Module 11: Innovation & Patents

Market Organization & Public Policy (Ec 731) · George Georgiadis

- Technological progress is crucial for improving welfare, but (very) costly.
  - How to incentivize firms to innovate?
- Suppose that a large number of firms engage in Cournot competition.
  - We have seen that the equilibrium price will be close to the marginal cost, and firms' profits close to 0.
  - Consider a firm's incentive to engage in costly R&D.
  - If other firms can imitate a new innovation, then the innovating firm will have little incentive to invest in the first place.
  - Therefore, a new firm must be guaranteed enough (expect) profits to recoup the R&D cost.
- *Enter:* Patents (that provide the innovating firm with a temporary monopoly).
- *Schumpeter (1943):* If one wants to induce firms to undertake R&D, then one must accept the creation of monopolies as a necessary evil.

The Value of Innovation

- A simple model of process innovation:
  - Assume that innovation lowers the (constant) marginal production cost from $\bar{c}$ to $\underline{c} < \bar{c}$.
  - How much would a firm be willing to pay to reduce its marginal cost, given that no other firm will (be allowed to) buy it?

Social Planner (First best):

- She sets price equal to marginal cost; *i.e.*, $p = \bar{c}$ before the innovation, and $p = \underline{c}$ after.
- Additional net social surplus p.u of time: $v^s = \int_{\underline{u}}^{\bar{u}} D(c)dc$
- The social planner's value from innovating is:

$$V^s = \int_0^{\infty} e^{-rt} v^s dt = \frac{1}{r} \int_{\underline{c}}^{\bar{c}} D(c)dc$$

Monopoly:

- Suppose that a firm is in a monopoly situation.
- Let Π^m denote monopoly profit p.u of time. Then:

$$\begin{aligned} \frac{d\Pi_m}{dc} &= \frac{d}{dc}\left[(p-c)\, D(p)\right] \\ &= \underbrace{\frac{\partial \Pi_m}{\partial p}}_{=0} \frac{dp^m}{dc} + \frac{\partial \Pi_m}{\partial c} = -D\left(p^m(c)\right) \end{aligned}$$

  - Application of the *Envelope Theorem*.

- The monopolist's value from innovating is:

$$\begin{aligned} V^m &= \int_0^{\infty} e^{-rt} \left[\Pi^m(\underline{c}) - \Pi^m(\bar{c})\right] dt \\ &= \frac{1}{r} \int_{\underline{c}}^{\bar{c}} \left(-\frac{d\Pi^m}{dc}\right) dc \\ &= \frac{1}{r} \int_{\underline{c}}^{\bar{c}} D\left(p^m(c)\right) dc \end{aligned}$$

- Because $p^m(c) > c$ and $D' < 0$, we have $D\left(p^m(c)\right) < D(c)$ for all c, and hence $V^m < V^s$.
- A monopolist has weaker incentives to innovate relative to a social planner.
  - *Intuitively:* Because he sets a higher price, the cost reduction pertains to a smaller number of units.

Competition:

- Suppose that 2 firms engage in Bertrand competition.

- Then $p = \bar{c}$, and firms earn 0 profits.

- The firm that obtains new technology with cost $\underline{c}$ is awarded a patent.
- Let $p^m(\underline{c})$ be the monopoly price when the cost is $\underline{c}$.
- **Case 1:** If $p^m(\underline{c}) \leq \bar{c}$, then we say that the innovation is *drastic*.
  - The innovator then charges $p = p^m(\underline{c})$, and obtains the entire market.
  - His value from innovating is V^m.
- **Case 2:** If $p^m(\underline{c}) > \bar{c}$, then we say that the innovation is *nondrastic*.
  - Both firms charge $p = \bar{c}$, and the innovator's profit p.u of time is $\Pi^c = (\bar{c} - \underline{c})\, D(\bar{c})$.
  - The value from innovating is

$$V^c = \frac{1}{r}(\bar{c} - \underline{c})\, D(\bar{c})$$

  - Because $\bar{c} < p^m(\underline{c}) < p^m(c)$, we have $D(\bar{c}) > D(p^m(c))$ for all $c \geq \underline{c}$, so

$$V^m = \frac{1}{r}\int_{\underline{c}}^{\bar{c}} D(p^m(c))\, dc < \frac{1}{r}\int_{\underline{c}}^{\bar{c}} D(\bar{c})\, dc = V^c$$

  - But $D(\bar{c}) < D(c)$ for all $c < \bar{c}$, so $V^s = \frac{1}{r}\int_{\underline{c}}^{\bar{c}} D(c)dc > \frac{1}{r}\int_{\underline{c}}^{\bar{c}} D(\bar{c})dc = V^c$.
  - Therefore, $V^c \in (V^s, V^m)$.
- Take-aways:
  - Even with patents of infinite duration, the innovator does not internalize the entire social surplus from the innovation.
  - A monopolist has less to gain from innovating than does a competitive firm. Why?

Monopoly Threatened By Entry

- Simple setting with two firms. Initially:
  - Firm 1 is a monopolist, produces at marginal cost $\bar{c}$, and earns profit $\Pi^m(\bar{c})$.
  - Firm 2 does not currently produce, but is a potential entrant.

- If only one of the firms has the opportunity to acquire the technology to reduce marginal cost to $\underline{c}$, then we have the same situation as before:
  - $V^c > V^m$, so innovation is more valuable for the entrant than for the monopolist.
- Now suppose that a 3^{rd} party generates the innovation, and auctions it to the two firms.
- We will see that in this case, the innovation is more valuable for the monopolist than for the entrant.

- If firm 1 obtains the innovation, then it remains a monopolist, and earns profit $\Pi^m(\underline{c})$.
- If firm 2 obtains the innovation, then both firms become duopolists.
  - Denote the profits of firm 1 and 2 by $\Pi^d(\bar{c}, \underline{c})$ and $\Pi^d(\underline{c}, \bar{c})$, respectively.
- The value of innovation for firm 1 is:

$$V^m = \frac{\Pi^m(\underline{c}) - \Pi^d(\bar{c}, \underline{c})}{r}$$

- The value of innovation for firm 2 is:

$$V^c = \frac{\Pi^d(\underline{c}, \bar{c})}{r}$$

- Assume that: $\Pi^m(\underline{c}) \geq \Pi^d(\underline{c}, \bar{c}) + \Pi^d(\bar{c}, \underline{c})$.
  - A monopolist earns greater profit than two non-colluding duopolists.
- Then: $V^m > V^c$. (Opposite from before!)
- Because competition reduces profits, the monopolist's incentive to remain a monopolist is greater than the entrant's incentive to become a duopolist.

- A monopolist may have incentives to obtain property rights on an innovation, even though he will make no use of it (often referred to as *patent shelving*).
  - The only purpose is to prevent an entrant from competing.

- Subject of many antitrust cases; generally considered anti-competitive behavior.
- In many countries, the patent law includes a compulsory licensing provision (*i.e.*, patent holder is forced to license if he does not utilize the innovation within a specified length of time).

Patent Races

- Insofar, we have considered

  1. the value of innovation in a situation where one firm has monopoly over R&D activities; and
  2. the value of innovation when monopoly power is auctioned to a monopolist and a potential entrant.

- In practice, R&D competition can be likened to a "race" for a patent.
  - Multiple firms invest in R&D simultaneously, and whichever firm innovates first, obtains a patent.
- We will study the so-called "Poisson" patent race.
  - Initially, there is a monopolist with cost $\bar{c}$, and a potential entrant.
  - The two firms compete in R&D activities, and the firm first to innovate (*i.e.*, obtain a technology with cost $\underline{c}$) obtains a patent.
- At every moment t, each firm i invests in R&D at rate $x_{i,t}$, and its innovation rate is $h(x_{i,t})dt$, where $h' > 0 > h''$.
  - If firm i invests x_i during $(t, t+dt)$, then it incurs cost $x_i dt$ and its probability of innovating is $h(x_{i,t})dt$.
  - This is called a "Poisson" race, because the probability of innovating during $(t, t+dt)$ is independent of investments at $t' < t$.
  - It follows that each firm's investment rate will be independent of t.
- If firm 1 obtains the patent, then the firms earn profits $\Pi^m(\underline{c})$ and 0, respectively.

- If firm 2 obtains the patent, then the firms earn profits $\Pi^d(\bar{c}, \underline{c})$ and $\Pi^d(\underline{c}, \bar{c})$, respectively.
- Assume that: $\Pi^m(\underline{c}) \geq \Pi^d(\underline{c}, \bar{c}) + \Pi^d(\bar{c}, \underline{c})$.

- During an arbitrary interval $(t, t+dt)$, firms 1 and 2 earn profit $[\Pi^m(\bar{c}) - x_1]\,dt$ and $-x_2 dt$, respectively.
  - With probability $h(x_1)dt$, firm 1 is first to innovate, and the firms will earn discounted profits $\frac{\Pi^m(\underline{c})-x_1}{r}$ and 0, respectively.
  - With probability $h(x_2)dt$, firm 2 is first to innovate, and the firms will earn discounted profits $\frac{\Pi^d(\bar{c},\underline{c})}{r}$ and $\frac{\Pi^d(\underline{c},\bar{c})}{r}$, respectively.
  - With probability $1 - h(x_1)dt - h(x_2)dt$, neither firm innovates during $(t, t+dt)$.
- The value of innovation to firm 1 is

$$\begin{aligned} V_1 &= [\Pi^m(\bar{c}) - x_1]\,dt + e^{-rdt}\left[h(x_1)dt\frac{\Pi^m(\underline{c})}{r} + h(x_2)dt\frac{\Pi^d(\bar{c},\underline{c})}{r} + (1 - h(x_1)dt - h(x_2)dt)\,V_1\right] \\ &= \frac{\Pi^m(\bar{c}) - x_1 + h(x_1)\frac{\Pi^m(\underline{c})}{r} + h(x_2)\frac{\Pi^d(\bar{c},\underline{c})}{r}}{r + h(x_1) + h(x_2)} \end{aligned}$$

  and for firm 2

$$\begin{aligned} V_2 &= -x_2 dt + e^{-rdt}\left[h(x_2)\frac{\Pi^d(\underline{c},\bar{c})}{r} + (1 - h(x_1)dt - h(x_2)dt)\,V_2\right] \\ &= \frac{-x_2 + h(x_2)\frac{\Pi^d(\underline{c},\bar{c})}{r}}{r + h(x_1) + h(x_2)} \end{aligned}$$

  - *Note 1:* $e^{-rdt} \simeq 1 - rdt$ for "small" dt (Taylor expansion)
  - *Note 2:* $dt^2 \simeq 0$
- A Nash equilibrium is a pair $\{x_1^*, x_2^*\}$ such that x_i^* maximizes V_i given x_{-i}^*.

- Which firm will have stronger incentives to invest in R&D?
- Depends on which of two effects dominates.

1. *Efficiency effect*: $\Pi^m(\underline{c}) \geq \Pi^d(\underline{c}, \bar{c}) + \Pi^d(\bar{c}, \underline{c})$ suggests that the monopolist has stronger incentives, and therefore, spends more on R&D.

2. *Replacement effect*: By increasing x_1, the monopolist (on expectation) brings the discovery date forward, thus hastening his own replacement. In contrast, the entrant does not forgo a flow profit during the R&D phase, and therefore has stronger incentives.

- What if we consider the case of a drastic innovation?
  - *i.e.*, whichever firm obtains the patent, becomes a monopolist, so $\Pi^d(\underline{c}, \bar{c}) = \Pi^m(\underline{c})$ and $\Pi^d(\bar{c}, \underline{c}) = 0$.
- Problems:
  - Excessive duplication of research
  - With multiple stages, as the gap between the firm widens, incentives weaken.

Welfare Analysis of Patent Protection

- Overall, economic research in this area is still nascent.
- *Main issues:*
  - Optimal patent length?
  - Optimal degree of patent protection?
  - Subsidies? (*e.g.*, in the US, tax credits for R&D investments)
- An example from *United States vs. Microsoft Corp*:
  - Microsoft was accused of becoming a monopoly and engaging in abusive practices, in violation of the Sherman Act.
  - *Central Issue*: Whether Microsoft was allowed to bundle its web browser (IE) with Windows. Allegedly, this restricted the market for competing web browsers.
  - Microsoft's argument:
    * While it possesses a lot of static market power, this is merely the fuel for stimulating dynamic R&D competition.
    * Antitrust intervention would run the risk of reducing the rate of innovation and welfare.

- Government's argument:
  - Microsoft's practices prevented entry of new firms and products, thus raising prices and retarding innovation.

- *Key trade-off:*
  - Policies that protect new entrants (*e.g.*, start-up) from incumbents (*e.g.*, Microsoft) raise a successful innovator's initial profits, and may thereby encourage innovation.
  - But entrants hope to become the next Microsoft, and will want to engage in similar entry-disadvantaging behaviors should they succeed. Thus by lowering the profits of incumbency, protective policies may actually retard innovation.

- Difficult problem to analyze, because it is inherently dynamic.
  - Need a model of successive patent races.
  - See Segal and Whinston, (AER, 2007).

Alternatives to Patents

- Patents incentivize R&D investments by conferring monopoly rights to an innovator.
- Can we (somehow) avoid the deadweight losses associated with monopoly?
- Yes:
  1. *Award system*
  2. *Procurement or contractual mechanism*
- Award system:
  - An entity (*e.g.*, government or a firm) designates a (well-defined) project, and grants a fixed sum of money to the first firm that completes the project.
  - After the prize is awarded, the innovation falls into the public domain.
  - *Examples:* XPrize, Innocentive, etc...
  - Advantage: Does not produce a monopoly!
  - Disadvantage: Difficult to implement!

        - Unlike with patents, the government must be highly knowledgeable about the demand for the project, which is crucial for determining the size of the award, which in turn, influences R&D incentives.
    - In practice, the size of the award will often be determined after the innovation has occurred, which raises hold-up issues.
        - Administrative authorities typically estimate the values of innovations conservatively.

- Procurement or contractual mechanism:
    - Similar to the award system, but the government controls access to the research market.
        - *i.e.*, chooses a certain number of firms and signs a contract with them.
    - Contract may specify that certain portion of the R&D costs will be borne by the government.
        - Raises incentives problems.
        - Can limit duplication of research.
    - As with the award system, the government must know the value of the innovation.
    - Often used in connection with space and defense projects.

References

Segal I. and Whinston M.D., (2007), "Antitrust in Innovative Industries", *American Economic Review*, 97 (5), 1703-1730.

Tirole J., (1988), *The Theory of Industrial Organization*, MIT Press.