

ECO 650: Firms' Strategies and Markets

Innovation

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To innovate enables firm to acquire a competitive advantage toward its rival.

- ▶ Lowering its production cost.
- ▶ Improving its quality.
- ▶ Create a new product (completely new, new variety, new formula, new packaging,...)

Protection-Patent

- ▶ The story of Robert Kearns and its “intermittent windshield wiper”
See The newyorker article: “the-flash-of-genius”: <https://www.newyorker.com/magazine/1993/01/11/the-flash-of-genius>
- ▶ If an innovation is not protected \Rightarrow The innovator fails to appropriate the rent of its innovation because of the risk of imitation
 - ▶ Large fixed cost difficult to recover for the innovator
 - ▶ Uncertainty: Proba for a new medicine to be approved for patient use is about 1/10 000, Proba to be published for a book, ...
- ▶ How to protect an innovation ?
 - ▶ Patents : In the US and EU the term of a patent is 20 years.
 - ▶ Copyright: Longer period \simeq 50 years
 - ▶ Secret: Coca-Cola

https:

//www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm

Table: Patents in the US

Year	Patent applications	Patents granted	Share
1973	110 000	79 000	71%
1983	112000	62000	55%
1993	189 000	110 000	58%
2003	366 000	187 000	49%
2015	630 000	325 000	52%
2019	669 434	391 103	52%

The patent dilemma

- ▶ A patent grants a “temporary” monopoly power to the innovator to protect the innovator and favor innovation
- ▶ The monopoly position creates a dead weight loss

Two key variables to control this balance:

- ▶ The length of the patent
- ▶ The breadth of the patent

The optimal length of a patent

Assumptions

- ▶ Assume an innovation creates a social surplus W at each period.
- ▶ The discount factor is δ .
- ▶ The innovation cost is C and is paid in $t = 0$.

The social value of Innovation is:

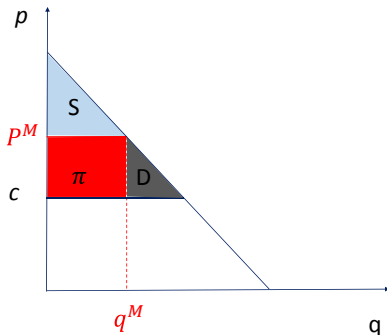
$$V = -C + W[\delta + \delta^2 + \dots + \delta^T]$$

When $T \rightarrow \infty$, $V \rightarrow W \frac{\delta}{1-\delta} - C$. V is increasing with δ . No reason to consider a limited time for the value of innovation.

The optimal length of a patent

Assumptions

- ▶ This innovation is protected by a patent for a length T .
- ▶ From $T + 1$ and on, there is Bertrand competition.
- ▶ We denote $\pi = \alpha W$ with $\alpha \in [0, 1]$ the profit of the monopolist innovator. We have $W = S + \pi + D$. We denote $D = \beta W$.



The social value of an Innovation protected by a brevet for T periods is:

$$V_B = \underbrace{W \frac{\delta}{1-\delta} - C}_{\text{Social Value of innovation}} - \underbrace{\beta W \delta [1 + \delta + \dots + \delta^{T-1}]}_{\substack{\text{Social cost of patent protection} \\ \text{L=Length of the patent}}}$$

The innovator's incentive to innovate is:

$$V_I = \alpha W L - C$$

Comparing V_I and V_B , we obtain :

$$\begin{aligned} V_I &< V_B \\ (\alpha + \beta)L &< \frac{\delta}{1-\delta} \end{aligned}$$

Using $L = \frac{\delta(1-\delta^T)}{1-\delta}$

$$\Rightarrow \alpha + \beta < \frac{\delta}{1-\delta} \frac{1}{L} = \frac{1}{(1-\delta^T)} > 1$$

True!

- ▶ A single innovator protected by a patent innovates less than what would be socially optimal.
- ▶ The social value of an innovation protected by a patent decreases with L which increases with T .
- ▶ What happens with competition?

Innovation-Patent and competition

Assumptions

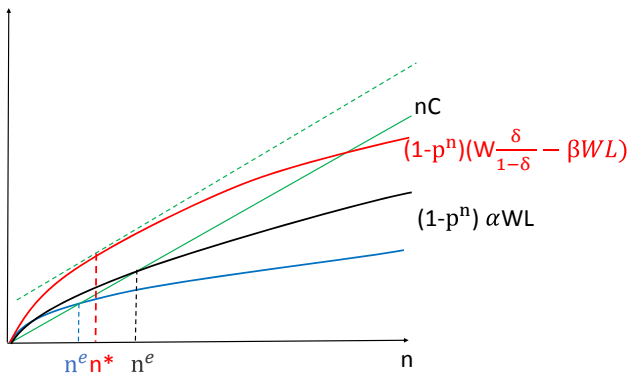
- ▶ Assume that there is free entry
- ▶ n firm can spend the cost C and each of them has a probability p to fail.
- ▶ Even if several firms innovate at the same time, only one gets the patent.

The probability that all firms fail is p^n .

The probability that at least one succeeds is $1 - p^n$.

Each firm has a probability $\frac{1}{n}$ to get the patent in case there is at least one innovation, i.e. $\frac{1}{n}(1 - p^n)$.

- ▶ At the social level, the optimal number of firm n maximizes $(1 - p^n)(W \frac{\delta}{1-\delta} - \beta WL) - nC$
- ▶ FOC: $\frac{\partial((1-p^n)(W \frac{\delta}{1-\delta} - \beta WL))}{\partial n} = \frac{\partial(nC)}{\partial n}$
- ▶ Because of free entry, the number of firms that innovates in equilibrium is such that $(1 - p^n)\alpha WL = nC$.



Remember

- ▶ When the length of the patent is too short, there is less firms that innovate compared to the social optimum.
- ▶ When the length of the patent is too long, there is too much entry. Race for patents leads to an overinvestment!
- ▶ The breadth of a patent defines how similar a product must be to infringe a patent. If the patent breadth is large it reduces the social value of the innovation and increases the profit of the innovator.
⇒ Patent breadth and length are substitutable tools.

Alternative incentive mechanisms: Prizes or Subsidies

- ▶ A reward $R = \alpha WL$ to the innovator: same incentive to innovate as with a patent of length L but no deadweight loss.
- ▶ Offering a reward $R = C + \epsilon$ works also. The innovator is paid back for its innovation cost. But impossible when success is random
- ▶ Prizes require information about W , α and $C +$ government funding \Rightarrow taxes?
- ▶ Prizes are often announced in advance : Lépine awards
- ▶ Numerous examples of targeted prizes:
 - ▶ **1795** : Napoleon 1st had organized a competition to reward the best food preservation process for army! Nicolas Appert invented "tinned food".
 - ▶ **1996** : The X prize (10 millions) to transport humans in space (100 km height)
 - ▶ **2006**: The H prize technical challenges (hydrogen production and storage, hydrogen vehicles, etc...)

The Arrow replacement effect

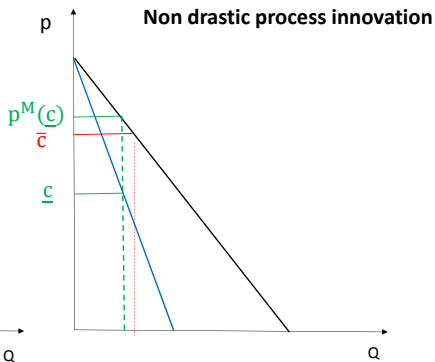
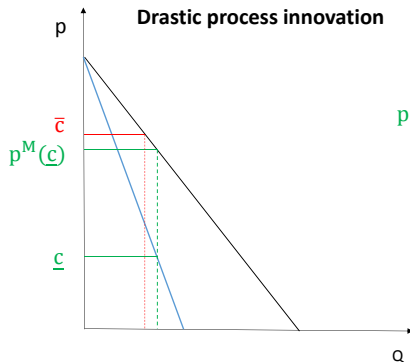
This effect highlighted by Arrow (1962) shows that paradoxically the innovation incentives of a monopoly might be lower than that of competing firms.

Assumptions

- ▶ Initially a firms' marginal cost is \bar{c} .
- ▶ In case of innovation the marginal cost is $\underline{c} < \bar{c}$.
- ▶ The monopoly price is denoted $p^M(c)$. In case of competition, firms compete a la Bertrand.
- ▶ Innovation can either be drastic or non drastic.

Innovation level

- ▶ Drastic innovation: $p^M(\underline{c}) < \bar{c}$
- ▶ Non drastic innovation: $p^M(\underline{c}) > \bar{c}$
- ▶ Monopoly price is such that : $Rm(q) = Cm(q)$



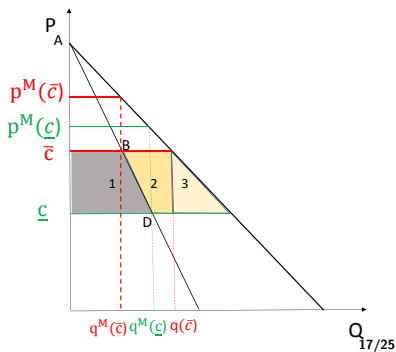
Competition vs Monopoly with drastic innovation

- ▶ Competitive situation [*ex post-ex ante*]
 - ▶ *ex ante*: 0
 - ▶ *ex post*: $(p^m(\underline{c}) - \underline{c})q^m(\underline{c})$
- ▶ Monopoly : [*ex post-ex ante*]
 - ▶ *ex ante*: $(p^m(\bar{c}) - \bar{c})q^m(\bar{c})$
 - ▶ *ex post*: $(p^m(\underline{c}) - \underline{c})q^m(\underline{c})$

It is immediate that incentives to innovate are lower in the monopoly case! This is because the monopoly replaces itself.

Competition vs Monopoly with non drastic innovation

- ▶ Competitive situation [*ex post-ex ante* = (1)+(2)]
 - ▶ *ex ante*: 0
 - ▶ *ex post*: $q(\bar{c})(\bar{c} - \underline{c})$
- ▶ Monopoly : [*ex post-ex ante* = (1)]
 - ▶ *ex ante*: $(p^m(\bar{c}) - \bar{c})q^m(\bar{c})$
 - ▶ *ex post*: $(p^m(\underline{c}) - \underline{c})q^m(\underline{c})$



Exercise 1:

Assumptions:

- ▶ Demand is linear, $p = a - q$
- ▶ Without innovation, the cost is \bar{c} .
- ▶ If one firm innovates, she has a unit cost \underline{c} .
- ▶ N firms compete a la Cournot.
- ▶ We denote $\phi = \frac{\bar{c} - \underline{c}}{a - \bar{c}}$ with $\phi < 1$.

Questions:

1. Determine the symmetric Cournot gain without innovation
2. and the net gain to innovation.
3. How does this net gain vary with n ?
4. What is the optimal market structure in terms of innovation incentive when $\phi = \frac{1}{4}$? when $\phi = \frac{1}{2}$? when $\phi = \frac{2}{3}$?

R&D diffusion and Cooperation

- ▶ Patent licensing
 - ▶ Incentive to sell the patent to other firms.
 - ▶ Patent trolls: Self defense system against infringement!
 - ▶ Patent pools : firms put in common their complementary patents often pro competitive (lower prices.)
- ▶ Firms voluntarily release their innovation : The open source software industry!
- ▶ R&D cooperation through "Research Joint Ventures" is often encouraged by antitrust legislation!
 - ▶ Obvious when research costs operate increasing returns to scale (e.g. high fix cost to build a lab)
 - ▶ More ambiguous with decreasing return to scale.

Patent Licensing

Assumptions:

- ▶ An innovation reduces the marginal cost of an innovator from c to $c - x$.
- ▶ The innovator can choose a royalty rate r at which it licenses its new technology.
- ▶ We consider a 3-stage game :
 1. The innovator sets r ,
 2. Other firms decide whether or not to become licensee,
 3. Firms compete à la Cournot.
- ▶ In a Cournot competition with n firms and an inverse demand $P = a - \sum_i^n q_i$, the optimal quantity is:

$$q_i^* = \frac{1}{n+1} \left(a - nc_i + \sum_{j \neq i} c_j \right)$$

Patent Licensing

- ▶ In stage 3), the innovator i has a cost $c - x$ and its $n - 1$ competitors have a cost $c - x + r$.

$$q_i^* = \frac{1}{n+1}(a - (c - x) + (n - 1)r)$$

$$q_i^* = \frac{1}{n+1}(a - 2r - (c - x))$$

and

$$P^* = \frac{a + n(c - x) + (n - 1)r}{n + 1}$$

- ▶ It is straightforward that a licensee accepts any royalty $0 < r \leq x$.
- ▶ The innovator chooses r to maximize its profit:

$$\pi_i = (P - c + x)q_i^* + r(n - 1)q_i^* = (q_i^*)^2 + r(n - 1)q_i^*$$

- ▶ The FOC is:

$$\frac{\partial \pi_i}{\partial r} = 2q_i^* \frac{\partial q_i^*}{\partial r} + r(n-1) \frac{\partial q_i^*}{\partial r} = 0$$

- ▶ We obtain $\frac{\partial \pi_i}{\partial r} = \frac{(n-1)(n+3)(a-c-2r+x)}{(n+1)^2} > 0$. Therefore, the maximum is obtained for $r = x$.
- ▶ With licensing the innovator's profit is

$$\pi_i^* = \frac{(a-c)^2 + (2n+n^2-1)(a-c)x + x^2}{(n+1)^2}.$$

- ▶ Without licensing, the profit of the innovator would be $\hat{\pi}_i = \frac{(a-c+nx)^2}{(n+1)^2}$.
- ▶ $\hat{\pi}_i < \pi_i^*$: Whether the innovator licenses its patent or not, the competitive situation is the same and the marginal cost of the innovator is $c - x$ whereas, at $r = x$, the licensee's cost is c . The innovator now gets the additional profit of licensees.

Open source

- ▶ Firms who sell softwares use object code
- ▶ Open source softwares making the “source code” available for free have grown.
 - ▶ The operating system Linux
 - ▶ Web server Apache,
 - ▶ Web browser Firefox;
- ▶ The main rationale are
 - ▶ The existence of spillovers: the innovator benefits from the feedback of developers who fix bugs but also add developments and extensions.
 - ▶ The existence of a specificity of the software for the innovator (unappropriable component).

Exercise 2: R&D Cooperation

Assumptions:

- ▶ Demand is linear, $p = 2 - Q$ and two firms $i \in \{1, 2\}$ compete à la Cournot.
- ▶ The cost of firm i is a function $c_i(w_i, x_j) = 1 - x_i - \beta x_j$ with $0 < \beta < 1$ representing a spillover, i.e. a benefit that a firm obtains from its rival's discovery (public part).
- ▶ We denote $\phi(x_i) = \frac{x_i^2}{2}$ the innovation cost.
- ▶ The timing we consider is 1) an investment stage which can be either non cooperative or cooperative, and 2) a competition stage.

Questions:

1. Determine the Cournot equilibrium in stage 2
2. Non Cooperative R&D: firms in stage 1 choose x_i and x_j . What is the equilibrium profit and quantity ?
3. Cooperative R&D: firms in stage 1 choose x_i and x_j that maximizes their joint profit. What is the equilibrium profit and quantity ?
4. Compare the outcomes in the two cases.

References

- ▶ Arrow K. (1962), Economic welfare and the allocation of resources for invention in *The Rate and Direction of Inventive Activity*, Princeton U.P., pp. 609-626.
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