Patents and innovation - the effect of monopoly protection, competitive spillovers and sympathetic collaboration.

Richard Fairchild
University of Bath
School of Management
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<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006.01</td>
<td>Neil Allan and Louise Beer</td>
<td>Strategic Risk: It’s all in your head</td>
</tr>
<tr>
<td>2006.02</td>
<td>Richard Fairchild</td>
<td>Does Auditor Retention increase Managerial Fraud? - The Effects of Auditor Ability and Auditor Empathy.</td>
</tr>
<tr>
<td>2006.03</td>
<td>Richard Fairchild</td>
<td>Patents and innovation - the effect of monopoly protection, competitive spillovers and sympathetic collaboration.</td>
</tr>
</tbody>
</table>
We develop a patent/innovation game in which innovative competition provides positive spillover effects (which strengthens innovative incentives) but negative profit dissipation effects (which weakens innovative incentives). We consider both the innovator’s incentives to apply for a patent, and the effect on welfare. It is shown that when spillover effects are large and/or profit dissipation is low, the innovator does not take the patent, and this maximises welfare. When spillover effects and profit dissipation are of a medium order, welfare is maximised by competition, but the innovator obtains a patent, minimising welfare. When spillover effects are low/profit dissipation is large, the innovator obtains a patent to eliminate competition. This is welfare maximising. Furthermore, we consider a version of our model in which researchers collaborate in a sympathetic manner. This increases innovation, and reduces the innovator’s welfare-minimising patent incentives.

1. Introduction.

Do patents promote or hinder innovation and economic growth? This is a controversial issue that has received considerable attention from the academic community, practitioners, and
policy makers alike. The traditional Schumpeterian view, as espoused by Nordhouse (1969), is that the incentive to innovate is diluted by rent-dissipating competition. The patent system enables firms to protect their monopoly rents, hence strengthening their innovative incentives and promoting economic growth. Furthermore, the patent system is viewed as a spur to competitive innovation, since it provides diffusion of knowledge to industry participants (Bessen 2005).

However, opponents of this view argue that the patent system is detrimental to growth, since innovative competition spurs rivals to ‘race’ for technologies, promotes knowledge sharing and provides positive spillover effects (O’Donaghue, Scotchmer and Thisse 1998, Bessen and Maskin 2000, Dreyfuss 2000, Merges (1999 and 2003), Panagopoulos 2004). Furthermore, some researchers have focussed on the inefficiencies in the patent system due to the large number of invalid patents that are granted (Merges 1999, Kesan and Banik 2001, Lemley and Shapiro 2004).

In this paper, we address the ambiguous nature of the relationship between valid patents and innovation. We develop a simple model that trades-off the positive effects of patents on a firm’s innovative incentives with the negative impediments to knowledge-sharing competitive innovation. We analyse both the innovator’s incentives to obtain a patent, and the effects on social welfare.

Before proceeding to our model, it will be worthwhile reviewing the literature on the relationship between patents and innovation in some depth. This will enable us to examine the key questions that our model should address.

Bessen and Maskin (2000) develop a dynamic model in which innovation is sequential (that is, each invention builds sequentially on the previous one), and rivals’ innovative activity is complementary, in that it enhances the probability of successful innovation. In this setting, patents inhibit innovative growth.
In similar vein, Panagopoulos (2004) builds on the work of Beath, Katsoulaskis and Ulph (1989), and Harris and Vickers (1987), in order to develop a dynamic and sequential tournament model of innovation. In his model, innovators race to be the first to create the greatest technology. At the end of each period, there is only one winner. The successful innovator can use his technology in the production of a consumption good. The remaining innovators can use their inventions as a basis for future research, but cannot produce in the current period.

In Panagopoulos’ model, patents have the traditional positive Schumpeterian effect on innovation, but also have two negative effects; they reduce innovative competition, and they reduce knowledge spillovers. He demonstrates that the negative patent effects dominate, such that “tournament competition positively affects innovation by increasing knowledge spillovers.” Using a computer simulation, Pananagopoulos discovers an inverted U-shaped relationship between patent breadth and output growth. This emphasises the ambiguous nature of patents; they may be good or bad for innovation and growth.

Some researchers (Dreyfuss 2000, Merges 1999, Jaffe and Lerner 2005) argue that a further impediment to growth is provided by the number of invalid patents granted to applicants. Jaffe and Lerner (2005) argue that invalid patents interfere with the innovative process, and result in high private and social costs due to potential ex post legal wranglings and litigations between patent holders and their competitors. The authors describe how administrative changes to the patent system in the USA enacted in 1982 made it easier for firms to obtain invalid patents, and easier for these firms to protect these patents in ex post legal battles. Jaffe and Lerner propose changes to the patent system in order to reduce the number of invalid patents.

Kesan and Banik (2001) consider the problem of invalid patents in the high technology sector. This sector may be characterised by asymmetric information, as the patent applicant may be
more informed about the prior art than the courts. Furthermore, contracts may be incomplete. Incomplete contracts (Grossman and Hart 1986) arise when all possible eventualities cannot be written in a contract. The problem then is that a particular action is observable, but not verifiable in a court of law. In Kesan and Banik’s model, the incomplete contract problem arises because the innovator does not know whether his successful patent application will be rescinded ex post (after he has exerted innovative effort). This weakens his ex ante innovative incentives.

In this setting, the optimal patent scheme assigns a high presumption of validity to the prior art disclosed in the patent. This reduces the ex post probability of litigation, which enhances the ex ante innovative incentives, and further provides incentives for a wider declaration of prior art. This greater information revelation enables the patent office to carry out more verification checks.

Traditionally, patents were reserved for tangible innovations in the manufacturing sector (for example, Edison’s lightbulb in the 1890’s). However, patents have recently been extended to areas previously believed to be non-patentable, such as software, business concepts, and financial innovation. There has been some conjecture over whether this is a desirable development to the patent system (Bessen and Maskin 2000, Merges 1999 and 2003, and Dreyfuss 2000). This has highlighted the ambiguous nature of the relationship between patents and innovation. For example, Bessen and Maskin use their innovation model to support their argument that there has been a slowdown in innovative growth since the advent of patents in the software industry. Dreyfuss similarly contends that business concept patents have been damaging to growth. However, Merges argues that patents will promote growth in business concepts and financial innovation.

Merges (2003) notes that the extension of patents to the areas of software, business concepts, and financial innovation was triggered by the landmark case of the Street Bank in Boston,
USA. In 1998, the State Street Bank successfully applied for a patent on a data processing system for its financial services. This transformed the patent system, making all business methods patentable.

Merges considers the desirability of patents on financial innovations. He considers both the incentives of innovators to obtain patents, and the effect on innovation and growth. In relation to incentives to obtain patents, he notes that patents on financial innovations are unnecessary. Such innovators have at least three methods other than patents to protect their innovations; cost-saving lead times (or “first-mover advantages”), asset specificity, and trade secrecy/tacit knowledge (reputational advantage). Hence, there were strong incentives to develop financial innovations long before they were patentable.

Regardless of the necessity for patents, Merges then considers the effect that patents will have on innovative growth. He observes many similarities between the explosion of patents in financial innovation and in the nineteenth century railroad industry. In both cases, firms were shocked and surprised by the disruptive effects of patents on innovation. In both industries, innovation was dominated by a few large firms. Furthermore, there were behavioral aspects relating to innovative processes. That is, there was a common culture of knowledge sharing, with the major railroads considering themselves to be part of an larger interfirm enterprise. Further, a railroad firm felt a sense of pride and enhanced reputation in developing an innovation that other firms could use. This suggests that the advent of patents would not hinder such progress, and, indeed, Merges concludes that patents “did not appear to slow the development of the industry in any significant way.”

Drawing a parallel with the US software and financial technology industries, Merges notes that both industries rely on ‘network effects’. Further,

1 These methods are discussed in more detail in Tufano’s (1989) empirical analysis of 58 financial innovations between 1974 and 1986.
2 We will observe the relevance of behavioral aspects (in particular, sympathetic collaboration) in the second version of our model.
“Perhaps there is a deeper path dependency in industrial development than we are aware. An industry, once started on a patent-free basis, establishes an innovation path that later proves relatively impervious to the imposition of patents. Perhaps patents overall simply do not affect the ‘big variables’ of economic life- industry structure, the basic pace of innovation etc. – in such an industry to any great extent…. While patents may play a key role in individual firms’ strategies, they may not have much impact on industry structure.”

Merges then considers a potentially positive aspect of the patent system in financial innovation; knowledge diffusion (as in Bessen 2005). Previously, information about financial innovation diffused to a very close-knit group of experts. Patents will have the effect of formalising knowledge transfer between rivals (in Merges’ words, patents will enable innovations to be ‘codified’).

In summary, Merges views patents in software and financial innovations positively, firstly due to the culture in these industries of knowledge-sharing and interfirm networking (as in the nineteenth century US railroad industry), and secondly, since it will promote knowledge diffusion.

In contrast, Dreyfuss (2000) is vehemently opposed to business concept patents. On the benefit side, he argues that considerable knowledge diffusion occurs naturally in business methods, even in the absence of patents. Secondly, he notes that firms have methods of retaining an adequate return on investment in the absence of patents (such as first-mover advantage, customer lock-in, network effects, and customer loyalty).

“In sum, while business innovations are certainly desirable, it is not clear that business method patents are needed to spur people to create them.”
Furthermore, he argues that the social costs of business patents are immense, particularly in interfering with sequential innovation and knowledge spillovers (as modelled by Bessen and Maskin 2000).

This discussion of the costs (interference with knowledge spillovers and sequential innovation) and benefits of patents (protection of innovative incentives) motivates our model. The arguments of Merges (2003) and Dreyfuss (2000) may be considered in these terms. They both view the benefits of patents, in terms of innovative incentives, as small, since firms can protect their rents even in the absence of patents. Dreyfuss views the costs of patents, in terms of interference with knowledge spillovers, as large. However, Merges views these as small (knowledge diffusion occurs with or without patents, and patents even promote knowledge diffusion).

Our model demonstrates that the efficacy of patents needs to be considered on a case-by-case basis. Indeed, having argued against business patent methods, Dreyfuss (2000) considers the view that method patents should be confined to ‘technological arts;’ that is, industrial rather than business applications.

“It isn’t clear to me that the word technology is unambiguous enough to create a clear judicial line. Most important, I don’t understand why that particular divide would distinguish between fields where patents make sense and fields where they do not. To me, the better way to define the scope of patent protection is by sticking with the question of rationales, by asking where a patent incentive is actually required to promote investment in innovation.”

This is the approach that our model adopts. We present two versions of the model. In the first version, each firm is only motivated by its own profits. However, Merges (2003) described
possible behavioral interfirm relationships (willingness to share innovations, pride, etc). Indeed, we consider the following from Merges (2003):

“Although scientists aggressively acquire property rights, they almost never assert them against other scientists engaged in academic research. A scientist who draws on the work of peers doing his or her own research follows a well-understood norm in the field: patents are asserted only against commercial entities. … Even though many academic scientists work across both circles on a regular basis, they recognise that property rights are only appropriate in the outer circle. … This is why, long after the advent of property rights revolution in science, pure academic research – and the open, property rights-free exchange of information it depends on – continues to thrive.”

In the second version of our model, we consider the effect of these incentives to cooperate, when we introduce a psychological innovation game of sympathy (based on Sally 2001a and 2001b). A psychological game is one in which the players make strategic choices over actions and emotions. In the Nash equilibrium, the actions and emotions must be rational, consistent with and best responses to the other player’s actions and emotions.

In Sally’s game, the emotion of sympathy has a natural strategic reciprocal effect. Sally considers effective sympathy, whereby if one player believes that the other player will be sympathetic, he will respond accordingly. On the other hand, if he thinks that the player is unsympathetic, he will act in an unsympathetic way.

We apply this to the patent/innovation game in order to consider the effect of innovative competition between sympathetic (eg universities) or non-sympathetic (eg universities and firms) researchers. Sally demonstrates that including sympathy as a strategic choice can change the equilibria of a game. We demonstrate that the players exert more innovative effort
in the sympathetic game, compared with the non-sympathetic version. Furthermore, the incumbent is more inclined not to take the patent, hence allowing competitive entry, in the sympathetic game. We argue therefore that policy makers could improve welfare by encouraging sympathetic collaborations.

The paper proceeds as follows. In section 2, we develop the model. In section 3, we introduce the sympathetic version. In section 4, we consider policy implications. Section 5 concludes.

2. The Model.

We consider a simple patent/innovation game in which an innovative firm (firm 1) faces potential competition from an imitating firm (firm 2). In the first stage of the game, firm 1 chooses whether to buy a patent. In the second stage, if firm 1 has bought the patent, it enjoys exclusive monopoly rights to its idea. It then decides on an amount of innovative investment, which affects the probability of success of the venture. If firm 1 has not bought the patent, firm 2 can enter and imitate firm 1 (exerting innovative effort of its own), and the firms compete as duopolists.

Although entry by firm 2 may compete away some of firm 1’s profits, we consider the possibility of complementary spillover effects, whereby innovative activity by both firms is of benefit to each firm. Therefore, firm 1 may or may not find it desirable to use a patent to exclude firm 2 from the market. We are particularly interested in analysing firm 1’s incentives to exclude or include firm 2, and the effect on welfare. In particular, when are firm 1’s incentives aligned with social welfare maximisation, and when are they in conflict?

3 In order to focus the analysis, we do not consider an initial innovation investment by firm 1, prior to firm 2 entering. This may seem unrealistic, but it sharpens the results concerning the effects of competition on innovative incentives and spillovers.
In the first version of our model, each firm is purely interested in its own profits. In the second version of the model, firms may exhibit collaborative sympathy (as in the case of university research, as identified by Merges).

We now describe the model in more detail. The timeline is as follows.

_Date 0:_ Firm 1 has an idea. Firm 1 decides whether or not to buy a patent at cost $C$. If firm 1 buys the patent, it has exclusive monopoly rights to the new project. If it does not buy the patent, firm 2 can enter and imitate/compete with firm 1.

_Date 1:_ If firm 1 bought the patent at date 0, it enjoys monopoly power, and exerts innovative effort. If firm 1 did not buy the patent, both firms enter and compete as duopolists. Both firms exert innovative effort.

In version 2 of our model, if both firms enter, they choose sympathy levels (to be analysed in more detail later) prior to exerting innovative effort.

The new innovation has a probability of success $P$. In the case where firm 1 has taken the patent, success will provide monopoly profits $\Pi_M = R$. In the case where firm 1 has not taken the patent, such that firm 2 enters and competes, success will provide each firm with duopoly profits $\Pi_D = \frac{R}{2}(1 + S)(1 - d)$. This formulation captures the idea that, with two firms entering, the firms share the market, hence splitting the profits ($R/2$). However, there are possible spillover effects from complementary innovative activity (represented by the parameter $S \geq 0$), and possible dissipation of profits due to competition (represented by the parameter $d \in [0,1]$).
We may consider the parameter $d$ as representing the firms’ product differentiation. Hence, if the firms enjoy local monopolies, $d = 0$, and there is no dissipation of profits. If the firms are subject to extreme Bertrand price competition, $d = 1$.

Note that the potential effects of spillovers could be very large, and hence we do not restrict the parameter $S$ to any finite interval in the positive domain.

If the project is unsuccessful (with probability $1 - P$), innovative activity fails, and the project provides zero income.

The probability of success is positively affected by the firms’ innovative efforts. For ease of analysis, we consider a specific probability function. That is, the probability of success is affected by the firms’ innovative activity, as follows;

$$P = \beta(\sqrt{I_1} + \sqrt{I_2}) \in [0,1],$$

(1)

with $\frac{\partial P}{\partial I_1} > 0$, $\frac{\partial P}{\partial I_2} > 0$, and $\frac{\partial^2 P}{\partial I_1^2} < 0$, $\frac{\partial^2 P}{\partial I_2^2} < 0$. That is, the success probability is increasing in each firm’s innovative effort, but at a decreasing rate.

We solve this game by backward induction.

Date 1: Innovative activity.

Firstly, take as given that firm 1 has taken the patent at date 1, and is therefore trading as a monopolist. Firm 1 chooses a level of innovation to maximise the expected innovative income, net of investment costs;
\( \Pi_1 = \pi R - I_1. \) \hspace{1cm} (2)

Substituting from (1), firm 1 maximises

\[ \Pi_1 = \beta (\sqrt{I_1} + \sqrt{I_2}) R - I_1. \] \hspace{1cm} (3)

Solving \( \frac{\partial \Pi_1}{\partial I_1} = 0 \), we obtain firm 1’s optimal innovative activity;

\[ I_1^* = \frac{\beta^2 R^2}{4}. \] \hspace{1cm} (4)

It is obvious that, since firm 2 has not entered, it will not exert any innovative activity; that is, \( I_2 = 0 \).

Therefore, the success probability of the innovation is \( P = \beta \sqrt{I_1} = \frac{\beta^2 R}{2} \). Substituting into (2), we obtain the monopolist’s equilibrium expected profit, \( \Pi_1 \). Defining welfare as the sum of the two firms’ profits, \( W = \Pi_1 + \Pi_2 \), we note that, when firm 1 takes the patent, welfare under monopoly, \( W_M \), is simply given by \( W_M = \Pi_1 \). Therefore,

\[ \Pi_1 = W_M = \frac{\beta^2 R^2}{4} - C. \] \hspace{1cm} (5)
Next, take as given that firm 1 has not taken the patent at date 0. Firm 2 enters and competes with firm 1. The duopolists choose their innovative activity to maximise

\[
\Pi_1 = P \frac{R}{2} (1 + S)(1 - d) - I_1, \quad (6)
\]

\[
\Pi_2 = P \frac{R}{2} (1 + S)(1 - d) - I_2. \quad (7)
\]

Solving \( \partial \Pi_1 / \partial I_1 = 0 \), and \( \partial \Pi_2 / \partial I_2 = 0 \), we obtain equilibrium innovative levels;

\[
I_1^* = I_2^* = \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2}{16}. \quad (8)
\]

Comparing (4) and (8), we observe that the duopolist’s innovative efforts are weakened because they share profits (following success, the duopolists achieve \( R / 2 \), whereas the monopolist achieves \( R \)). Further, innovative efforts are reduced due to profit dissipation \( d \). On the other hand, their incentives are enhanced by the expected spillover effects \( S \).

Substituting (8) into (1), the probability of success is

\[
P = \beta (\sqrt{I_1} + \sqrt{I_2}) = \frac{\beta^2 R (1 + S)(1 - d)}{2}. \]

Substituting into (6) and (7), we obtain the duopolists’ equilibrium expected profits;

\[
\Pi_1 = \Pi_2 = \frac{3\beta^2 R^2 (1 + S)^2 (1 - d)^2}{16}. \quad (9)
\]

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Therefore, if firm 1 does not take the patent, the welfare under duopoly is

\[ W_D = \frac{3\beta^2 R^2 (1 + S)^2 (1 - d)^2}{8}. \]  

(10)

In order to examine the effects of patents on welfare, and firm 1’s incentives to take patents, we initially assume that the cost of patent is zero; that is, \( C = 0 \).

Lemma 1 compares (5) and (10) in order to examine whether patents are welfare-improving or welfare-reducing.

**Lemma 1:** The effect of patents on welfare (for \( C = 0 \)):

\[ 3\beta^2 R^2 (1 + S)^2 (1 - d)^2 \geq \frac{\beta^2 R^2}{4} \Rightarrow (1 + S)^2 (1 - d)^2 \geq \frac{2}{3}. \]

**a)** Competition is welfare increasing/patents are welfare-reducing iff

\[ 3\beta^2 R^2 (1 + S)^2 (1 - d)^2 < \frac{\beta^2 R^2}{4} \Rightarrow (1 + S)^2 (1 - d)^2 < \frac{2}{3}. \]

**b)** Competition is welfare reducing/patents are welfare-increasing iff
Define the spillover/profit dissipation product; \((1 + S)^2(1 - d)^2\). Lemma 1 reveals that patents are welfare-reducing if this product is large, that is, if spillover effects are large and/or competitive dissipative effects are small. Patents are welfare-improving if this product is small; that is, if spillover effects are small and/or competitive dissipative effects are large.

Next, consider firm 1’s incentives to take the patent if the cost of patent is zero. Lemma 2 compares (5) and (9), with \(C = 0\).

**Lemma 2**: Firm 1’s incentives to take the patent (for \(C = 0\)):

a) Firm 1 takes the patent at date 0 iff

\[
\frac{\beta^2 R^2}{4} \geq \frac{3\beta^2 R^2 (1 + S)^2 (1 - d)^2}{16} \Rightarrow (1 + S)^2 (1 - d)^2 \leq \frac{4}{3}.
\]

b) Firm 1 does not takes the patent at date 0 iff

\[
\frac{\beta^2 R^2}{4} < \frac{3\beta^2 R^2 (1 + S)^2 (1 - d)^2}{16} \Rightarrow (1 + S)^2 (1 - d)^2 > \frac{4}{3}.
\]

Since firm 1 only captures half of the welfare under duopoly, conflicts may arise between firm 1’s incentives to take the patent and the welfare maximising policy. Proposition 1 combines lemmas 1 and 2 in order to examine this conflict.
Proposition 1: Intervals of conflict and alignment between the incumbent firm’s incentives and welfare maximisation in the non-sympathy game.

a) If \((1 + S)^2(1 - d)^2 > \frac{4}{3}\), firm 1 does not take the patent for any level of patent cost \(C\).

\[
\text{The policy maker maximises welfare by setting patent cost } C = 0. \text{ This provides maximum welfare } W_D = \frac{3\beta^2R^2(1+S)^2(1-d)^2}{8}.
\]

b) If \(\frac{4}{3} > (1 + S)^2(1 - d)^2 > \frac{2}{3}\), firm 1 takes the patent if \(C = 0\). This is welfare-minimising, since \(W_M = \prod_1 = \frac{\beta^2R^2}{4}\). The policy maker can induce the welfare-maximising policy by setting the cost of patent such that

\[
\frac{\beta^2R^2}{4} - C < \frac{3\beta^2R^2(1+S)^2(1-d)^2}{16}.
\]

This prevents firm 1 taking the patent, and now welfare is maximised, with \(W_D = \frac{3\beta^2R^2(1+S)^2(1-d)^2}{8}\).

c) If \(\frac{2}{3} > (1 + S)^2(1 - d)^2\), firm 1 takes the patent. The policy maker maximises welfare by setting \(C = 0\). This provides maximum welfare \(W_D = \frac{3\beta^2R^2(1+S)^2(1-d)^2}{8}\).

Hence, when the spillover/ profit dissipation product is large (proposition 1a), competitive innovation is welfare maximising. The incentives are strong enough such that firm 1 adopts the welfare-maximising patent policy for any patent cost. Therefore, the policy maker maximises welfare by setting the patent cost to zero.
When the spillover/ profit dissipation product is at a medium level (proposition 1b), competitive innovation is welfare maximising, but the incentives for firm 1 to allow entry are not strong enough. Hence firm 1 takes the patent when the cost of the patent is low. Hence, the policy maker maximises welfare by setting a high cost of patent in order to induce firm 1 not to take the patent.

When the spillover/ profit dissipation product is small (proposition 1c), monopoly innovation is welfare maximising. Firm 1 obtains a patent for any patent cost. Therefore, the policy maker maximises welfare by setting the patent cost to zero.

We demonstrate these results in the diagram at the end of section 3.


Thus far, we have assumed that the firms act in a purely self-interested manner. That is, they are only interested in private profit, and are not interested in the effects of their actions on social welfare. Motivated by Merges’ (2003) discussion of collaborative innovation, we now consider the effect of sympathy on the equilibrium of the patent game. Following Sally’s (2001) seminal psychological game of sympathy, we amend the firms’ objective functions as follows;

\[ V_1 = \Pi_1 + A_2 \Pi_2, \]  

(11)

\[ V_2 = \Pi_2 + A_1 \Pi_1, \]  

(12)
where \( \Lambda_j \) is a measure of \( i \)'s “effective” sympathy for \( j \). Following Sally, this is given by

\[
\Lambda_2 = \lambda_2 + \lambda_2 (\lambda_1 - \lambda_2),
\]

(13)

\[
\Lambda_1 = \lambda_1 + \lambda_1 (\lambda_2 - \lambda_1),
\]

(14)

where \( \lambda_j \) represents \( i \)'s fellow-feeling (or liking) for \( j \). Note that \( \lambda_j \) is a strategic choice variable for \( i \), and is affected by \( i \)'s expectation of \( j \)'s fellow-feeling for \( i \), given by \( \lambda_i \).

As described previously, in this version of the game, if firm 1 has not taken the patent at date 0, such that both firms enter at date 1, then the firms choose their sympathy levels \( \lambda_2 \) and \( \lambda_1 \) prior to choosing their innovation levels. We solve the game by backward induction.

Firstly, take as given that firm 1 has not taken the patent at date 0, such that both firms enter and compete at date 1. Furthermore, take as given that the firms have chosen sympathy levels \( \lambda_2 \) and \( \lambda_1 \). Therefore, the firms choose their innovative investment levels to maximise \( V_1 \) and \( V_2 \).

Solving \( \partial V_1 / \partial I_1 = 0 \) and \( \partial V_2 / \partial I_2 = 0 \), we obtain the optimal investment levels

\[
I_1^* = \frac{B^2 R^2 (1 + S)^2 (1 - d)^2 (1 + \lambda_2)^2}{16},
\]
Therefore, the firms’ utility functions become

\[ I_1^* = \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2 (1 + \Lambda_i)^2}{16}, \]

\[ I_2^* = \frac{3 + 2\Lambda_1 - \Lambda_2^2 + \Lambda_1 (3 + 2\Lambda_1 - \Lambda_2^2)}{16} \beta^2 R^2 (1 + S)^2 (1 - d)^2. \]

Note that, when \( \Lambda_2 = 0 \) and \( \Lambda_1 = 0 \), we obtain the innovation levels and firm values achieved in the previous non-sympathetic game.

**Equilibrium sympathy levels.**

We now move back to solve for the equilibrium sympathy levels. In order to simplify the analysis, we assume that the firms choose sympathy from a discrete set as follows:

\[ \lambda_j \in \{0, 0.5, 1\}. \]

That is, they choose from zero sympathy, medium sympathy, or high sympathy. We proceed to solve for the Nash equilibria of the normal form game.

Firstly, we derive the rivals’ expected payoffs for the different combinations of sympathy levels.

If \( \Lambda_2 = \Lambda_1 = 0 \) (the firms have no fellow-feeling for each other), or if \( \Lambda_2 = 0, \Lambda_1 = 1 \) (firm 2 has fellow-feeling for firm 1, while firm 1 has no fellow feeling for firm 2), effective
sympathy (from equations 13 and 14) is zero, \( \Lambda_2 = \Lambda_1 = 0 \). Note that we then have exactly the same results as in the unsympathetic equilibrium (see case 1). That is,

\[
V_1^* = V_2^* = \frac{3\beta^2 R^2 (1 + S)^2 (1 - d)^2}{16}.
\]

If \( \dot{\lambda}_2 = \dot{\lambda}_1 = 0.5 \), then (again using equations 13 and 14) \( \Lambda_2 = \Lambda_1 = 0.5 \). The firms exhibit medium effective sympathy. Therefore,

\[
V_1^* = V_2^* = \frac{45\beta^2 R^2 (1 + S)^2 (1 - d)^2}{128}.
\]

If \( \dot{\lambda}_2 = \dot{\lambda}_1 = 1 \), then \( \Lambda_2 = \Lambda_1 = 1 \). The firms are totally sympathetic. Therefore,

\[
V_1^* = V_2^* = \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2}{2}.
\]

If \( \dot{\lambda}_2 = 0.5, \dot{\lambda}_1 = 0.5 \), then \( \Lambda_2 = 0.25, \Lambda_1 = 0.25 \). Therefore,

\[
V_1^* = \frac{3\beta^2 R^2 (1 + S)^2 (1 - d)^2}{16}.
\]

\[
V_2^* = \frac{45\beta^2 R^2 (1 + S)^2 (1 - d)^2}{128}.
\]

If \( \dot{\lambda}_2 = 0.5, \dot{\lambda}_1 = 1 \), then \( \Lambda_2 = 0.25, \Lambda_1 = 0.75 \). Therefore,
\[ V_1^* = 0.32 \beta^2 R^2 (1 + S)^2 (1 - d)^2, \]
\[ V_2^* = 0.39 \beta^2 R^2 (1 + S)^2 (1 - d)^2. \]

We now move back to solve for the equilibrium sympathy levels. In order to do so, we solve the following normal form game (for brevity, we only show the numerical coefficient of the payoffs).

\[
\begin{array}{|c|c|c|c|}
\hline
& 2 \lambda_1 = 0. & 2 \lambda_1 = 0.5. & 2 \lambda_1 = 1. \\
\hline
1 \lambda_2 = 0. & \frac{3}{16}, \frac{3}{16} & \frac{3}{16}, \frac{45}{128} & \frac{3}{16}, \frac{3}{16} \\
\hline
1 \lambda_2 = 0.5. & \frac{45}{128}, \frac{3}{16} & \frac{45}{128}, \frac{45}{128} & 0.32, 0.39 \\
\hline
1 \lambda_2 = 1. & \frac{3}{16}, \frac{3}{16} & 0.32, 0.39 & \frac{1}{2}, \frac{1}{2} \\
\hline
\end{array}
\]

We solve for the equilibrium by considering each firm’s best responses to each of the other firm’s sympathy levels. Firm 1’s best responses are denoted by +. Firm 2’s best responses are denoted by −.

Consider firm 2’s best responses to each of firm 1’s sympathy levels (by symmetry, these are also firm 1’s best responses to each of firm 2’s sympathy levels). If firm 2 chooses \( 2 \lambda_1 = 0 \), firm 1’s best response is to select \( 1 \lambda_2 = 0.5 \). If firm 2 chooses \( 2 \lambda_1 = 0.5 \), firm 1’s best response is again to select \( 1 \lambda_2 = 0.5 \). If firm 2 chooses \( 2 \lambda_1 = 1 \), firm 1’s best response is to select \( 1 \lambda_2 = 1 \).

Hence, we observe multiple sympathetic equilibria as follows,
Lemma 3:

The multiple equilibria are as follows. Either

a) both firms exhibit medium sympathy levels; \( \lambda_2 = \lambda_1 = 0.5 \), achieving utility of

\[
V_1^* = V_2^* = \frac{45 \beta^2 R^2 (1 + S)^2 (1 - d)^2}{128}, \quad \text{and total welfare of}
\]

\[
W^* = \frac{45 \beta^2 R^2 (1 + S)^2 (1 - d)^2}{64}, \quad \text{or}
\]

b) both firms exhibit maximum sympathy levels; \( \lambda_2 = \lambda_1 = 1 \), achieving utility of

\[
V_1^* = V_2^* = \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2}{2}, \quad \text{and total welfare of}
\]

\[
W^* = \beta^2 R^2 (1 + S)^2 (1 - d)^2.
\]

c) An equilibrium does not exist in which the firms exhibit minimum sympathy, \( \lambda_2 = \lambda_1 = 0 \).

Note that welfare is maximised when both firms exhibit maximum sympathy. We assume that the firms coordinate on this equilibrium.

We now compare the results of this case with the case 1 (the unsympathetic case).

If the innovative firm 1 takes the patent at cost \( C \), such that firm 2 dose not enter, then firm 1’s monopoly profits, and welfare, remain as (5), that is \( \Pi_1 = W = \frac{\beta^2 R^2}{4} - C \).

If firm 1 does not take the patent, then, as before, both firms enter and compete. Since it is assumed that the sympathetic firms coordinate on the maximum sympathy equilibrium, we...
analyse firm 1’s incentives to take the patent, and the effect on total welfare, by comparing
firm 1’s duopoly profits and total welfare from lemma 5 b) with (5). Hence, we derive the
following results.

**Lemma 4: The effect of patents on welfare (for C = 0):**

c) Competition is welfare increasing/patents are welfare-reducing iff

\[ \beta^2 R^2 (1 + S)^2 (1 - d)^2 \geq \frac{\beta^2 R^2}{4} \Rightarrow (1 + S)^2 (1 - d)^2 \geq \frac{1}{4}. \]

d) Competition is welfare reducing/patents are welfare-increasing iff

\[ \beta^2 R^2 (1 + S)^2 (1 - d)^2 < \frac{\beta^2 R^2}{4} \Rightarrow (1 + S)^2 (1 - d)^2 < \frac{1}{4}. \]

Note the contrast with the unsympathetic case (lemma 1). In that case, the critical product at
which competition became welfare increasing was \( \frac{2}{3} \). In the maximum sympathy case, this
product becomes \( \frac{1}{4} \). That is, due to sympathy, competition becomes welfare increasing at a
lower critical product.

**Lemma 5: Firm 1’s incentives to take the patent (for C = 0):**

a) Firm 1 takes the patent at date 0 iff
\[
\frac{\beta^2 R^2}{4} \geq \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2}{2} \Rightarrow (1 + S)^2 (1 - d)^2 \leq \frac{1}{2}.
\]

b) Firm 1 does not take the patent at date 0 iff

\[
\frac{\beta^2 R^2}{4} < \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2}{2} \Rightarrow (1 + S)^2 (1 - d)^2 > \frac{1}{2}.
\]

Note the contrast with the unsympathetic case (lemma 2). In that case, the critical product at which firm 1 switched from taking the patent to not taking the patent was \(\frac{4}{3}\). In the maximum sympathy case, the critical product is \(\frac{1}{2}\). That is, due to sympathy, firm 1 will not take the patent, and hence invite competition, at a lower critical product.

As in the non-sympathetic case, we now combine lemmas 3 and 4 in order to examine conflicts between firm 1’s incentives to take the patent and the welfare maximising policy. The results are presented in proposition 2.

**Proposition 2:** Intervals of conflict and alignment between the incumbent firm’s incentives and welfare maximisation in the sympathy game.

a) If \((1 + S)^2 (1 - d)^2 > \frac{1}{2}\), firm 1 does not take the patent for any level of patent cost \(C\).

The policy maker maximises welfare by setting patent cost \(C = 0\). This provides maximum welfare \(W_D = \beta^2 R^2 (1 + S)^2 (1 - d)^2\).
b) If $\frac{1}{2} > (1 + S)^2 (1 - d)^2 > \frac{1}{4}$, firm 1 takes the patent if $C = 0$. This is welfare-minimising, since $W_M = \prod_1 = \frac{\beta^2 R^2}{4}$. The policy maker can induce the welfare-maximising policy by setting the cost of patent such that

$$\frac{\beta^2 R^2}{4} - C < \frac{\beta^2 R^2 (1 + S)^2 (1 - d)^2}{2}.$$  

This prevents firm 1 taking the patent, and now welfare is maximised, with $W_D = \beta^2 R^2 (1 + S)^2 (1 - d)^2$.

c) If $\frac{1}{4} > (1 + S)^2 (1 - d)^2$, firm 1 takes the patent. The policy maker maximises welfare by setting $C = 0$. This provides maximum welfare $W_D = \beta^2 R^2 (1 + S)^2 (1 - d)^2$.

We now compare proposition 1 (the unsympathetic game) with proposition 2 (the sympathy game). We note the following. The critical products at which competitive innovation is welfare maximising, and at which the incumbent firm allows competitive entry (by not taking a patent) are lower in the sympathetic case. Furthermore, the conflict interval (where the incumbent firm obtains a welfare-reducing patent) is smaller in the sympathetic case. Finally, welfare under competitive competition is higher in the sympathetic case.

The following chart compares propositions 1 and 2. The horizontal line represents the incumbent firm’s payoff (which is identically equal to social welfare) in the monopoly case (that is, in the presence of patents). This line applies in both the non-sympathetic and sympathetic games.
The lowest inclined line represents firm 1’s payoff in the non-sympathetic duopoly case (that is, in the absence of patents). The next lowest inclined line represents social welfare in the non-sympathetic case. The upper two inclined lines represent the sympathy game, with the top line representing welfare and the second line representing the incumbent firm’s duopoly payoff.

The chart demonstrates the following. A) The firm’s incentives to obtain a patent, and the effect on social welfare is crucially affected by the spillover/profit dissipation product. B) The firm’s incentives to obtain a patent, and the effect on social welfare is crucially affected by the type of game (non-sympathetic or sympathetic). C) The policy maker can use the chart to decide whether to allow the firm to decide on obtaining a patent, or whether to interfere in setting the cost of the patent prohibitively high.

We observe that welfare, and the incumbent firm’s duopoly payoff, is higher in the sympathy game. The firm chooses to obtain the patent when its duopoly payoff is below the horizontal line, but welfare is maximised by duopoly competition when the welfare lines are above the horizontal line. In the sympathy game, duopoly welfare exceeds monopoly welfare when the spillover/profit dissipation product exceeds $1/4$. However, the firm takes the patent unless the product exceeds $1/2$. Therefore, for zero patent costs, the locus of welfare in the sympathy game follows the horizontal line until the first vertical dotted line, along the vertical line to point A, and then along the inclined line representing sympathetic duopoly welfare.
In the non-sympathy game, duopoly welfare exceeds monopoly welfare when the spillover/profit dissipation product exceeds $2/3$. However, the firm takes the patent unless the product exceeds $4/3$.

Therefore, if patent costs are low, the locus of welfare in the non-sympathy game follows the horizontal line until the second vertical dotted line, along the vertical line to point B, and then along the inclined line representing non-sympathetic duopoly welfare.

In the conflict intervals, if the policy maker sets a high patent cost (as described in proposition 1b and 2b), the locus of welfare follows the horizontal line to the first and third inclined lines (in the sympathy and non-sympathy games respectively), and then follows the inclined lines. Hence, in the conflict intervals, the policy maker can improve welfare by setting prohibitively high patent costs.

4. Policy Implications.

We have developed a model that analyses the effects of competitive profit dissipation, spillovers and sympathetic collaboration on the welfare properties of the patent system, and
the innovator’s incentives to apply for a patent. We now use this model to consider policy implications, with particular reference to the discussion of Merges (2003) and Dreyfuss (2000).

a) Firstly, we have addressed whether patents are welfare-improving due to the Schumpeterian argument that innovative activity needs to be protected from rent-diluting competition, or welfare-reducing, since they reduce innovative competition and spillovers. We have demonstrated that the innovator’s incentives to take patents, and the effect on welfare, is crucially affected by the extent of rent-dilution and innovative spillovers.

Merges (2003) conjectures that patents will not hinder innovation and growth in the financial innovation and software industries. He argues that these firms have methods of protecting their market power and rent in the absence of patents. In terms of our model, this implies low competitive profit dissipation (low $d$). Furthermore, he claims that, although, due to network effects, knowledge transfer is extensive in the absence of patents, it can be increased by the patent system (for example, by ‘codifying’ information (hence, $S$ is small). In our model, a small $d$, combined with a small $S$, may make patents welfare-improving, and may induce innovators to obtain a patent.

In contrast to Merges, Dreyfuss (2000) argues that business concept patents are damaging to innovation. Following Merges, he argues that firms have methods of protecting their market power and rent in the absence of patents (low $d$). However, he believes that the spillover effects of competition are large (hence, $S$ is large). In our model, a small $d$, combined with a large $S$, may make competition welfare-improving, and may induce innovators not to obtain a patent.
However, Dreyfuss argues that this needs to be considered on a case-by-case basis. For example, he considers the software industry.

“At this point in time, the software industry is mature; new developments are hard-fought- increasingly expensive to create (low $S$ in our model), yet they remain cheap to copy (high $d$ in our model) . I think we can assume that the State Street decision is good law. If so, then perhaps those business methods that partake of the software rationale should also be candidates for protection.”

On the other hand, in the field of financial innovation, Dreyfuss argues that junk bonds do not need patent protection, since they “do not need the special incentives of exclusive rights regimes. Junk bonds are good examples of inventions that generate their own rewards (low $d$ and/or high $S$ in our model).

b) We suggest that policy makers could use patent fees ($C$ in our model) as a policy instrument. When patents are welfare reducing, the cost of patents should be increased. When patents are welfare increasing, the cost of patents should be reduced. Indeed, this echoes Merges’ (1999) and Jaffe and Lerner’s (2005) analysis of invalid patents. The latter authors argue that there has been an explosion in the use of invalid patents because administrative changes to the PTO have made invalid patents easier to obtain. Merges (1999) argues that an increase in patent fees would reduce the number of invalid patent applications.
c) Merges (2003) argues that network effects may increase collaboration and knowledge sharing/spillovers. Some competitors are naturally more sympathetic to each other than others (eg Universities as opposed to firms). By comparing non-sympathetic and sympathetic equilibria, we demonstrate that sympathy encourages collaboration, and is indeed welfare-improving. Therefore, steps should be taken to encourage collaboration and cooperation across institutions, and an attempt should be especially made to break down the mistrust that exists between industry and academia.

5. Conclusion.

We have developed a patent/innovation model in order to analyse the effects of competitive profit dissipation and spillovers on an innovative firm’s incentives to take patents, and on economic welfare. We demonstrate the following. When spillovers are small, and/or profit dissipation is large, the incumbent has an incentive to obtain a patent in order to protect its monopoly position. This is welfare maximising. When spillovers and profit dissipation are of medium order, welfare is maximised by innovative competition, but the incumbent’s incentive to obtain a patent remains. The policy maker can address this by setting prohibitively high patent costs. When spillovers are large, and profit dissipation is low, the incumbent does not obtain a patent, and this is welfare maximising. When firms exhibit sympathetic collaboration, duopoly welfare is higher for any combination of spillover and profit dissipation, and the interval of conflict between the firm and the policy maker is smaller.

Our model has two main policy implications. Firstly, the efficacy of the patent system should be considered on a case-by-case basis. For relatively new, well-differentiated fast-growing industries, patents should be restricted. For more mature industries, the patent system may be
desirable. Secondly, our sympathy game shows that policy makers should encourage collaboration and fellow-feeling between researchers. Collaborative university research provides a model for this, and should be extended to relationships between universities and industry.

The model provides scope for future research. Firstly, it should be developed to consider a sequential game a la Bessen and Maskin (2000) or Panagopoulos (2004).

Secondly, consideration of Kesan and Banik’s analysis suggests an important future development of our model. That is, we could incorporate incomplete contract problems at the ex post stage, relating to litigation and patent invalidation. This would provide a more complete analysis of the effects of the patent system on innovation and growth.

Thirdly, our model could incorporate the knowledge diffusion effects of patents (Bessen 2005). Furthermore, in our analysis, if the incumbent takes a patent, the rival can never enter. In a future development, we will consider a model which incorporates the following interesting trade-off; if the incumbent takes the patent, this will exclude the rival for a period, but lead to high knowledge diffusion, whereas, if the incumbent does not take the patent, the rival can enter immediately, but knowledge diffusion will be low.

Finally, our model should be developed as a tool in order to inform policy makers in designing patent systems. This is a very important step, given the controversy surrounding the relationship between patents and innovation.
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