When to Patent - A War of Attrition Perspective

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An Extended Abstract

The influence of patent policy on innovations in general and sequential innovations in particular was extensively discussed in previous research. A concern common to all innovation activities is the tradeoff between welfare loss due to the monopoly power awarded to the innovators and the profit to the innovators, necessary to induce the innovative activity to start with. In this paper we identify yet another cost of the patent system of particular importance in the case of sequential innovations. This cost originates from the ability of an innovator to wait out a patent by delaying the introduction of her innovation.

To study this cost we introduce and analyze two basic structures of sequential innovation, a regular pyramid and an inverse pyramid. A regular pyramid structure occurs when the realization of each innovation gives rise to several follow-up innovations in the next period. An inverse pyramid structure occurs when the realization of a set of related innovations gives rise to a single follow-up innovation in the subsequent period. A regular pyramid structure is typical to the introduction of a new technology with an expanding set of possible patentable applications. An inverse pyramid structure is typical to scenarios where the solution of several "smaller" problems leads to a general solution of a more wide-ranging problem.

In a two period model, we find a substantial difference between the firms' decisions on when to patent their innovations in each of the structures. In a regular pyramid the delay effect is present just in the second period, furthermore the delay decision of each firm does not affect the profits of other firms. In the inverse pyramid structure waiting out effects may appear in both periods depending on relative patent values. The delay decision of one firm affects the profits of the other firms which may lead to

a war of attrition scenario. Each innovator would like to delay patenting, increasing the probability that other patents expire, so as to collect more royalties in the next period. These differences lead to distinct policy recommendations for the two structures.

In a regular pyramid lower innovation values in the first period imply patent duration should be expanded. Whereas, in an inverse pyramid, lower innovation values in the first period serve to increase the probability of a war of attrition which in turn may render the patent extension less effective in incentivizing innovation in the first period.

We consider a two-period model with innovations taking place in both. Patenting an innovation is necessary to realize current and next period profits from the innovation. The innovator can choose to delay patenting. The delay reduces current profits due to additional labor and administration costs and possible decrease in the intrinsic value of the innovation. On the other hand it might increase revenues due to the expiration of former or complementary innovations.

The current period profit from an innovation of a firm, patented at time t is $(1-\alpha(t,z))v$ where v is the intrinsic value of the innovation and $\alpha(t,z)$ captures the cost of waiting. $z \in \mathbb{R}$ is independently distributed across firms according to a distribution function $F(z)$. We assume $\alpha(0,z)=0$, $\alpha_1(t,z)>0$. Patent length is denoted by $0 \leq T < \infty$.

The **regular pyramid** structure consists of $n+1$ firms, 1 in period 1 and n in period 2. The Period 1 firm decides when to patent its innovation. After the first innovation has been patented, Period 2 firms can realize their innovations based on it and have to decide when to patent them. After patenting the innovation, A Period 2 firm pays license fees to the Period 1 firm only if it has a valid patent. We assume any innovation value is equally shared among the (valid) patent holder and the innovator.

We solve for the equilibrium strategies and show that in order to minimize the expected time needed to achieve all the innovations, patent length should be either very short or very long, that is intermediate length patents should be avoided.

The **inverse pyramid** structure consists of n+1 firms, n in period 1 and 1 in period 2. Each period 1 firm decides when to patent its innovation. Once all the first period innovations have been patented, the period 2 firm can realize the innovation based on

them and has to decide when to patent it. After patenting the innovation, the period 2 firm pays license fees to all the period 1 firms whose patents did not expire. Again we assume any innovation value is equally shared among the (valid) patent holders and the innovator.

For simplicity, we analyze the case of 3 firms (firms 1 and 2 in period 1, and firm 3 in period 2), the basic insights regarding the war of attrition carry over to the n firm case. We Let t_i be the time at which firm i patents its innovation, and let $\tilde{t} = |t_1 - t_2|$. We first determine the equilibrium strategies of firm 3 in period 2. Then we determine the equilibrium strategies of period 1 firms. Firm 3 after observing its cost (z) and $\tilde{t}$, chooses the best option among waiting out zero, one or two patents. In the first period we assume that the interaction of the two firms takes place at two levels. The parent game takes place over a discrete set (possibly infinite) of time intervals (stages) in the first period and ends once one of the firms has decided to patent. At the beginning of each stage at the first level, first period firms simultaneously decide whether to patent (P) or to wait (W). If both decided to patent the parent game ends, and period 2, where firm 3 has to decide when to patent starts. If only one firm decided to patent, the game moves to the second level where the other firm decides how long to wait before introducing its own patent that is choosing $\tilde{t}$ ($\tilde{t}$ is assumed to be continuous). If both firms decided to wait, the parent game moves into the next stage and repeats itself.

We show for a more specific cost structure ($\alpha(t,z)=z*\beta(t)$ with $\beta'(t)>0$, $\beta(0)=0$) that whenever one firm in period 1 decides to patent its innovation, the revenue maximizing choice of the other firm depends on the ratio v_1/v_2 (where v_i is period i's innovation value). If it is large enough, Period 1 firm's best response is to patent immediately. If it is small enough, Period 1 firm's best response maybe to wait, in order to increase the probability that the Period 2 firm will wait out only one patent, and then increase its future license fees.

In the second scenario, where for each Period 1 firm, whenever the other firm patents its innovation, its best response is to wait, we get a war of attrition. Both Period 1 firms fight on some future gain, but may lose their waiting cost in any stage.

Finally we solve for equilibrium strategies and outcomes for the case of linear waiting cost functions.

So far we have assumed that R&D costs are relatively small, and innovation is always profitable. Hence the main question is whether patenting will happen right away or not, and patent protection was evaluated by its effect on delay times. When R&D costs are more substantial, patent protection is judged by both its effect on the probability of innovation and delay decisions.

We proceed to introduce non-negligible R&D costs and solve for the optimal patent length. The main goal is to analyze the case where the value of first period innovations is small and later innovations are much more profitable. In this scenario, Period 2 innovations are always worthwhile, whereas Period 1 innovations need to be supported by the patent system. We examine the relationship between patent values and optimal patent length taking into account the possibility of wars of attrition.

Our main finding is that in a regular pyramid, as the value of the innovation in the first period decreases, patent length should be increased. Whereas, in the case of an inverse pyramid where a war of attrition may occur, it might be optimal to decrease patent length following a decrease in innovations value in the first period. The intuition underlying this result is due to that fact that for any realization of z, the derivative of the revenues generated in the war of attrition by T decreases. This implies that the marginal benefit of a patent may decrease in T in the case of a war of attrition. In this scenario, as the value of the Period 1 innovation decreases, the resulting increase in the probability of a war of attrition may lead to a decrease in the optimal patent length. Therefore, extending patent length is less effective in increasing the probability to innovate in the first period when a war of attrition occurs. This is troubling since in the cases where firms need the patent protection most (low values of v_1) the probability of a war of attrition is higher and thus extending patent length may be detrimental.