Bridging the Science to Market Gap: Academic Entrepreneurs and the Role of Patents

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Abstract

Warning: This is an extremely prelimary version. It is closer to 'Joyceian stream of conscience' than standard 'academic' writing. Don't even think of quoting from it. All comments welcome.

1 Introduction

Policy makers are frequently concerned with the gap between the scientific breakthroughs of universities and governmental research institutions on the one hand, and industry on the other. Worrying about how scientific ideas can find their way into industrial applications, they look, among other things, at the role of patents (e.g., the Bayh-Dole act). Unfortunately, economic theory has surprising little to say about this problem. Economic theories of patents typically assume that ideas disseminate easily, and that once an idea is expressed (put in the public domain), everybody can copy and use it. In fact, the economic literature views patents as a means of restricting the dissemination of information. It focuses mostly on the role of patents as a reward mechanism, providing incentives for the generation of new ideas.

Recent empirical work has challenged this limited view on the role of patents. While there is a lively and on-going debate about the effectiveness of patents in stimulating innovation, a smaller parallel literature has documented a strong and consistent positive role of patents for the dissemination of innovative ideas. (Henderson, Jaffee and Trajtenberg (1998), Jaffee and Lerner (2001), Lamoreaux and Sokolow (1999)). These empirical findings validate the concerns about a science – market gap, and provide a challenge to the prevalent economic view of patents.

To explain the benefits of patents for the dissemination of scientific discoveries, a typical economic argument might go as follows. Consider a scientist who has made a discovery that no one knows about. The scientist can invest some time and money into promoting her discovery, searching for an appropriate firm that can use the discovery for the development of some new application - be it a process or product innovation. Without patent protection, when the scientist discloses the discovery to the firm, the firm can simply use the discovery without paying for it. This ruins the scientist's incentives to find firms in the first place. As a result, the discovery remains unused. Patent protection can change this sad state of affairs, since it allows the scientist to collect a licensing fee from her discovery. Thus patents motive scientists to promote their discoveries.

Though deceptively simple and elegant, this argument is highly incomplete. It assumes a one-sided matching process, where scientists seek out firms to promote their scientific discoveries. Presumably these discoveries constitute technological "solutions." The scientists' challenge is to find a suitable "problem," i.e., a market need that can be addressed with their scientific discovery. Common sense suggests that it might be more efficient to have problems seeking solutions, rather than solutions seeking problems. In our context, we need to ask whether it is more efficient to have firms searching from science, or the other way round. More generally, we need to examine by what process scientists and firms can find each other to exchange their respective needs and discoveries.

The central question we ask in this paper is the role of patents in organizing the bridging of science and industry. For this we need to model the search and matching process both in the absence and presence of patents. We need to examine the role of matching technologies. We can ask about the efficient structuring of the market for ideas. And we examine determinants of the likelihood that scientific discoveries find their way through the gap into industrial applications.

This paper develops an economic theory of the matching process between scientists and firms. We do not want to rely on traditional incentive theories for the generation of new ideas, and therefore take the existence of scientists with their discoveries as given. We assume that most discoveries are irrelevant for most firms, but that occasionally there is a match between a scientist and a firm. To find a match, firms and scientists invest in search. We use the term search in a broad sense. For scientists this might include promoting their discoveries or making them more accessible to non-scientists. For firms, this might include investing in so-called 'receptive capabilities' (e.g. hiring managers who's role it is to interact with academia), as well as communicating their own technological needs. A match means that the scientist and firm see an opportunity to develop (or co-develop) a discovery with the hope of finding a profitable application.

In the absence of patents, the firm can appropriate all the value from the discovery.[1] With patents, the scientist can extract some albeit not all of the value from development, typically through licensing fees. We also provide a simple model of patent strength, where stronger court enforcement increases the scientist's ability to

[1]This would not necessarily be true in the setting of Anton and Yao. Our model uses different base assumptions than Anton and Yao. It is possible to extend our model to make compatible with Anton and Yao, and still the same results.

command higher licensing fees.

In a one-sided search model, where scientists promote their ideas to firms, but not vice versa, we find that increasing patent strength always increases the scientists' search incentives, and thus the expected time to find a match. In this case, patents are always socially desirable. But this conclusion is easily challenged in a two-sided search model, where stronger patents promote scientists' search, but discourage the firm's search. The desirability of increasing patent strength depends on the relative search efficiencies of these two parties. The model also predicts a U-shaped relationship between patent strength and licensing (matching). That is, improving patent strength from a low (high) basis will increase (decrease) the licensing rate.

The effect of patenting depends on how the scientists' and firms' search activities interact. If there are strong complementarities - this happens, for example, if scientists can only be found if they are actively searching themselves - then the market easily collapses in the absence of patents, precisely because scientists never have an incentive to make themselves visible in the first place. Even with patents, there may be multiple equilibria, some with low and some with high levels of search activity.

One criticism of awarding patents to scientists is that scientists become excessively engaged in commercial rent seeking, at the expense of their basic research activities. Our model suggests an interesting counterpoint: patent allow for delegation and may actually free up time for scientists to remain focussed on research. In the absence of patents, it is impossible to delegate search and promotion. But with a patent, it is easy to write contracts with intermediaries, such as university licensing offices, patent lawyers, or the proverbial entrepreneurial Ph.D. student. Indeed, in many cases the optimal contract is simply the sale of a patent to an entrepreneur. That is, the scientist passes on to someone else the challenge of finding an industrial development partner.

The analysis hopes to make some thought-provoking policy suggestions. The two-sided search model reveals a new and interesting reason as to why scientists' may invest too little in search: scientists have an option value of waiting. Rather than granting long patents, it is better to create urgency, to give scientists strong incentives to promote their discoveries quickly. The paper makes several suggestions for creating urgency: by awarding short patent length, by charging high renewal fees or even by transferring patents to a new patent holder, if an existing patent holder fails to find a development partner within a certain time.

Future drafts will include a proper discussion of the related literature. The current very preliminary and highly incomplete version of the paper is structures as follows. Section 2 introduces the base model. Section 3 examines the bargaining game to determine equilibrium licensing fees. Section 4 describes the main results. Section 5 discusses the role of patent for delegation. Section 6 provides comments on the design of patent systems.

2 Base model

Suppose there is a large number of scientists (denoted by S) who all have a single scientific discovery. And there is a large number of firms (denoted by F) who might be able to apply these scientific discoveries to improve their existing products or services, or develop new ones. The number of scientists and firms are given by n_S and n_F. All parties are risk-neutral. There is an infinite horizon, and we focus on steady state equilibria. Let Δ be the length of any one period. To consider the continuous time case, we will focus mostly on the case of $\Delta \to 0$. All parties use a discount rate r.

Most discoveries are irrelevant to most firms. However, there are some matches between scientists and firms that constitute development opportunities. Development is costly - d denotes these development costs - and risky: with probability p development results in a usable innovation of value of x, but with probability $\overline{p}$ (throughout the paper, a bar above a probability denoted the complement, e.g., $\overline{p} = 1-p$), nothing valuable comes out. We denote the expected return from development by $\pi = px - d$ (NPV at the time of matching). We assume that if one firm invests in developing a discovery, no other firm wants to compete with it.

Below we provide a simple model of variable patent strength, ranging from no to full patent protection. We assume that patents do not affect the value of x. This says that the firm's innovations are naturally protected buy other competitive advantages, such as complementary skills or brand name. This assumption allows us to focus on the role of patents for the dissemination of information.

When a firm uses a patented discovery, in pays a licensing fee, denoted by a. Without patents, we simple have $a = 0$ in the base model. At the time of matching, the utilities of developing a discovery are given by $u_F = \pi - a$ and $u_S = a + \beta$, where $\beta(\geq 0)$ are the private benefits that scientists get from the development of their discovery - this may include any rents that the scientist can extract by virtue of having a superior understanding of the discovery that requires her on-going involvement with the development project (see Jensen and Thursby). Below we derive the equilibrium value of a.

Central to the model is the matching process by which firms and scientists find each other. We note that the probability that a given scientist finds some firm in a given period is different from the hazard that a given firm finds some scientist, simply because there are different number of scientists and firms. Let $e_S\Delta$ be the probability that a specific scientist finds a specific firm in any one period. And let $e_F\Delta$ be the probability that a specific firm finds a specific scientist in any one period. For now we assume that all these finding probabilities are independent - we relax this below. For Δ sufficiently small, we can ignore all probabilities that multiple matches occur in the same period (these probabilities are all of the order Δ^2 or higher, naturally vanish for $\Delta \to 0$). With this, the probability that a specific scientist finds some firm is given by $n_F e_S \Delta$, and the probability that she is found by some firm is given by $n_F e_F \Delta$. Let $m_S = n_F(e_F + e_S)$, then the probability that a specific scientist finds a match in period t is simply given by $m_S\Delta$. Using analogous reasoning, the probability that a specific firm finds a match in period t is simply given by $m_F\Delta$ where $m_F = n_S(e_F + e_S)$.

Finding a match requires costly search efforts. The per-period cost of search is thus given by Δc_S, where we assume standard convex search costs, i.e., $c_S(e_S)$ satisfies $c_S' > 0$, $c_S'' > 0$ and $c_S(0) = 0$. Similar for $c_F(e_F)$.

We denote the utility of a scientist in period t by $U_S(t)$. This is given by

$$U_S(t) = m_S(t)\Delta u_S(t) + (1 - m_S(t)\Delta)\frac{1}{1 + r\Delta}U_S(t + \Delta) - c_S(t)\Delta$$

In a steady state equilibrium we have after simple transformations $U_S = \dfrac{1 + r\Delta}{r + m_S}[m_S u_S - c_S]$. For $\Delta \to 0$ we obtain

$$U_S = \frac{m_S u_S - c_S}{r + m_S}$$

Scientists are assumed to have a single idea and then exit the market. In contrast, firms are assumed to participate in the market all the time, and develop all good ideas that they can find.[2] The utility of a firm is thus given by

$$U_F(t) = m_F(t)\Delta u_F(t) + \frac{1}{1 + r\Delta}U_F(t + \Delta) - c_F(t)\Delta$$

In steady state with $\Delta \to 0$ we get

$$U_F = \frac{m_F u_F - c_F}{r}$$

3 Bargaining game

We assume that all bargaining follows the Nash bargaining solution (see Binmore, Rubinstein and Wolinsky for an extensive game form justification).

3.1 No patent protection

The base model without patents is straightforward. The firm listens to the discovery, and since there is no patent protection, it makes no transfer to the scientist. The scientist also has no incentive to disclose the idea to any other firm, given our prior assumption that no second firm would want to develop in parallel. Without patents we therefore get $a = 0$ and $u_S = \beta$.

[2] This assumptions seems the most natural. The model where firms exit once they found a development project is analogous and yields the same insights.

3.2 Full patent protection

After a scientist has disclosed the idea to a firm, thee two parties can bargain over the licensing fee. We use the Nash bargaining solution. The firm's outside option is simply to forgo the opportunity, which yields a normalized utility of zero. The scientists outside option is to search for another firm. Since this simply means starting all over, it yields the same utility as next period's ex-ante utility $\frac{1}{1+r\Delta}U_S$. Using $\Delta \to 0$, we obtain the following simple expression for the Nash value: $u_S = U_S + \frac{1}{2}[(\pi+\beta) - U_S] = \frac{(\pi+\beta)+U_S}{2}$. Using $U_S = \frac{m_S u_S - c_S}{r+m_S}$ we obtain after simple transformations[3]

$$u_S^* = \frac{(\pi+\beta)(r+m_S) - c_S}{2r+m_S} \text{ and } U_S = \frac{m_S(\pi+\beta) - 2c_S}{2r+m_S}$$

Intuitively, the higher the scientist's search cost, the weaker her bargaining power.

The equilibrium licensing fee a^* is simply given by $a^* = u_S^* - \beta$. Note that for β very large, we get $a < 0$, suggesting that the scientist would be willing to pay the firm to develop the idea. But since the firm does not require to be paid, the scientist is better off to simply give the firm a free license. Formally, this means that a^* is bounded below by 0 (in addition, the scientist may be wealth constrained anyway). We will focus on the case where β not too large. In this case, $a^* > 0$ and the scientist gets a higher utility u_S with a patent than without a patent.

3.3 Weak patent protection

To model weak patent protection, we use a very simple model of imperfect courts. We also allow for efficient pre-trial bargaining. After disclosing her discovery to the firm, suppose that patent protection is sufficiently uncertain that the first firm is willing to invest even without a patent - below we derive the formal condition for this. In this case, it can expect to be sued for infringement at a later date, after its investments are sunk.

We model this as follows. Let q be the probability that a court upholds the patent. For simplicity suppose that there are symmetric costs of going to trial. It is convenient to express these costs as a fraction of the value at stake x, i.e., suppose costs are given by ψx where $\psi < 1$. If the patent is upheld, we assume that the

[3] We have $2u_S = (\pi+\beta) + \frac{\mu_S u_S - c_S}{r+\mu_S} \Leftrightarrow 2u_S(r+\mu_S) = (\pi+\beta)(r+\mu_S) + \mu_S u_S - c_S \Leftrightarrow u_S(2r+\mu_S) = (\pi+\beta)(r+\mu_S) - c_S \Leftrightarrow u_S = \frac{(\pi+\beta)(r+\mu_S)-c_S}{2r+\mu_S}$ and $U_S = \frac{\mu_S u_S - c_S}{r+\mu_S} = \frac{\mu_S}{r+\mu_S}\frac{(\pi+\beta)(r+\mu_S)-c_S}{2r+\mu_S} - \frac{c_S}{r+\mu_S} = \frac{\mu_S(\pi+\beta)(r+\mu_S) - \mu_S c_S - (2r+\mu_S)c_S}{(r+\mu_S)(2r+\mu_S)}$ $= \frac{\mu_S(\pi+\beta)(r+\mu_S) - 2(r+\mu_S)c_S}{(r+\mu_S)(2r+\mu_S)} = \frac{\mu_S(\pi+\beta)-2c_S}{2r+\mu_S}$.

offender has to pay the patentee a licensing fee of x, i.e., the full economic value of the patent. If the court revokes the patent, the alleged offender can proceed freely. Prior to going to court, the two parties can settle. The expected utilities of going to court are $qx - \psi x$ for the patentee and $\overline{q}x - \psi x$ for the alleged offender. For $q < \psi$, the patentee is better off not going to court, and so the offender can simply ignore the patent and proceed to use the discovery. For $q > 1 - \psi$, the offender is better off not using the patent than going to court, so he always prefers to obtain a license. For $\psi < q < 1 - \psi$, the two parties settle out of court. The gains from a pretrial settlement are the legal cost savings $2\psi x$. The Nash bargaining solution yields $qx - \psi x + \frac{1}{2}2\psi x = qx$ for the patentee, and $\overline{q}x - \psi x + \frac{1}{2}2\psi x = \overline{q}x$ for the alleged offender.

With this, we obtain the following utilities at the development stage. For $\psi < q < 1 - \psi$ we get $u_S = pqx + \beta$ and $u_F = p\overline{q}x - d$. Rather than proceeding without a patent and relying on a pre-trial settlement, the two parties can strike a licensing deal before development. In this case we simply get $a = pqx$. This assumes that the firm is willing to invest without a license. The necessary and sufficient condition for this is $u_F = p\overline{q}x - d \geq 0$. For $q > \frac{px-d}{px}$, the firm would not want to invest without a license in hand. In this case the model reverts back to the case of full patent protection. The same also applies for $q > 1 - \psi$. Finally, for $q < \psi$, the threat of an infringement lawsuit is not credible. In this case the model reverts to the case without any patent protection.

In general we note that the model with weak patent protection spans the spectrum from no to full patent protection. This means that for every a between 0 and a^*, we can find a corresponding q that generates that value of a.

4 Results from the base model

4.1 One-sided search

We first solve the one-side model, where only scientists search for firms. This model corresponds to "standard" economic reasoning why patents protect the investments of the discovery's generators. This model ignores search by firms, so that we set $e_F = 0$.

The scientist's search costs are private investments. Every period she maximizes $U_S(t)$ with her optimal choice of $e_S(t)$. The first-order condition is given by $\frac{dm_S(t)}{de_S}[u_S(t) - \frac{1}{1+r\Delta}U_S(t+\Delta)]\Delta - c_S'(t)\Delta = 0$. Using $\frac{dm_S(t)}{de_S} = n_F$ we get

$$n_F[u_S(t) - \frac{U_S(t+\Delta)}{1+r\Delta}] - c_S'(t) = 0$$

The first term captures the marginal benefit while the second the marginal cost. The marginal benefit naturally scales with the number of firms n_F. The most interesting term is $u_S(t) - \frac{U_S(t+\Delta)}{1+r\Delta}$. This measures the the difference in utilities between finding a partner now, versus not finding one now and continuing to look for one. A key insight is that the search incentives depend a lot on the urgency that the scientist perceives for finding a partner. We return to this insight below.

For the steady state, using $\Delta \to 0$, we define $\theta_S \equiv u_S - U_S$, and rewrite the first order condition as

$$n_F \theta_S - c_S' = 0.$$

Using $U_S = \frac{m_S u_S - c_S}{r + m_S}$ we get after simple transformations $\theta_S = \frac{r u_S + c_S}{r + m_S}$. We assume that c_S'' sufficiently convex to always satisfy the second order condition. With this, we note that the optimal choice e_S^* is increasing in a and β. Straightforward calculations also reveal that e_S^* is also increasing in n_F and r.[4]

To compare the equilibrium outcome to the socially efficient outcome, we note that in addition to the private benefits and profits generated from the innovation, an innovation may also create some additional consumer surplus or other social value. We denote this by $\sigma(\geq 0)$. The total expected value of development is $v = \pi + \beta + p\sigma$. Using a standard additive social welfare function, the socially efficient level of e_S maximizes

$$V(t) = m_S(t)\Delta v + (1 - m_S(t)\Delta)\frac{1}{1+r\Delta}V(t+\Delta) - c_S(t)\Delta$$

implying a first-order condition

$$n_F[v - V] - c_S'(t) = 0.$$

Note that $\theta_V \equiv v - V = \frac{rv + c_S}{r + m_S} > \frac{r u_S + c_S}{r + m_S} = \theta_S$, so that there is always too little search, even with perfect patent protection. Improving patent protection (e.g., increasing q) is always socially efficient, since it increases the scientist's level of search.

Proposition 1 *In a one-sided search model, better patent protection of scientific discoveries is always socially more efficient.*

[4]For $\frac{de_S^*}{dr}$ we note that u_S independent of r, but U_S decreasing in r, thus θ_S is increasing in r. For $\frac{de_S^*}{dn_F}$ we have $\frac{d}{dn_F}[n_F \frac{r(a+\beta)+c_S}{r+n_F e_S}] = \frac{r(a+\beta)+c_S}{r+n_F e_S} - n_F e_S \frac{r(a+\beta)+c_S}{(r+n_F e_S)^2} = \frac{1}{(r+n_F e_S)^2}[(r(a+\beta)+c_S)(r+n_F e_S) - n_F e_S(r(a+\beta)+c_S)] = \frac{1}{(r+n_F e_S)^2}[r^2(a+\beta)+r c_S + r(a+\beta)n_F e_S + c_S n_F e_S - n_F e_S r(a+\beta) - n_F e_S c_S] = \frac{r^2(a+\beta)+r c_S}{(r+n_F e_S)^2} > 0.$

4.2 Two-sided search

The model with two-sided search is analogous to the one-sided model, except that scientists and firms make simultaneous search decisions. The firm maximizes by $U_F(t)$ choice of $e_F(t)$. The first order condition is given by $\frac{dm_F(t)}{de_F}\Delta u_F(t) - c_F'(t)\Delta = 0$. For $\Delta \to 0$ and using $\frac{dm_F(t)}{de_F} = n_S$ we get

$$n_S u_F(t) - c_F'(t) = 0.$$

Note that while scientists promote a single idea, firms are always looking for lots of ideas. That explains why their marginal incentive is not affected by concerns of urgency. Indeed, the optimal choice of e_F^* does not depend on r. Nor does it depend on e_S, i.e., firms set their search efforts independently of the scientists' search efforts. e_F^* does depend positive on the number of scientists n_S.

The scientist's first order condition is as before. Interestingly, however, we now note that while $e_S(t)$ does not depend on the contemporaneous $e_F(t)$, it does depend on all future $e_F(t+i\Delta)$ $(i = 1, 2, ...)$ through $U_S(t+\Delta)$. In steady state, U_S is an increasing function of m_S (since $\frac{dU_S}{dm_S} = \frac{ru_S + c_S}{(r+m_S)^2} > 0$), and therefore an increasing function of e_F. Thus e_S^* is decreasing in e_F. Intuitively, more search by firms increases the value of waiting, and therefore reduces the scientist's urgency to search for firms themselves.

Reconsider now the role of patents. As before, better patent protection increases e_S^*. But since higher a also reduce u_F, better patent protection decreases e_F^*. That is, better patent protection reduces the firm's incentives for search.

In general, we can now trace out a frontier between e_S^* and e_F^*, where better patent protection increases e_S^* at the expense of e_F^* - note, however, that below we will argue that alternative patent polices might be able to shift the frontier. In general, this frontier will be concave. We can then use our welfare function V to derive a social indifference curve. This is in general convex. The optimal level of patent protection is identified with a standard separating hyperplane argument.

The effect of increasing patent protection therefore boils down which side of the optimal patent protection we are. The social desirability of patents hence depends critically on the shape of $c_S(e_S)$ and $c_F(e_F)$, as well as the current level of patent protection q.

Basically, the more effective firms are at search, the less desirable are patents. To formally show this, it is straightforward to parametrize the cost functions. I omit the details.

We can point out some extreme cases. Suppose that scientists are completely incapable of finding firms, so that $e_S = 0$. In this case patents are always undesirable, since they only undermine the firms' incentives for search.

Another interesting implication of this model is that the benefit of patent protection may be a U-shaped. Lerner finds some evidence of U-shaped benefits to patenting. The standard argument relies on trading off ex-ante incentives between first and subsequent inventors. This model shows that U-shaped benefits naturally fall out of a simple model of two-sided post-invention search.

Proposition 2 *In a two-sided search model the social desirability of patents depends on the relative efficiency of search technologies. The social benefits of patenting can be U-shaped, so that they are positive at low levels of patent protection (low q), but negative negative at high levels of patent protection (high q).*

4.3 Meeting model

We will now relax our assumption about the matching process consisting of independent searches. Consider an alternative model where it is impossible to find a firm, unless it makes an effort to be found - and similarly for a scientist. One can think of a variety of model specification here, but we focus on a simple of model "double coincidence." For a match to occur in such a model, both parties have to find each other. A simple example would be if firms and scientist have to rely on meeting each other in a common location (such as a conference). The probability of a match in such a model is simply given by $e\Delta = (e_S * e_F)\Delta$. This alters the steady state first order conditions, which are now given by

$$n_F e_F \theta_S - c'_S = 0 \text{ and } n_S e_S u_F - c'_F = 0$$

Clearly we have $\frac{de_F^*}{de_S} > 0$. It is easy to show that we also have $\frac{de_S^*}{de_F} > 0$.[5] This means that there are strategic complementarities between the scientists' and firms' search intensities. In general, it is possible that the reaction functions intersect more than once. This means that there may be multiple equilibria, including a minimal and maximal one (see Milgrom and Roberts). This in an interesting result. If matching requires a double coincidence, there may be a low (high) equilibrium where scientists invest little (a lot) in search, since it is hard (easy) to find firms, and firms invest little (a lot) in search, since it is hard (easy) to find scientists.

Another interesting result of the meeting model concerns the role of patents. Consider first the case of $\beta = 0$, so that scientists require financial rewards to be willing to shop around their ideas. Without patents there are no rewards, so that $u_S = 0$. But this implies $e_S = 0$. But if scientist are impossible to find, no firm will want to search either, so that $e_F = 0$. We have a total market collapse. Patent can

[5] We need to show that $n_F e_F \theta_S$ is increasing in e_F. We have $\theta_S = \frac{ru_S + c_S}{r + m_S} = \frac{ru_S + c_S}{r + n_F e_S e_F}$ and thus $n_F e_F \theta_S = n_F e_F \frac{ru_S + c_S}{r + n_F e_S e_F} = n_F \frac{ru_S + c_S}{\frac{r}{e_F} + n_F e_S}$, which is clearly increasing in e_F.

therefore play an important role in creating an environment where scientist and firms can meet at all. Obviously, this extreme result depends on $\beta = 0$. For $\beta > 0$ scientists are always willing to shop their ideas a little. Still, having no patents can lead to a very inefficient outcome. We note that the frontier of e_S^* and e_F^* bends backwards for low values of a. This means that having too little patent protection becomes a problem even for firms. They would prefer that scientists get somewhat more rents, to give them the necessary incentives to participate in the meeting market. Indeed, in the absence of patents, firm might want to commit to rewarding scientists' ideas, in order to promote the dialogue between science and industry.

Somewhat an opposite scenario occurs when scientist have an effective search technology (e_S^* is large), but firms do not (e_F^* is small). In this case, it is possible that a patent rewards scientists too much. In fact, owning patents may actually harm the scientists' own self-interest, namely if it deters firms from engaging in the matching process. Under such circumstances we could even expect scientist to want to commit to low licensing rates, in order to bring firms back into the matching process.

Proposition 3 *Suppose that finding a match requires a double coincidence. If $\beta = 0$ and there is no patent protection, then the search market collapses. Even with patent protection, there may be multiple equilibria.*

5 Patents for delegation

Basic idea is that patents allow an intermediary market to be created. Suppose a scientist wants to delegate the promotion of a discovery to some intermediary. This could be his/her Ph.D. student (which appears to be a common phenomenon), a university licensing office, or more generally, some entrepreneur. The key reason for delegation is that the intermediary has a better (i.e., lower cost) search technology. Formally, suppose that $c_I(e_I) < c_S(e_S)$ and $c_I'(e_I) < c_S'(e_S)$. The intermediary may also have greater visibility among firms, so that $c_F|_S < c_F|_I$ and $c_F'|_S < c_F'|_I$. Unlike the scientist, however, the intermediary has no private benefit from promoting the discovery. Lacking any intrinsic motivation, the scientist has to provide the intermediary with some positive incentives.

With patents, this is easily done. The scientist promises the intermediary to share a fraction ι of the licensing fee. Baring any wealth constraints or adverse selection problems, the optimal contract typically sets $\iota = 1$. That is, the scientist collect all revenues from an unconditional transfer payment. This is equivalent to selling the patent to the intermediary.[6]

Without patents, there is no way to write a contract with the intermediary that compensates the intermediary for finding a development partner. This is because

[6] One interesting exception is when the scientists knows that she has too much market power, to the point of scaring away firms. In this case, delegation can also be used to commit to a lower licensing fee.

there never is a verifiable transaction with a development partner.

Proposition 4 *Patent protection, even if is weak (low q), enables contracting and therefore delegation.*

So far we assumed that the scientific discovery necessarily requires a development partner. Consider briefly the case where the scientist could also attempt developing the discovery on his/her own, without any resources from other firms. Suppose also that going alone is inefficient, i.e., $\pi > \pi_{alone} > 0$. The going-alone option will not affect the equilibrium with patents, as long as $U_S > \pi_{alone} + \beta$. But without patents, or with sufficiently low patent protection, the scientist may decide to attempt develop alone. Again we find that patents may have the beneficial effect of allowing scientists to delegate the development of their discoveries, preventing them for pursuing inefficient stand-alone development.

6 Designing patent policies

A key insight from the model is that the scientists' incentive to promote their ideas depends on $u_S(t) - \dfrac{U_S(t+\Delta)}{1+r\Delta}$, i.e. on the difference between the utility of finding a partner today versus continuing the search tomorrow. The possibility of collecting the rewards from the patent in the future therefore lower the scientists' incentives to promote their patents today.

We propose some innovative and hopefully thought-provoking policy remedies. Naturally, the practical applicability of either of these policies remains to be seen, and would require much additional research. However, the point of these suggestions is to challenge traditional thinking about key areas of patent design, namely patent length and renewal fees.

Consider patent length. In reality, patents have known end date. Unfortunately, this greatly complicates the dynamic analysis, since it destroys the steady state property. We therefore analyze a model that is a "close cousin" to finite patent length, but preserves the steady state structure of the model. In particular, suppose that between any two periods, there is a probability ϕ that the patent expires. We can think of higher expiry probabilities as lower (expected) patent length. Expiry affects the scientists' incentives. For simplicity we focus on the case of $\beta = 0$, so that the scientists simply stops when expiry occurs. The utility function is thus given by

$$U_S(t) = m_S(t)\Delta u_S(t) + (1 - m_S(t)\Delta)(1-\phi)\frac{1}{1+r\Delta}U_S(t+\Delta) - c_S(t)\Delta$$

The steady state first order condition is now given by

$$n_F(u_S - (1-\phi)U_S) - c'_S = 0$$

It is immediate that e_S^* is increasing in ϕ. That is, greater expiry risk (corresponding to a shorter expected patent length) creates urgency, increasing the scientists' incentive to search.

A possible downside of creating urgency is that after expiry the scientist simply stops to promote the discovery. This suggests an even more radical departure from standard reasoning in the patent literature: why not transfer the patent to another scientist or patent intermediary? In this case, we can have a sequence of patent holders. Each one faces great urgency and therefore provides a high level of search effort. Indeed, by choosing an appropriate level of ϕ, it is possible to increase e_S^* without affecting e_F^*. This is equivalent to shifting the frontier. It might even be possible to set q such that firms provide socially first-best effort, and set ϕ such that scientists provide socially first-best effort. Combining patent strength and patent length can thus improves the two-sided incentive problem.

One problem with the above rotation system is that it is not clear whom to give the patent to next. Giving the patent to an arbitrary agent is problematic, because that agent is unlikely to have the right skills to promote the patent. One mechanism frequently advocated by economists is auctions. If there is a sufficient number of informed bidders, then this would be an effective mechanism. Given the information-intensive nature of science-based patents, however, there may not be enough informed bidders.

Indeed, let us consider the extreme case where the scientist is the only informed party. In this extreme case patent transfer don't help. A different way of creating urgency might be to tax the future. This can be naturally done through renewal fees. Suppose that the patent holder has to pay a regular renewal fee (ideally, this should be waved once the patent has been licensed out for development). Such a fee reduces the value of waiting, similarly to increasing ϕ. Scientists therefore feel greater urgency and again increases their search efforts.

Proposition 5 *Creating urgency, such as through patent expiry, patent rotation and/or high renewal fees can improve social welfare by increasing scientists' search incentives.*

7 Conclusion

TBD

8 References

TBD