Context

• Increasing importance of **intangible assets** (i.e., human knowledge or ideas to which a legal entitlement, called **Intellectual Property (IP)**, is usually attached)
  • Firms transform their business models around IP.
    • Firms increasingly seek patents, grant licenses, litigate...
  • Knowledge may also be created collectively.
    • Open source software

• **IP stands at the heart of economic policy.**
  • Innovation = source of economic growth

• Need for careful analyses of the mechanisms and institutions governing the production, use and diffusion of **IP**
Organization of Part VII

- **Chapter 18** → more positive analysis
  - Two-way relationship between market structure and incentives for R&D
  - Pros and cons of various forms of cooperative R&D relative to noncooperative R&D for firms competing in a product market.

- **Chapter 19** → more normative analysis
  - Economic rationale of IP (patents & copyright)
  - Patent length and breadth
  - Perverse effects of the patent system
  - Protecting sequential and cumulative innovations?
  - Effects of digital technologies and the Internet on the protection of IP?
Chapter 18. Learning objectives

• Examine the interplay between market structure and innovation.
  • Understand that firms’ incentives to invest in R&D depend on the structure of the product market they are acting in.
  • Understand how firms may use R&D to shape the structure of their market.

• Analyse the pros and cons of ‘patent races’.

• Understand how R&D investment decisions change when firms recognize the strategic nature of these decisions, and when they are allowed to coordinate them.
Innovation and market structure

- Complex issue → simplifying assumption
  - Firms can somehow appropriate the return from R&D.

- Analysis broken down in 3 separate issues
  - How does market structure affect incentives for R&D?
    - Measured by the profit increase gained from the innovation.
    - *Nature of technical progress*: R&D investment determines (instantaneously and for sure) the size of the innovation; only a single firm ends up using the innovation.
  - How can innovation influence market structure?
    - Monopoly using innovation to prevail over time.
    - Races to be the first to innovate
    - *Nature of technical progress*: ‘tournament technical progress’; timing of innovation is uncertain and depends on the R&D investments of all firms; size of the innovation is fixed.
Innovation and market structure (cont’d)

• Analysis broken down in 3 separate issues (cont’d)
  • How do firms use R&D strategically?
    • Do firms invest more or less when they recognize the strategic nature of their R&D decisions?
    • Should firms be allowed to coordinate decisions at R&D stage?
    • *Nature of technical progress*: like 1st issue + size of innovation depends on the intensity of the firm’s R&D investment (and potentially on the other firms’ investments as well); firms have simultaneous opportunities to achieve competing innovations.

• 2 types of innovative environments
  • Issue (1) → Ideas are scarce
    • No substitute idea addresses the same economic need.
  • Issues (2) and (3) → Ideas are common knowledge
    • Any good idea is likely to be had and implemented by someone else.
Preliminary definitions

• Process vs. product innovation
  • **Process innovation**: generation, introduction and diffusion of a new production process (with the products remaining unchanged).
  • **Product innovation**: generation, introduction and diffusion of a new product (with the production process being unchanged).

• Drastic vs. nondrastic process innovation
  • **Drastic (or major) innovation**: allows the innovator to behave as a monopolist without being constrained by price competition in the industry.
  • **Nondrastic (or minor) innovation**: innovator may gain some cost advantage over its rivals but competition constrains the innovator.

• Graphical illustration on next slide
Preliminary definitions (cont’d)

- Homogeneous product market
- Firms produce at $c_0$ and compete in prices.
- Innovation $\downarrow$ cost below $c_0$

Drastic innovation if the monopoly price corresponding to the new cost falls below the cost of the non-innovating firms.
Market structure and incentives to innovate

• **Schumpeter** (*Capitalism, Socialism, and Democracy*, 1943)
  • Stresses link between market structure and R&D
  • Necessity of tolerating the creation of monopolies as a way to encourage the innovation process.
    • Economic rationale behind protection of IP (see Chapter 19)
  • R&D efforts are more likely to be undertaken by large firms than by small ones.
    • Large firms have a larger capacity to undertake R&D → deal better with 3 market failures (see Chapter 19)

• Do large firms have larger incentives to R&D?
  • **Profit incentive** to innovate: which market structure, monopoly, oligopoly or perfect competition, provides firms with the highest incentives to undertake R&D?
  • What about **strategic incentives**?
Monopoly/perfect competition: replacement effect

• How much is a firm willing to pay for an innovation that it would be the only one to use?

• Model
  • Homogeneous product, constant marginal cost of production
  • Minor innovation ↓ cost from $c_0$ to $c_1 < c_0$
  • Profit incentive: willingness to pay for the innovation measured by the increase in profit that the innovation generates

• Comparison between
  • Competitive situation (n firms competing à la Bertrand)
  • Monopoly situation
  • Social planner (benchmark)

• Lesson: A competitive firm places a larger value on a minor process innovation than a monopoly does.
Replacement effect (cont’d)

- Graphical analysis

Per-period value of the innovation
- for competitive firm: sum of areas 1 and 2
- for monopolist: area 1
- for social planner: sum of areas 1, 2 and 3

Competitive firm willing to pay more than monopolist. Why? Replacement effect
→ prior to the innovation, the monopolist already earns a positive profit, whereas the competitive firm just recoups its costs.

Value for competitive firm < social value
Why? Competitive firm fails to appropriate the increase in consumer surplus (area 3).
Case. Microsoft’s incentives to innovate

• The argument about the replacement effect can be extended to a multiproduct firm.
  • Prediction: higher incentives to innovate on market segments where firm faces competition than on those segments where it enjoys significant market power.

• Microsoft’s launch of the Xbox in 2005
  • "It is surely no coincidence that Microsoft's hidden ability to innovate has become apparent only in a market in which it is the underdog and faces fierce competition. Microsoft is far less innovative in its core businesses, in which it has a monopoly (in Windows) and a near monopoly (in Office). But in the new markets of gaming, mobile devices and television set-top boxes, Microsoft has been unable to exploit its Windows monopoly other than indirectly -- it has financed the company's expensive forays into pasture new."
    ("The meaning of XBox," *The Economist*, November 24, 2005)
Incentives to innovate in oligopolies

• Conjecture
  • Oligopolies = intermediate market structure between monopoly and perfect competition \( \Rightarrow \) incentives to innovate in oligopolies are between the low incentives in monopoly and the high incentives in perfect competition.

• This conjecture is wrong!

• Intensity of competition depends on
  • Number of firms
  • Degree of product differentiation
  • Type of competition (price or quantity).

• In general: these 3 variables affects incentives to innovate in non-monotonic, different, and potentially opposite ways.
Incentives to innovate in oligopolies (cont’d)

• Impact of the number of firms
  • Simple linear Cournot model with $n$ firms
  • Profit incentive may follow an inverse U-shape as $n \uparrow$.
  • See analysis in book

• **Lesson**: In a Cournot industry with a homogeneous product, the market structure that gives the largest profit incentive to innovate is monopoly when the innovation size is not too large; it is oligopoly otherwise (and the ‘ideal’ number of firms in the industry increases with the innovation size).

• **Intuition**: 2 opposite effects when $n \uparrow$
  • **Competition effect**: profits for all firms $\downarrow$
  • **Competitive advantage**: cost advantage of innovator $\uparrow$ with $n$
When innovation affects market structure

• What if ideas are common knowledge?
  • Several firms have the simultaneous opportunity to achieve competing innovations.
  • Innovation becomes a competitive tool in itself.
  • How does it affect market structure?

• 3 settings
  • Incentive to innovate for monopoly threatened by entry → does monopoly persist because of innovation?
    • Static setting with certain innovation
    • Dynamic setting with uncertain innovation
  • Dynamic R&D competition between symmetric firms
    • Comparison of private and social incentives to innovate
Monopoly threatened by entry: efficiency effect

- **Model**
  - Incumbent and entrant can both acquire innovation (which ↓ marginal cost from $c_0$ to $c_1 < c_0$).
  - Entrant can enter profitably only with innovation.
  - Who will place the highest bid for the innovation?

- **Payoffs**
  - If **incumbent** gets the innovation, then entrant stays out:
    - Incumbent’s profit: $\pi^m(c_1)$
    - Entrant’s profit: 0
  - If **entrant** gets the innovation, then entrant enters:
    - Incumbent’s profit: $\pi^d(c_0, c_1)$
    - Entrant’s profit: $\pi^d(c_1, c_0)$
Efficiency effect (cont’d)

• Incentives to innovate
  • \( V_I = \pi^m(c_1) - \pi^d(c_0,c_1) \) and \( V_E = \pi^d(c_1,c_0) - 0 \)
  • Higher incentives for the incumbent if \( V_I > V_E \iff \pi^m(c_1) > \pi^d(c_1,c_0) + \pi^d(c_0,c_1) \)
    → satisfied when firms’ products are close substitutes

• **Lesson**: A monopoly threatened by entry is willing to pay more for a minor innovation than a potential entrant who can produce a close substitute to the monopolist’s product.

• **Efficiency effect**: fear of losing its monopoly position provides the incumbent with a stronger incentive
  → monopoly position is prolonged through innovation
Asymmetric patent races

• Differences with previous model
  • Addition of time and uncertainty
  • Objective of R&D: be the 1st to come up with an innovation → patent race

• Firms decide about
  • Intensity of R&D investments
  • Timing of R&D investments

• Combined influence of
  • Replacement effect: monopoly power = disincentive to R&D for incumbent
  • Efficiency effect: threat of entry = incentive to R&D for incumbent
Asymmetric patent races (cont’d)

• **Lesson**: In a patent race, it is in general ambiguous whether the incumbent or the entrant has a stronger incentive to invest.

• **Intuition**: outcome depends on balance between
  
  • **Efficiency effect** → higher incentives for incumbent
    • Net flow profit incumbent receives by preempting the entrant is larger than what the entrant gains by being first.

  • **Replacement effect** → lower incentives for incumbent
    • Marginal productivity of R&D expenditure for the incumbent ↓ with its initial profits (by investing more, incumbent moves discovery date forward and hastens its own replacement).

• **See details in math slides.**
Case. The race for cleaner cars

• Who, in the near future, is going to come up with an affordable car with much lower emissions of green-house gas?

• A traditional player (incumbent)?
  • Toyota seems to have taken the lead with its gasoline-electric hybrid, the Prius.
  • Other carmakers are developing cars powered by hydrogen fuel cells.

• An outsider (entrant)?
  • Tesla Motors, a Silicon Valley upstart, has come up with an all-electric sports car, largely made of lightweight composites (“greener than a Prius and faster than a Ferrari”).
Socially excessive R&D in a patent race

• ‘Winner-takes-all’ nature of patent races
  • $\rightarrow$ potential for socially wasteful duplication of efforts

• Model
  • 2 symmetric firms
  • $f$: cost of establishing a research division
  • $\rho$: probability of success
  • $\pi^m$: monopoly profit earned if sole innovator
  • $\pi^d$: duopoly profit earned if both firms find new product

• We compare the conditions for...
  • Nash equilibrium with both firms investing
  • Social optimum with both firms investing
    • Measure of social surplus $= \text{aggregate profits}$
Socially excessive R&D in a patent race (cont’d)

- Normal form game

<table>
<thead>
<tr>
<th>Investment (I)</th>
<th>No investment (I)</th>
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<tbody>
<tr>
<td>I  ( \rho(1 - \rho)\pi^m + \rho^2\pi^d - f ), ( \rho(1 - \rho)\pi^m + \rho^2\pi^d - f )</td>
<td>( \rho\pi^m - f, 0 )</td>
</tr>
<tr>
<td>NI</td>
<td>( 0, \rho\pi^m - f )</td>
</tr>
</tbody>
</table>

- Nash equilibrium with both firms investing if

\[ \rho(1 - \rho)\pi^m + \rho^2\pi^d - f \geq 0 \iff f \leq \rho(1 - \rho)\pi^m + \rho^2\pi^d \equiv f_{\text{priv}}^2 \]

- Aggregate profits are higher with two rather than one firm investing if

\[ 2(\rho(1 - \rho)\pi^m + \rho^2\pi^d - f) \geq \rho\pi^m - f \]

\[ \iff f \leq \rho(1 - \rho)\pi^m + \rho^2\pi^d - \rho^2(\pi^m - \pi^d) \equiv f_{\text{publ}}^2 < f_{\text{priv}}^2 \]
Socially excessive R&D in a patent race (cont’d)

• Comparison

  • Socially excessive R&D if \( f \) is between the 2 thresholds.

    • Both firms invest but it would be preferable if only one did so.
    • Firms don’t take into account the negative effect their R&D effort has on the rival firm’s profits.
    • Yet, from the industry point of view, the cost of R&D duplication is larger than the expected benefits stemming from the increase in the probability of finding the new product.

• Lesson: Since a firm ignores the effect of its R&D efforts on the rival’s profits, imperfectly competitive firms tend to overinvest.
R&D cooperation and spillovers

• **Innovative environment**
  • Ideas are common knowledge (e.g., automobile industry).
  • R&D investments result immediately and for sure into an innovation (no tournament, no uncertainty).
  • R&D investments are a form of strategic commitment.
  • R&D leads to spillovers which benefit other firms.
  • Firms may cooperate on R&D decisions to internalize spillovers.

• **Issues**
  • Do firms invest more or less when they recognize the strategic nature of their R&D decisions?
  • Should firms be allowed to coordinate their decisions at the R&D stage?
R&D cooperation and spillovers (cont’d)

• **Setting**

  • 2 symmetric firms compete in a 2-stage game
  • (1) R&D stage
    • Firms choose R&D expenditures $r(x_i)$ to reduce their marginal costs by $x_1$ and $x_2$, respectively:
      \[ c_i(x_i, x_j) = c - x_i - \beta x_j \]
      with $\beta \in [0, 1]$ is the spillover coefficient
    • Decreasing returns in R&D: $r' > 0$ and $r'' > 0$
  • (2) Market competition stage (substitutable products)
    • Firms choose $\sigma_i$
    • Either quantity ($\sigma_i = q_i$) or price competition ($\sigma_i = p_i$)
    • Suppose a unique Nash equilibrium exists:
      \[ \{\sigma^*_1(x_1, x_2), \sigma^*_2(x_1, x_2)\} \]
Effects of strategic behaviour

- **Methodology**

  - 2-stage game → firms can’t commit to product market decisions when they choose R&D → strategic R&D investments (as they are chosen with a view to affecting product market competition)

  - To isolate this effect, comparison with a 1-stage game in which all decisions are taken at the same time.

- 1\(^{st}\) stage

  - Firm \(i\) chooses \(x_i\) to maximize

  \[
  \tilde{\pi}_i(x_i, x_j) = \pi_i \left[ c_i(x_i, x_j), \sigma_i^*(x_i, x_j), \sigma_j^*(x_i, x_j) \right] - r(x_i)
  \]
Effects of strategic behaviour (cont’d)

**1st stage** (cont’d)

- **First-order condition**

\[
\frac{d\tilde{\pi}_i}{dx_i} = 0 \iff \frac{\partial \pi_i}{\partial c_i} \frac{\partial c_i}{\partial x_i} + \frac{\partial \pi_i}{\partial \sigma_i} \frac{\partial \sigma_i^*}{\partial x_i} + \frac{\partial \pi_i}{\partial \sigma_j} \frac{\partial \sigma_j^*}{\partial x_i} = r'(x_i)
\]

**Direct effect** (cost-minimizing)

Only effect at work if firms are non-strategic

In the absence of strategic behaviour and of R&D cooperation, the marginal private return to R&D per unit of output is simply the reduction in the firm’s own unit costs

**Strategic effect**

*i*’s investment changes *j*’s 2nd-stage action, and this changes *i*’s profit

SIGN?
Effects of strategic behaviour (cont'd)

- Sign of strategic effect

\[ \frac{\partial \pi_i}{\partial \sigma_j} < 0 \text{ if } \sigma_j = q_j \]
\[ \frac{\partial \pi_i}{\partial \sigma_j} > 0 \text{ if } \sigma_j = p_j \]

\[ \frac{\partial \sigma_j}{\partial x_i} \]

\[ x_i \uparrow \rightarrow c_i \downarrow \text{ and } c_j \downarrow \] (unless \( \beta = 0 \))
\[ \rightarrow i \text{ and } j \text{ become stronger competitors} \]
\[ \rightarrow \text{net effect depends on} \]
\[ * \text{ nature of strategic variables} \]
\[ * \text{ degree of spillovers} \]

Quantity competition
\[ \frac{\partial q_j^*}{\partial x_i} < 0 \text{ for } \beta < \bar{\beta} \]
\[ \frac{\partial q_j^*}{\partial x_i} > 0 \text{ for } \beta > \bar{\beta} \]

Price competition
\[ \frac{\partial p_j^*}{\partial x_i} < 0 \text{ for all } \beta \]
Effects of strategic behaviour (cont’d)

• **Lesson**: The strategic effect of an increase in the R&D of one firm on its own profit is
  • positive for small spillovers and negative for large spillovers under quantity competition,
  • always negative under price competition.

• **Intuition**
  • R&D expenditure ↑ → firm is tougher competitor
  • → worth investing more only if tough behaviour is met by a soft response of the rival firm
    • OK under quantity competition provided that spillovers are small enough (because otherwise, the other firm also becomes a tougher competitor)
    • Never OK under price competition.
Effects of R&D cooperation

- **Methodology**
  - Firms coordinate R&D decisions (not 2\textsuperscript{nd}-stage decisions)
  - Cooperation leaves $\beta$ unchanged (to be relaxed later)

- **1\textsuperscript{st} stage**
  - F.O.C. for joint profit maximization

\[
\frac{d(\tilde{\pi}_i + \tilde{\pi}_j)}{dx_i} = 0 \iff \left\{ \begin{array}{l}
\frac{\partial \pi_i}{\partial c_i} \frac{\partial c_i}{\partial x_i} + \frac{\partial \pi_i}{\partial \sigma_i} \frac{\partial \sigma_i}{\partial x_i} + \frac{\partial \pi_i}{\partial \sigma_j} \frac{\partial \sigma_j}{\partial x_i} \\
\text{Direct effect} \quad \quad = 0 \\
\frac{\partial \pi_j}{\partial c_j} \frac{\partial c_j}{\partial x_i} + \frac{\partial \pi_j}{\partial \sigma_i} \frac{\partial \sigma_i}{\partial x_i} + \frac{\partial \pi_j}{\partial \sigma_j} \frac{\partial \sigma_j}{\partial x_i} \\
\text{Spillover effect} \quad \quad \text{Strategic effect 1} \\
\text{Strategic effect 2} \quad \quad = 0 \\
\end{array} \right.
\]

Only 2 effects at work if firms are non-strategic

Negative whatever the nature of competition. Weakens when spillovers get stronger.
Effects of R&D cooperation (cont’d)

**Summary**

- R&D activities with spillovers create 2 externalities
  - **R&D affects overall industry profits.**
    - This externality ↑ with the level of spillovers.
    - Ignored when firms choose R&D separately
    - Internalized when firms choose R&D cooperatively
  - **R&D affects a firm’s competitive advantage w.r.t. its rival.**
    - This externality ↓ with the level of spillovers
    - Present when firms choose R&D separately
    - Internalized when firms choose R&D cooperatively

**Lesson**: When firms behave strategically, R&D cooperation leads to more (less) R&D when spillovers are large (small).
Effects of R&D cooperation (cont’d)

- **R&D cooperation and information sharing**
  - Previous mode of R&D cooperation: “R&D cartel”
  - If also complete sharing of information: “Cartelized Research Joint Venture”
    - $\rightarrow \beta$ internally set to unity
    - $\rightarrow$ cooperation even more attractive from a welfare viewpoint

- **Antitrust implication**
  - Public authorities should permit simultaneous R&D sharing and coordination of R&D decisions among firms that compete in a product market.
  - Corresponds to what is currently done in the US, in the EU and in Japan.
Effects of R&D cooperation (cont’d)

• Further analysis

• Nature of R&D spillovers
  • Previous model: spillovers = “manna from heaven”
  • But R&D is also needed to ↑ firm's ability to identify, exploit and assimilate existing information from the environment.
    ✓ R&D contributes to develop a stock of prior knowledge
    ✓ so-called ‘absorptive capacity’
  • 2 opposite effects in strategic R&D games
    ✓ firm ↑ R&D to learn more from the rival
    ✓ This ↑ rival's incentive to free-ride → less to learn from
  • The presence of absorptive capacities may induce larger R&D investments for a similar (ex post) spillover rate.
  • Intuition: a positive learning effect mitigates the negative free-riding effect of spillovers on R&D investments.
Effects of R&D cooperation (cont’d)

• Further analysis (cont’d)
  • Design of R&D cooperation
    • What if more than 2 firms?
    • Previous analysis still holds when comparing complete no-cooperation in R&D with industrywide R&D cooperation.
    • But intermediate form of cooperation exist in many industries:
      ✓ several RJV compete with each other
      ✓ firms' R&D cooperation is bilateral and nonexclusive in nature (i cooperate with j, j with k, but not k with i)
  • Modelization
    ✓ Formation of RJVs → partition of the set of firms (each firm belonging to one RJV only) → coalition structure
    ✓ Formation of RJVs → collection of 2-player relationships → network structure
Effects of R&D cooperation (cont’d)

• Further analysis (cont’d)

• R&D cooperation and product market collusion
  • What if firms extend cooperation to the product market?
  • If so, R&D cooperation and information sharing should not necessarily be permitted (even less encouraged)...
    ✓ Public policy trade-off between market power (because of collusion) and efficiency (thanks to R&D cooperation)
    ✓ Not clear how this trade-off balances out
  • ⇒ Antitrust authorities must make sure that cooperation is limited to R&D activities.
Case. Research joint ventures (RJV) and collusion

• May collusive behaviour be facilitated by RJVs?
  • Empirical answer is difficult → need to isolate impact of returns to collusion on decision to join an RJV.
  • Strategy of Goeree and Holland (2008)
    • If product market collusion is not a motivation to form an RJV then, after controlling for firm, RJV and industry characteristics, the propensity to enter into an RJV should not be impacted by changes in the antitrust policy aimed at deterring collusion in the final goods market.

• Experiment
  • US telecom industry → 38% of firms involved in RJVs
  • Antitrust policy became tougher in 1993 and 1995.
  • Probability telecom firms join a given RJV ↓ by 25%.
Review questions

• Why does a monopolist have less incentives to innovate than a perfectly competitive firm? Explain the meaning of the ‘replacement effect’.

• Why does a monopolist threatened by entry have more incentives to innovate than a potential entrant? Explain the meaning of the ‘efficiency effect’.

• Explain why firms might invest too much in R&D (from a social point of view) when they are racing to obtain a patent on an innovation.

• Discuss the effects of strategic behaviour on firms’ investments in R&D.

• Is it a sensible policy to allow firms to coordinate their R&D decisions? Discuss.
Part VII. R&D and intellectual property

Chapter 19. Intellectual property
Chapter 19. Learning objectives

• Understand the appropriability problem of innovation, and the rationale behind public and private solutions to this problem.

• Analyze how intellectual property (IP) protection should optimally be organized.
  • What length and breadth should patents have?
  • How do the market for licenses and the possibility of pooling patents affect the optimal design of the IP system?

• Be able to apply the general analyses to the specificities of the digital economy.
Information and appropriability

• Activities generating information suffer from the 3 generic sources of market failure.
  
  **Indivisibilities**
  
  • R&D programmes involve high fixed set up costs, display economies of scale (from extensive division of highly specialized labour)
  
  • Knowledge is inherently discrete.
  
  **Uncertainty**: 2 sources of uncertainty for R&D
  
  • Technological uncertainty → how to make a new product and how to make it work?
  
  • Market uncertainty → how to sell the new product and make it a commercial success?
  
  • + moral hazard problems (why does it fail? inherent scientific difficulty or lack of effort?)
Information and appropriability (cont’d)

• 3 generic sources of market failure (cont’d)
  • **Externalities** → information is a public good
    • Information is nonrival
      ✓ Its consumption by one person doesn’t prevent (rival) its consumption by another person.
      ✓ At any level of production of information, the marginal cost of delivering it to an extra consumer is zero.
    • Information is nonexcludable
      ✓ One person cannot exclude another person from consuming information.
      ✓ Excludability depends on the available technology for exclusion and on the institutional (legal) framework.

• 3 market failures ⇒ problem of appropriability
  • General presumption: markets provide too little incentive to introduce new innovations.
Intellectual property protection

• **Intellectual property (IP)**
  • Legal rights resulting from intellectual activity in the industrial, scientific, literary and artistic fields.
  - **Industrial property branch** → inventions, business methods, industrial processes, chemical formulae, unique names
  - **Copyright branch** → all information products that derive their intrinsic value from creative expression, literary creation, ideas, or presentations

• **Main objective** of IP law
  • To promote innovation and aesthetic creativity.
  • How? By granting exclusive use of the protected knowledge or creative work to the creator.
Intellectual property protection (cont’d)

• **Incentives** versus **use**
  - Nonexcludability $\rightarrow$ hard to appropriate the returns from intellectual activities $\rightarrow$ **underproduction problem**
  - But exclusivity allows creators to set prices above (zero) marginal costs $\rightarrow$ **underutilization problem**

• **IP law solves the 2 problems sequentially**
  - Legal protection makes the good excludable
    - $\Rightarrow$ Creators have incentives to produce new information.
  - Once protection is over, the good falls in public domain.
    - All users may access the good for free (i.e., at marginal cost).

• **IP law strikes a balance between**
  - **Incentives** to create and innovate
  - **Use** of the results of creation and innovation
**Lesson**: IP law attempts to find the best possible compromise between dynamic efficiency considerations (how to provide the right incentives to create and innovate), and **static efficiency considerations** (how to promote the diffusion and use of the results of creation and innovation).

<table>
<thead>
<tr>
<th>INCENTIVES &amp; USE</th>
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<tbody>
<tr>
<td><strong>Dynamic efficiency</strong></td>
</tr>
<tr>
<td>Improvement of technological progress</td>
</tr>
<tr>
<td>infinite and very broad protection</td>
</tr>
</tbody>
</table>

*Balance is necessarily imperfect*
Intellectual property protection (cont’d)

• **Incentives versus use**

• Graphical analysis

Diffusion makes the deadweight loss disappear (consumer surplus now equals $1 + 2 + 3$).

Temporary deadweight loss for society. Price to pay for the innovation to take place.

A temporary reduction in static efficiency enhances dynamic efficiency.
### Main IP regimes

<table>
<thead>
<tr>
<th>Patent</th>
<th>Copyright</th>
</tr>
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</table>
| Requirements for protection | (EU) Novelty, inventive step, industrial use  
(US) Novelty, non-obviousness, utility | Originality, authorship, form of expression |
| Ownership | (EU) First to file  
(US) First to invent | Author/creator |
| Rights | *Bundle of rights extending to the idea: exclusive rights against all commercial uses (make, use, sell the innovation)* | *Economic and moral rights on the form of expression: exclusive rights against copying (rights of performance, display, reproduction, derivative works)* |
| Scope of protection | Wide | Narrow |
| Duration | 20 years from filing | Life of author + 70 years |
| Costs of protection | Filing, issue, and maintenance fees; litigation costs | No filing necessary; suit requires registration; litigation costs |
Case. Software protection: copyright or patent?

• 2 types of protection required
  • Against consumers’ copying → copyright
  • Against competitors’ imitation → patent?

• Is patent protection too strong for software?
  • Yes, given low costs of software innovation.
  • No, given that software innovation is cumulative.
    • See below
  • Yes, given that software generate network effects.
    • See Chapter 20
  • No, given that software are durable products.
    • See Chapter 10
  • Net effect???
Intellectual property protection (cont’d)

• Gradual reinforcement of IP protection
  • Strengthening
    • US, early 1980s: legal and procedural reforms provided stronger protection to holders of existing patents.
    • EU: move towards a European patent
  • Broadening
    • New categories of inventions have been protected, either through an extension of patent protection (software, business methods, genetic inventions) or through the creation of ‘sui generis’ rights (semiconductors, databases).

• International harmonization
  • TRIPS Agreement, 1994: includes a general definition of patents, which adopts US criteria and, thereby, broadens the scope of patentable inventions internationally.
Subsidization and secrecy

- **Subsidies and prizes**
  - Government finances technical and artistic creation.
  - Static efficiency: free access → no deadweight loss, but taxation → distorsions (for patents, product users pay)
  - Dynamic efficiency: uncertainty about costs/benefits of research → subsidy might give too little (too much) incentive (no need for such information to implement patents)

- **Secrecy**
  - No need for public intervention
  - Information is still non-rival but the absence of diffusion creates a cost for society.
  - Offers no protection against independent innovations
Protection of IP in practice

• Survey of innovators

• Managers claim that “lead time, learning curves, and sales or service efforts are substantially more effective in protecting IP than patents are”. (Anand and Galetovic, 2004)

• Patents are seen as a secondary or complementary instrument for protecting IP.

• Why? Firms often consider that a patent …
  • can easily be 'invented around' by imitators,
  • is costly to obtain and to enforce,
  • is detrimental because of the disclosure requirement.

• Exceptions: chemical and pharmaceutical sectors
  • R&D processes are long, very costly and highly uncertain.
  • Knowledge is more codified → lower imitation costs
Protection of IP in practice (cont’d)

- **Patent explosion**
  - US, 1980-2001: # of patent grants more than tripled
  - Europe: comparable trend
  - Private value of these patents? (Scotchmer, 2004)
    - The values of patent rights are very dispersed.
    - The distribution of values is very skewed, with most of the value provided by a few high-earning patents.
    - The average value of patent rights is much lower than the average R&D cost of innovation.

- **Patent paradox?**
  - Huge ↑ in patents >< patents seen as weak protection
  - Potential explanation: patents = ‘trading device’
    → **Patent portfolio theory**: patents are more valuable when aggregated than when taken individually.
Case. Patent indicators

• Few available indicators of technology output.
• Patent indicators are the most frequently used.

• **Advantages**
  • Patents have a close link to invention.
  • Patents cover a broad range of technologies on which there are sometimes few other sources of data.
  • The contents of patent documents are a rich source of information (on applicant, inventor, technology category, claims, ...).
  • Patent data are readily available from patent offices.

• **Disadvantages**
  • Many inventions are simply not patented.
  • Differences in the interpretation of patent counts
    • Costs & benefits of patents differ across countries.
    • Technologies differ in importance of patents as protection.
    • Firms differ in propensity to patent.
    • Patent law differ over the years.
Optimal patent length

**Objective**
- Determine the right balance between
  - incentives (= private return on R&D investments accruing to the innovator during the duration of the patent)
  - and use (= social benefits accruing to consumers and other firms once the patent expires and competition emerges).

**Model**
- Innovator with strictly convex cost function

\[ C(x) = \frac{1}{2} \phi x^2 \]

- \( \phi \): exogenous efficiency of innovation technology
- Assume \( \phi \) large enough \( \rightarrow x \) always \( < 1 \) \( \rightarrow x \) can be seen as success probability of innovation.
Optimal patent length (cont’d)

- **Innovator’s problem**
  - With prob. $x$, innovation successful $\rightarrow$ innovator obtains
    - During patent life (patent length = $T$): monopoly profit $\pi^m$
    - After patent expiration: competitive profit $\pi$, with $0 \leq \pi < \pi^m$
  - PDV of innovator’s return in case of success
  
  $$
P(T) = \int_0^T e^{-rt} \pi^m dt + \int_T^\infty e^{-rt} \pi dt
  $$

  - Innovator choose $x$ to maximize $xP - (1/2)\phi x^2$
    
  $$
x^*(T) = \frac{P(T)}{\phi}
  $$

  - $P(T) \uparrow$ with $T \rightarrow x^*(T) \uparrow$ with $T \rightarrow$ the longer the patent protection, the higher the innovator’s return and, hence, his incentive to invest in R&D.
Optimal patent length (cont’d)

• **Policymaker’s problem**
  - Social return on innovative effort
  
  \[
  S(T) = \int_0^T e^{-rt} W^m dt + \int_T^\infty e^{-rt} \overline{W} dt, \text{ with } \overline{W} > W^m
  \]
  
  • Task: choose \( T \) to maximize \( S(T) \) given \( x^*(T) \)
  
  \[
  \max_T x^*(T)S(T) - \frac{1}{2} \phi\left(x^*(T)\right)^2
  \]

• **F.O.C.**

  \[
  \frac{\partial x^*(T)}{\partial T} S(T) = x^*(T) \left( \phi \frac{\partial x^*(T)}{\partial T} - \frac{\partial S(T)}{\partial T} \right)
  \]

  Marginal dynamic gain  \hspace{1cm} Marginal static loss

  Trade-off between static and dynamic efficiency
Optimal patent length (cont’d)

• Conclusion

• Optimal length balances 2 effects of longer patent
  • Marginal dynamic gain: innovation ↑
  • Marginal static loss: R&D cost ↑ and consumer surplus ↓

• Optimal patent duration is finite. Why?
  • Diminishing returns to R&D: it will take progressively greater increases in $T$ to achieve a given probability of success
  • Discounting: consumer benefits from innovation won’t be realized until after the patent expires → the larger $T$, the smaller the present value of those benefits.

• Lesson: A patent that is unlimited in duration cannot be welfare maximizing.
Case. Extension of the copyright term in the US

- 1998: Copyright Term Extension Act (CTEA)
  - extends duration of existing US copyrights by 20 years.
- 1999: constitutionality of CTEA is challenged
  - By a group of commercial and non-commercial interests relying on the public domain for their work.
- 2002: 17 economists support the petitioners
  - “It is highly unlikely that the economic benefits from copyright extension under the CTEA outweigh the costs.”
  - Arguments drawn from previous framework:
    - The revenues earned during the additional 20 years of protection are so heavily discounted that they lose almost all value, while the extended protection of existing works generates immediate deadweight losses (which are even larger when taking the increased cost of creating new derivative work into account).
Optimal patent breadth

- Extent of monopoly power can also be curbed by limiting patent breadth.
- **Breadth?** Measures **degree of patent protection**
  - Not directly defined in IP law; matter of interpretation
    - **Patent office**: is innovation novel, inventive (non-obvious)? How legitimate are the claims put forward by the applicant?
    - **Courts**: is there infringement?
- **Economists study breadth in 2 ways**
  - Innovation is threatened by **horizontal** competition
    - **Product space**: broader patents excludes more substitutes
    - **Technology space**: cost of inventing around the patent?
  - Innovation might be supplanted by **improved** innovation
    - See **cumulative innovations** below
Optimal patent breadth (cont’d)

- **Horizontal competition**
  - Extension of previous model
  - \( b \in [0,1] \) measures breadth

\[
\begin{align*}
\pi(b) & \text{ with } \pi(1) = \pi^m \text{ and } \pi(0) = \bar{\pi} \\
W(b) & \text{ with } W(1) = \pi^m \text{ and } W(0) = \bar{\pi}
\end{align*}
\]

\( \pi'(b) > 0 \) and \( W'(b) < 0 \) → breadth exerts, like length, opposite effects on innovator’s profit and social welfare

- Private and social returns on innovation

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

\[
S(T,b) = \int_0^T e^{-rt} W(b) \, dt + \int_T^\infty e^{-rt} \bar{W} \, dt
\]
Optimal patent breadth (cont’d)

**Horizontal competition** (cont’d)
- Innovator’s solution
  \[ x^*(T,b) = \frac{P(T,b)}{\phi} \]
- Totally differentiating
  \[ \frac{dT}{db} = - \frac{\partial P / \partial b}{\partial P / \partial T} < 0 \]

**Length and breadth are substitutable policy tools.**

- Policymaker’s task: find optimal patent breadth–length mix, anticipating innovator’s optimal conduct.
  - Max \( S \) w.r.t. \( T \) and \( b \), fixing innovation activity \( x \) at some required level
  - Define \( T(b) \) by solving above equation
  - Express \( S(T(b),b) \)
Optimal patent breadth (cont’d)

- **Horizontal competition** (cont’d)
  - Differentiate $S(T(b), b)$

  \[
  \frac{dS}{db} = \frac{\partial S}{\partial T} \frac{dT}{db} + \frac{\partial S}{\partial b} = -\frac{\partial S}{\partial T} \frac{\partial P / \partial b}{\partial T} + \frac{\partial S}{\partial b}
  \]

  So, $\frac{dS}{db} > 0 \iff \frac{\partial P / \partial b}{\partial P / \partial T} > \frac{\partial S / \partial b}{\partial S / \partial T}$

  - An increase in patent breadth stimulates investment in innovation relatively more than patent length while reducing the post-innovation welfare relatively less.
  - \(\rightarrow\) Increasing breadth is welfare-enhancing
    \(\rightarrow\) optimal patent is broad and short.

  - Otherwise, if $dS/db < 0$
    - \(\rightarrow\) Increasing breadth is welfare-detrimental
      \(\rightarrow\) optimal patent is narrow and long.
Optimal patent breadth (cont’d)

• **Lesson**: If the marginal rate of substitution of patent length for breadth is larger on the incentive to innovate than on social welfare, the optimal patent is broad and short; otherwise, it is narrow and long.

• **Sleeping patents**
  • Observed fact: same firm patents a large number of related processes or products, using only one of them and leaving the other ones ‘sleeping’.
  • Why?
    • Duplication of efforts, lack of complementary assets to market innovation, poor fit between innovation and firm’s objectives.
    • **Strategic motive**: block entry → **efficiency effect**: incumbent might want to patent products or processes that could threaten its monopoly position if they were owned by rival firms.
Optimal patent breadth (cont’d)

- **Cumulative innovations**
  - Competition from improved innovations
    - Different forms of cumulativeness: improved quality of an existing product, reduced cost of an existing production process, or discovery of new applications of an invention
    - Widespread in information technology, biotechnology
  - Recall: double purpose of patents
    - Protect R&D investments and ease diffusion of knowledge
    - Latter purpose is more important for cumulative innovations.
  - Optimal patent length-breadth mix?
    - Q1: Should the initial innovator have a right on subsequent innovations?
    - Q2: Insofar as subsequent innovations are not necessarily substitute to the initial innovation, should they be considered as infringements?
Cumulative innovations (cont’d)

• To provide each innovator with proper incentives
  • YES to Q1: earlier innovators should be compensated for their contributions by being granted some right on subsequent innovations
  • NO to Q2: if all subsequent innovations were considered as infringements, later innovators would have no incentive to invest

• BUT, contradiction:
  • the larger the rights granted to one innovator, the lower the incentives for the other one...
  • How to divide profits between successive innovators? IP appears as a blunt instrument in that respect...

• 2 tentative lessons
  • Sequential innovations call for broad (and short) patents.
  • The benefits of broad patents disappear if licensing fails.
Patent licensing

• Patents are transferable rights (through licenses).
• Importance of transferability
  • Ensures that innovations and artistic creations are used by the agents who value them most.
  • Additional source of profit to the innovator
• Mode of patent licensing
  • Royalty per unit of output produced with technology (influences price of final product)
  • Fixed fee (influences the division of profits)
  • Combination of the previous two options
• Terms
  • Any firm can buy one license?
  • Auction a limited number of licenses?
Patent licensing (cont’d)

• **Social viewpoint**
  - Licenses ↑ diffusion and use of knowledge

• **Private viewpoint**
  - Do licenses ↑ incentives to innovate?
  - Additional source of profits for the innovators
    - Only effect if licensee operates in a totally different market from the licensor.
  - Potential negative effect if licensor and licensee are direct competitors
    - Net effect depends on
      - Size of innovation
      - Market structure
  - What if innovations are cumulative?
Licensing to rival firms

- **Drastic (major) innovations**
  - **Cournot** competition → no incentive to license
    - No license: innovator becomes monopolist
    - License: duopoly at lower cost; innovator can reap total duopoly profit, but this is smaller than monopoly profit.
  - **Bertrand** competition → no incentive to license
    - Exact same argument

- **Nondrastic (minor) innovations**
  - **Bertrand** competition → no gain from licensing
    - No license: \( p = c - \varepsilon \) → margin of \( (x - \varepsilon) \) on each unit sold
    - Any license: only sensible royalty rate is \( r = x - \varepsilon \)
      - Quantity sold doesn’t change
      - Innovator secures a margin of \( (x - \varepsilon) \) on the units she sells
      - Innovator collects a royalty of \( r = x - \varepsilon \) on the units sold by the licensees.
Lesson: It is not profitable for an incumbent innovator to license its cost-reducing innovation to its industry rivals when the innovation is drastic, or when the innovation is nondrastic and Bertrand competition prevails on the product market.
Licensing to rival firms (cont’d)

- **Nondrastic (minor) innovations** (cont’d)
  - **Cournot** competition → general model
    - Inverse demand: \( p = a - Q \)
    - \( n \) firms, with pre-innovation constant marginal cost of \( c \)
    - Innovation ↓ cost from \( c \) to \( c - x \) (with \( 0 < x < a-c \))
    - 3-stage game
      - Incumbent innovator selects royalty rate \( r \)
        → it selects \( r < x \)
      - Other firms decide whether or not to become licensees
        → they all buy a license because this ↓ marginal cost from \( c \) to \( c - x + r \)
      - Cournot competition among all firms
        → i.e. 1 firm with cost \( c - x \) and \( n-1 \) firms with cost \( c - x + r \)
Licensing to rival firms (cont’d)

- **Nondrastic (minor) innovations** (cont’d)
  - **Cournot** competition → analysis
    - Equilibrium quantity and profit for typical firm $k$
      \[
      q_k^* = \frac{1}{n+1} \left( a - nc_k + \sum_{j \neq k} c_j \right)
      \]
      \[
      \pi_k^* = (q_k^*)^2
      \]
    - Apply to innovator and licensees
      \[
      q_{inn}^* = \frac{a - c + x + r(n - 1)}{n+1}
      \]
      \[
      \text{and } q_{lic}^* = \frac{a - c + x - 2r}{n+1}
      \]
    - Innovator’s profit
      \[
      \pi_{inn} = (q_{inn}^*)^2 + r(n - 1)q_{lic}^*
      \]
Licensing to rival firms (cont’d)

- **Nondrastic (minor) innovations** (cont’d)
  - **Cournot** competition → analysis

  - Optimal royalty rate
    \[
    \frac{\partial \pi_{inn}}{\partial r} = \frac{(n - 1)(n + 3)}{(n + 1)^2} \left( a - c + x - 2r \right) > 0 \Rightarrow r^* = x
    \]

  - Equilibrium innovator’s profit
    \[
    \pi_{inn}^* = \frac{(a - c)^2 + (2n + n^2 - 1)(a - c)x + x^2}{(n + 1)^2}
    \]

  - Innovator’s gain from licensing
    \[
    \pi_{inn}^* - \pi_{inn}\no license = \frac{(n - 1)(a - c - x)x}{n + 1} > 0
    \]

  - Society also gains from licensing
    ✓ Consumers and rivals are as well off but innovator is strictly better off.
Licensing to rival firms (cont’d)

**Lesson**: In the case of quantity competition on the product market, it is always profitable for an incumbent innovator to license a nondrastic cost-reducing innovation to its industry rivals. Licensing also benefits society.

**Intuition**

- Same competitive situation if license or not
  - Marginal costs: $c \times x$ for innovator, $c$ for rivals
  - $\rightarrow$ same (direct) profit for innovator in both situations
- If licensing, innovator also collects royalties $\rightarrow$ higher total profit
Review questions

• Explain how IP law strikes a balance between dynamic and static efficiency considerations or, in other words, between incentives and use.

• What is behind the so-called ‘patent paradox’? How can it be explained?

• Why isn’t it optimal in terms of public policy to have patents that last forever? Discuss.

• Does a firm have incentives to license its innovation to rival firms? Discuss.