Chapter 10: Research and Development and Patents

3 stages of research:
- basic research,
- applied research,
- development.

2 kinds of innovation:
- Product innovations: create new goods.
- Process innovations: reduce the cost of producing existing product.

- R&D and monopoly

  “If one wants to induce firms to undertake R&D one must accept the creation of monopolies as a necessary evil” (Schumpeter, 1943).

- Firms need incentive to undertake R&D project.
- Innovation can be assimilated to a public good, so no firm wants to bear the R&D cost alone.
- **Patent** system: one system of encouraging R&D.
- There exist alternative systems: Prize, Contractual mechanism (Wright, 1983).

- Characteristic of R&D
  - randomness of the return from the investment,
  - preemption effect of patentable innovation,
  - public good aspect of patentable innovation.

OUTLINE
- The economics of Patents: an Overview
- “Pure” private and social incentives to innovate
- Incentive to innovate in patent race
1 The Economics of Patents (Langinier-Moschini, 2002)

- **Patent**: a document granting the right to exclude anyone else from the production of a new product temporarily (20 years from the date of filing).

- Patents must be renewed (3 times in US).

To be **patentable**, an innovation must be

- **new**: not in the public domain;

- **non obvious** to a person with ordinary skill in the particular field;

- **useful**: to have at least one application.

**Costs and benefits of patents**

- **Advantages**

  - promote new discovery;

  - help dissemination of knowledge;

  - help technological transfer and commercialization;

  - the number of patents can be an indicator of inventive activity.
► Disadvantages

- a monopoly is socially inefficient;
- duplication of spending (patent races);
- disclosure allows rapid catching up;
- monitoring to detect infringement must be done by the patentholder: **imperfect protection.**

> “Unless one is willing to sue on it, a patent is virtually useless, just a fancy piece of paper with a gold seal that looks good on the wall”.


- Costs
  - R&D costs (example: Polaroid paid US$600 millions for its project)
  - registration costs (about US$ 5,000)
  - renewal costs (about US$ 6,000)
  - monitoring costs (????)
  - litigation costs (Kodak had paid US$454,205,801 to Polaroid....)
Scope of patent protection:

- **height**: set of possible improvements or applications of the innovation;
- **breadth**: set of protected products;
- **length**: patent duration.

Trade-off between
- limiting the monopoly power,
- giving enough incentive to do R&D.

- The **length**: duration of the monopoly power
- The **breadth** and **height**: intensity of monopoly power.
1.1 Length of patent

- A patent protection too short discourages innovation,
- A patent protection too long gives excessive monopoly power to the patentholder and reduces the number of further improvements.

In order to reduce the monopoly distortion, depending on the industrial sector,
- patent duration must be finite (Nordhaus (1969));
- should depend on the specific industry.

1.2 Patent breadth and height

- **Breadth** of patent: protection against imitation. It is endogenous and depends on
  - the claims of the innovators,
  - and the examination of the PTO (Patent Trademark Office).

- Too broad: excessive monopoly power;
- Too narrow: too little incentive to do R&D.
• What is the **optimal patent breadth?**
  – Narrow and long patents can be optimal (Gilbert and Shapiro (1990), Klemperer (1990)).
  – Broad and short patents can be optimal (Klemperer (1990), Gallini (1992)).

• **Height** of patent (or novelty requirement): protection against improvements.
  – Height, van Dijk (1992),

• Too high a patent gives excessive monopoly power.
• A patent of infinite duration and finite height can be optimal (La Manna (1992)).

• Height is also related to **cumulativeness** of innovation (Scotchmer and Green (1990), Scotchmer (1991)…).
2 The value of innovation

- No competition at the R&D level.
- What is the “pure” incentive to innovate?
- Innovation is protected by a patent of infinite duration.
- Process innovation: cost from \( \overline{c} \) to \( c \) where \( \overline{c} > c \).
- No R&D cost.

A. Benchmark: social planner

- Incentive to innovate = incremental net social surplus
- Price is MC, \( \overline{c} \) before \( c \) after.
- Additional net social surplus per unit of time

\[
v^s = \int_{c}^{\overline{c}} D(c) dc
\]

- Discounted present value of the change is

\[
V^s = \int_{0}^{\infty} v^s e^{-rt} dt
\]

\[
V^s = \frac{1}{r} \int_{c}^{\overline{c}} D(c) dc
\]
B. Monopoly

- Profit of monopoly is
  \[ \Pi^m(p, c) = (p - c)D(p) \]

- Maximization of the profit gives \( p^m(c) \) and thus the optimal profit is
  \[ \Pi^m(p^m(c), c) \]

- Derivative of the profit with respect to \( c \)
  \[ \frac{d\Pi^m}{dc} = \frac{\partial\Pi^m}{\partial p^m} \frac{\partial p^m}{\partial c} + \frac{\partial\Pi^m}{\partial c} = -D(p^m(c)) \]

- The incentive to innovate of the monopolist is
  \[ V^m = \int_0^\infty [\Pi^m(c) - \Pi^m(\bar{c})]e^{-rt}dt \]
  \[ = \frac{1}{r} [\Pi^m(c) - \Pi^m(\bar{c})] = \frac{1}{r} \int_{\bar{c}}^c -\frac{\partial\Pi^m}{\partial c} dc \]

\[ V^m = \frac{1}{r} \int_{\bar{c}}^c D(p^m(c)) dc \]
• Since \( p^m(c) > c \) for any \( c \),
  \[
  V^m < V^s
  \]
  – Socially, a monopolist has too low an incentive to innovate.
  – Because the monopolist cannot appropriate the CS.

C. Competition

• Initially Bertrand competition: firms produce a homogeneous good at price=MC \( \bar{c} \).

• The firm that obtains the new technology, at MC \( \bar{c} \), is awarded a patent, and sets monopoly price \( p^m(\bar{c}) \).

• 2 cases:
  
  (i). \( p^m(\bar{c}) > \bar{c} \), non drastic innovation. Monopoly price must be \( p^m = \bar{c} \).

  (ii). \( p^m(\bar{c}) \leq \bar{c} \), drastic innovation.

  (i). Non drastic innovation (\( p^m = \bar{c} \))

• Profit of the innovator per unit of time
  \[
  \Pi^c(\bar{c}) = (\bar{c} - c)D(\bar{c})
  \]

• Incentive to innovate is
  \[
  V^c = \int_0^\infty [\Pi^c(\bar{c}) - \Pi^c(\bar{c})]e^{-rt}dt
  \]
\[
\begin{align*}
\frac{1}{r} (\bar{c} - c) D(\bar{c}) \\
= \frac{1}{r} \int_{c}^{\bar{c}} \frac{\partial \Pi^c}{\partial c} dc = \frac{1}{r} \int_{c}^{\bar{c}} D(\bar{c}) dc \\
\end{align*}
\]

\[
V^c = \frac{1}{r} D(\bar{c}) \int_{c}^{\bar{c}} 1 dc
\]

- Comparison

\[[V^s > V^c > V^m]\]

(ii). Drastic innovation \((p^m(c) < \bar{c})\)

- Profit of the innovator per unit of time

\[\Pi^c(c) = (p - c) D(p)\]

- Incentive to innovate is

\[
V^c = \int_{0}^{\infty} \left[ \Pi^c(p^m(c)) - \Pi^c(\bar{c}) \right] e^{-rt} dt
\]

\[
= \frac{1}{r} (p^m(c) - c) D(p^m(c))
\]

- Comparison

\[[V^s > V^c > V^m]\]

- The monopolist gains less from innovating that does a competitive firm

- Replacement effect
D. Monopolist threatened by entry

- 2 firms
- Before innovation:
  - firm 1 is a monopolist, MC is \( \overline{c} \); profit is \( \Pi^m(\overline{c}) \);
  - firm 2 is a potential entrant.
- If only firm 1 can acquire a new technology: case B. Incentive \( V^m \).
- If only firm 2 can acquire a new technology: case C. Incentive \( V^c \).
  - the innovation is more valuable for the entrant.
- If neither firm has an acquisitional monopoly over the new technology: competition....

- If the entrant adopts the new technology:
  - Profit per unit of time for the monopolist
    \[ \Pi^d(\overline{c}, \overline{c}) \]
  - For the entrant
    \[ \Pi^d(\underline{c}, \overline{c}) \]
- Value of the innovation for the entrant
  \[ V^c = \frac{1}{r} \Pi^d(\underline{c}, \overline{c}) \]
• Value of the innovation for the monopolist

\[ V^m = \frac{1}{r}[\Pi^m(c) - \Pi^d(\bar{c}, \bar{c})] \]

• Assumption: **Efficiency effect** (a monopolist does not make less profit than non colluding duopolists)

\[ \Pi^m(c) \geq \Pi^d(\bar{c}, \bar{c}) + \Pi^d(c, \bar{c}) \]

• Thus

\[ V^m \geq V^c \]

• The monopolist incentive to remain a monopolist is greater than the entrant incentive to become a duopolist.
3 Patent races

- Competition at the level of R&D.

- In patent race:
  - uncertainty concerning the discovery date,
  - uncertainty concerning the identity of the “winner”.

- Is a monopolist more likely to innovate than an entrant? (persistence of monopoly)

- 2 firms: firm 1 (monopoly), firm 2 (entrant)
- Competition in R&D activity
- The first firm to innovate obtains a patent of infinite duration.

- Before innovation
  - profit per unit of time earned by the monopolist is $\Pi^m(\bar{c})$
  - profit earned by the entrant is 0.
• After the innovation is made
  – if monopolist makes it,
    \[ \Pi^m(c) \text{ for monopolist} \]
    \[ 0 \text{ for the entrant.} \]
  – If the entrant makes it
    \[ \Pi^d(c, c) \text{ for monopolist} \]
    \[ \Pi^d(c, \bar{c}) \text{ for the entrant.} \]
• Assumption: **Efficiency effect**
  \[ \Pi^m(c) \geq \Pi^d(c, c) + \Pi^d(c, \bar{c}) \]
• Each firm spends \(x_i dt\) between \(t\) and \(t + dt\).
• Probability of making the discovery between \(t\) and \(t + dt\) is \(h(x_i) dt\).
• \(h(x_i)\) concave, increasing.
• R&D expenditure intensities of each firm are \(x_1\) and \(x_2\).
• Random date of discovery
  \[ \tau \sim Exp(h) \]
  where \(h\) is the hazard rate, \(f(\tau) = he^{-\tau h}\) the density, and \(E\tau = 1/h\).
• Expected profit of firm 1 is

\[ V_1(x_1, x_2) = \frac{\Pi^m(\bar{c}) + h(x_1)\frac{\Pi^m(c)}{r} + h(x_2)\frac{\Pi^d(c,c)}{r} - x_1}{h(x_1) + h(x_2) + r} \]

and the expected profit of firm 2 is

\[ V_2(x_1, x_2) = \frac{h(x_2)\frac{\Pi^d(c,c)}{r} - x_2}{h(x_1) + h(x_2) + r} \]

• A **Nash equilibrium** is a set of research intensities \((x_1^*, x_2^*)\) such that \(x_i^*\) maximizes \(V_i(x_i, x_j^*)\) for \(i, j = 1, 2\) and \(i \neq j\).

• Which firm spends more on R&D? It depends on
  – the replacement effect
  – the efficiency effect

• The efficiency effect is reflected in the numerator;

• The replacement effect

\[ \frac{\partial}{\partial \Pi^m(\bar{c})} \left( \frac{\partial V_1}{\partial x_1} \right) < 0 \]

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Either of the two effects may dominate...

2 extreme cases

**Drastic innovation:**
- the entrant becomes a monopolist,
- no efficient effect
- The payoffs are

\[
V_1(x_1, x_2) = \frac{\Pi^m(c) + h(x_1)\frac{\Pi^m(c)}{r}}{h(x_1) + h(x_2) + r} - x_1
\]

\[
V_2(x_1, x_2) = \frac{h(x_2)\frac{\Pi^d(c, c)}{r}}{h(x_1) + h(x_2) + r} - x_2
\]

- Only one effect: the replacement effect, and thus (Reinganum (1983))

\[x_1^* < x_2^*.
\]

**Non drastic innovation:**

\[x_1^* > x_2^*.
\]