Patentability, Industry structure, And Innovation

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I. Basic Idea

. This paper presents a model of sequential innovation in which industry structure is endogenous and a standard of patentability determines the proportion of all inventions qualify for protection.

. The rate of innovation initially rises as this standard is raised from very low levels, but eventually falls as the standard is raised to very high levels. Hence, there is a unique patentability standard that maximizes the rate of innovation.

. This critical standard is more stringent for industries which innovate more rapidly.
II. The Model

**Assumption 1:** An infinite sequence of stochastic patent races

At the beginning of a race, firms simultaneously choose their R&D intensity, denoted $h_i \in [0, \bar{h}]$. The cost of conducting R&D is $C(h_i)$. The sunk cost of setting up an R&D lab is $K$.

A firm’s discoveries arrive through time according to a Poisson process. The probability that firm $i$ discovers an invention before date $t$ in the patent race is $1 - e^{-\lambda h_i t}$. 


**Assumption 2: A passive incumbent**

A firm that owns a patented invention is an “incumbent”. The other firms are “challengers”.

The model assumes a firm that makes a patentable discovery does not compete in the subsequent patent race.

**Assumption 3: The nature of inventions and a system of property rights**

A discovery is an improvement in product quality. The extent of an improvement during the $q_{th}$ patent race is denoted $u_q \in [0, \bar{u}]$. 
For each innovation, $U$ is drawn from a distribution with cumulative density $F(u)$.

Not all inventions will be protected, let $s \in [0, \bar{u}]$ denote the minimum extent of improvement for which the patent office is willing to grant a patent. This is the inventive step. An invention whose extent is less than $s$ will not be protected and becomes available to all firms.

If an invention satisfies the standard of patentability, the inventor may use all prior discoveries without licensing them. It implies that there is always at most one protected invention. The life of a patent is the amount of time until the next patentable invention.
Assumption 4: The output market and flow profits

Let \( \hat{u}_q \) denote the extent of the innovation protected during patent race q.

Aggregate demand is normalized to one. \( p \) is the price of the final good relative to the R&D inputs.

The reservation value of the final product to consumers is the level of its quality \( \hat{u}_q \) multiplied by \( p \).
Firms compete in prices and the cost of production is zero. Thus the equilibrium price of the final good and the incumbent’s flow profit during the $q_{th}$ race is $p\hat{u}_q$.

**There are two cases:**

**Flow profits earned during patent race $q+1$**

<table>
<thead>
<tr>
<th><strong>The firm is:</strong></th>
<th><strong>Innovation $q+1$ is:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The leader from race $q$</td>
<td>Patentable: 0, Unpatentable: $p\hat{u}_q$</td>
</tr>
<tr>
<td>The winning challenger $i$</td>
<td>Patentable: $p\hat{u}_{q+1}$, Unpatentable: 0</td>
</tr>
<tr>
<td>All other challengers</td>
<td>Patentable: 0, Unpatentable: 0</td>
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III. Equilibrium

During the current race, challengers select the R&D intensity that maximizes expected current profit plus the expected present value of competing optimally in future races.

1. The stationary symmetric equilibrium of the game

In a stationary equilibrium where firms choose identical strategies, there is the following proposition:

**Proposition 1:**
There exists a unique, stationary, symmetric equilibrium of the game, characterized by the pair \((\sigma^*, n^*)\), where there are \(n^*\) challengers who choose a R&D intensity \(\sigma^* \in (0, h]\).

\((\sigma^*, n^*)\) is characterized by the following two expressions:

\begin{equation}
C'(\sigma).\sigma = C(\sigma) + rk \quad (1)
\end{equation}

\begin{equation}
C'(\sigma) = \frac{\theta \lambda (p \tilde{u} - rk)}{r + \theta \lambda n \sigma} \quad (2)
\end{equation}

2. Properties of the equilibrium

**Proposition 2:**

(a) \(\sigma^*\) is independent of \(p\) & \(\lambda\), and
increasing in r and k.

(b) \( n^* \) is increasing in \( p & \lambda \), and decreasing in r and k.

(c). \( n^* \cdot \sigma^* \) is increasing in \( p & \lambda \), and decreasing in r and k

Proposition 2 shows that if R&D is cheaper, more firms will enter the industry and the industry will innovate more rapidly.

Standard of patentability will affect the number of firms engaged in R&D. They show this in the following proposition:

**Proposition 3:**

In the stationary symmetric equilibrium:

(a) \( \sigma^* \) is independent of s
(b) there exists $s^* \in [0, \overline{u}]$, $\forall s \in [0, s^*)$, $n^*$ is increasing in $s$ and $\forall s \in (s^*, \overline{u}]$, $n^*$ is decreasing in $s$.

(c). $s^*$ is increasing in $p \& \lambda$, and decreasing in $r$ and $k$.

From proposition 3, we know that differences in the standard of patentability do not affect the R&D intensity of individual firms, but they do affect the number of firms engaged in R&D, hence the industry-wide rate of innovation.

For a given set of parameters, there is a unique standard $s^*$ that maximizes the number of firms engaged in R&D.
Suppose two industries A & B, A has a smaller fixed cost $K$ than B:

1. According to proposition 2, industry A will innovate more rapidly than B.

2. From proposition 3 part (c), the R&D maximizing standard of patentability $S^*$ is stricter for A. If this standard is set for each industry, a smaller proportion of innovations would qualify for protection in industry A than B.