Strategic Patent Breadth for Drastic Product Innovations

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1. Introduction

Patents are the most powerful form of intellectual property protection and they have been used for the last 500 years as a mechanism to stimulate the production of knowledge. They are of particular importance in research intensive industries, like biotechnology, where the ability to appropriate the benefits from innovation is crucial for covering high research costs and generating further investment in the field. Innovators seek patent protection as a means of safeguarding the technological territory covered by their inventions. The granting of exclusive rights by the patent for a given time period – patent length – does not automatically imply protection and the ability to appropriate innovation rents or to exert monopoly power in a market. Instead, the main determinant of the rents an innovator can appropriate with a patent is the scope or breadth of the protection that the patent grants.[1]

Patent breadth determines the technological territory claimed and protected by the patent – the area in the technological space in which competitors cannot offer rival inventions without infringing the patent. The breadth of protection granted by a patent is case specific. Thus, unlike patent length, patent breadth cannot be pre-specified, pre-announced or standardized. The main determinants of patent breadth are the number and the nature (general/specific) of the claims that the patentee requests in the patent application and that are subsequently upheld by the Patent Office and the courts. The greater the number of claims made and upheld and the more general are these claims, the greater is the protection granted.[2]

[1] The terms width and height have also been used interchangeably with patent scope in the patent literature.
[2] Miller and Davis (1990) state that in patent claims 'more means less'. The view that detailed claims imply less protection is known in the patent literature as the 'more is less' principle (Matutes et. al. 1996).

The innovator plays a crucial role in the patenting process and in the determination of the protection that is granted. The innovator's claims determine whether the patent will be granted (claims must satisfy the patentability requirements of novelty, utility, nonobviousness and enablement) and the breadth of patent protection. The breadth of the patent claims in turn determines the effective patent life. As will be discussed in more detail below, patent claims are often contested, either because the patent is infringed or because its validity is challenged. Court rulings on patent infrigement and validity depend to a large extent on the claims that have been made.

Existing economic studies of the patenting behavior of the innovator/patent applicant have been limited to the analysis of the decision to patent the innovation or to keep it a secret (Horstmann et. al. 1985, Waterson 1990). The innovator's role in the determination of the scope of protection covered by the patent (once the decision to patent has been made) has not been explored in the literature. Instead, studies on optimal patent policy and patent breadth in particular assume that the innovator will apply for the broadest patent protection possible (Gilbert and Shapiro 1990, Merges and Nelson 1990, Schotchmer 1991). The decision making process of the patent applicant is thus assumed rather than derived in these studies.

The purpose of this paper is to explicitly model the patenting behavior of an innovator who applies for patent protection and to determine the patent breadth that provides the maximum benefits to the patentee. It is assumed in this paper that the patentee acts strategically and with foresight, taking into consideration the effect that the patent claims will have on potential competitors. In addition, the patentee incorporates the transaction costs associated with the granting of patents. These transaction costs are incurred when resolving disputes concerning the validity and/or infringement of a patent and/or when negotiating a settlement.

The paper focuses on patents that involve drastic product innovations. Drastic product innovations are innovations that generate new demand or meet demand not previously met, thus enabling the innovator to exert monopoly power in the market. We focus on drastic innovations because the innovation rents that are at stake are substantial, thus increasing the probability of litigation and the incurring of transaction costs. In addition, according to the Patent Office's policy, drastic innovations are usually granted broader protection (EPO 2000, USPTO 1999).[3] Thus, claims to drastic inventions are often allowed to cover areas beyond the area examined and disclosed by the inventor. Nelson and Merges (1990) observe that the narrowing of the claims of pioneering/drastic inventions is left to the courts.

The rest of the paper is organized as follows. Section two describes the relationship between patent breadth and the flow of profits to the innovator. Section three describes the market conditions, defines patent breadth and models the choice of patent breadth as a sequential game of complete information. Section four concludes the paper.

2. Patent Breadth and Innovation Rents

The standard argument in the economics literature on patent breadth is that the patent applicant will apply for the broadest scope of protection possible. This argument is based on two assumptions. The first is that a positive relationship can be assigned

[3] According to the EPO (2000) 'an invention that opens up a whole new field is entitled to more generality in the claims than an invention that is concerned with advances in a known field of technology'. This is due to the fact that the more pioneering is an innovation, the harder it is for an examiner to object to broad claims as the harder it is to find something in the prior art to demonstrate that embodiments of the claimed invention would be impossible to make without undue experimentation. In other words, the burden falls on the examiner who must disprove enablement (Merges and Nelson 1990).

between patent breadth and the flow of profits to the innovator (Gilbert and Shapiro 1990, Gallini 1992). The second assumption is that the Patent Office will prune back or reject broad claims and will determine the 'optimal' breadth of protection. If the first assumption holds, then a profit-maximizing innovator should apply for the broadest protection possible. If the second assumption is true, then the optimal patent breadth will always be determined by the Patent Office. The innovator in this case should apply for the broadest protection, since the breadth of protection granted cannot be greater than the breadth of protection claimed.[4]

Patent breadth determines the effective patent life and the degree of competition allowed in the market, which in turn determine the reward to the innovator. It is generally true that a patent with a very narrow protection (zero breadth) can be of no use to the patentee as competitors with almost identical inventions can enter his market.[5] It is also generally true that the broader the protection granted by the patent, the harder it is, *ceteris paribus*, for a new technology to render the existing one obsolete without infringing the patent. Thus, broader patents are associated with a longer effective patent life. In addition, the broader is the patent protection, the less competitive is the market since the harder it is for a competitor to enter without infringing the patent. Given that the longer is the effective patent life and the smaller is the number of competitors that can successfully enter the patentee's market the greater are the profits for the patentee, it is a reasonable conclusion that there is a positive relationship between patent breadth and patent profits.

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[4] In other words, if the innovator applies for a very narrow protection the Patent Office cannot extend his claims and grant him broad protection even if that would have been optimal.

[5] In the present context zero breadth means protection only against duplication of the patented product. This is the type of protection offered in the early days of the patent system. Klemperer (1990) gives the example of the cotton gin first patented by Eli Whitney in 1794 which offered him practically no protection since his competitors could get patents on almost identical inventions.

The above argument holds true as long as the patent, once granted, is not challenged legally. This has not been the case, however. A patent may be contested in different ways after it has been granted, which could lead to the narrowing of the breadth of its protection, or to elimination of protection if the patent is found to be invalid (Merges and Nelson 1990). A patent is contested either when the patented subject matter is infringed or when its validity is challenged (Cornish 1989). The validity of the patent may be challenged either directly by launching an opposition in the Patent Office or in the patent courts or indirectly during an infringement trial.

A direct challenge to patent validity may be launched in the Patent Office within nine months of the patent being granted. Statistics from the USPTO on patents whose validity was opposed show that less than one quarter of the re-examined patents survive without change (Barton, 2000). The validity of the patent may also be attacked when the patentee tries to enforce his patent rights by filling an infringement lawsuit, since the claim that the patent is infringed is usually met with a counterclaim by the accused infringer that the patent is invalid. Accused infringers have been successful in invalidating patents – U.S. courts have found patents to be invalid more often than valid (Miller and Davis 1990).

The role of the courts in refining patent scope has been crucial as they have often invalidated or made a ruling that effectively narrowed the scope of a broad patent (Merges and Nelson, 1990). In fact, the broader is the patent protection, the higher is the probability that the patent will be challenged legally, that it will overlap another patent and/or that the courts will invalidate it or narrow its scope (Lerner 1994). Lanjouw and Schankerman (2001) have found that there is a positive relationship between the number of claims and the risk of litigation. Given the above, a broader patent breadth may shorten the effective patent life, which in turn means that a positive relationship between patent breadth and patent profits cannot be assumed.

Even though the role of the courts in refining patent scope is acknowledged in the literature (Merges and Nelson 1990, Scotchmer and Green 1990, Lerner 1994), existing studies on optimal patent policy do not incorporate the transaction costs related with the use of the legal system.[6] Litigation and settlement costs can be substantial, effectively diminishing the value of the patent and consequently the incentive to seek patent protection and to invest in research. The American Intellectual Property Law Association in its 1999 Economic Report estimates that average litigation costs are 1.5 million dollars per side (Barton 2000). Hofer and Edmundson (1999) claim that settlement costs have, in some cases, exceeded 100 million dollars.

The assumption that the Patent Office will always eliminate broad claims and will determine the optimal scope of protection is also not realistic. Barton (2000) points to resource limitations at the USPTO generated by the increase in patent applications over the last decade,[7] and estimates that a patent examiner spends on average only twenty five to thirty hours on each application. The time limitations adversely affect the examiner's ability to conduct effective searches and to evaluate the patent claims. One consequence is that the examiner often sides with the applicant and grants broad claims. Lerner (1994) observes that the USPTO often awards broad patents that appear to overlap, leading to

[6] Waterson (1990) introduces transaction costs related with the use of the legal system. He does not study patent breadth though. Instead, he examines the effect of the patent system on the efficient number of products in a market. The patenting behaviour of the innovator in his model consists only of the decision to patent or not patent. His model assumes that the protection granted by the patent will cover the entire market.

[7] Voss (1999) claims that the number of applications in the USPTO increases by more than 8% annually mainly due to software and biotechnology applications.

disputes that are resolved through either negotiations or litigation.

Despite the above-mentioned problems related to patent breadth, we do observe broad patents in practice, especially in biotechnology, which implies that the innovator has applied for broad protection. This is mainly due to the fact that biotechnology is an area that generates many drastic innovations, which as was mentioned above are usually granted broader protection. Lentz (1988) also refers to the myopic behavior of the innovator when he concludes that broad biotechnology patents are observed due to the 'inherent imprecision of the biological studies, overreaching and/or naivete'. Another explanation could be that the innovator relies on the Patent Office to structure his claims. Given the tendency of the Patent Office to grant broad patents to drastic innovations and the fact that broad patents are often overturned, patentees need to carefully consider the breadth of the patent they are claiming.

3. Modeling the Patenting Process

The patenting process that will determine the strategic patent breadth for drastic product innovations is modeled as a sequential game of complete information. The agents involved in the game are a patentee who applies for a patent and decides on the breadth of protection claimed, and a (potential) entrant who decides where to locate in the product space and who competes with the patentee in the market. We assume that the patentee has invented a product that meets the patentability requirements and that the regulator (i.e. Patent Office) always grants the patent as claimed; thus the regulator is not explicitly modeled. The latter assumption is made to reflect the case under which the innovator has no help from the Patent Office in determining the breadth of protection.

The patentee in our model determines the breadth of protection that will allow the maximum appropriation of innovation rents. The patentee is foresighted and acts strategically taking into consideration the entrant's responses to his choice of patent breadth. He is aware that the probability of the patent being attacked and/or invalidated increases with the breadth of protection and that a broad patent could impede his ability to enforce his rights if the patent is infringed. In addition, the innovator does not rely on the Patent Office to structure his claims. He is aware of the inefficiencies in the determination of patent breadth in the Patent Office and of the fact that his effort to safeguard his technological territory does not usually conclude with the granting of the patent. He thus takes into consideration the transaction costs associated with the granting of patents when he determines the breadth of protection claimed.

The game consists of three stages. At the first stage of the game the patentee, having invented a drastic product (which will allow him to exert monopoly power in the market) and having decided that he wants to patent it, determines the breadth (b) of protection that will be claimed. In the second stage an entrant observes the patentee's product and the breadth of protection granted to it and chooses the characteristics of his product (his location in the product space). In the third stage two cases may prevail, depending on where the entrant has located. In the first case both the patentee and the entrant market their products and compete in prices. In the second case the entrant is not allowed to market his product and the patentee acts as a monopolist. We assume that both the patentee and the entrant are rational and foresighted. Thus, they both fully anticipate the reaction of their opponent to their actions.

The patentee's decisions to invent (i.e. his choice of the innovation's specifications) and patent are not examined – these decisions are treated as exogenous to this game. The only decision that the patentee has to make involves the breadth of protection that will be claimed – the length of protection is predetermined and it is the same for all patents. In addition, we assume that the production process is deterministic, so that once the entrant chooses a location he can produce the chosen product with certainty. Finally, we assume that there is no time lag between making and realizing a decision.

- ***Market conditions and determination of patent breadth***

The market that the patentee operates in is characterized by the following conditions. First, the market can only support two products. Every product i has an inherent quality represented by the parameter q_i. The quality parameter q_i takes values in the interval $[\underline{q}, \overline{q}]$ where $\underline{q}$ corresponds to the lowest quality that can be allowed in the market while $\overline{q}$ corresponds to the highest quality that is technologically feasible. All consumers agree that higher quality is preferred to lower quality. We also assume that every product can be completely described by its quality alone (i.e., only one variety of the product can be produced).

The market consists of differentiated consumers uniformly distributed in the interval [0, 1] each buying one unit of either product 1 or 2 but not both. The consumers differ with respect to some attribute λ uniformly distributed with unity density $f(\lambda)=1$ in the interval $\lambda \in [0, 1]$. The attribute λ determines a consumer's willingness to pay for quality. Consumers differ in their willingness to pay due to differences in income, age, education and other characteristics. The utility function for the consumption of product i is given by:

(1) $U_i = V + lq_i - p_i$

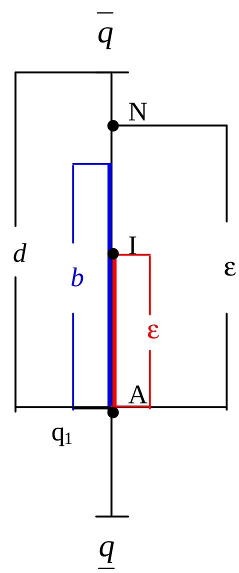
where p_i is the product price and V is a base level of utility. Product i will be consumed as long as $U_i \geq 0$ and $U_i > U_j$. We assume that V is large enough for $V \geq p_i \ \forall i=1,2$ to hold true so that the market is always served by at least one product. The consumer who is indifferent between products 1 and 2 will have a λ value denoted by $\hat{l}$ and given by:

(2) $$U_1 = U_2 \Rightarrow \hat{l} = \frac{(p_2 - p_1)}{(q_2 - q_1)} = \frac{(p_2 - p_1)}{e}$$

Figure 1 presents the one-dimensional product space where quality is depicted on the vertical axes. In this product space point A represents product 1 with characteristic q_1. Assume that product 1 is patented and has been given a patent breath b. We consider the case where the patentee anticipates that the entrant enters with a product of a better quality, such that $q_2=q_1+\varepsilon$ where $\varepsilon \in (0, (\bar{q}-q_1)]$.

When b takes its minimum value of zero the protected area is just a point in the product space, point A. This case represents the minimum breadth of protection granted by the patent, namely zero breadth. With zero breadth of protection, the entrant can locate anywhere in the product space except at point A. The maximum value that b can take is given by $d = \bar{q} - q_1$. To normalize the model, we assume that $(\bar{q}-q_1)=d=1$. Thus $b \in [0,1]$ and $\varepsilon \in (0,1]$.

Figure 1. The product space and the breadth of patent protection



■ ***The entrant's location choice***

Upon entry, the entrant produces a product of quality $q_2 > q_1$. We further assume that the patentee and the entrant have the same production cost structure and that the per unit production costs are independent of the level of quality and are equal to zero. The patentee and the entrant do not have the same fixed costs, however. To produce a product i of a given quality (q_i), fixed sunk costs (R&D costs) must be incurred. These fixed costs – denoted by $F_R(q)$ –are an increasing function of quality:

$$F_R = b\,\frac{q^2}{2} \qquad \text{where } b \geq \frac{4}{9}.$$

It is assumed that the patent achieves perfect information disclosure, which, in the absence of protection, enables the entrant to reproduce the patented product without incurring the R&D costs. Perfect information disclosure implies that $F_R(q_1)=0$ for the entrant. Since $q_2=q_1+\varepsilon$ the R&D costs incurred by the entrant for the production of q_2 are a function of the distance ε away from q_1 that the entrant locates, namely:

$$F_R(q_2) = b\frac{e^2}{2}.$$

After observing the patentee's product and the breadth of the patent, the entrant has two choices: (1) to locate inside the patentee's claims (ε < b – see point I in Figure 1); or (2) to locate outside (ε ≥ b – point N in Figure 1). The first choice corresponds to a decision to infringe the patent, while the second corresponds to a decision not to infringe the patent. We assume that when the entrant locates at a distance ε<b away from q_1, a trial always takes place, either because the patentee files an infringement lawsuit or because the entrant directly challenges the validity of the patent. We further assume that the filling of an infringement lawsuit is always met with a counterclaim by the accused infringer that the patent is invalid.[8]

The patent system being modeled is assumed to be that of the fencepost type, in which claims define an exact border of protection. Under the fencepost system, infringement will always be found when an entrant locates within the patentee's claims, unless the entrant proves that the patent is invalid (Cornish 1989).[9] The implication of assuming a fencepost patent system is that the probability that the patent will be infringed (given that the entrant locates at ε<b distance away from q_1) is equal to the probability that the validity of the patent will be upheld. The probability that infringement is found is denoted by μ.

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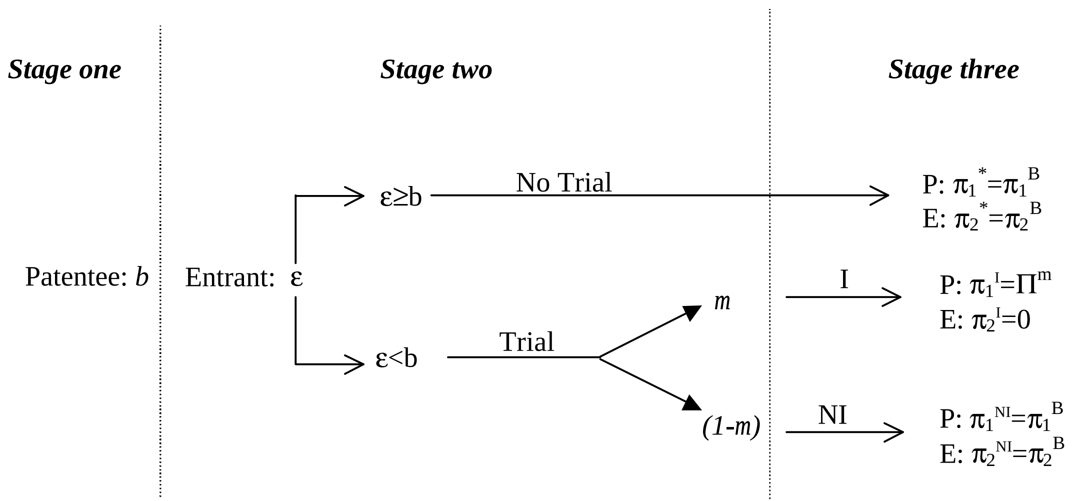
[8] This is a standard defence adopted by accused infringers. For more details see Cornish (1989) chapters II and VI.

[9] In contrast, a signpost patent system implies that claims provide an indication of protection and the claims are interpreted using the doctrines of equivalents and reverse equivalents. The fencepost patent system implies that the events that the patent is infringed and that the patent is invalid can be treated as mutually exclusive and exhaustive.

The greater is the breadth of the patent, the smaller is the probability that the patent will be found to be valid (or equivalently that infringement will be found). This assumption follows in part because the broader is the protection claimed, the harder it is to avoid obviousness, to differentiate the innovation from prior art (to show novelty) and to demonstrate that the innovation is enabling. As well, this assumption is in accordance with evidence from the literature that courts tend to uphold narrow patents and invalidate broad ones (Waterson 1990, Cornish 1989, Merges and Nelson 1990). It is also assumed that when the maximum breadth is claimed (b=1), the patent will always be found to be invalid. These assumptions are captured by assuming that $\mu = 1 - b$.

Figure 2. Determination of the strategic patent breadth



A summary of the formal strategic patent game is presented diagrammatically in Figure 2. In Stage one, the patentee chooses patent breadth b. In Stage two, the entrant chooses where to locate in the quality space by choosing the distance ε. The choice of ε determines whether a trial occurs. No trial occurs if the entrant chooses ε b – in this case, the two competitors both produce their respective products. A trial occurs if the entrant chooses $\varepsilon < b$. At the trial, the probability is μ that infringement is found. If this is the outcome of the trial, the entrant is not allowed to market its product in Stage three of the game and the patentee operates as a monopolist. When infringement is not found (with probability $(1-\mu)$) both the entrant and the patentee market their products. While there is no protection for the patentee's product in this case, the entrant has no incentive to relocate within the quality space (i.e., the entrant has no incentive to move from point I in Figure 1).

Transaction costs incurred during the infringement trial are denoted by C_T and they are assumed to be the same for both the patentee and the entrant. These costs are assumed to be independent of the breadth of protection and of the entrant's location. These costs will only be incurred if $\varepsilon<b$ and they are assumed to be sunk – once made they cannot be recovered by either party.[10]

The sub-game perfect equilibrium of this patenting game is found using backwards induction. We first solve the game under the assumption of no protection to determine where it would be optimal for the entrant to locate when he is not constrained by the patent breadth.

- ***No patent protection***

The pricing equilibrium. In stage three, the quality choice has been made and fixed costs have been sunk. Given equation (2) the demand for the patentee's and the entrant's product are given by $y_1=\hat{l}$ and by $y_2=1-\hat{l}$, respectively. The patentee and the entrant maximize their profits given respectively by:

[10] With this assumption we exclude the possibility of the court awarding lawyers' fees to either party.

$$\text{(3)} \qquad \text{P:} \quad \max_{p_1} p_1^B = p_1 y_1 = p_1 \frac{p_2 - p_1}{e}$$

$$\text{E:} \quad \max_{p_2} p_2^B = p_2 y_2 = p_2 (1 - \frac{p_2 - p_1}{e})$$

Optimization of the objective functions in (3) yields the following first order conditions:

$$\text{(4)} \qquad p_1^* = \frac{p_2}{2}$$

$$p_2^* = \frac{p_1 + e}{2}$$

Simultaneously solving the equations in (4) yields the equilibrium prices, quantities and profits in the final stage of the game:

$$\text{P:} \; p_1^* = \frac{e}{3}, y_1^* = \frac{1}{3}, p_1^B = \frac{e}{9}.$$

$$\text{E:} \; p_2^* = \frac{2e}{3}, \; y_2^* = \frac{2}{3}, \; p_2^B = \frac{4e}{9}.$$

Since it has the higher quality product, the entrant charges the higher price. The entrant serves two thirds of the market, while the patentee serves one third of the market. Profits are increasing in the distance ε between the location of the patentee and the entrant. The greater is the difference in quality, the less intense is the competition in the final stage of the game.

The location choice. The entrant chooses the distance ε away from q_1 that will maximize its objective function at the second stage of the game. The objective function of the entrant is given by:

$$\text{(5)} \qquad \text{E:} \; \max_e \Pi_2^{NP} = p_2^B - F_{R2} = \frac{4e}{9} - b\frac{e^2}{2}$$

Optimization of equation (5) yields the following first order conditions for a maximum:

(6) $$e^{NP} = \frac{4}{9b}$$

The *no protection* location choice for the entrant is thus $q_2 = q_1 + e^{NP} = q_1 + \frac{4}{9b}$ which holds for $b \geq \frac{4}{9}$ since ε∈(0,1].

The results of the pricing game show that it is not optimal for the entrant to locate next to the patentee (i.e., the Bertrand profits are increasing in ε). Instead, as shown by the result of the location game (equation 6), the entrant locates as far away from the patentee as the R&D costs allow him to. Thus, when β takes its minimum value $(b = \frac{4}{9})$ the entrant locates at the edge of the market (ε=1) maximizing differentiation between his product and the patentee's product.[11]

The *no protection* profits for the patentee and the entrant are obtained by substituting equation (6) in the profit functions. This substitution yields the following payoffs:

P: $$\Pi_1^{NP} = \frac{e^{NP}}{9} = \frac{4}{81b}$$

E: $$\Pi_2^{NP} = \frac{4e^{NP}}{9} - b\,\frac{(e^{NP})^2}{2} = \frac{8}{81b}$$

The above relationships show that the greater is β, the closer the entrant locates to the patentee since the more expensive it becomes to produce the better quality product. The

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[11] This is a well-established result in the product differentiation literature. When competitors first choose their locations in the product space and then compete in prices they choose maximum differentiation to relax competition in the pricing stage that would curtail their profits (Lane 1980, Motta 1993, Shaked and Sutton 1982).

closer the entrant locates to the patentee the smaller are the profits for both the patentee and the entrant.

- ***Patent Protection b Î [0,1]***

Given the assumption of complete information, the patentee knows how the entrant will react to its choice of patent breadth. The patentee thus chooses the breadth of protection that induces the desired behavior from the entrant. To choose breadth, the patentee compares its payoffs under the *no trial* outcome to its expected payoffs under the *trial* outcome. If the former payoffs are greater than the latter, the patentee always claims a patent breadth below the entrant's optimal location choice under the *no protection* outcome. If the latter payoffs are greater, the patentee chooses breadth so as to induce the entrant to locate within his claims.

<u>No trial outcome</u>. If the patentee chooses $b \leq \frac{4}{9b}$ it is always optimal for the entrant to locate at $e = \frac{4}{9b}$ and no trial will occur (the *no trial* outcome in Figure 2). This outcome leads to the same payoffs as the *no protection* outcome analyzed above. Thus, $\Pi_1^{NT} = \Pi_1^{NP} = \frac{4}{81b}$, $\Pi_2^{NT} = \Pi_2^{NP} = \frac{8}{81b}$.

<u>Trial outcome</u>. If the patentee chooses $b > \frac{4}{9b}$ the entrant infringes the patentee's product. To find which location is optimal for the entrant under this case we solve the game under the trial outcome.

<u>*The pricing equilibrium*</u>. If infringement is found during trial the entrant will not be allowed to market his product and he will make zero profits in the final stage of the game,

$p_2^I = 0$. The patentee on the other hand will be operating as a monopolist until his patent expires. The patentee's monopoly profits are given by $p_1^I = \Pi^m$.

If infringement is not found, the patent will be invalidated and the entrant will be allowed to remain in the market and to produce the quality of product that it has chosen. Both the entrant and the patentee will market their products and they will compete in prices in the third stage of the game. Their Bertrand profits are given by $p_1^{NI} = p_1^B = \frac{e^T}{9}$ and $p_2^{NI} = p_2^B = \frac{4e^T}{9}$ where ε^T is the optimal location choice under the *trial* outcome.

<u>*The location choice*</u>. The location of the entrant will be determined through the optimization of expected profits given by:

(7) E: $\max_e \mathrm{E}(\Pi_2) = m \cdot p_2^I + (1-m)\cdot p_2^B - F_{R2} - C_T = 0 + b\cdot\frac{4e}{9} - b\,\frac{e^2}{2} - C_T$

Optimization of the objective function in equation (7) yields the first order conditions:

(8) $e^T = \frac{4}{9b} b$

For breadth values larger than the optimal location under the *no protection* outcome ($b > \frac{4}{9b}$), the entrant finds it optimal to locate at a distance proportional to the breadth of the patent. Note that because there is uncertainty with respect to whether the entrant will be able to continue in the market, he 'underlocates'. In order to reduce the R&D costs (which are incurred with certainty), the entrant moves closer to the patentee than would be the case if infringement was not a possibility.

<u>*The patent breadth choice*</u>. Substitution of the optimal location choice (equation (8)) in

the profits of the third stage yields: $p_1^{NI} = p_1^{B} = \frac{4b}{81\beta}$. The patentee maximizes his expected profits under the trial outcome. His objective function is given by:

(9) $$\text{P: } \max_b \mathrm{E}(\Pi_1) = \mu \cdot \Pi^m + (1-\mu) \cdot p_1^{B} - C_T = (1-b)\Pi^m + b\frac{4b}{81\beta} - C_T$$

The first order conditions to the maximization problem yield the optimal breadth of protection claimed under the *trial* outcome. This is given by:

(10) $$b^T = \frac{81\Pi^m \beta}{8}$$

Since b$\in$[0,1] the above relationship implies that a solution exists as long as $\Pi^m \leq \frac{8}{81\beta} = \Pi_2^{NP}$. Thus, under the *trial* outcome the monopoly profits cannot be greater than the profits that the entrant makes under the *no trial* outcome.

Equation (10) shows that the breadth claimed is proportional to the level of monopoly profits that the patentee can obtain from his innovation and to the entrant's R&D cost parameter β. The result that the greater are the monopoly profits, the greater is the incentive to claim broad protection is obvious and expected.

The less obvious result is that the more costly it is for the entrant to introduce a better quality product (the greater is the value of β), the greater is the patent breadth claimed by the patentee. The intuition behind this result is that the greater is β, the closer the entrant will locate to the patentee and the smaller will be the Bertrand profits. By claiming a protection that is broader than the entrant's optimal location choice, the patentee induces the entrant to infringe (since it becomes expensive for the entrant to locate outside the patentee's claims when $b > \frac{4}{9\beta}$). Given that infringement has occurred, the patentee can make monopoly profits with probability μ.

Substitution of equation (10) in equation (8) gives:

(11) $$e^{T} = \frac{4}{9b}\frac{81\Pi^{m}b}{8} = \frac{9}{2}\Pi^{m}$$

which when it is substituted in equation (7) yields the optimal expected profits for the entrant under the trial outcome. The expected profits are given by:

(12) $$E(\Pi_{2}) = \frac{81b(\Pi^{m})^{2}}{8} - C_{T}$$

For the expected profits in (12) to be positive, the trial costs have to be bounded from above, that is $C_{T} \leq \frac{81b(\Pi^{m})^{2}}{8}$. We assume that the trial costs are low enough to guarantee that the entrant will always enter in the market.

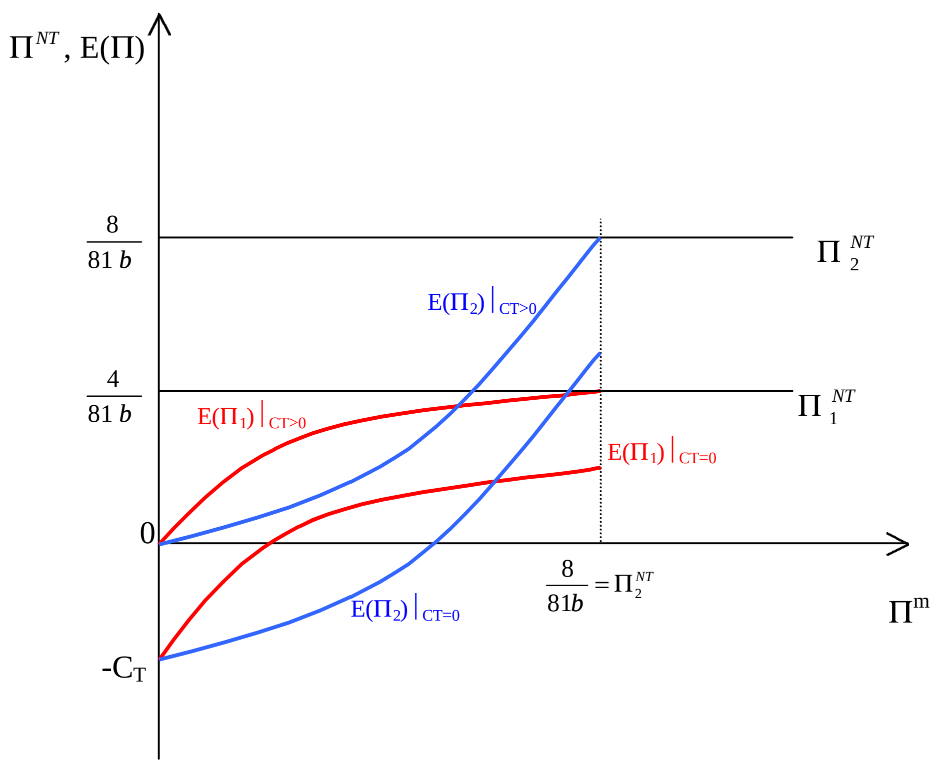
The substitution of equation (10) and (11) into equation (9) gives the optimal expected profits for the patentee under the *trial* outcome:

(13) $$E(\Pi_{1}) = \Pi^{m} - \frac{81b(\Pi^{m})^{2}}{16} - C_{T}$$

Having estimated the patentee's payoffs under both the *trial* and the *no trial* outcome we can determine the strategic breadth of protection. The patentee chooses the breadth of protection that results in the highest payoff. For given values of β and C_T the maximum value that expected profits could attain is when monopoly profits take their maximum value, $\Pi^{m} = \frac{8}{81b}$. For this value of monopoly profits the expected profits are given by $E(\Pi_{1}) = \frac{4}{81b} - C_{T}$ which is always smaller than $\Pi_{1}^{NT} = \frac{4}{81b}$ for positive trial costs.

For the entrant, substitution of the maximum value that monopoly profits can attain in the optimal expected profits (equation 12) yields $E(\Pi_2) = \frac{8}{81b} - C_T$ which is always smaller than $\Pi_2^{NT} = \frac{8}{81b}$ for positive trial costs. Figure 3 depicts this result for trial costs small enough to guarantee that expected profits are positive ($C_T < \frac{4}{81b}$).

Figure 3. The relationship between payoffs under the trial and no trial outcomes



The above results suggest that that it is always optimal for the patentee to claim a breadth of protection that yields the *no trial* outcome – i.e., the breadth of protection chosen is always smaller than the entrant's optimal location choice under no protection. The *no trial* outcome is also always optimal for the entrant. When trial costs are zero and monopoly profits are at their maximum value, the patentee is indifferent between choosing a breadth of protection that results in a trial and a breadth of protection that would yield the *no trial* outcome.

Our model suggests that it is not generally optimal for the patentee to claim the broadest protection possible. By claiming broad protection the patentee forces the entrant to infringe the patent, which induces him to under invests in quality and to locate closer to the patented product than he would have located under no infringement. The closer the entrant locates to the patentee the more intense is competition at the pricing stage of the game (because the closer substitutes are the products) and the smaller are the profits for both parties. The only case where it is optimal for the patentee to apply for the broadest protection possible is when it is optimal for the entrant to locate at the edge of the market (when $b = \frac{4}{9}$).

Given the above, the optimal breadth claimed should be determined in relation to the entrant's optimal location choice under no protection. This is so because in the absence of protection the entrant has an incentive to locate the further away possible from the patentee. This behavior results in the maximum differentiation possible between the patentee's and the entrant's product, which relaxes price competition in the final stage of the game and maximizes profits for both parties.

4. Conclusions

Economic patent studies have limited the study of the patenting behavior of the innovator to the analysis of his decision to patent or not to patent the innovation. The innovator's decision to determine the breadth of protection that he will claim, which in turn determines whether the patent will be granted, the breadth of protection granted and the viability of the patent has not been explicitly modeled in the literature. Instead, various studies have assumed that a profit-maximizing innovator will always apply for the broadest protection possible.

This paper uses a simple model to describe the patenting behavior of the innovator who, having invented a drastic product innovation and having decided to seek patent protection, determines the breadth of protection that maximizes the appropriation of the innovation rents from the invention. To determine the optimal breadth of protection claimed, the patentee acts strategically, choosing the breadth of protection that induces the desired behavior by the entrant. The patentee is foresighted and anticipates that he may have to incur costs to enforce his patent rights. Our model suggests that for positive trial costs, the patentee always claims a breadth that induces the entrant to locate outside the area in the product space protected by the patent claims.

Contrary to what it is traditionally assumed our results show that it is not generally optimal for the patentee to claim the maximum breadth possible. In fact, knowing that he cannot prevent entry, the patentee allows the entrant to enter without infringing the patent. This result occurs because if the patentee claims too large a breadth, the entrant is forced to infringe the patent and he is induced to restrict its investment in quality. This means that the entrant will produce a closer substitute to the patentee's product, an outcome that is harmful to both parties.

Our results hold under the assumption of a fencepost patent system, which implies that the events that the patent is infringed and the patent is invalid can be treated as mutually exclusive and exhaustive. In addition, we have assumed that the market can only support two products, that entry will always occur and that the production process is deterministic. Relaxing the above assumptions is the focus of our future research.

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