Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

ECO 650: Firms' Strategies and Markets
Innovation

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Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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,...)

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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 $\backsimeq$ 50 years
  - ▶ Secret: Coca-Cola

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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%

Introduction
Intellectual Property – Patent
Market structure and innovation incentives
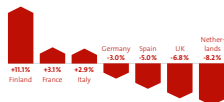R&D diffusion and Cooperation

Trends in patenting
2020

Europe is an **attractive technology market** for European and international companies

Patent applications
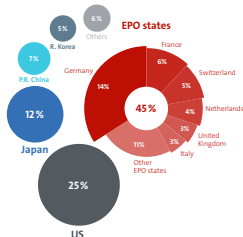at the European Patent Office 2018 - 2020

174 481	181 532	-0.7% 180 250
2018	**2019**	**2020**

Countries of origin:
The 38 member states of the EPO account for almost half of all European patent applications

- Others 6%
- R. Korea 5%
- P.R. China 7%
- **Germany** 14%
- **Japan** 12%
- **US** 25%
- **EPO states** 45%
  - France 6%
  - Switzerland 5%
  - Netherlands 4%
  - United Kingdom 3%
  - Italy 3%
  - Other EPO states 11%

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	-3.0% Germany	-5.0% Spain	-6.8% UK	-8.2% Netherlands

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
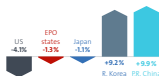
All figures are based on European patent applications. Status: 1.2.2021
epo.org/patent-index2020

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation
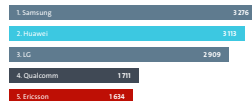
The patent dilemma

▶ 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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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 $t = 0$.
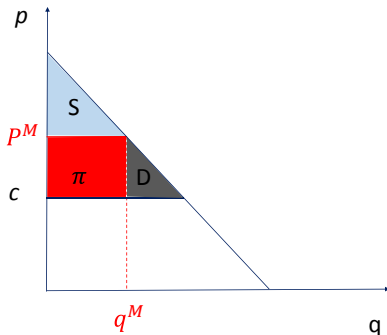
The social value of Innovation is:

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

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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 $D = \beta W$.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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

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

The innovator's incentive to innovate is:

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

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!

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

▶ 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?

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

Innovation-Patent and competition
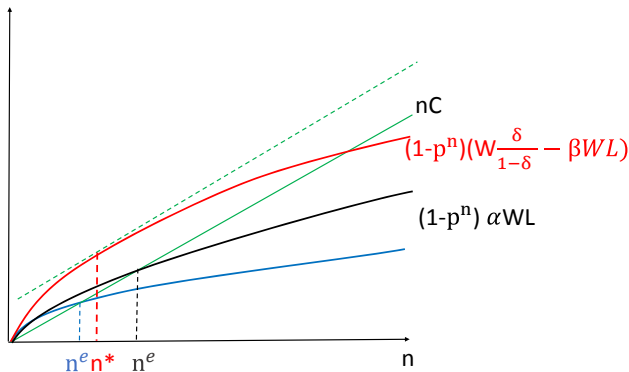
Assumptions

- ▶ 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. $\frac{1}{n}(1 - p^n)$.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

▶ 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 $(1 - p^n)\alpha WL = nC$.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.
⇒ Patent breadth and lenght are substitutable tools.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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...)

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
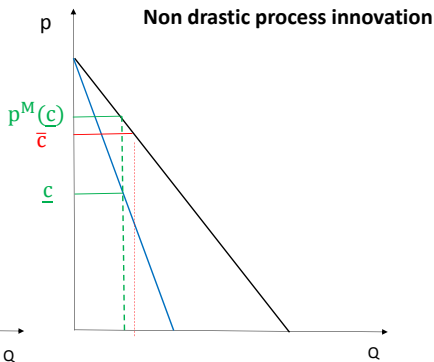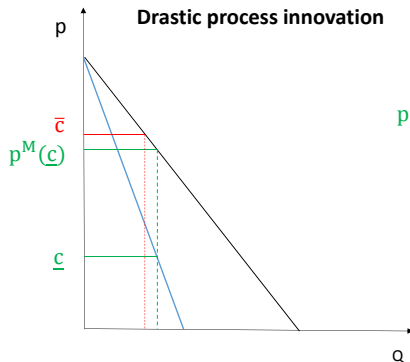R&D diffusion and Cooperation

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 drastic.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation
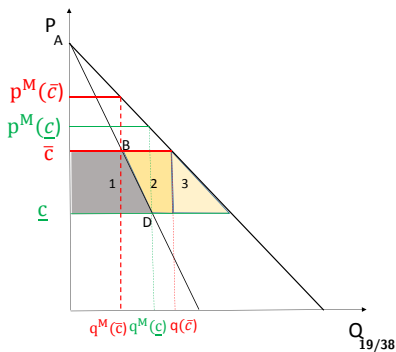
Innovation level

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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*: $(p^m(\underline{c}) - \underline{c})q^m(\underline{c})$

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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:

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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:

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

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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?

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

1. Determine Π_1, i.e. the profit when only firm is active , firm 1 say for $V > 3t$.

a) Determine the demand of firm 1.

The address of the consumer indifferent between buying the product or not is $V - tx^2 - p \geq 0 \Leftrightarrow \hat{x} = (\frac{V-P}{t})^{1/2}$

b) Write down the profit of firm 1 and determine its optimal price and the value of Π_1.

The profit of firm 1 is $p(\frac{V-P}{t})^{1/2}$. It is maximized for $p_1 = \frac{2V}{3}$ and the corresponding demand is $(\frac{V}{3t})^{1/2}$. However, for $V > 3t$ it means that the demand is larger than 1 which is not possible.

This implies that in equilibrium the market is covered, all consumers are served and the price is the largest such that it serves all consumers, i.e. $p_1 = V - t$, and $\Pi_1 = V - t$.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

Exercice 1: Solution

2. Determine the profit π_2 when the two firms are active on the market.

Here, we determine the address of the consumer indifferent between the two firms.

$$V - tx^2 - p = V - t(1-x)^2 - p \Leftrightarrow \tilde{x} = \frac{1}{2} - \frac{(p_1 - p_2)}{2t}.$$

Thus firm 1 maximizes

$$p_1\left(\frac{1}{2} - \frac{(p_1 - p_2)}{2t}\right)$$

with respect to p_1. The FOC is :

$$\frac{1}{2} - \frac{p_1}{t} + \frac{p_2}{2t} = 0.$$

Using symmetry, we obtain as usual that $p_1 = p_2 = t$ and $\Pi_2 = \frac{t}{2}$.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

Exercice 1: Solution

3. Determine the profit Π_2 that a merged entity would get from a second innovation.

▶ If the merged entity has one innovation, it obtains Π_1.

▶ With two innovations, it can instead of competing coordinate the prices of the two labs.

▶ Suppose that the merged firm sets the same price p at both labs. It serves all consumers as long as the consumer located at the center, i.e. in $x = \frac{1}{2}$ buys the product, i.e. as long as $p \leq V - \frac{t}{4}$. Therefore, $\Pi_2 = V - \frac{t}{4}$.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

4. Is there more or less innovation after the merger?

▶ We directly apply the condition of Federico, Angus &Valletti (2017)

▶ $\Pi_2 - \Pi_1 = (V - \frac{t}{4}) - (V - t) = \frac{3t}{4}$.

▶ $\pi_2 = \frac{t}{2}$ and therefore we have that $\Pi_2 - \Pi_1 \geq \pi_2$ which implies that there is more innovation after the merger.

Conclusion: in presence of strong differentiation among innovations, the merger boosts the incentives to innovate.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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:

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

▶ 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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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).

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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:

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

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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.

Introduction
Intellectual Property -Patent
Market structure and innovation incentives
R&D diffusion and Cooperation

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