Innovation, R& D and Intellectual Property

Industrial Organization

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Innovation: facts and basic issues

Long term growth per capita only explained for 10% by capital accumulation (Solow); it is mostly driven by technical progress and improvement of human capital (education)

Technical progress: emergence of new products, of new processes; points to the role of research and development (R&D)

Huge R&D spending (in Bn USD in 2016) and concentrated on some sectors

- Apple: 8.1, Alphabet: 12.3, Amazon: 12.5, Microsoft: 12
- VW: 13.2 , Toyota: 8.8, GM 7.5
- Roche: 10, Novartis: 9.5, Johnson& Johnson: 9, Pfizer: 7.7, Merck: 6.7

Innovation: facts and basic issues

Production of information / knowledge (fundamental research), possibly incorporated in new materials, algorithms or protocols (applied research), ultimately leading to marketable products or standardized production processes (development).

3 sources of market failure:

- uncertainty: technological risk, commercial risk, ... giving rise to incomplete markets, moral hazard problems
- indivisibility: large fixed setup costs and low marginal cost for a 0/1 outcome, leading to natural monopolization
- public good / externality: non-rivalry

Hence, in general, problem of appropriation of the benefits of innovation because of imitation and copy: sub-optimal production of information / knowledge. Some form of protection, of incentives must be provided.

(Caveat: open science, free software,...)

A system of Intellectual Property Protection (IPP) aims at:

- ensuring appropriation by innovators of (some of) the value created by their innovations, so as to incentivize to R&D,
- while preserving consumers' surplus and diffusion of innovations in the economy

System of IP Protection

- IP protection framework aims at restoring dynamic efficiency, i.e. incentives for innovation
- To do so, IP Law makes information / knowledge excludable by legal means: exclusive use to the innovator
- Creates monopoly situation, hence under-utilization problem: i.e. static inefficiency
- Trade-off dynamic efficiency vs static efficiency: necessarily imperfect (Nordhaus,1969)

IP = industrial property branch (patents, trade secrets, trademarks) + copyright branch

System of IP Protection

About Patents:

- Requirements: novelty, inventive step (US: non-obviousness), industrial use (US: utility)
- Owner: First to file (US/ to invent)
- Rights: exclusive rights against all commercial uses (make, use, sell) = wide protection
- Duration: 20 years (if maintained)

IP Protection strengthened in 80s (US Court of Appeals, EPO), broadened (software, business methods, genetic inventions, *sui generis* rights for semiconductors and databases), harmonized worldwide (TRIPS agreements 1994)

System of IP Protection

A few facts about IPP:

- Relying on trade secrets remains the major means of protection in many industries (except pharma & chemical)
- From 1980 to 2001, number of patents (applications or issuances) multiplied by 3 in the US; from 2000 to 2015 multiplied by 2
- Huge numbers: In 2015, 630.000 applications to USPTO (326.000 granted), 160.000 applications to EPO
- Boom mostly in biotech and ICT, due mostly to big innovative firms
- Maintained strong activity in big pharma

System of IP Protection

Many problems with the patent system:

- Weird patents (watch for dogs), problematic patents (Amazon's one-click, State Street Bank's matrix inversion,...), undue patents (hyperlink), excessive width (on genes)
- Many concerns in biotech and ICT: cumulative and complementary innovations
- Issues about "patent or not patent": commercial methods, software, mathematical methods, living species,...
- International tensions: IPP is local in a global world, issue of development,...

Road map for today

General theory of innovation and R& D:

- Value of innovation in a given market structure (basic under-provision)
- Innovation races (models of the 80s)
- Normative discussion: optimal patent format ?

More advanced topics: sharing and diffusion of innovation are more complex

- Patents and licensing of innovations
- Sequential and complement innovations
- Patent pools

Value of an innovation

Schumpeter (1943): Innovation and monopolistic market structure closely related. Influential contribution.

- Incentive to innovate comes from future appropriation of (part of) the surplus that is created and the only way is through monopoly power *de facto* (temporary, secrecy) or *de jure* (legal protection): a necessary evil
- Large dominant firms are better fitted for R& D than small firms: no rivals hence no imitation, more qualified to exploit increasing returns in R& D, more diversified to face risks

Confusing argument: size vs market power.

Value of an innovation

Only one agent / firm has the idea to innovate (scarce ideas). Should it do it ?

Value of a process innovation that reduces unit cost of a good with demand $D(.)$ from c_0 to $c_1 < c_0$ and gives rise to an indefinite protection (patent of infinite length):

- For social welfare:

$$V^{SW} = \frac{1}{r}\int_{c_1}^{c_0} D(x)dx$$

- Firm in (perfectly) competitive market will charge c_0 or slightly below for non-drastic innovation ($p^M(c_1) > c_0$)

$$V^{C} = \frac{1}{r}\int_{c_1}^{c_0} D(c_0)dx$$

- For a monopolistic firm

$$V^{M} = \frac{1}{r}\int_{c_1}^{c_0} D(p^M(x))dx$$

Value of an innovation

Value of an innovation

$$V^M < V^C < V^{SW}$$

- Imperfect appropriation of the social surplus created in any market structure: under-incentives to innovate
- Monopoly has less incentives to innovate than a competitive firm

Effect also true for a drastic innovation, i.e. an innovation such that $p^M(c_1) < c_0$

Value of an innovation

Replacement effect, due to Arrow (1962); Contradicts Schumpeter's intuition.
Monopolist already earns a rent prior to innovation while the competitive firm earns zero rent, monopolist replaces itself.

In an oligopolistic industry, the conclusion is not intuitive: under Cournot competition, incentives to innovate are larger for the monopoly if the innovation size is small, they are larger for an intermediate oligopoly if large innovation...

What if there is no monopoly on ideas, i.e. ideas are around and anyone can innovate? Innovation becomes a competitive tool and it affects market structure

Value of innovation under the threat of entry

An incumbent monopolist (i) and a potential entrant (e) can acquire a given innovation: who is willing to pay more for the innovation?

- $\pi^m(c)$: monopolist's profit with unit cost c, entrant cannot enter without the innovation
- $\pi^i(c_i, c_e)$ and $\pi^e(c_i, c_e)$: duopoly profits when the incumbent has cost c_i and the entrant has cost c_e
- Value of acquiring the innovation for the entrant compared to the incumbent acquiring it: $V^e = \frac{1}{r}[\pi^e(c_0, c_1) - 0]$
- Value of acquiring the innovation for the incumbent compared to the entrant acquiring it: $V^i = \frac{1}{r}[\pi^m(c_1) - \pi^i(c_0, c_1)]$

Value of innovation under the threat of entry

Comparison hinges on:

$$\pi^m(c_1) > \text{ or } < \pi^i(c_0, c_1) + \pi^e(c_0, c_1)$$

In a duopoly with close enough substitutes, the monopoly makes larger profits than the sum of the duopolists' profits: then, the innovation is more valuable for the monopoly under the threat of entry. There is persistence of the monopoly

Fear of losing monopoly position induces stronger incentives to innovate: efficiency effect

Patent race models

Previous analysis simply captures the value of innovation: does not model the actual competition among firms to innovate, the risk inherent in R&D activities and the dynamic dimension of this competition

Dynamic stochastic games of innovation formalized as races:

- Stochastic process of Poisson type
- At time t, if one firm invests x in R&D, its probability of success is formalized as hazard rate $h(x)$, independent of other firms' investments and of past investments; $h(.)$ concave and Inada conditions
- Firms choose their $x_j(t)$, but memoryless property implies x_j constant in time
- So probability firm j innovates before some date t, starting from time 0, is $1 - \exp(-h(x_j)t)$.

Patent race models

Consider again incumbent vs entrant, with same notation as before. Firms engage in an innovation race and decide x_i and x_e.

Using: $\int_0^\infty e^{-rt} e^{-[h(x_i)+h(x_e)]t}.vdt = \frac{v}{r+h(x_i)+h(x_e)}$

$$V^i = \frac{\left(\pi^m(c_0) - x_i + h(x_i)\frac{\pi^m(c_1)}{r} + h(x_e)\frac{\pi^i(c_0,c_1)}{r}\right)}{r + h(x_i) + h(x_e)}$$

$$V^e = \frac{\left(-x_e + h(x_e)\frac{\pi^e(c_0,c_1)}{r}\right)}{r + h(x_i) + h(x_e)}$$

Patent race models

Natural question: does the incumbent invest more / less than the entrant, i.e. is there monopoly persistence (stochastic sense) or (stochastic) entry?

Comparing the R&D intensities:

- The efficiency effect shows in the comparison of gains after innovation (comparing equilibrium conditions)
- The replacement effect shows as increasing $\pi^m(c_0)$ decreases the slope of V^i wrt to x_i, hence smaller equilibrium x_i.

In general, it is ambiguous !

- With a drastic innovation, no dissipation of monopoly rent, i.e. no efficiency effect: entry
- With quick innovation process, monopolist more worried about entry than replacement: persistence

Patent race models

Symmetric patent races among n firms to study the impact of the degree of competition on the speed of innovation

When n increases:

- the expected gain from R&D decreases for each firm: a force towards low investment in R&D
- but more firms engage in R&D and overall speeds up the date of innovation: a force towards more expenditure **during the race**
- Fixed upfront costs of R&D decrease but R&D expenditure along the race increase
- Overall, industry innovates more rapidly

Optimal patent design

Basic trade-off between dynamic efficiency and static efficiency translates into the optimal design of a patent: length / life, width / breadth

- Length / life simple: how long does the patent last?
- Width / breadth less clear: degree of protection, how easy it is to invent around? E.g.: how "different" a non-infringing innovation must be, cost of imitation

Patent format (life, breadth) determines the incentives to innovate, hence the rate of innovation. It should be designed to maximize inter-temporal welfare subject to this impact on innovation rate

Model

- Innovative sector has cost $C(a) = \frac{1}{2}Ra^2$ to generate a probability of invention a (R large enough)
- Without protection: $\bar{\pi}$ for the innovative sector and social welfare $\bar{W}$ per period
- Patent (T, b) yields monopoly profits $\pi^m(b) > \bar{\pi}$ during life T; private return of innovation increasing in (T, b)

$$P(T,b) = \int_0^T e^{-rt}\pi^m(b)dt + \int_T^\infty e^{-rt}\bar{\pi}dt$$

- Determines the rate of innovation: $a(T, b) = P(T, b)/R$

Optimal patent design

The issue of patent length: Omit b and focus on T

$$\max \left\{ a(T)S(T) - \frac{R}{2}a(T)^2 \right\}$$

with

$$S(T) = \int_0^T e^{-rt} W^m dt + \int_T^\infty e^{-rt} \bar{W} dt$$

with $W^m < \bar{W}$, $S(T)$ decreasing in T

FOC:

$$a'(T)S(T) = a(T) \left[Ra'(T) - S'(T) \right]$$

Marginal dynamic gain of longer protection = marginal static loss
(diminishing returns in R&D and delayed consumers' benefit)

Optimal patent design

Length vs breadth: reintroduce b and simplify social objectives to maximizing S subject to $a(T,b) = a_0$ pre-determined rate of innovation

Length and breadth are substitutes: $\frac{dT}{db}\mid_{a_0} = -\frac{\partial P}{\partial b} / \frac{\partial P}{\partial T} < 0.$

Define $T(b)$ that solves $a(T,b) = a_0$ with minimal length T_0 and minimal breadth b_0 such that: $a(T_0, 1) = a(\infty, b_0) = a_0$

Problem is now to maximize $S(T(b), b)$ in $b \in [b_0, 1]$

Optimal patent design

Using elasticities: ϵ_{ik} for $i = P$ or S and $k = T$ or b

Optimal patent design

If $\frac{\epsilon_{Pb}}{\epsilon_{PT}} < \frac{\epsilon_{Sb}}{\epsilon_{ST}}$ (resp. $>$), length (resp. breadth) has relative large impact on incentives to innovate, then $T = \infty$ and $b = b_0$ (resp. $T = T_0$ and $b = 1$)

Using $I(b) = \pi^m(b) - \bar{\pi}$, a measure of relative incentive to innovate:

Corollary (Denicolo, 1996)

If $S(b)$ and $I(b)$ are convex in b, maximal breadth and minimal length; if both concave, minimal breadth and infinite length; if both linear, combination breadth / length irrelevant.

Denicolo's result weaker than general proposition

Patents and licensing

Process of innovation is not only about firms racing to obtain the temporary monopoly rent associated with protection

Firms also trade information and rights to use the technology in exchange of payments through patent licensing, which makes competition for innovation much richer.

- The only source of revenues for a pure R&D firm ! What about licensing to rivals?
- The possibility of licensing a patent impacts incentives to do R&D ex ante to obtain this patent
- Impacts also incentives to R&D after the patent to obtain a further patent, in particular in applications or further developments: critical for sequential innovations

How to license a patent?

Suppose the patent exists. Several licensing methods, with different impact on industry structure and innovator's profit:

- Selling a predetermined number k of licenses via first-price auction
- Selling an undefined number of licenses at a predetermined fee per license α
- Applying a predetermined royalty fee r for all use of the technology

Critical dimension: whether the licensor is or is not an industry participant !

How to license a patent?

Model: Kamien (Handbook of Game Theory, 1992), Kamien-Tauman (Manchester School, 2002)

- $n+1$ firms, unit cost c
- Linear demand $D(p) = a - p$
- Inventor ($i = n+1$ or I if participant, O if outsider) has technology that reduces to $c - \epsilon$
- Non-drastic innovation (i.e. $a - c > \epsilon$)

Timing:

1. Method is announced, parameter (k, α or r) chosen;
2. Firms then decide to participate / buy;
3. Cournot competition with relevant cost after licensing

How to license a patent?

Licensing by an outsider inventor

Licensing via a FP auction $>$ licensing via a fixed fee $>$ licensing via a royalty.

- If n and ϵ are large, $\frac{a-c}{\epsilon}$ licenses, Cournot price driven to c and bids are ϵ
- (If n and ϵ are small, n licenses with a reserve price in the auction)

It is then possible to find the optimal number of firm in an industry for an outsider inventor: $\sqrt{\frac{2(a-c+\epsilon)}{\epsilon}} - 1$ (...!)

- It decreases with the magnitude of the invention ϵ
- For $\epsilon = a - c$ and the optimal number is 1
- Innovators are more likely to develop major innovations for monopolized or non-competitive industries

How to license a patent?

The main proposition goes a bit against casual observation: royalties are prevalent in the business of licensing patents ...!

What if the inventor is a participant in the industry ?

Licensing by a participating inventor

If n and ϵ are large, licensing by means of a royalty $>$ licensing via a FP auction $>$ licensing via a fixed fee

- Licensing at $r = \epsilon$, all firms become licensee in SPE (although indifferent as $c - \epsilon + r = c$)
- Inventor's profit = Cournot profit + licensing revenues, highest for large n
- Innovators are more likely to develop innovations for perfectly competitive industries .... Contrast !

Impact of licensing on the pattern of innovation

What if we endogenize R&D ? How does the possibility of licensing affects incentives to R&D ? And the dynamics of R&D?

First generation of models: multi-contracting steps, but one-R&D step (Reinganum, Bell 1983, Gallini-Winter, RAND 85):

- Firms have possibly different technologies
- They may license their initial technology for future production (ex ante)
- They decide how to invest in R&D
- They may license their new technology (ex post)
- They produce and compete on the market

Question: impact of licensing opportunities on R&D intensity?

Impact of licensing on the pattern of innovation

Gallini-Winter model:

- Duopolists with initial unit costs (m_1, m_2)
- Engage in R&D or not: R&D costs K and yields a new technology with random unit cost c_i distributed on interval, same distribution across firms, independent of initial technology.
- Cournot-type competition in product market
- If one technology is licensed by i to j (meaningful iff i's unit cost is smaller than j'), j can use this technology in exchange for a royalty r
- Licensor proposes a take-it-or-leave-it offer

Impact of licensing on the pattern of innovation

Equilibrium analysis without any possibility of licensing:

- When both (m_1, m_2) are small (compared to K), no R&D
- When both (m_1, m_2) are large, both firm engage in R&D
- With very asymmetric costs, the high-cost firm engages in R&D while the low cost firm does not

Now introduce the possibility of licensing technologies: instead of creating a monopoly situation, patents here open a market for information about technologies !

Impact of licensing on the pattern of innovation

Impact of ex post licensing (given an ex ante license agreement):

- Eliminates an inefficient technology, hence a rent, royalty fixed equal to the difference in costs ex post
- Ex post licensing means additional (royalty) revenues
- If low-cost firm innovates, high cost firm's production is smaller than if no innovation, hence royalty revenues are reduced compared to what they would be with the existing ex ante contract: effect ambiguous
- But if high-cost firm innovates, no such effect: additional royalty revenues provide additional incentives to engage in R&D
- Ex post licensing with similar costs then reduces the set of parameters such that there is no R&D at all

Impact of licensing on the pattern of innovation

Impact of ex ante and ex post licensing: in general ambiguous! The set of (m_1, m_2) for which there is no R&D at all shrinks around $m_1 = m_2$ but expands for very asymmetric (m_1, m_2)

- Ex post licensing makes R&D more likely for similar initial costs
- Ex ante licensing can eliminate R&D efforts that are globally unprofitable for the industry (because driven by business stealing)
- Low cost firm (say 1) may license its technology so that $m_1 + R$ is low enough to kill firm 2's incentive to R&D
- This is profitable for firm 1 as it eliminates the threat that firm 2 comes up with a strong innovation and becomes the most efficient firm
- Killing firm 2's incentives requires that costs are asymmetric.

Sequential innovations, complementary innovations

ICT has been a very active domain of innovation in the past 30 and continuing to be so.

- A domain where innovations are sequential: "Standing on the shoulders of giants"
- Windows Excel today builds on previous versions of excel, themselves on Lotus 1.2.3., itself on VisiCalc,...

- A domain where several different approaches are followed at the same time to come up with a new functionality: complementary as they increase the probability of this invention in a given time
- Suggested by the many approaches followed for voice-recognition software

Focus of the rest of these slides on this industry

Sequential innovations, complementary innovations

Sequentiality of innovations raise a new issue in terms of licensing: how are the innovations rents distributed among the various innovators, given that late innovations cannot emerge without the early ones

The social value of a pioneering innovation may rest in the commercial value of later applications.

- Green-Scotchmer (RAND 95): Optimal design when a first patent can be licensed (ex ante and/or ex post) with sequential innovations
- Scotchmer (RAND 96), Bessen-Maskin (RAND 2009): Reconsidering patent protection and licensing with sequential and complementary innovations

Division of profit in sequential innovation

- 1st innovation by firm 1 requires cost c_1 and patented
- Idea for a 2nd innovation by firm 2: y "size of improvement", c_2 cost to implement, random ex ante
- π_1^m, π_{12}^m: monopoly profits basic innovation or basic + application; π_1^c and π_2^c : duopoly profits; related to social values
- Implicitly, profits depend upon patent length, innovations simultaneous

Efficiency: social value of 1st innovation = social value if marketed + option value of marketing application: hence, role of firm 1's appropriation of some of applocation value

Division of profit in sequential innovation

1st patent breadth y^*: if $y < y^*$, infringement so that firm 2 has to negotiate with firm 1

Licensing possibilities:

- Ex post: after c_2 is sunk and 2nd innovation infringes
- Ex ante: before c_2 is sunk, after it is realized

Ex ante licensing critical: if no ex ante licensing,

- If application infringes, bargaining and firm 2 gets: $\frac{1}{2}(\pi_{12}^m - \pi_1^m) - c_2$; possible under-investment in application.
- If application does not infringe, firm 1 gets: $\pi_1^c - c_1$, under-investment in basic innovation.

Ex ante licensing can help: no firm would agree ex ante to smaller profits than they would get by forgoing ex ante agreement

Division of profit in sequential innovation

Ex ante licensing can ensure that valuable application is implemented (gains from agreements, efficient). However, firm 1's profit is always smaller or equal (sometimes strictly smaller) than $\pi_{12}^m - c_1 - c_2$

1. If $\pi^c - c_2 > 0$ and $y > y^*$ (Firm 2 invests if does not infringe), 1st innovator leaves some rent due to ex post competition and inability to collect royalties on application
2. If $\frac{1}{2}(\pi_{12}^m - \pi_1^m) - c_2 > 0$ and $y < y^*$ (Firm 2 invests if infringes and ex post negotiates), 1st innovator leaves rent due to ex post bargaining
3. If $\frac{1}{2}(\pi_{12}^m - \pi_1^m) - c_2 < 0$ and $y < y^*$ (Ex post negotiation not sufficient to let firm 2 invest), 1st innovator leaves rent in order to induce investment in application

Division of profit in sequential innovation

Solution is intuitive: larger breadth ! If all uncertainty about c_2 and y resolved before investment in application, the optimal breadth is $y^* = \infty$

Yet, broad patents may not be the solution if uncertainty about y is not resolved !

A very broad patent gives firm 2 a credible threat not to invest, if it knows that ex post bargaining will erode its profits with high probability. Hence, firm 2 bargains ex ante for half the incremental value of the application.

A narrower patent means that firm 2's investment may be profitable as less often infringing: kills off firm 2's threat while giving less that half the incremental value of the application.

Alternatives to patents

Recognizing that innovations need be protected does not mean patents constitute necessarily the solution !

ICT, software, semiconductor,... long story of absence of patents before the mid 80s with high innovation rate; drastic change in 80s, and some evidence that big innovative firms have reduced their R&D investments

Surveys suggest firms (outside pharma) often rely on alternative means of protection:

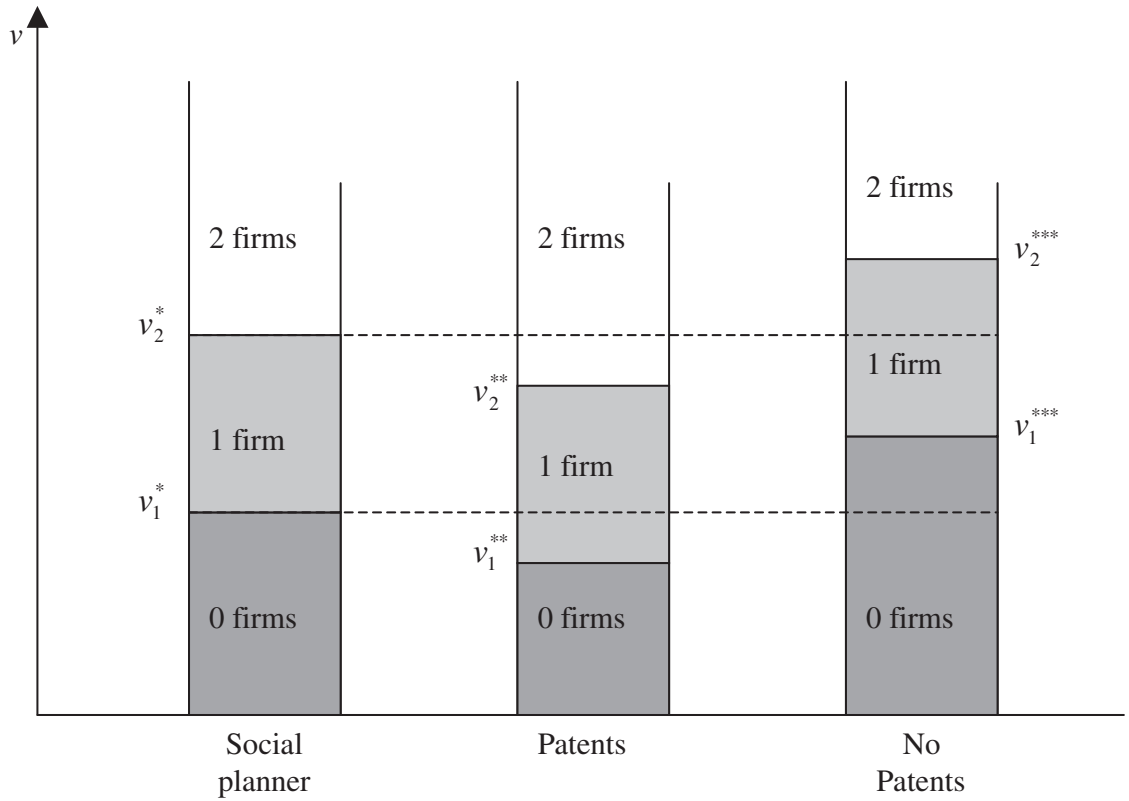
- Secrecy, which allows licensing but not diffusion of knowledge
- Quick development / marketing steps: market first-mover advantage, in a dynamic setting

Static model: patent or not patent?

- 2 ex ante symmetric firms chooses to invest in R&D or not
- Innovation has social value v
- R&D cost is c with proba q and 0 with probab $1-q$, private information of each firm
- Proba of discovery if one firm searches: p_1; Proba of discovery by at least one firm if 2 firms search: p_2 with: $p_1 < p_2 < 2p_1$; complementarity
- Protected innovator gets v; if not protected, innovator and imitator get sv, with $s < 1/2$
- Scenarios: social planner (conditional recommandation under incomplete info), competition w/o patent
- Asymmetry (priority firm 1) in all scenarios (optimal or selection)

Static model: patent or not patent?

STATIC MODEL—R&D THRESHOLDS FOR HIGH-COST FIRMS



Static model: patent or not patent?

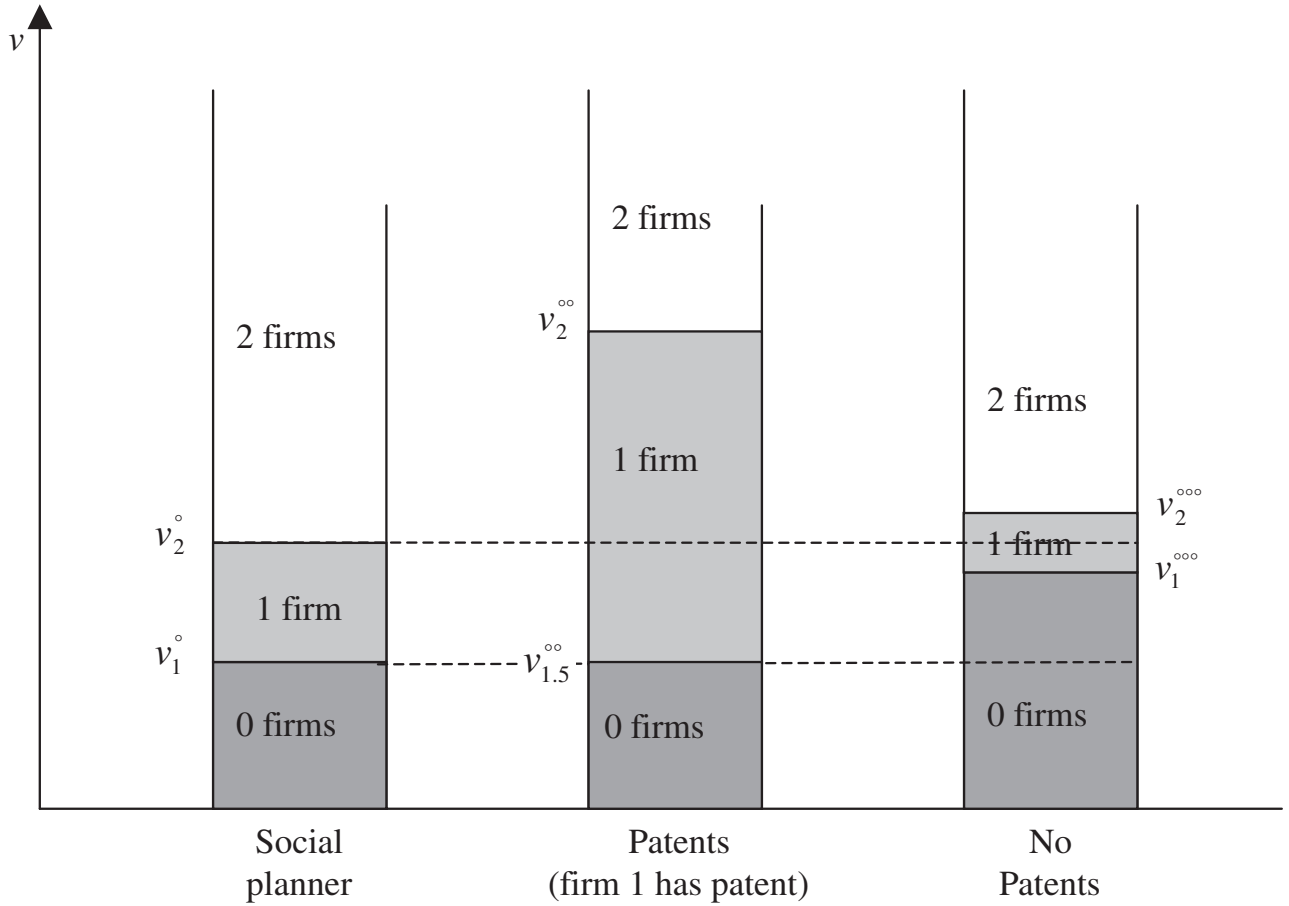
- No surplus appropriation: $v_1^* < v_1^{***}$; and $v_2^* < v_2^{***}$: imitation rather than R&D from 2nd firm although efficient
- $v_1^{**} < v_1^*$ and $v_2^{**} < v_2^*$: patents fix this
- Patents protect from imitation AND encourage would-be imitators to R&D
- Overshooting, overinvestment in R&D: business stealing (negative externality on other firm not internalized)
- "Patents" > "No Patents" (for ex ante welfare), as encourages many (condition on fat enough upper tail for v) large value projects
- Firms better off if no competitor
- Firms better off if patent protection

Sequential model: patent or not patent?

- Inifinite sequence of innovations, v incremental value
- Independence of costs (q small enough), v perfectly correlated over time
- No advantage of innovator for next innovation except if patent: patent blocks innovation sequence for rival (absent licensing)
- Equilibrium with patents: complicated, keep track of who got previous patent, look at licensing fees ...!
- Licensing assumed to allow further innovation by licensee, but with no dissipation of profit from licensor, i.e. keeps property right of next patent and licensing arrangement has to leave enough to licensee so that he invests in R&D

Sequential model: patent or not patent?

DYNAMIC MODEL—R&D THRESHOLDS FOR HIGH-COST FIRMS



Sequential model: patent or not patent?

- More R&D than in static setting in social optimum and under no patents: value of future innovations.
- Too little R&D under no patents; but inefficiency smaller (ex ante, under same tail condition) than in static model: case for patents weaker
- (Overinvestment in R&D before 1st patent reward)
- Underinvestment in R&D after patent, because licensing (under incomplete information) at high enough fee so that licensee does not get it and not invest in R&D when cost c
- Critical tradeoff for patent holder: induce p_2 instead of p_1 by lowering franchise fee
- Overall (Tail condition), social welfare without patents $>$ with patents!
- Even firms may prefer no patents if s close to $1/2$.

Complementarity of innovations and patent pools

- New technology in ICT relies on many functionalities that are covered by many patents that are all necessary ("essential") to implement the technology
- Example of MPEG3 standard: more than 600 "essential" patents, at least 23 IP owners
- "Patent thicket": many patents overlapping, each blocking, endow owners with market power and generate "royalty stacking"
- Akin to double (multiple) marginalization
- In turn, this limits subsequent innovation, hence profitability of patents, hence incentives to innovate in the first place

Complementarity of innovations and patent pools

- Possible solution: Patent Pools
- i.e. cooperative marketing agreement among patent holders...
- ... but obvious risk of cartel !
- History of patent pools reflects this ambiguity
  - Pools appeared in the US in the 1856 (sewing machine pool)
  - Along XX century, harsher anti-competitive view: pools disbanded
  - 1995: new guidelines DoJ and FTC recognizes pro-competitive aspects of pools
  - Today most prevalent in industries setting up standards (ICT, hard/soft ware, biotech): MPEG-n, DVD-x, 3G, 1394-Firewire, AVC, Bluetooth,...

Efficient Patent Pools

Basic idea of complementarity vs subsitutability:

- Two perfect complement patents: each has monopoly power, hence double marginalization, a pool is socially and privately beneficial
- Two substitutes patents: Bertrand competition yields efficiency, a pool implies perfect socially damageable cartelization

How to screen good from bad pools ?

- More complex patterns of complements / substitutes: depends on price levels, varies in time,...
- Complete knowledge of the technology by authorities is not realistic

Lerner-TIrole (AER 2004)

Model of Patent Pools

- 2 firms, each with a relevant patent
- Mass 1 of users who can adopt technology: they benefit V if both patents, $V - e$ if only one (symmetry) and 0 otherwise
- $e \in [0, V]$ measures essentiality: $e = 0$ perfect substitutes, $e = V$ perfect complements
- θ users' cost of adopting technology, $F(.)$ on $[0, V]$
- Demand for bundle $D(P) = F(V - P)$ for P price of the bundle; demand for one single license $D(p+e) = F(V-e-p)$ for p price of the license (assume $D' + PD'' < 0$)
- Monopoly price $P^m = 2p^m = \arg\max_P PD(P)$ (if both), $p^m(e) = \arg\max_p pD(p + e)$ (if only one)

Model of Patent Pools

Game-theoretic framework

- Simultaneous price setting game, $p_i \in [0, V]$
- Indivisibility in patent choice...
- When p_1 increases, two things may happen:
  - adopters may cease purchasing license 1, hence incomplete technology: competition margin binds
  - fewer adopters of the more expensive technology, but still complete technology: demand margin binds
- Look for symmetric equilibrium in either case

When demand margin binds in equilibrium

- $p_1 = r(p_2) \equiv \arg\max_p pD(p + p_2)$
- $-1 < r'(p_2) < 0$
- Patents are complements and strategic substitutes
- Unique fixed point $\hat{p} = r(\hat{p})$: equilibrium
- Double marginalization: $\hat{p} > p^m$, as i does not internalize the demand increase for j.
- Compare: $P^m = \arg\max_P PD(P)$ and $\hat{P} = \arg\max_P (P - \hat{p})D(P)$
- Regime requires that $\hat{p} \leq e$

Model of Patent Pools

When competition margin binds in equilibrium

- License is evicted from basket when its price increases if $p_i \geq e$
- In this range, patents are substitutes and strategic complements
- Bertrand-type equilibrium leads to $p_i = e$, where users can be assumed to buy both patents

Best responses and Equilibrium

- Complete BR: if $p_2 \leq e$, then $p_1 = min\{e, r(p_2)\}$
- Symmetric Nash equilibrium: $p^N = min\{\hat{p}, e\}$.

Welfare analysis of the pool leading to P^m

- When demand margin binds, $\hat{P} > P^m$ so that the pool is welfare-increasing
- When competition margin binds, the pool is welfare-increasing if and only if $2e > P^m$
- Welfare-decreasing pool with low essentiality, welfare-increasing with high enough essentiality

Pools with independent licensing

Independent licensing

- In most proposed pools, provision: individual patents may still be licensed
- Idea: with strong substitutability, it enables a patent holder to undercut the pool profitably, while with complementarity, no firm benefits from reintroducing double marginalization
- Game with IL:
  - Pool price chosen P
  - All patent holders fix IL prices p_i
  - Users choose: not buying at all, buying the pool package, buying some or all licenses as IL

Pools with independent licensing

Definition of stability

- A pool is (strongly) stable to IL if (in all symmetric pure-strategy) equilibrium in the continuation game after P^m, users purchase the pool package
- A pool is (strongly) unstable to IL if (in all symmetric pure-strategy) equilibrium in the continuation game after any $P > P^N$, users purchase IL

Screening pools with IL – 2 patents

- A welfare-increasing pool is strongly stable to IL
- A welfare-decreasing pool is strongly unstable to IL

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