ECO 650: Firms' Strategies and Markets

Innovation

Claire Chambolle

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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`

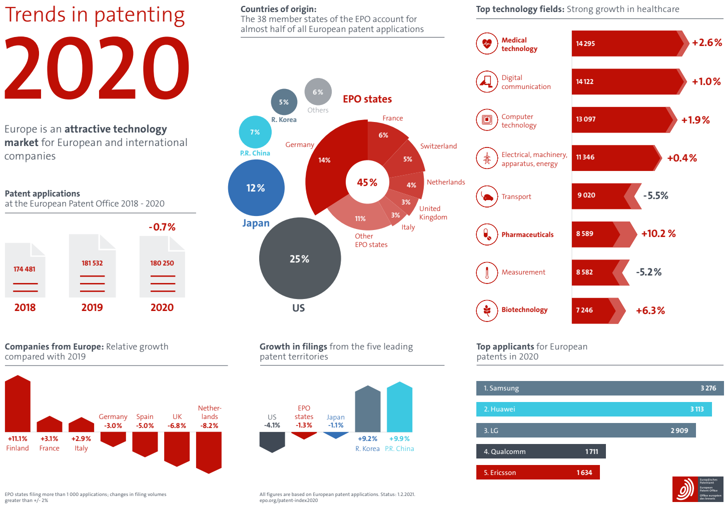
- If an innovation is not protected $\Rightarrow$ The innovator fails to appropriate the rent of its innovation because of the risk of imitation
  - Large fixed cost difficult to recover for the innovator
  - Uncertainty: Proba for a new medecine to be approved for patient use is about 1/10 000, Proba 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%


Trends in patenting
2020
Europe is an attractive technology market for European and international companies
Patent applications
at the European Patent Office 2018 - 2020
174 481
2018
181 532
2019
-0.7%
180 250
2020
Countries of origin:
The 38 member states of the EPO account for almost half of all European patent applications
EPO states
45%
France 6%
Switzerland 5%
Netherlands 4%
United Kingdom 3%
Italy 3%
Other EPO states 11%
Germany 14%
US 25%
Japan 12%
P.R. China 7%
R. Korea 5%
Others 6%
Top technology fields: Strong growth in healthcare
Medical technology 14 295 +2.6%
Digital communication 14 122 +1.0%
Computer technology 13 097 +1.9%
Electrical, machinery, apparatus, energy 11 346 +0.4%
Transport 9 020 -5.5%
Pharmaceuticals 8 589 +10.2 %
Measurement 8 582 -5.2%
Biotechnology 7 246 +6.3%
Companies from Europe: Relative growth compared with 2019
+11.1% Finland
+3.1% France
+2.9% Italy
Germany -3.0%
Spain -5.0%
UK -6.8%
Netherlands -8.2%
EPO states filing more than 1 000 applications; changes in filing volumes greater than +/- 2%
Growth in filings from the five leading patent territories
US -4.1%
EPO states -1.3%
Japan -1.1%
+9.2% R. Korea
+9.9% P.R. China
All figures are based on European patent applications. Status: 1.2.2021.
epo.org/patent-index2020
Top applicants for European patents in 2020
1. Samsung 3 276
2. Huawei 3 113
3. LG 2 909
4. Qualcomm 1 711
5. Ericsson 1 634

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 lenght of the patent
- The breadth of the patent

The optimal lenght 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:

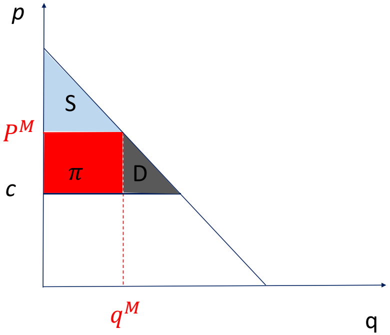
$$V = -C + W[\delta + \delta^2 + ...\delta^T]$$

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 lenght of a patent

Assumptions

- This innovation is protected by a patent for a lenght T.
- From $T+1$ and on, there is Bertand 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:

$$V_B = \underbrace{W\frac{\delta}{1-\delta} - C}_{\texttt{Social Value of innovation}} - \underbrace{\beta W \overbrace{\delta[1+\delta+...+\delta^{T-1}]}^{\texttt{L=Lenght of the patent}}}_{\texttt{Social cost of patent protection}}$$

The innovator's incentive to innovate is:

$$V_I = \alpha WL - C$$

Comparing V_I and V_B, we obtain :

$$V_I < V_B$$

$$(\alpha+\beta)L < \frac{\delta}{1-\delta}$$

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

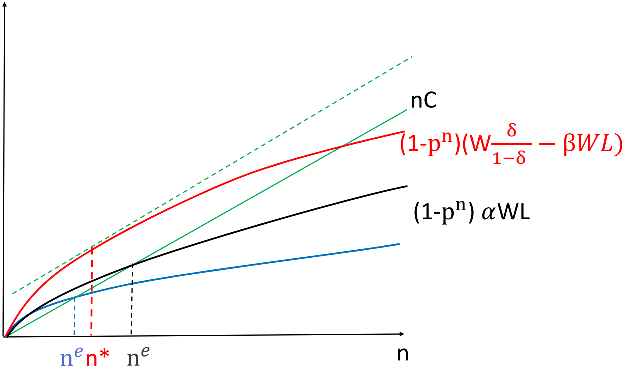
- Assume that there is free entry
- n firm can spend the cost C and each of them has a probability p to fail.
- Even if several firms innovate at the same time, only one gets the patent.

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 lenght of the patent is too short, there is less firms that innovate compared to the social optimum.
- When the lenght 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.
  $\Rightarrow$ Patent breadth and lenght 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 lenght 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?
- Prices 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...)

Market structure and innovation incentives

The Shumpetarian view is often opposed to the Arrow view.

- Arrow (1962) shows that paradoxically the innovation incentives of a monopoly might be lower than that of competing firms.
- Federico, Angus and Valletti (2017) show that the merger may either reduce or boost the overall level of innovation.
- Aghion et al (2005) find an inverted U shape between innovation and concentration.

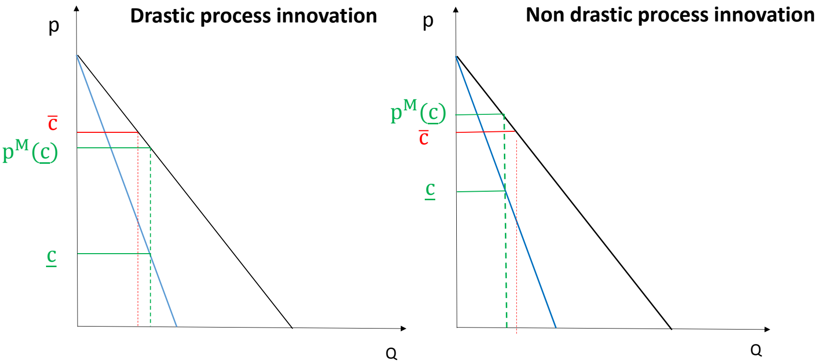
The Arrow replacement effect

Assumptions

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

Innovation level

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



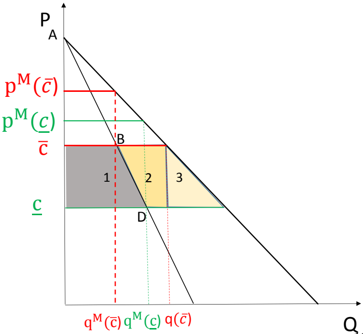
Competition *vs* Monopoly with drastic innovation

- 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*: $(p^m(\overline{c}) - \overline{c})q^m(\overline{c})$
  - *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*:$q(\overline{c})(\overline{c} - \underline{c})$
- Monopoly :[*ex post*-*ex ante*$=$ (1)]
  - *ex ante*: $(p^m(\overline{c}) - \overline{c})q^m(\overline{c})$
  - *ex post*: $(p^m(\underline{c}) - \underline{c})q^m(\underline{c})$



Federico, Angus &Valletti (2017)

Assumptions

- Each firm 1 and 2 is a research lab that searches for an innovation that will create a new market.
- A firm innovates with probability λ_i at a convex cost $C(\lambda_i)$.
- If only one firm succeeds, it obtains Π_1 and the other firm gets 0.
- If both firms succeed, each obtains π_2.
- We analyze in turn the case in which the two research labs compete and the case of merger between the two labs.

Federico, Angus &Valletti (2017)

Competition Case

- Each firm i chooses its innovation level that maximizes its profit:

$$E(Profit_i) = \lambda_i((1-\lambda_j)\Pi_1 + \lambda_j \pi_2) - C(\lambda_i)$$

The FOC is symmetric and in equilibrium λ^* is defined by:

$$(1-\lambda^*)\Pi_1 + \lambda^* \pi_2 = C'(\lambda^*)$$

Federico, Angus &Valletti (2017)

Merger Case

- The new merged entity now chooses its level of innovation for its two research labs.
- If both labs innovate, they do not compete as fiercely as before and thus obtain a joint profit $\Pi_2 \geq \Pi_1$.
- Cost convexity ensures that it prefers investing in both labs rather than closing one lab. Given the symmetry, its profits becomes:

$$E(Profit_m) = 2\lambda((1-\lambda)\Pi_1 + \lambda^2\Pi_2 - 2C(\lambda)$$

The FOC defines the equilibrium λ^m as:

$$(2 - 4\lambda^m)\Pi_1 + 2\lambda^m\Pi_2 = 2C'(\lambda^m)$$

$$\Leftrightarrow (1-\lambda^m)\Pi_1 + \lambda^m(\Pi_2 - \Pi_1) = C'(\lambda^m)$$

Federico, Langus &Valletti (2017)

Result

- The merged entity invests less in innovation than the duopoly firms if and only if $\Pi_2 - \Pi_1 \leq \pi_2$, i.e. when the merged entity incremental gain from a second innovation is smaller than the profit of an innovator when both firms innovate in the pre-merger scenario.
- In the homogeneous Cournot case for instance π_2 would be the Cournot profit of one firm and innovation being undifferentiated, we would have $\Pi_2 = \Pi_1$. In that case the merger always reduces the level of innovation.
- The exemple of Hotelling –See Exercise 1– provides an opposite result.

Exercise 1:

Assumptions:

- Consider that consumers are uniformly distributed along the Hotelling line $[0, 1]$.
- Two firms 1 and 2 are located at the extreme.
- Consumers incurs a quadratic transportation cost and the utility is of the form : $V - td^2 - p$ where $d = |x_i - x|$ is the distance to firm i.
- We apply the model of Federico, Angus & Valletti (2017) and thus look for the profit that firms obtain in all cases, i.e. Π_1, π_2 and Π_2.

Questions:

1. Determine Π_1, i.e. the profit when only firm is active, firm 1 say.
   a) Determine the demand of firm 1 for $V > 3t$.
   b) Write down the profit of firm 1 and determine its optimal price and the value of Π_1.
2. Determine the profit π_2 when the two firms are active on the market.
3. Determine the profit Π_2 that a merged entity would get from a second innovation.
4. Is there more or less innovation after the merger?

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 ambigous 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.

Patent Licensing

- Each firm maximizes her profit $\pi_i = (a - \sum_i q_i - c_i)q_i$.
- The FOC is:

$$a - 2q_i - \sum_{j \neq i} q_j - c_i = 0$$

- Summing all the first order conditions, we obtain:

$$na - Q - nQ - \sum_i c_i = 0$$

which implies that $Q = \frac{na - \sum_i c_i}{n+1}$.

- $P = \frac{a + \sum_i c_i}{n+1}$ and the optimal quantity is:

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

- In equilibrium firm *ui* obtains $\Pi_i^* = (q_i^*)^2$

Patent Licensing

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

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

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

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:

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

- The FOC is:

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

- 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 (unapropriable component).

A simple model of Open Source

Assumptions:

- Demand is linear: $p = a - Q$ where $Q = \sum q_i$ and $i = 1, ...n$ firms are competing à la Cournot.
- All firms have initially a unit cost $c > 0$
- If firm i innovates, her cost reduces to $\underline{c} = c - x$
- The firm can choose to keep secret or disclose her innovation.
- In case of disclosure, her cost becomes $\underline{c}' = c - \alpha x$ with $\alpha > 1$ to reflect the benefit withdrawn from others' code developments.
- In case of disclosure, the cost of the innovator's rivals becomes $\hat{c} = c - \alpha\beta x$ with $\beta < 1$ to reflect the specificity of firm 1 innovation.

A simple model of Open Source

- In a Cournot competition with n firms and an inverse demand $P = a - \sum_i^n q_i$, the optimal quantity is:

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

  and

$$\Pi_i = (q_i^*)^2.$$

- The profit of firm if she keeps her innovation secret is:

$$\Pi_i^S = \frac{1}{(n+1)^2}(a - n(c-x) + (n-1)c)^2$$

- The profit of firm if she discloses her innovation is:

$$\Pi_i^D = \frac{1}{(n+1)^2}(a - n(c-\alpha x) + (n-1)(c - \alpha\beta x))^2$$

A simple model of Open Source

Comparing Π_i^S with Π_i^D, we obtain the following result. The innovator prefers to disclose her innovation whenever

$$\alpha > \frac{n}{n - \beta(n-1)}.$$

- It is simple to show that this threshold increases with n and β.
- The intensity of competition and the absence of specificity in the innovation reduce the incentive for disclosure.

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