European Summer School on Industrial Dynamics

MODELLING PATENTS

Basic features and issues for IP policy

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❶ INTRODUCTION

- General matter

Models in the mainstream / neoclassical tradition

Dynamic models = time always comes into consideration

We won't discuss too much the assumptions and conclusions of the various models since we will focus on modelling techniques

Of course, in another time and another place, this discussion would be central for in the mainstream tradition, assumptions as well as conclusions are usually very strong

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❶ INTRODUCTION

- The central problem

Private incentive to innovate = discounted value of the innovator's stream of instantaneous profits brought about by the innovation

Social value of the innovation = discounted value of society's (innovator + consumer + patent office + etc.) stream of instantaneous surplus brought about by the innovation

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Discrepancy between private and social value of innovation as a result of market structure, poor information, inadequate patent design, …
$\Rightarrow$ innovation in a decentralized market economy does not lead to optimal performance

An issue for patent policy : what can be done to make things better?

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❶ INTRODUCTION

- What is an innovation?

Process innovation = lowers the production cost of a given product on a market

Product innovation = differentiation) differentiated goods	raises the quality of a given product on a market (vertical brings about a new product on a given market with horizontally

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❶ INTRODUCTION

- How do innovations come about?

Innovations randomly appear in the economy (no attention at all is paid to the very process by which innovations are produced)

We will consider only models where the arrival of innovations is a Poisson process:
– the number N of innovations that arrive between time t_1 and time t_2 follows a Poisson law of parameter $\alpha \cdot (t_2 - t_1)$, i.e. $P(N=k) = e^{-\alpha(t_2-t_1)} \cdot \alpha^k (t_2-t_1)^k / k!$ (α = rate of arrival)
– the number N_{12} of innovations that arrive between time t_1 and time t_2 is statistically independent from the number N_{34} of innovations that arrive between time t_3 and time t_4 (a process without memory)

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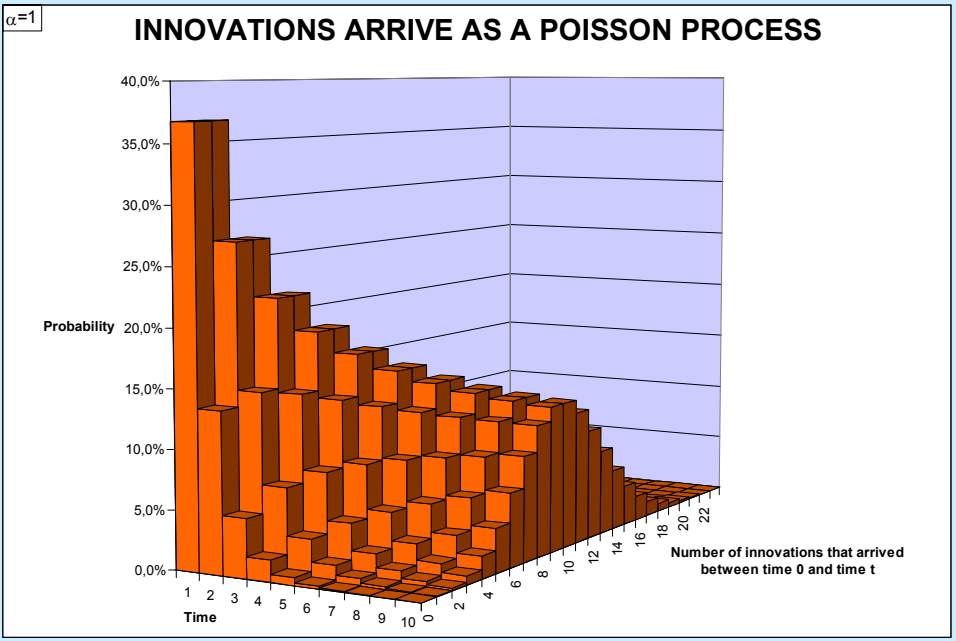
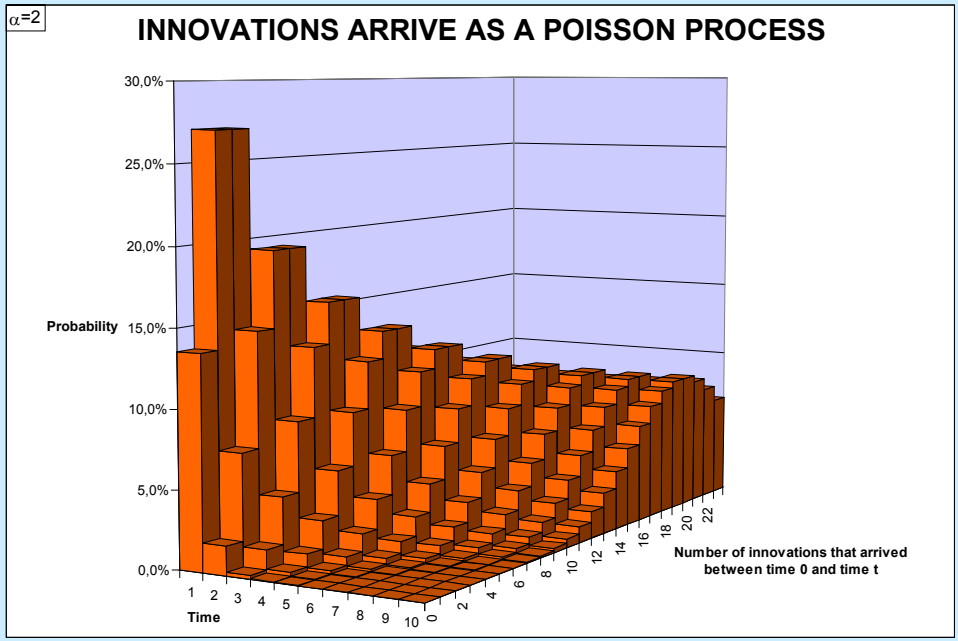
❶ INTRODUCTION

- How do innovations come about?





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❶ INTRODUCTION

- What is an R&D investment?

R&D investment by a firm can positively affect the rate of arrival of innovations to the firm (variable R&D investment as in patent race models)

Or R&D investment by a firm can be considered a fixed investment that is necessary to transform an “idea” into an innovation (in that case, the Poisson process delivers ideas)

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❶ INTRODUCTION

- What kind of competition is at stake?

In most cases, competition among firms is effective through prices (à la Bertrand)

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❶ INTRODUCTION

• What is a patent?

A patent gives to its owner the exclusive right to exploit a given innovation ; as such, it allows its owner to escape (part of the) competition (monopoly)

A fixed cost of deposit paid to the patent office can be required to get a patent

The protection attached to the patent lasts for time *T* (patent duration)

In the space of differentiated products (vertically or horizontally), the patent's breadth denotes the set of products that can not be produced because they infringe the patent, be it inferior products (lagging breadth) of superior products (leading breadth)

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❷ INNOVATION AND MARKET STRUCTURE

- The problem / the assumptions

Drawn from Tirole J.,(1988) : The theory of Industrial Organization, MIT Press

The so-called Schumpeter hypothesis: is monopoly or competition better from the point of view of innovation?

A process innovation lowers the production cost of a good from $\overline{c}$ to $\underline{c}$

The demand for the good is $D(p)$

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❷ INNOVATION AND MARKET STRUCTURE

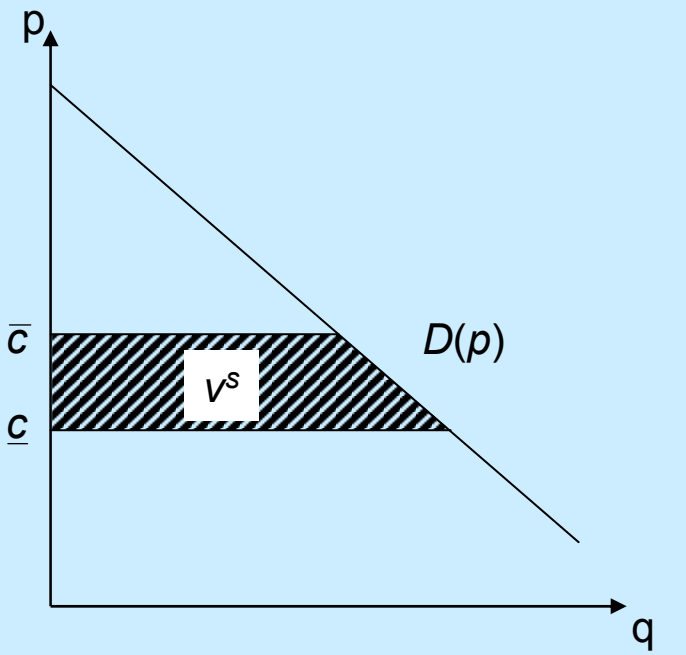
A *THE TRUE VALUE OF INNOVATION*

- Social planner

The social planner sets the price equal to marginal cost to maximise social surplus
$\Rightarrow$ the price drops from $\bar{c}$ to $\underline{c}$

With the innovation, the instantaneous social surplus increases by $v^s = \int_{\underline{c}}^{\bar{c}} D(c) \cdot dc$

Through time, the social value of innovation is equal to $V^s = \int_0^{\infty} e^{-rt} v^s \cdot dt = \frac{1}{r} \cdot \int_{\underline{c}}^{\bar{c}} D(c) \cdot dc$



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❷ INNOVATION AND MARKET STRUCTURE

A *THE TRUE VALUE OF INNOVATION*

- Monopoly

For the monopolist, the incentive to innovate is equal to the discounted value of the incremental flow of instantaneous profits :

$$V^m = \int_0^\infty e^{-rt}\left(\Pi^m(\underline{c}) - \Pi^m(\overline{c})\right)\cdot dt = \frac{1}{r}\left(\Pi^m(\underline{c}) - \Pi^m(\overline{c})\right) \quad \text{or} \quad V^m = \frac{1}{r}\cdot\int_{\underline{c}}^{\overline{c}}\left(-\frac{d\Pi^m}{dc}\right)\cdot dc$$

$\Pi^m(c)$ (resp. $p^m(c)$) is the monopolist's equilibrium profit (resp. price) when he produces at cost c $\Pi^m(c) = \left(p^m(c) - c\right)\cdot D\left(p^m(c)\right)$

So with $d\Pi = \frac{\partial\Pi}{\partial p}\cdot dp + \frac{\partial\Pi}{\partial c}\cdot dc$ we get $\frac{d\Pi^m}{dc} = \frac{\partial\Pi}{\partial c} = -D\left(p^m(c)\right)$

Finally, $V^m = \frac{1}{r}\cdot\int_{\underline{c}}^{\overline{c}} D\left(p^m(c)\right)\cdot dc$ and $V^m < V^s$ because $p^m(c) > c$

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❷ INNOVATION AND MARKET STRUCTURE

A *THE TRUE VALUE OF INNOVATION*

- Competitive sector

Many firms produce an homogeneous good at cost $\bar{c}$; they compete through prices à la Bertrand such that each firm sells the good at price $\bar{c}$ and makes zero profit

One firm only discovers the innovation (patent protection) and thus produces at cost $\underline{c}$

Here we have two possibilities :
– either $p^m(\underline{c}) < \bar{c}$ (major innovation) then the innovator totally escapes the competition,
– or $p^m(\underline{c}) \geq \bar{c}$ (minor innovation) then competition pulls monopoly price down to $\bar{c}$

With a major innovation, we have $V^c = \int_0^\infty e^{-rt}\left(\Pi^m(\underline{c}) - 0\right)\cdot dt = \frac{1}{r}\Pi^m(\underline{c})$ and thus $V^c > V^m$

With a minor innovation, we have $V^c = \int_0^\infty e^{-rt}(\bar{c} - \underline{c})D(\bar{c})\cdot dt = \frac{1}{r}(\bar{c} - \underline{c})D(\bar{c})$, that is $V^c = \frac{1}{r}\int_{\underline{c}}^{\bar{c}} D(\bar{c})\cdot dc$; with $p^m(c) \geq \bar{c}$ we get again $V^c > V^m$; moreover, $V^c < V^s$

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A *THE TRUE VALUE OF INNOVATION*

- Summing up

The value of innovation in various market structures ranks as follows : $V^m < V^c < V^s$

A firm in a competitive sector receives more incentive to innovate than a monopolist because it allows the firm to escape from competition, whereas a monopolist replaces himself (*replacement effect* identified by Arrow)

Moreover, the innovator is ex post in a monopoly position (be it a monopolist or a competitive firm ex ante) : he sells a smaller quantity of good at a higher price than what is socially optimal ; thus, **the private value of innovation is smaller than its social value**

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❷ INNOVATION AND MARKET STRUCTURE

B *THE STRATEGIC VALUE OF INNOVATION*

- What is strategic R&D interaction?

In the preceding developments, one firm has the monopoly of R&D (≠ monopoly on the product market)

Now what happens if many firms are potential innovators?

⇒ strategic R&D interaction : the value of innovation to one firm depends on the others' decision to innovate or not

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❷ INNOVATION AND MARKET STRUCTURE

B *THE STRATEGIC VALUE OF INNOVATION*

- Monopoly with entry threat

A monopolist produces the good with the inferior technology (at cost $\overline{c}$) and is threatened by an outsider ; both firms have the opportunity to innovate (the results aren't changed if one firm only can innovate) ; the firm that implements the innovation is protected by an infinite-life patent

For the outsider, strategic R&D interaction does not change anything :
– if he innovates, he produces at cost $\underline{c}$ and competes through prices with the former monopolist that produces at cost $\overline{c}$ $\Rightarrow$ value of innovation is equal to V^c,
– if he does not innovate, he can not enter the market and keeps receiving zero profit

For the monopolist, things change with strategic R&D interaction :
– if he innovates, he remains a monopoly on the product market and produces at cost $\underline{c}$ $\Rightarrow$ value of innovation is equal to V^m,
– if he does not innovate, he looses his monopoly position and the associated stream of profits if the outsider innovates

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❷ INNOVATION AND MARKET STRUCTURE

B *THE STRATEGIC VALUE OF INNOVATION*

- A reversed result

Denote by $\Pi^d(\bar{c},\underline{c})$ (resp. $\Pi^d(\underline{c},\bar{c})$) the monopolist's (resp. the outsider's) instantaneous profit if the latter implements the innovation ; both firms then compete in a duopoly

For the outsider, the value of innovation is :

$$V^o = \int_0^\infty e^{-rt}\left(\Pi^d(\underline{c},\bar{c}) - 0\right)\cdot dt = \frac{\Pi^d(\underline{c},\bar{c})}{r}$$

For the monopolist, the value of innovation is :

$$V^{m/o} = \int_0^\infty e^{-rt}\left(\Pi^m(\underline{c}) - \Pi^d(\bar{c},\underline{c})\right)\cdot dt = \frac{\Pi^m(\underline{c}) - \Pi^d(\bar{c},\underline{c})}{r}$$

The *efficiency effect* states that on a given market, a monopoly always makes more profits than two non-cooperating firms (i.e. competition erodes profits) ; it follows that

$\Pi^m(\underline{c}) \geq \Pi^d(\bar{c},\underline{c}) + \Pi^d(\underline{c},\bar{c})$ (loose inequality : see what happens if the outsider implements a major innovation)

Finally, this inequality gives $V^{m/o} > V^o$

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B *THE STRATEGIC VALUE OF INNOVATION*

- Summing up

With strategic R&D interaction, **a monopolist receives more incentive to innovate than an outsider**, despite the fact that the innovation is in itself more valuable to the latter

According to the efficiency effect, competition dissipates profits, and the monopolist's incentive to remain a monopolist is stronger than the outsider's incentive to become a duopolist

Were the innovation sold on an auction market, the monopolist would bid higher than the outsider ; he could win the auction at price $\Pi^d(\underline{c},\bar{c})/r$ and remain a monopolist (Gilbert & Newberry, 1982)

Building on this model, one can understand that a monopolist can be willing to get a property right on an innovation not for its true value (it can even be negative) but only to prevent outsiders from becoming actual competitors (strategic pre-emption, socially wasteful)

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❷ INNOVATION AND MARKET STRUCTURE

C *PATENT RACE*

- R&D, a rent-seeking activity

Discovering an innovation and protecting it with a patent yields a rent to the innovator (the incentive to innovate) ⇒ firms compete to capture it

In patent race models, this competition is focused on R&D expenses that firms incur in order to try to discover the innovation first

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❷ INNOVATION AND MARKET STRUCTURE

C *PATENT RACE*

- Monopoly with entry threat

The economy is structurally the same as in 🕐B ; but here, we consider that the probability that a firm discovers the innovation $\bar{c} \searrow \underline{c}$ depends on its R&D expenses

The innovation arrives to firm *i* as a Poisson process with rate of arrival $h(x_i)$ where x_i is the instantaneous R&D expense by firm *i* and $h(\cdot)$ is positive, increasing and concave (the R&D "technology")

Main shortcoming of these assumptions :
a Poisson process has no memory $\Rightarrow$ the probability that a firm discovers the innovation at time *t* depends on its current R&D expense, not on its accumulated experience (R&D not an investment)

but analytical convenience :
the sub-game that starts at time *t* is identical to the initial game ; thus x_i^*, the optimal R&D expense for firm *i*, does not depend on time

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❷ INNOVATION AND MARKET STRUCTURE

C *PATENT RACE*

- Calculating each firm's value of innovation

Let 1 (resp. 2) denote the monopolist (resp. the outsider) ; between time t and $t+dt$:

– 1 receives profit	$\left(\Pi^m(\bar{c}) - x_1\right)\cdot dt$	if no one has discovered the innovation yet
2 " "	$-x_2\cdot dt$	Prob $= e^{-[h(x_1)+h(x_2)]\cdot t}$)
– 1 receives the rent	$\Pi^m(\underline{c})/r$	if the monopolist discovers the innovation and no one has discovered the innovation yet
2 " profit	0	Prob $= e^{-[h(x_1)+h(x_2)]\cdot t}\times h(x_1)\cdot dt$
– 1 receives the rent	$\Pi^d(\bar{c},\underline{c})/r$	if the outsider discovers the innovation and no one has discovered the innovation yet
2 " the rent	$\Pi^d(\underline{c},\bar{c})/r$	Prob $= e^{-[h(x_1)+h(x_2)]\cdot t}\times h(x_2)\cdot dt$

So we find the value of innovation for each firm :

$$V_1 = \int_0^\infty e^{-rt}e^{-[h(x_1)+h(x_2)]t}\times\left(\Pi^m(\bar{c}) - x_1 + h(x_1)\cdot\Pi^m(\underline{c})/r + h(x_2)\cdot\Pi^d(\bar{c},\underline{c})/r\right)\cdot dt$$

$$V_2 = \int_0^\infty e^{-rt}e^{-[h(x_1)+h(x_2)]t}\times\left(-x_2 + h(x_1)\times 0 + h(x_2)\cdot\Pi^d(\underline{c},\bar{c})/r\right)\cdot dt$$

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❷ INNOVATION AND MARKET STRUCTURE

C *PATENT RACE*

- Nash equilibrium

More simply, we have :

$$V_1 = \frac{\Pi^m(\bar{c}) - x_1 + h(x_1)\cdot\Pi^m(\underline{c})/r + h(x_2)\cdot\Pi^d(\bar{c},\underline{c})/r}{r + h(x_1) + h(x_2)} \qquad V_2 = \frac{-x_2 + h(x_2)\cdot\Pi^d(\underline{c},\bar{c})/r}{r + h(x_1) + h(x_2)}$$

x_1 and x_2 are the strategic variables of the firms ; a couple (x_1^*, x_2^*) is a Nash equilibrium of the patent race if and only if x_1^* is the monopolist's best response when the outsider's decision is x_2^*, and vice-versa.

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❷ INNOVATION AND MARKET STRUCTURE

C *PATENT RACE*

- A balance between the replacement effect and the efficiency effect

Key question = which firm has the higher R&D expense ? Or conversely which firm has the higher probability to discover the innovation first ?

Answer depends on the relative balance between replacement (structural) and efficiency (strategic) effects :
– replacement effect : the monopolist gives up profit $\Pi^m(\bar{c})$ if he discovers the innovation, while the outsider gives up no profit if he is the innovator,
– efficiency effect : for the monopolist, the differential profit between being the innovator or letting the outsider be the innovator is equal to $\Pi^m(\underline{c}) - \Pi^d(\bar{c},\underline{c})$, an amount that is superior to $\Pi^d(\underline{c},\bar{c}) - 0$, the equivalent differential profit for the outsider

Specific cases :
– if a major innovation is at stake then the efficiency effect is null ; it is possible to show that $x_2^* > x_1^*$ (the outsider is the most probable first innovator),
– if $h(\cdot)$ is very big then the replacement effect is null ; it is possible to show that $x_1^* > x_2^*$ (the monopolist is the most probable first innovator)

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❸ THE PATENT AS A PROTECTION DEVICE

- The problem

Drawn from O'Donoghue T., Scotchmer S., Thisse J.-F., (1998) : « Patent Breadth, Patent Life, and the Pace of Technological Progress », Journal of Economics & Management Strategy, 7(1), p. 1-32.

Innovations are cumulative ⇒ severe dilemma :
– a given innovation can have a strong social value with respect to the spillovers it generates for future innovations (knowledge, …),
– but from the private point of view, future innovations are a competitive threat for the present innovator

Patent breadth tells which innovations or imitations cannot (resp. can) be developed because they infringe (resp. do not infringe) on the patent

Lagging breadth protects against imitation (inferior products or processes) whereas leading breadth protects against subsequent innovation (superior products or processes)

Question about patent design : is it better to protect the innovation narrowly for a long period of time or rather against a wide range of competing products / processes but for a shorter time ? Which kind of patent breadth should be favoured ?

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❸ THE PATENT AS A PROTECTION DEVICE

- The assumptions

Cumulative product innovations : products are vertically differentiated according to a quality ladder

Innovation i = quality improvement Δ_i over existing quality $\quad q_i = q_{i-1} + \Delta_i$

Once quality q_i has been discovered, all inferior qualities can technologically be produced ; but not all of them can be exploited because of the patents in force

Implementing an innovation requires getting an idea Δ + investing a fixed R&D cost c (the strategic decision) :
– c is the same for all innovations,
– Δ is statistically distributed according to function $F(\cdot)$

Ideas arrive in the economy according to a Poisson process of parameter λ ; a given idea reaches one firm only among many firms and one firm cannot get two consecutive ideas

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❸ THE PATENT AS A PROTECTION DEVICE

- The assumptions

Instantaneous demand for the good with quality q_i is zero or one depending on the price charged p ; the consumer surplus is $q_i - p$

Competition through prices à la Bertrand :
a firm that sells quality q_i when the immediately inferior quality is q_{i-1} sets its price at $p = q_i - q_{i-1}$; thus, if an innovator is granted a patent that fully protects his innovation Δ_i (i.e. lagging breadth = Δ_i), he can charge price Δ_i

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❸ THE PATENT AS A PROTECTION DEVICE

- Social planner

An innovation Δ brings a quality increase that lasts forever ; its social value is :

$$\int_0^{\infty} e^{-rt}\Delta \cdot dt - c = \frac{\Delta}{r} - c$$

Thus, an innovation is socially desirable if and only if $\Delta \geq \Delta^{opt} = r \cdot c$

The rate of innovation measures the quality improvement per unit of time ; when all ideas Δ such that $\Delta \geq \underline{\Delta}$ are transformed into innovations, this rate is equal to :

$$\Phi(\underline{\Delta}) = \lambda \cdot \int_{\underline{\Delta}}^{\infty} \Delta \cdot f(\Delta) \cdot d\Delta$$ (decreasing in $\underline{\Delta}$)

The socially optimal rate of innovation is $\Phi(\Delta^{opt})$

The only possible social inefficiency relates to the fact that there may be too little innovations in the economy, i.e. $\Phi < \Phi(\Delta^{opt})$ (no deadweight loss associated with monopoly power since demand is zero or one)

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❸ THE PATENT AS A PROTECTION DEVICE

- The limits of lagging breadth

Consider patents with no leading breadth ; to look at the most favourable case within this set of patents, consider that an innovator can that fully protects his innovation Δ (i.e. lagging breadth = Δ) for an infinite period of time

The firm that discovers quality q_i earns profit Δ_i up until quality q_{i+1} is discovered (no leading breadth) ; let us calculate Π_i, the value of the innovation for the firm

If firms invest in all ideas Δ such that $\Delta \geq \underline{\Delta}$ then the rate of arrival of innovations is

$$\Gamma(\underline{\Delta}) = \lambda \cdot \text{Prob}(\Delta \geq \underline{\Delta}) = \lambda \cdot [1 - F(\underline{\Delta})]$$

Thus, the probability that no innovation $\Delta \geq \underline{\Delta}$ arrives in the economy between time 0 and time t is equal to $e^{-\Gamma(\underline{\Delta})\cdot t}$

So $$\Pi_i = \int_0^{\infty} e^{-rt} e^{-\Gamma(\underline{\Delta})\cdot t} \Delta_i \cdot dt - c = \frac{\Delta_i}{r + \Gamma(\underline{\Delta})} - c$$

Let Δ^* be the equilibrium value of quality improvement that allows the firm to reimburse its R&D cost c ; Δ^* satisfies $$\frac{\Delta^*}{r + \lambda \cdot [1 - F(\Delta^*)]} = c$$

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❸ THE PATENT AS A PROTECTION DEVICE

- Summing up

Firms invest in ideas Δ if and only if $\Delta \geq \Delta^*$

In the most general case $\Delta^* > \Delta^{opt}$ meaning that some socially desirable ideas are not transformed into innovations by the firms which discover them, a result of the lack of incentives provided by the patent without leading breadth

As a consequence $\Phi(\Delta^*) < \Phi(\Delta^{opt})$; **the rate of innovation performed by the decentralized market economy is socially sub-optimal**

Despite the fact that appropriate lagging breadth allows the innovator to reap all the social surplus brought about by his innovation, without leading breadth this stream of profits ends as soon as a subsequent innovation arrives and pushes the former out of the market (effective patent life = $1/\Gamma(\Delta^*)$)

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❸ THE PATENT AS A PROTECTION DEVICE

- Introducing leading breadth

In the following developments, lagging breadth is considered to fully protect the quality improvement Δ

Let K be the patent's leading breadth ; if a good with quality q_i is sold on the market, an innovation that brings about a quality improvement Δ such that $\Delta \leq K$ infringes on the patent and thus does not terminate it

With a patent (K,∞), if $K < \Delta^*$ then nothing changes since investing in R&D is conditional on the fact that $\Delta \geq \Delta^* > K$ (non-infringing innovation)

But if $K \geq \Delta^*$ then the effective patent life rises from $1/\Gamma(\Delta^*)$ up to $1/\Gamma(K)$; if they could, firms would invest in all ideas $\Delta \geq \Delta^K$ where $\Delta^K = c\left[r + \lambda \cdot (1 - F(K))\right]$

$\Delta^K < \Delta^*$ in the most general case, which is positive from the rate of innovation's point of view

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❸ THE PATENT AS A PROTECTION DEVICE

- The need for license agreements

The problem is that firms cannot invest in these smaller quality improvements because for $\Delta \in [\Delta^K, K]$ ideas are profitable yet they are infringing on the patent in force

Things are worse in the end because with leading breadth firms can only invest in non-infringing ideas, i.e. ideas such that $\Delta > K \geq \Delta^*$ (social waste)

It is nevertheless possible to foster investment in ideas such that $\Delta < \Delta^*$ and increase the rate of innovation if a firm that discovers a profitable yet infringing innovation can exploit it after having negotiated a license with the incumbent (owner of the infringed patent)

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❸ THE PATENT AS A PROTECTION DEVICE

- Efficient bargaining process

Incumbent sells good with quality q_i and earns instantaneous profit Δ_i , which ends if a license is sold for a superior yet infringing quality $q_i + \Delta$; the licensee sells his good at price $\Delta_i + \Delta$ as a result of price competition with quality q_{i-1}

The license and its owner's flow of profits stop when the licensor's patent ends, an event that can have two origins :
– with a patent of the (K,∞) type, the patent terminates when a non-infringing innovation arrives,
– with a patent of the (∞,T) type, the patent terminates when it reaches the end of its statutory life

Assume that the bargaining process for the license is efficient, i.e. a license is traded if and only if the infringing innovation yields a positive incremental profit (to be shared between the partners)

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❸ THE PATENT AS A PROTECTION DEVICE

- Leading breadth fosters innovation

Consider a patent (K,∞) ; the incremental profit brought about by the infringing innovation is equal to : $\Pi_{i+\Delta} = \int_0^{\infty} e^{-rt} e^{-\Gamma(K)\cdot t} \Delta \cdot dt - c = \frac{\Delta}{r+\Gamma(K)} - c$

License agreements offer the opportunity that mutually beneficial deals be achieved ; thus, it becomes a reality that all profitable ideas turn into innovations, for firms invest in ideas Δ if and only if $\Delta \geq \Delta^K$ with $\Delta^K = c\left[r + \lambda \cdot (1 - F(K))\right]$

$\Delta^K < \Delta^*$ so the rate of innovation is increased compared with a patent without leading breadth : $\Phi(\Delta^K) > \Phi(\Delta^*)$

Moreover, as K increases Δ^K decreases and $\Phi(\Delta^K)$ increases
Finally, $\lim_{K\to\infty} \Delta^K = r \cdot c = \Delta^{opt}$ and consequently $\lim_{K\to\infty} \Phi\left(\Delta^K\right) = \Phi\left(\Delta^{opt}\right)$

When he is granted a patent **with infinite leading breadth and infinite length**, the innovator is in a total and eternal monopoly position ; if he is given the opportunity to sell licenses, he acts as a social planner and thus **the rate of innovation is socially optimal**

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❹ THE PATENT AS A REVELATION MECHANISM

- The problem

Drawn from Hopenhayn H.A., Mitchell M.F., (2001) : « Innovation variety and patent breadth », Rand Journal of Economics, 32(1), p. 152-166.

Innovations are heterogeneous ; they differ with respect to a characteristic θ about which innovators have a private information, the patent office being not able to observe it (you can think of θ as being the innovation's fertility with respect to subsequent innovations)

The patent is modelled as a three instruments device (B, T, F) respectively its breadth, length and deposit cost

The problem is a typically of the "revelation of information" type : given the innovations' unobservable heterogeneity, how should the patent office design patent(s) in order to maximise social surplus

Instead of designing only one patent for the innovators, it may be better for the patent office to propose a menu of patents that fit better with innovations' variety

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❹ THE PATENT AS A REVELATION MECHANISM

- The assumptions

Consider J innovations differing from the point of view of a characteristic $\theta \in \{1,\ldots,J\}$ that is a private information of the innovator ; suppose an innovator discovers idea θ with probability $g(\theta)$ and suppose he must spend R&D cost c and get a patent to develop the innovation

The innovator's net profit when he exploits innovation θ with a patent (B, T, F) is :

$\Pi(B,T,\theta) - c - F$ with $\frac{\partial \Pi}{\partial B} > 0$, $\frac{\partial \Pi}{\partial T} > 0$ and $\Pi(0,T,\theta) = \Pi(B,0,\theta) = 0$

Society benefits from development of innovation θ with patent (B, T, F) according to the function $S(B,T,\theta)$ with $\frac{\partial S}{\partial B} < 0$, $\frac{\partial S}{\partial T} < 0$ for B and T endow the innovator with socially wasteful monopoly power, while F is neutral as a simple transfer between innovator and patent office

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❹ THE PATENT AS A REVELATION MECHANISM

- Revealing private information

The problem of the patent office is to design an optimal menu of patents $\{b_j, t_j, f_j\}$ (one for each type of innovation), i.e. one that maximises social surplus while revealing the innovators' private information

Formally : $\max_{B(\theta),T(\theta),F(\theta)} \sum_{\theta=1}^{J} S[B(\theta),T(\theta),\theta] \cdot g(\theta)$

under constraints

IR $\Pi[B(\theta),T(\theta),\theta] - c - F(\theta) \geq 0 \qquad \forall \theta$

IC $\Pi[B(\theta),T(\theta),\theta] - c - F(\theta) \geq \Pi[B(\hat{\theta}),T(\hat{\theta}),\theta] - c - F(\hat{\theta}) \quad \forall \theta, \hat{\theta}$

MH $F(\theta) \geq 0 \qquad \forall \theta$

<u>Decoded version :</u>

each innovator chooses the patent that brings him the more profit conditional on the type θ of his innovation (auto-selection) ; so the patent office maximises social surplus providing that each innovator is willing to patent his innovation whatever its type θ (IR) and that an innovator that patents his innovation of type θ will choose among all patents the patent that was designed for him (IC) (MH makes sure that it is not possible to make money out of an innovation with no value)

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- Preliminary theorem

If the conditions $\frac{\partial^2 \Pi}{\partial \theta \partial B} > 0$, $\frac{\partial^2 \Pi}{\partial \theta \partial T} < 0$ and $\Pi(B,T,\theta)$ is monotonic in θ are verified then there exists an optimal menu of patents $\{b_j , t_j , f_j\}$ such that all deposit costs are null :
$f_j = 0 \quad \forall j \in \{1,\ldots, J\}$ (corner solution)

These conditions are called the sorting conditions :
– the higher the θ the more the innovator benefits from marginal increase in patent breadth,
– the higher the θ the less the innovator benefits from marginal increase in patent length so sorting innovators by type is equivalent to sorting them by increasing favor for breadth and by decreasing favor for length ($\Rightarrow$ trade-off between B and T)

Intuition for the theorem :
From the social point of view F is neutral whereas increasing B or T is costly (confers monopoly power to the innovator) ; on the contrary, F on the one hand and (B,T) on the other hand are equivalent from the private point of view ; so you can leave unchanged the private incentives produced by a patent menu by lowering f_j and (b_j ,t_j) at the same time for patents with $f_j > 0$, a transformation that increases social surplus

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- An illustration : assumptions

Model resembles O'Donoghue, Scotchmer & Thisse (1998) : cumulative and overlapping innovations consisting in vertically differentiated products (quality)

At time t=0 a first innovator discovers product with quality π and fertility θ (both uncorrelated) ; he must spend R&D cost *c* and get a patent to exploit it

An innovation arrives to second innovator as a Poisson process of parameter θ , and brings about a quality increase of Δ to the product (Δ is distributed according to function $H(\cdot)$ on R_+) ; so the higher the θ , the faster the second innovation arrives ; denote by $P(t, \theta)$ the probability that innovation 2 arrives in the time interval $[0, t]$

Instantaneous demand is zero or one depending on the price charged *p* ; the consumer surplus is $q - p$ where *q* is the product's quality (π or $\pi + \Delta$)

Firms compete à la Bertrand :
– if only innovation 1 is sold on the market, price is π, the first innovator reaps all surplus,
– if both products are sold, the inferior product is pushed out of the market and the superior product is sold at price Δ ; the consumer gets surplus π

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- An illustration : the patent design

First innovator chooses patent ($B(\theta)$, $T(\theta)$, $F(\theta)$) among those proposed by patent office $F(\theta)$ is the deposit cost ; $B(\theta)$ and $T(\theta)$ are respectively patent breadth and length, i.e. first innovator is protected from competition due to innovations bringing about quality increase $\Delta < B(\theta)$ as long as $t < T(\theta)$; competition is on if $t > T(\theta)$ whatever Δ or $\Delta > B(\theta)$ whatever t

Assume second innovator cannot buy first innovator's patent or negotiate a license

Patent office must design patent menu in order to maximise social surplus while having the innovators reveal their private information about their innovation's fertility θ

The only social waste potentially comes from delaying quality improvement Δ associated with second innovation (no deadweight loss as demand is zero or one)

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- An illustration : the value of innovation

Let us calculate the value of innovation for the first innovator when he protects his innovation with patent (B, T, F) ; between time t and $t+dt$:

– he receives profit $\pi \cdot dt$ as long as second innovator has not discovered the second innovation yet
Prob $= 1 - P(t, \theta)$

– " " " $\pi \cdot dt$ if second innovator discovers the second innovation but it infringes the patent ($\Delta \leq B$ and $t \leq T$)
Prob $= P(t, \theta) \cdot H(B)$

– " " " zero if second innovator discovers the second innovation and it pushes out the first ($\Delta > B$ and $t \leq T$)
Prob $= P(t, \theta) \cdot [1 - H(B)]$

– " " " zero if $t > T$)(first innovation fall in public domain)

So $$\Pi(B,T,\theta) = \int_0^T e^{-\rho t} \pi \left[1 - P(t,\theta) + P(t,\theta) \cdot H(B)\right] \cdot dt - c$$

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- An illustration : checking for the sorting conditions

First note that $\frac{\partial \Pi}{\partial B} = \int_0^T e^{-\rho t}\pi \cdot P(t,\theta)\cdot h(B)\cdot dt > 0$ $\quad \frac{\partial \Pi}{\partial T} = e^{-\rho t}\pi\left[1 - P(t,\theta) + P(t,\theta)\cdot H(B)\right] > 0$

Moreover :

$$\frac{\partial \Pi}{\partial \theta} = -\int_0^T e^{-\rho t}\pi \cdot \frac{\partial P(t,\theta)}{\partial \theta}\cdot(1 - H(B))\cdot dt < 0 \quad \text{for} \quad \frac{\partial P(t,\theta)}{\partial \theta} > 0$$

$$\frac{\partial^2 \Pi}{\partial \theta \partial B} = \int_0^T e^{-\rho t}\pi \cdot \frac{\partial P(t,\theta)}{\partial \theta}\cdot h(B)\cdot dt > 0$$

$$\frac{\partial^2 \Pi}{\partial \theta \partial T} = -e^{-\rho t}\pi \cdot \frac{\partial P(t,\theta)}{\partial \theta}\cdot(1 - H(B)) < 0$$

So the sorting conditions are verified ; thus, there exists an optimal patent menu $\{b_j, t_j, f_j\}$ such that all deposit costs are null

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- An illustration : the optimal patent menu

Some more simplifying assumptions :
suppose quality improvement Δ is deterministic ($\Delta = \overline{\Delta}$) ; suppose moreover that there exists two levels of fertility (two types) θ_1 (low) and θ_2 (high)

Consider a patent with no breadth and length T ; the IR constraint for innovator of type θ is : $\int_0^T e^{-\rho t}\pi\left[1-P(t,\theta)\right]\cdot dt \geq c$

Suppose there exists T_1 such that : $\int_0^{T_1} e^{-\rho t}\pi\left[1-P(t,\theta_1)\right]\cdot dt = c$

Innovator with type θ_1 is willing to patent his innovation when patent = $(0, T_1)$

First innovator is granted monopoly power for statutory time T_1 but competition wipes his profits as soon as second innovator discovers innovation 2 (quality improvement $\overline{\Delta}$)

Social surplus is maximum because quality improvement is not delayed at all

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- An illustration : the optimal patent menu (2)

Suppose that θ_2 is big enough so that $\int_0^{\infty} e^{-\rho t}\pi\left[1-P(t,\theta_2)\right]\cdot dt < c$

To justify this, note that when $\theta_2 \rightarrow \infty$, first innovation's fertility is so strong that second innovation arrives almost instantaneously so the discounted value of profit flows is almost null for first innovator

In clear, first innovator can never reimburse his R&D cost *c* with a patent without breadth whatever its length $\Rightarrow$ to have the high type innovator patent his innovation, the patent office must offer him breadth

As quality improvement brought about by second innovation is equal to $\overline{\Delta}$, patent breadth should be $\overline{\Delta}$ (offering more breadth is socially costly)

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- An illustration : the optimal patent menu (3)

Patent office designs a patent $(\overline{\Delta}, T_2)$ for high-type innovator where T_2 is such that

$$\int_0^{T_2} e^{-\rho t}\pi \cdot dt = c$$

Innovator with type θ_2 is willing to patent his innovation when patent = $(\overline{\Delta}, T_2)$

This patent induces social cost for quality improvement cannot be brought about before T_2 ; but patent office cannot offer less monopoly power to high-type innovator

Comparison of the two patents $(0, T_1)$ and $(\overline{\Delta}, T_2)$:

– $B_2 > B_1$

– $1 - P(t, \theta_1) < 1$ so $T_1 > T_2$

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- An illustration : the optimal patent menu (4 and conclusion)

Let us check for revelation properties of patent menu $\{(0, T_1) ; (\overline{\Delta}, T_2)\}$:
– innovator with low-type θ_1 exactly reimburses his R&D cost c with both patents so he is indifferent between both (IC constraint binding)
– innovator with high-type θ_2 has negative profit with patent $(0, \infty)$ so a fortiori with patent $(0, T_1)$; therefore he prefers the patent $(\overline{\Delta}, T_2)$ designed for him

In conclusion, patent menu $\{(0, T_1) ; (\overline{\Delta}, T_2)\}$ is optimal :
– each innovator wishes to patent his innovation whatever the fertility and chooses the patent designed for him (so private information is revealed through auto-selection),
– social cost attached to granting patents is minimised as only improvements over highly fertile first innovations will be delayed and for a period of time as short as possible

Offering a unique patent is inefficient :
– highly fertile innovations need to be protected against further improvements, although for a relative short period of time,
– lowly fertile innovations require longer monopoly protection but no exclusion right against further improvements