a future cooperation, or to block other companies from entering the territory. To the degree that techniques for predicting technological trajectories become more fine-tuned and accurate, it would in our game raise the costs of implementing an alternative strategy, and (due to backwards induction) make entry even more unlikely

project with patentable results, project C (with the same aim as projects A and B), as opposed to a potentially prize winning project, project D, where the aim is to enter and win a prize contest. Assume that all the potential projects lie within the firm's core competencies. In making his choice, this third manager must first calculate how the committee will review a potential project D.

First, let us assume that the firm is competing in an industry characterized by "complex" technologies (Cohen, Nelson, and Walsh, 2000), where firms use "block to play" patenting strategies. Here, the third manager might be concerned that the committee would raise the question as to whether the opportunity costs of supporting project D and winning a non-patentable prize might be too high. The committee's rationale would be that "We are engaged in a race with our competitors here. Projects A and B will probably have patentable outcomes. Given that we know our competitors, and have negotiated cross-licensing deals with them in the past, and that our ultimate success in this race is by no means assured, it is worth our while to invest in A and B, because patents from these projects are negotiable. Project D may, on the other hand, lead nowhere in this regard, since the outcome will not be patentable. Furthermore, pursuing project D might lead to future retaliation from our competitors, as they would feel compelled to join the contest so as not to be outdone."

A set of such ad hoc inferences by the committee could lead to the conclusion that projects A and B should receive support, and project D should not. The third manager would reason: "Given that the committee does not fully know my competence in this area, they could interpret my support for project D as mistaken, and ruin my chances for future promotion. Alternatively, even if they do not interpret my advancing project D as a signal of my incompetence, they would still likely refuse support given the advantages of projects with patentable outcomes. In either case, I am better off choosing project C and rejecting project D." The result of this calculation is that the third manager would not advance prize-related project D. He would choose project C, the safer alternative.

More broadly, if the R&D managers of one firm infer in this manner, it is highly likely that the managers of competing firms will do likewise, either from the same *ad hoc* induction, or

by following the signals given off by those deciding not to participate. The probable result would be that no firms join the prize contest.

Now assume that the firm is competing in an industry characterized by "discrete" technologies. We maintain that the third manager, considering projects C and D, would reason in a similar manner. But he would assign the R&D/Innovations management committee a somewhat different set of inferences: "Given that projects A and B will give us the opportunity to "block to protect' our existing patents, and that project D does not, it is too costly to invest in project D." Here too, managers in competing firms would most likely reach a similar inference. Again, the probable result would be that no firms join the prize contest.

5. Crowding out III: Prizes with patents

Thus the fate of any prize system where contestants cannot patent their findings is problematic. But what about contests where patents are permitted? Here, one would sacrifice the welfare benefits inherent in a pure prize system, since entries would be patentable. Would this loss be offset by other types of gains? Arguably, as we will demonstrate below, the outcome of prize contests where patenting is allowed is only marginally different.

For example, in our simple game, if the potential contestant takes out patents at C_1, she does not eliminate a future patent challenge. While she will have a bargaining chip to use in a later challenge, and may reduce her losses should she be challenged by a blocking (or perhaps a submarine patent), she will be still confronted with the costs of applying for and enforcing her patent rights. Countering this disadvantage, patents could give the prize contestant a means of leveraging her efforts towards winning the prize. (Under this scenario, the prize contestant patents a solution necessary but not sufficient to win a prize, and this patent proves so valuable that licensing fees from other firms give the contestant financial leverage and reduces the costs of the prize contest. Yet it is unlikely that the potential prize contestant at C_1 can foresee such a future scenario, or, if such a scenario is foreseen, the size of future licensing revenues). Generally speaking, depending on prize size, costs, and probabilities of a patent challenge, entry into a prize contest will still be a dubious affair.

15

An additional problem is that of patent breadth in relation to existing patents. Assume that a patent holder A has blanketed the most promising innovative technological avenues to winning a prize with patents. In such a case any other potential candidate, B, C or D, will hesitate to enter the contest. While this game is virtually identical to the one discussed in the previous section, the stakes are different, given the possibility of the mutual use of patents as bargaining chips.

Nor is the situation changed if one looks at issues from the perspective of the corporate project management committee. For a contestant to find it advantageous to enter a prize contest, the associated patents should be desirable in and of themselves, for other strategic purposes. Thus a patent taken out to support development of prize winning solution 'x' should be of value to develop product or process 'y'.

One potential benefit of prize contests that permit patenting concerns contest design. For example, prize sponsors frequently design closed contests. To enter, firms must prove their competencies to the sponsors. There are many reasons for such closure. It can reduce transaction costs by limiting the number of contestants, and ease the problems of rendering judgment and awarding. Prize sponsors can eliminate what are perceived to be frivolous entrants. Further, an element of closure is necessary even if the contest is not formally closed. For example, contests with specific rules will have to vet contestants to ensure that these will abide by the rules of the contest. Finally, closure can limit the contest to major contenders with the economic resources to see the winning solution through its further refinement, commercial development and initial marketing stages, stages beyond the resources of smaller potential entrants. (The disadvantages of this, of course, would be to exclude from consideration small companies that invent promising products and license out the rights to larger firms.)

Here, the role of patents can be illustrated as a game of asymmetric and imperfect information. Assume that there are two types of entrants to a prize contest. One player type is imperfectly informed about his chances to win the prize, and therefore has a skewed probability assessment of his chances of winning. The other player type, while

asymmetrically informed, has a realistic notion of his chances for success. Within each type, players may either be patent-holders, or not. The only manner in which a prize sponsor can discriminate between the two is through his interpretation of their signals. A vital signal would be a patent portfolio closely related to the means by which the potential contestant proposes to solve the prize problem. Two outcomes are possible.

Firstly, the sponsor could conclude that both patent-holders and non-patent-holders are equally likely to be mistaken in their beliefs that they could win the prize. By the passive conjecture criterion, the sponsor would then admit both patent-holder and non-patent-holder into the contest. There is a pooling equilibrium. Pooling equilibria would also occur if the sponsor attached little value to the use of existing patent portfolios as a sorting mechanism, believing that the more contestants, the better.

Alternatively, the sponsor, reading the signals sent him, could conclude that patent holders have a more accurate notion of the probabilities of winning the prize. Such contestants would be less likely to make an error and apply for contest entry. In this situation, the sponsor would accept all players with relevant patents in the field (or related fields), and exclude other players, as there would be an increased likelihood that these would commit errors in applying. This would be a separating equilibrium.

The key factor here would be the weight prize sponsors place on patent signaling as a sign of competence. Complicating sponsor evaluation would be assigning values to various patent portfolios. Determining which portfolios contain valuable patents, and which contain invalid or worthless patents, could entail substantial sponsor costs. Yet lack of such controls could lead to false signaling by contest entrants, who misrepresent or otherwise exaggerate their competence. Quite likely, however, there is a sponsor predisposition towards the separating equilibrium scenario described here. Entrants showing competence through displaying relevant patent portfolios will likely be preferred.[11]

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[11] In practice, the degree to which prize sponsors actually utilize patent signaling as a sorting mechanism is doubtful. It is perhaps important in competition for government R&D contracts. But for prizes, other sorting mechanisms seem to be used. Two of these are limiting competitors to those of a particular nationality and the use of pre-qualification contests, preliminary contests which sort out the more competent entrants from their less competent competitors on the basis of their ideas, design and/or prototype performance. Winners from the pre-qualifications alone can compete in the final prize competition. Both of these sorting mechanisms were used

6. Concluding remarks

In this paper, we have argued that the impact of patent signaling on prize contests may circumscribe any future wider role for prize contests, and limit their major putative welfare advantage: the placement of prize-winning solutions into the public domain. In contests where patenting is allowed (with the associated deadweight welfare losses associated with patenting), the entry problems, we found, resemble those in contests without patenting. Patent signaling, however, can have some benefits in relation to contest design. All in all, we conclude, prize contests are liable to fail through the lack of potential entrants. Both for contests that allow patenting, and those that do not, patents "crowd out" prizes. Logically, firms capable of backwards induction will not find it in their interests to enter prize contests.

This conclusion is supported by the anecdotal evidence, which suggests that prize contests do not, in fact, attract the interest of commercial firms, but are dominated by enthusiasts – "mom and pop" organizations – lured by other than purely economic interests. For such organizations, considerations such as the potential existence of blocking patents, and project pipeline decision-making, do not weigh heavily. The successful contests described in the introduction were dominated by teams of university academics and/or professional engineers working in their spare time. Some may be sponsored by commercial firms, but this sponsorship seldom involves any technology transfer or other than financial commitment.

For example, competition for the DARPA 131.6 mile robot Mohave prize attracted no fewer than 43 teams. A majority of these were from university engineering faculties. Stanford took first prize with "Stanley". The next two of the four "winners" that finished within the ten hour time frame, named "Sandstorm" and "Highlander," were backed by Carnegie Mellon. The fourth finisher, "Kat5" was backed by a Tulane University team sponsored by an insurance company Gray Insurance. Other entrants read like a "who's who" of U.S. engineering schools (among the 20 other university teams were Cornell, Virginia Tech,

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in the DARPA contest mentioned in this text. Another criterion which has been used is market size. (This criterion was the basis of a 1991 US Environmental Protection Agency 'Golden Carrot'/SERP prize program promising an award of $30 millions to the white ware firm producing the most energy efficient refrigerator).

Auburn, Tulane, and Ohio State). All of the non-university teams, with names such as "Overbot" and "Team Banzai," consisted largely of engineers working for other firms, but who dedicated their free time to the prize competition. Firms associated with DARPA prize teams were (1) small, (2) essentially team sponsors, (3) contributing the vehicles or computer programs involved, or most often all three of the above.

Similarly, 22 of the 23 "firms" entering the Ansari X Prize competition were teams organized by engineering enthusiasts to win precisely that prize. With the exception of the Scaled Composites, the eventual winner, these were largely "mom and pop" organizations. And even Scaled Composites might not have been successful had it not patented the technologies involved and raised necessary seed money through licensing arrangements with Mojave Enterprises. While the names of all the contenders for the Grainger Prize for the elimination of arsenic in drinking water have not been made public, the leading designs in contention are those developed by university researchers. Two of the more promising are a $16 sand, brick chips, gravel and iron filter design developed by the engineering faculty of MIT, and a $35 "three bucket sand and iron system" designed by researchers from George Mason University in Virginia, Wagner College in Staten Island in New York, and the University of Dhaka in Bangladesh.

While these three contests are a very small sample, we believe that they are likely to be representative of inducement prize contestants in general. Prize contestants are unlikely to include Fortune 500 firms with large patent portfolios. But is it sufficient that prize contests are limited to academic teams? Firms that back such teams reap important reputational rewards (their logo can be featured on the winning entry, for example). But they pass on the risk of possible patent infringement suits to the contestants themselves, as well as the risks of not being able to patent the results at all due to prior patents covering the invention. Academic research teams, by definition, do not possess the resources of large firms to determine *ex ante* whether or not their inventions might be infringing other patents. No studies, to our knowledge, have investigated what happens to prize-winning academic teams who run into these problems. It could provide an area for interesting future research.[12]

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[12] An important additional caveat to our arguments is that participants in prize contests can reap valuable benefits from entering, even if they do not win the prize. Prize-related investments are not necessarily sunk. To the degree that these investments can be put to alternative uses, a company might find it worth entering a prize

Moreover, when prize winning results are published, they can never be patented. This is because the invention cannot fulfill the strict criterion of patentability in the patent law that the invention must be novel. As a result, socially valuable ideas may languish, since no firm is willing to proceed to commercialize them without patent protection. On the other hand, before the prize is published, the contestant might seek to keep the valuable knowledge generated secret. But suppose this knowledge leaks to a competitor? The competitor might then be able to patent the discovery, and the contestant would find herself licensing her own innovation! These issues could all be fruitfully addressed by future research.

A potential solution to the problems outlined in this paper may lie in Kramer's 1997 proposal of patent buy-outs substituting for fixed prizes. Here, the value of a patented innovation would be determined through an auction, and the patent bought out by the prize sponsor at the auction pre-determined price. Yet while this proposal is appealing, and while it has been the subject of several elaborations (see for example Shavell and Van Ypersele, 2001 and Llobet, Hopenhavn and Mitchell, 2000), its practicality has yet to be proven. While the organization of the details of the patent auction may be difficult, no less difficult will be determining some of the variables discussed in this paper: the validity of the patent involved and the subsequent inability of the prize winner to use the patent as a bargaining chip in its dealings with its technological rivals. While one can claim that an auction should "winkle out" invalid patents, the potential winner's inability to use the patents involved as bargaining chip to subsequently improve their licensing position can lead to contestant's eschewing the option of entering the contest in the first place.

Another possible solution would be to increase the size of the prize to make entry more profitable. The Ansari X prize, for example, was worth $10 million; Scaled Composites paid twice that amount to develop its winning entry. Had the company been able to predict this, might it have entered the contest to begin with? The main problem with this solution is that

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contest anyway, at least temporarily. Another advantage of entering prize contests would be to enjoy the associated reputational benefits, particularly in the case of worthy causes such as removing arsenic from drinking water in the Third World. Companies could feature this in their advertisements, to attract socially conscious consumers. University administrators could leverage the publicity to attract extra students, and university researchers could find it an important selling point in applying for research grants.

due to asymmetric information, it can be very difficult to determine how large the prize should be. If the sum offered is too great, it will wastefully induce excess effort in the area of the prize, diverting innovative resources from more productive uses, creating another form of deadweight welfare loss. Other disadvantages of the prize system, including the possibility that the invention might have been made anyway (without the prospect of the prize), and the problem of bias in the selection process, will only be enhanced if the prize sum is set too high.[13] And as emphasized above, there are other benefits to participating in prize contests beyond the size of the prize.

Finally, our arguments clearly have relevance for the continuing debate on the need for patent reform (see for example, Thurow, 1997, Jaffe and Lerner, 2004). Too many patents are being taken out, these scholars argue, and the quality of issued patents is not good enough. As a result, the current patent system may function more to block innovation rather than to promote it, as was its original rationale. Our paper offers a further reason for reform of the patent system. If the arguments in this paper are convincing, and if the benefits of prizes are as important as argued in most studies (cited in the Introduction), then the best way to create "room" for an effective prize system would be to reform the patent system. Suggestions include raising the criteria of patentability (thereby reducing the number of patents), shortening the patent term (thereby putting the technology into the public domain sooner), narrowing the acceptable breadth of patent claims, or a greater use of compulsory licensing, which might be applicable with regard to socially valuable technologies that had won a prize but could not be implemented because they were blocked by a patent.

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[13] For reasons of space, we have not fully considered the impact of the welfare costs of the prize system in this paper, given our specific focus on how patent signalling can affect prize contest entry decisions.

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Figure 1: Time Line: Prize and Patents Game

| 1	2	3	4	5
Contestant C either enters the prize contest or does not enter (exit)	Nature (patent holder) reveals/does not reveal whether a blocking patent covers the field of C's prospective innovative activity	Depending on patent validity C either exits the prize contest or adopts an alternative strategy to continue (licensing, inventing around, or cooperating with the patent-holder).	Nature (patent holder) reveals/does not reveal another blocking patent	Depending on patent validity and litigation costs, C either adopts an alternative strategy (enabling her to proceed to submit the prize winning solution to the sponsoring committee), or exits

Figure 2. The Patent-Prize Game: Extensive Form
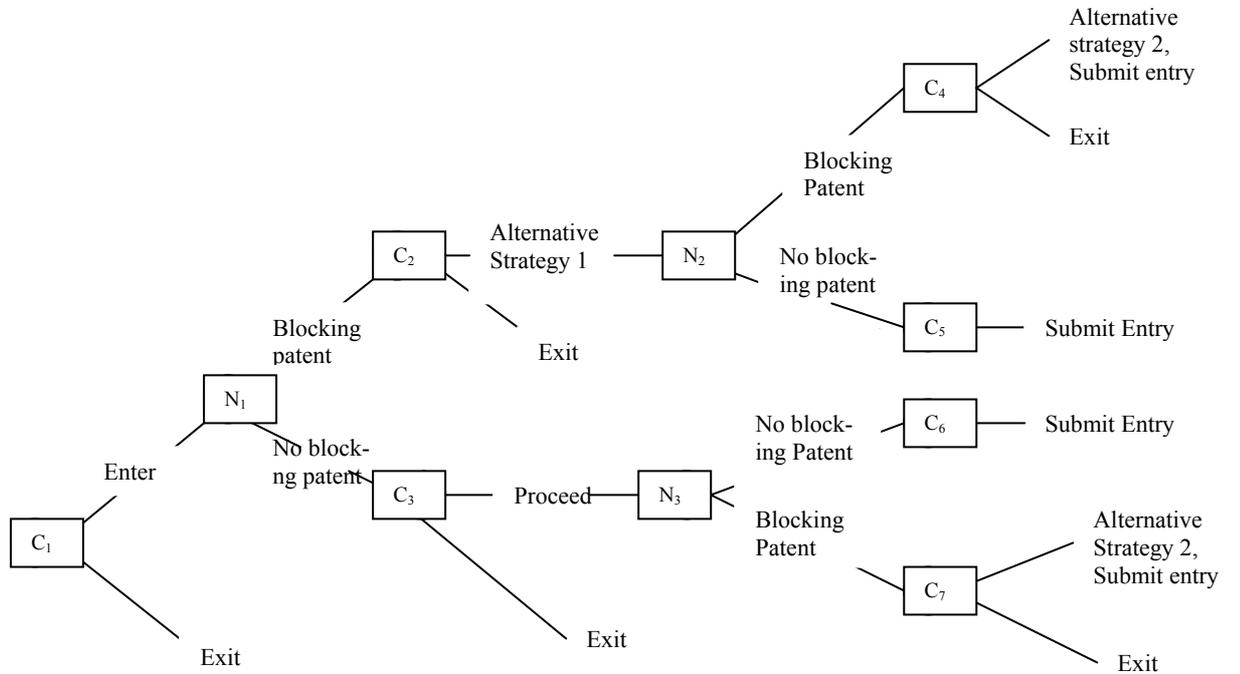
Figure 3: The Patent-Prize Game II: Extensive Form with Pay-offs