Industrial Organization

Research and Development

Issues Involved

Q) What are the factors determining R&D expenditure?

1. Market Structure: The nature and extent of competition in the industry plays a vital role.

2. Timing: Consider a situation where a firm in an industry innovates the production process in such a manner that cost of production decreases for the firm. As long as other firms don't innovate, it enjoys monopoly profits.

3. Laws: Patent laws are the incentives to indulge in R&D. The innovation done by a firm , if protected by patent laws, can earn the firm monopoly profits and market power. The stronger the laws are and the longer the span of protection, higher will be the incentive to innovate.

Issues Involved (Continued)

4. Other important issues involved are – piracy, imitation, technology transfer etc.

- Hence, we can summarize the issues as –

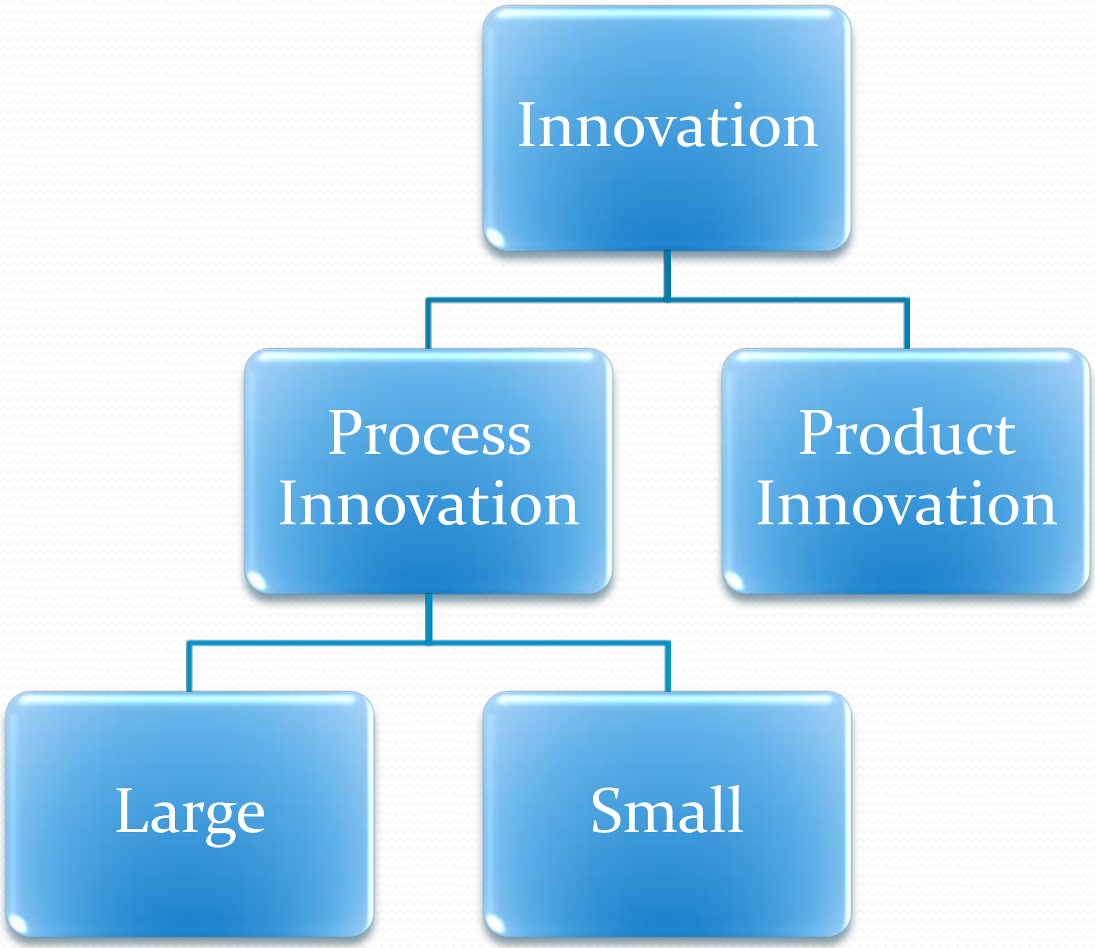
i) Types of innovation
ii) Timing of innovation and the decision to invest in R&D
iii) Market structure and innovation

- We will consider a simple duopolistic market structure

- We will allow for spill-over effects

- We will show that R&D expenditure differs given co-operative solution vis-à-vis non-cooperative operation

Types of Innovation



Types of Innovation(Continued)

- Process Innovation: It is a new way to produce a product that already exists in the market. Motive behind is simply to bring down the cost of production at the margin.

- Product Innovation: Process of developing a new product that never exited in the market. You can redefine this as a process innovation whose previous cost of production was infinite.

- Let's consider a Bertrand duopoly in a homogeneous commodity. Initially $P = MC$

  Assume one firm makes a process innovation but the ensuing reduction in cost of production doesn't enable it to charge monopoly price.

  Why? Monopoly price given such reduced cost exceeds initial price. What he can do? Charge a price $P - \varepsilon$ and capture the entire market.

  Result: price falls a little but market size remains the same (appx.)

Types of Innovation(Continued)

- This is a case of **small** process innovation.

- Consider a situation where an innovation reduces the cost in such a way that the producer can charge a monopoly price.

  Why? Such monopoly price given reduced cost is $\leq$ initial price.

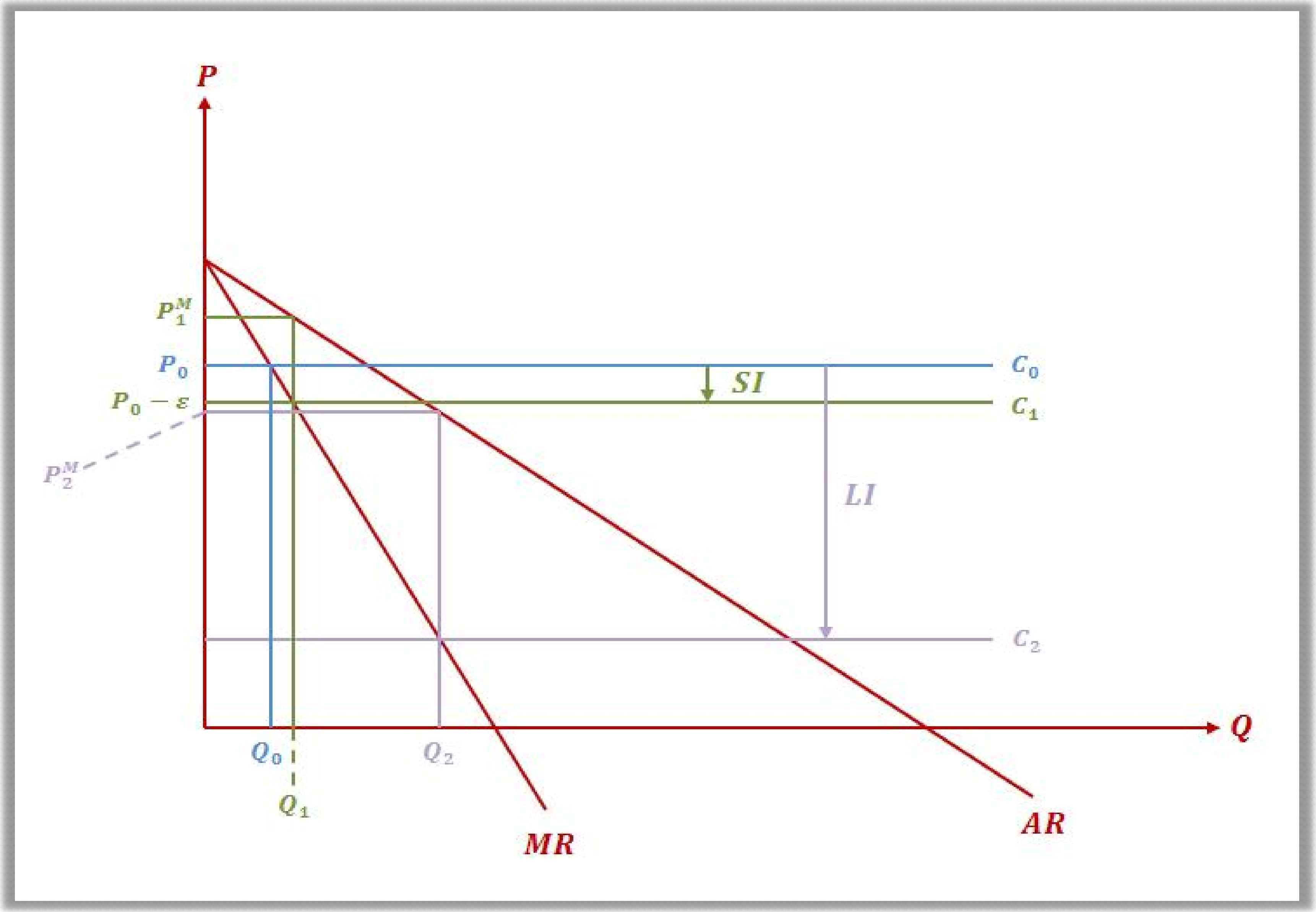
  Result: Market expands as fall in price is considerable. The innovator becomes a monopolist and captures the entire market.

- This is the case of **large** innovation.

- The market structure changes: from duopoly to monopoly. The large innovator can charge a monopoly price, sell a monopoly quantity and earn monopoly profit.

- In both the cases, innovator captures the entire market.

Types of Innovation(Continued)



R&D and Competition

- Let's consider a two-stage Cournot game where in the first stage he firms decide on how much to invest in R&D and in the second stage they decide how much to produce given cost structure.

- Remember:

1. Co-operation implies joint profit maximization and non-cooperation implies maximizing own profits.

2. Positive Spillover implies cost of production reduces for both even when one of the firms innovate.

   Negative spillover implies that innovation done by one firm creates a hindrance for the other firm and, as a result, the cost of production of the non-innovator increases.

Formal Model

- Two firms – *i* and *j*.

- R&D expenditure: x_i, x_j

- Cost of Production: $c_i(x_i, x_j) = c - x_i - \beta x_j$

  If neither innovates, they have the same constant unit cost of production given by c. If firm *i* innovates, then, $c_i(x_i, x_j)$ falls by x_i units and firm *j*'s cost $c_j(x_i, x_j)$ falls by β units per unit increase in x_i

- Cost of innovation: $\frac{1}{2} x_i^2$

- Positive spillover implies $0 < \beta < 1$

  Negative spillover implies $-1 < \beta < 0$

- Inverse Demand Function: $p = a - bq; q = q_1 + q_2$

Reaction Functions

- Stage II: They choose quantity by maximizing their profit functions

$$\pi_i = \tfrac{1}{9b}(a - 2c_i + c_j)^2$$

- Stage I: The firms choose optimal (x_i, x_j)

$$\tilde{\pi}_i = \tfrac{1}{9b}[a - 2(c - x_i - \beta x_j) + (c - x_j - \beta x_i)]^2$$

- Show that the firms face the following reaction functions:

$$\partial \tilde{\pi}_i / \partial x_i = 0$$

$$\Rightarrow x_i = \frac{2(a-c)(2-\beta) + 2x_j(2-\beta)(2\beta - 1)}{[9b - 2(2-\beta)^2]}$$

$$\Rightarrow x_i = \tilde{R}_i(x_j)$$

Nash Equilibria

- Show that solving the RFs we get the non-cooperative CNE as:

$$x_i^* = x_j^* = x^{NC} = \frac{2(a-c)(2-\beta)}{9b - 2(2-\beta)(1+\beta)}$$

- Similarly we can find out the co-operative CNE. The problem here is to maximize $\underset{x_i}{Max}\ (\pi_i + \pi_j)$

- Hint: $\partial(\pi_i + \pi_j)/\partial x_i = \partial \pi_i/\partial x_i + \partial \pi_j/\partial x_i = 0$

- Solve to find the co-operative CNE as:

$$x_i^* = x_j^* = x^C = \frac{2(a-c)(\beta+1)}{9b - 2(1+\beta)^2}$$

Social Optima

- R&D is higher in which case?
- Compare x^{NC} and x^{C}
- Show that $\beta > \frac{1}{2} \Longrightarrow x^{C} > x^{NC}$ and vice-versa.
- In case $x^{C} > x^{NC}$, cost reduction is more, price will fall and market will expand.
- Also show that co-operative equilibrium is socially optimal as

$$\beta > \tfrac{1}{2} \Longrightarrow q^{C} > q^{NC}$$

R&D Race

- Two firms: $k = 1,2$
- Each firm can engage in R&D by investing an amount I
- Probability of success α
- Profit: sole innovator (V), if both innovates $(V/2)$

- Investment feasibility condition: $i_k = I \text{ if } \alpha V - I \geq 0$

  $= 0 \text{ otherwise}$

- Expected profit of one firm when both invests:

$$E\pi_k(2) = \alpha(1-\alpha)V + \alpha^2 \frac{V}{2} - I$$

- Investment done by both iff

$$\frac{\alpha(2-\alpha)V}{2} \geq I$$

Social Optima

- Let $E\pi_s(n)$ be the industry's expected profit when n firms undertake R&D.

- When $n = 1$ we have: $E\pi_s(1) = \alpha V - I = E\pi_1(1)$

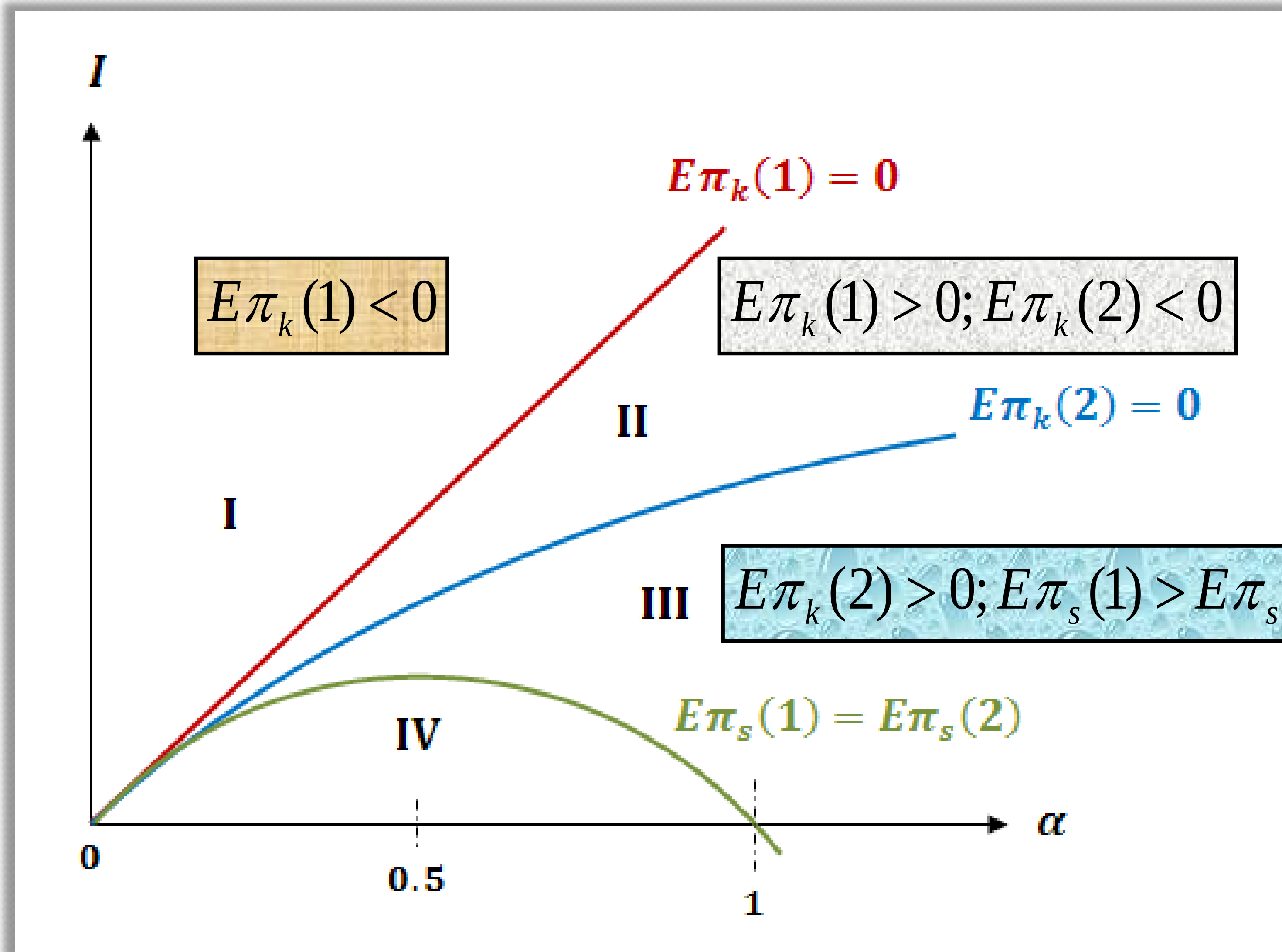
- When $n = 2$ we have: $E\pi_s(2) = 2\alpha(1-\alpha)V + \alpha^2 V - 2I$

- Comparing: $E\pi_s(2) \geq E\pi_s(1) \ iff \ \alpha(1-\alpha)V \geq I$

- Graphically we can represent the above results in the form of four zones:

1. Region I: No R&D (High I and low α)
2. Region II: Only one firm can undertake R&D
3. Region III: Market Failure
4. Region IV: Both invest in R&D (low I and high α)

Social Optima Graph



Expected Date of Discovery

- Consider discrete time periods: $1, 2, \cdots, n-1, n, n+1, \cdots$
- Remember: $\sum_{t=1}^{\infty} t\delta^{t-1} = \dfrac{1}{(1-\delta)^2}$
- ET when one firm invests:

$$ET(1) = \alpha.1 + (1-\alpha)\alpha.2 + (1-\alpha)^2\alpha.3 + \cdots$$

$$= \alpha \sum_{t=1}^{\infty} t(1-\alpha)^{t-1} = \alpha \big/ [1-(1-\alpha)]^2 = 1 \big/ \alpha$$

- Probability that neither makes a discovery (invention):

$$(1-\alpha)^2$$

- Probability that at least one makes a discovery (invention):

$$1-(1-\alpha)^2 = (2-\alpha)\alpha$$

Expected Date of Discovery

- ET when one firm invests:

$$ET(2) = (2-\alpha)\alpha.1 + (2-\alpha)\alpha(1-\alpha)^2.2 + (2-\alpha)\alpha(1-\alpha)^4.3 + \cdots$$

$$= \alpha(2-\alpha)\sum_{t=1}^{\infty} t(1-\alpha)^{2(t-1)}$$

$$= \alpha(2-\alpha)\sum_{t=1}^{\infty} t\{(1-\alpha)^2\}^{(t-1)}$$

$$= \frac{\alpha(2-\alpha)}{[1-(1-\alpha)^2]^2}$$

$$= \frac{1}{\alpha(2-\alpha)}$$

- It is evident that $ET(1) > ET(2)$