Chapter 1 Research and Development

- Innovation Race
- Cooperation and Competition of R&D
- Patent
- Government's Subsidy on R&D

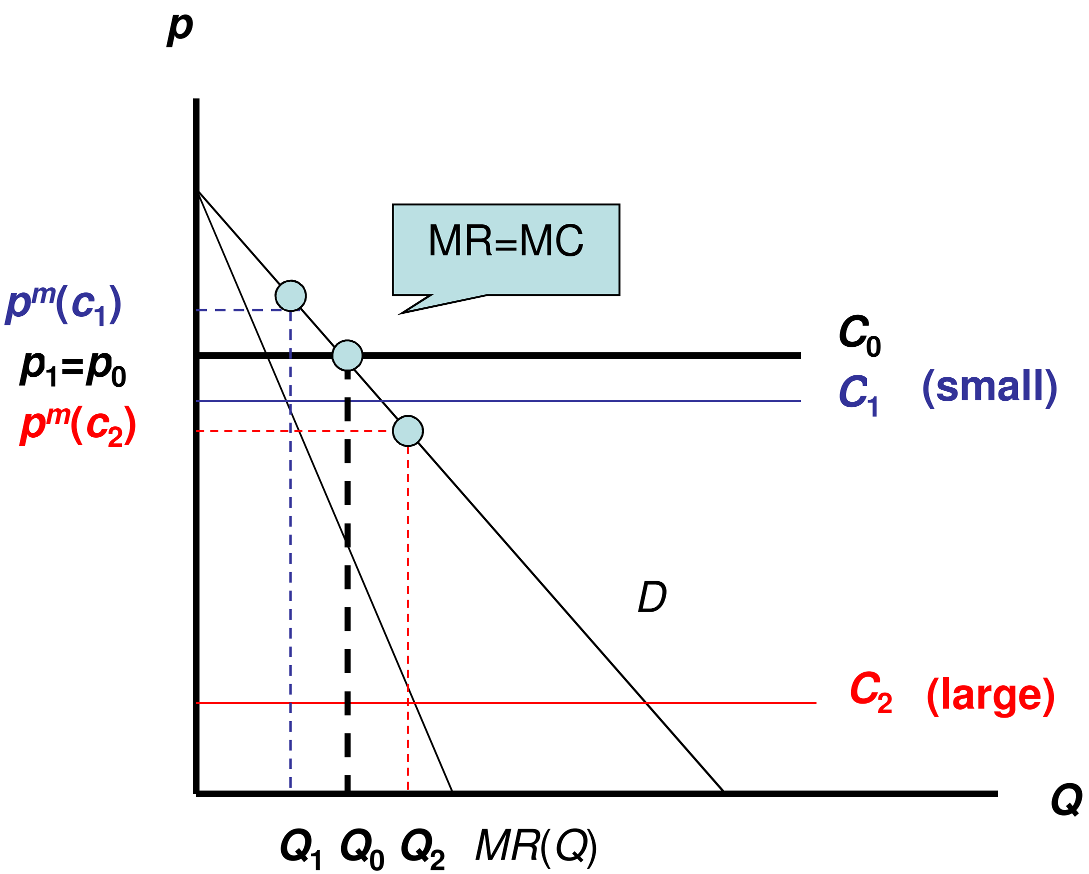
Chapter 1 Research and Development

- Ratio of R & D to output sales (OECD 1980)
  - Aerospace (23%)
  - Office machines and computers (18%)
  - Electronics (10%)
  - Drugs (9%)
  - Food, oil refining, printing, furniture, and textiles (1%)

Classifications of Process Innovation

- Process innovation
  - The investment in labs searching for cost-reducing technologies for producing a certain product
- Product innovation
  - The search for technologies for producing new products

Classifications of Process Innovation (cont')



Classifications of Process Innovation

- Definition.
  - In a perfect competitive market $p_1=c_0$
  - Let $p_m(c)$ denote the price that would be charged by a monopoly firm whose unit production cost is given by c
  - (1) Innovation is said to be large (or drastic, or major) if $p_m(c)<c_0$. That is, if innovation reduces the cost to a level where the associated pure monopoly price is lower that the unit production costs of the competing firm
  - (2) Innovation is said to be small (or nondrastic, or minor) if $p_m(c)>c_0$

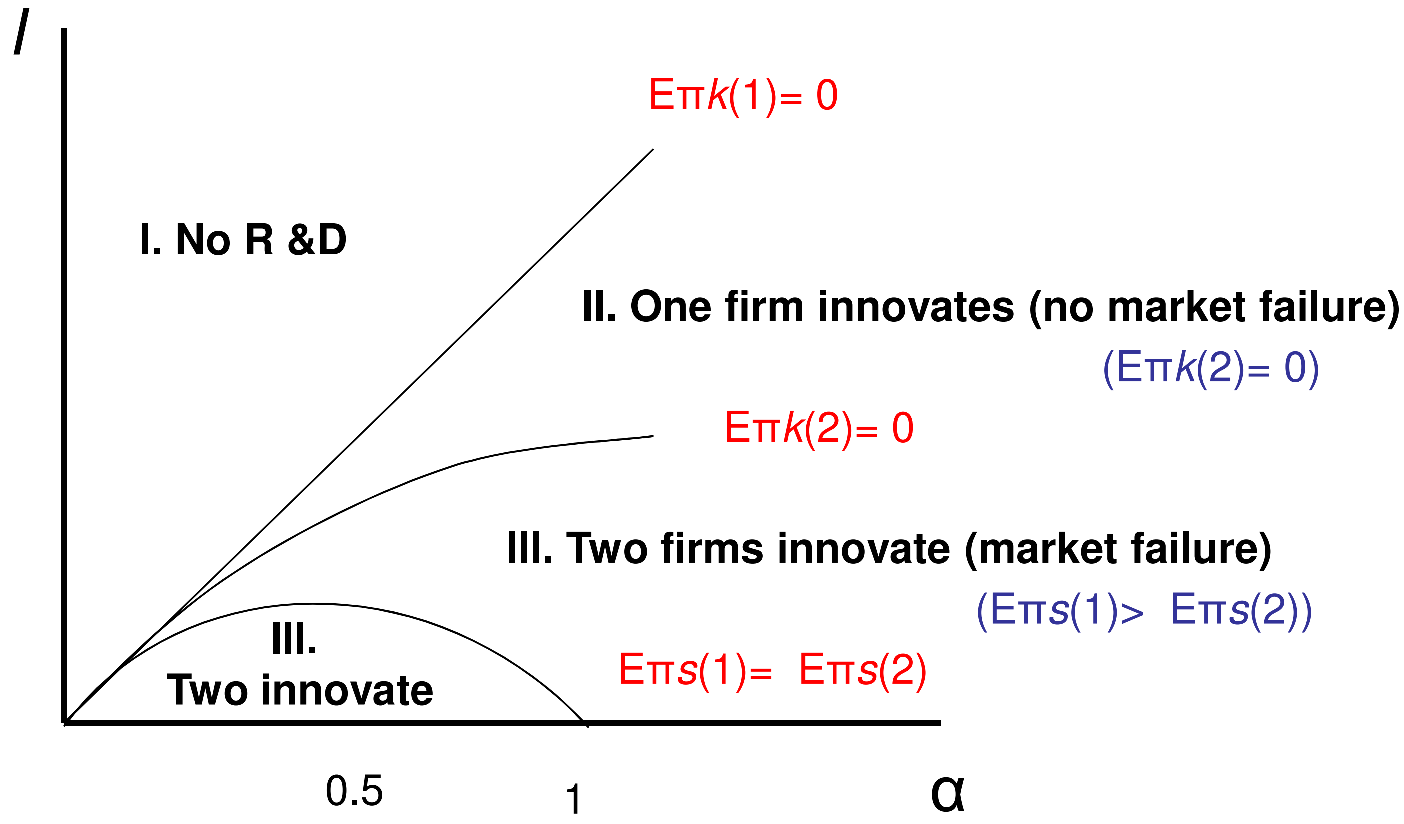
Innovation Race

- Assumption: once a firm invests $\$I$ in a lab, it has a probability α of discovering a technology that
  - yield a profit of $\$V$ if the firm is the sole discover,
  - \$v/2 if both firms discover, and \$0 if i does not discover
- $E\pi_k(n)$: the expected profit of firm k from investing innovation when the total number of firms engaging in similar R&D is n
- $E\pi^s(n)$: the industry's expected profit when n firms undertake R&D
- *Denote* i_k is the investment expenditure of firm k

Innovation Race (cont')

- A single firm undertaking R&D
  - $E\pi_k(1) = \alpha V - I$
  - $E\pi^s(1) = \alpha V - I$
- Two firms engage in R&D
  - $E\pi_k(2) = \alpha(1-\alpha)V + \alpha^2 V/2 - I$
  - $E\pi^s(2) = 2\alpha(1-\alpha)V + \alpha^2 V - 2I$

Innovation Race (cont')



Innovation Race (cont')

- Expected date of discovery
  - A single firm engage in R&D

$$ET(1) = \sum_{t=1}^{\infty} t\alpha(1-\alpha)^{t-1} = \frac{\alpha}{\left[1-(1-\alpha)\right]^2} = \frac{1}{\alpha}$$

  - Two firms engage in R&D

$$ET(2) = \sum_{t=1}^{\infty} t \cdot \alpha\left(2-\alpha\right)[(1-\alpha)^2]^{t-1} = \frac{2(2-\alpha)}{\left[1-(1-\alpha)^2\right]^2} = \frac{1}{\alpha(2-\alpha)}$$

Cooperation in R&D

- Denote x_i the amount of R&D undertaken by firm i, i=1,2, and $c_i(x_1,x_2)$ the unit production cost of firm i
  - $c_i(x_1,x_2) = 50-x_i-\beta x_j$, where β measures the effect of firm j's R&D level on the unit production cost of firm i
- Denote $TC_i(x_i)$ the cost (for firm i) of operating an R&D lab at a research level x_i
  - $TC_i(x_i)= (x_i)^2/2$
- Assume demand function p=100-Q

Cooperation in R&D (cont')

- Noncooperative R&D
  - The second period : choose quantity competitively

    Cournot profit level is given by

$$\pi_i(c_1, c_2) = \frac{(100 - 2c_i + c_j)^2}{9}$$

  - The first period : choose R&D level competitively

$$\max_{x_i} = \frac{(100 - 2c_i + c_j)^2}{9} = \frac{1}{9}[50 + (2-\beta)x_i + (2\beta - 1)x_j^{\ *}]^2 - \frac{(x_i)^2}{2}$$

First order condition ⇨ $\frac{\partial \pi_i}{\partial x_i} = \frac{2}{9}[50 + (2-\beta)x_i + (2\beta - 1)x_j^{\ *}](2-\beta) - x_i = 0$

Symmetric Nash equilibrium ⇨ $x_1^{\ nc} = x_2^{\ nc} = x^{nc} = \frac{50(2-\beta)}{4.5 - (2-\beta)(1+\beta)}$

Cooperation in R&D (cont')

- Cooperative R&D
  - The second period : choose quantity competitively

$$\pi_i(c_1, c_2) = \frac{(100 - 2c_i + c_j)^2}{9}$$

  - The first period : choose R&D level cooperatively

$$\max_{x_1, x_2} (\pi_1 + \pi_2)$$

First order condition ⇨

$$\frac{\partial(\pi_1 + \pi_2)}{\partial x_i} = \frac{2}{9}[50 + (2-\beta)x_i + (2\beta - 1)x_j](2-\beta) - x_i + \frac{2}{9}[50 + (2-\beta)x_j + (2\beta - 1)x_i](2\beta - 1)$$

Symmetric Nash equilibrium ⇨

$$x_1^c = x_2^c = x^c = \frac{50(\beta + 1)}{4.5 - (\beta + 1)^2}$$

Cooperation in R&D (cont')

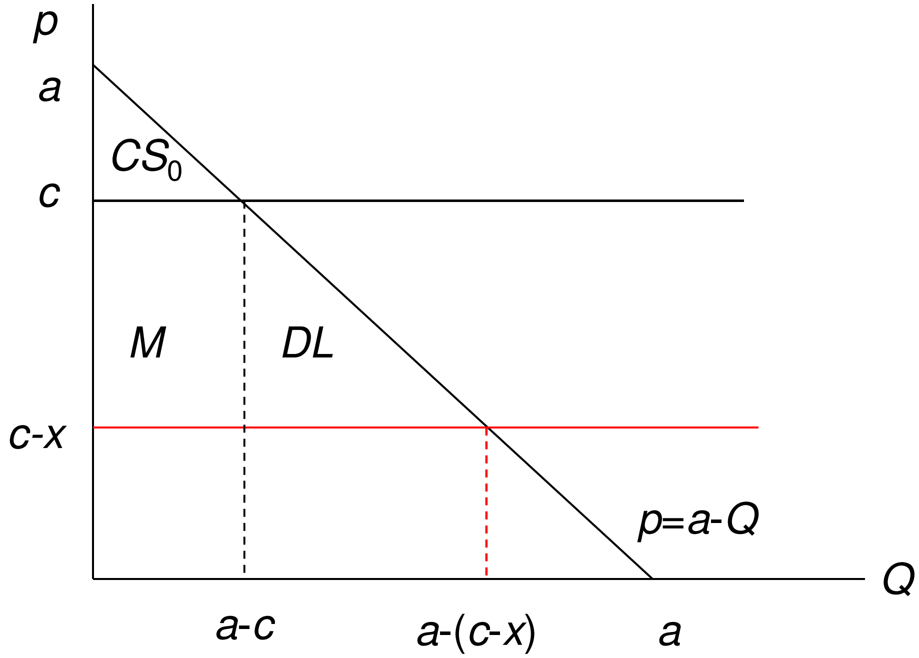
- Implication
  - Cooperation in R& D increases firms' profits
  - If R&D spillover effect is large, then the cooperative R&D levels are higher than the noncooperative R&D levels. Formally if $\beta>1/2$ then $x^c>x^{nc}$. In this case $Q^c>Q^{nc}$
  - If R&D spillover effect is small, then the cooperative R&D levels are lower than the noncooperative R&D levels. Formally if $\beta<1/2$ then $x^c<x^{nc}$. In this case $Q^c<Q^{nc}$

Patents

- The goals of the patent systems
  - To provide firms with incentives for producing know-how
  - To make the new information concerning the new discoveries available to the public as fast as possible
- Tradeoff the patents
  - Patent systems reward innovators
  - Patent systems creates price distortion
- Example
  - Seventeen years of protection in the US
  - Twenty years of protection in Europe

Patents (cont')

- Nordhaus 1969 and Scherer 1972
- An investment of x in R&D reduces the firm's unit cost from c>0 to c-x



Patents (cont')

- Assuming the government sets the patent life for T>=0
- The innovator enjoys a profit of M for T periods, and zero profit from T+1 and on
- In periods t=1,2,..,T, the society's benefit from the innovation is only the monopoly's profits M. The investment cost is $TC(x)=x^2/2$
- In periods $t=T+1, T+2, \ldots$, The gain of the society is the sum of the areas, $M+DL$

  $M(x)=(a-c)x$

  $DL(x)=x^2/2$

Patents (cont')

- Innovator's choice of R&D level for a given duration of patents
  - Denote $\pi(x;T)$ the innovator's present value of profits when the innovator chooses R&D level
- The innovator chooses R&D level x to maximize the present value of profit

$$\max_x \pi(x;T) = \sum_{t=1}^{T} \rho^{t-1} M(x) - TC(x) = \frac{1-\rho^T}{1-\rho}(a-c)x - \frac{x^2}{2}$$

$$\Rightarrow \quad x^I = \frac{1-\rho^T}{1-\rho}(a-c)$$

Patents (cont')

- Society's optimal duration of patents
  - The society's welfare is CS_0+M from the date the invention occurs and CS_0+M+DL from the date when the monopoly's patent right expires
- The socially planner's optimal decision problem

$$\max_T W(T) = \sum_{t=1}^{\infty} \rho^{t-1}[CS_0 + M(x^I)] + \sum_{t=T+1}^{\infty} \rho^{t-1} DL(x^I) - \frac{(x^I)^2}{2}$$

$$s.t.\ x^I = \frac{1-\rho^T}{1-\rho}(a-c)$$

$$\Rightarrow T^* = \frac{\ln[3+\sqrt{6+\rho^2-6\rho}-\rho]-\ln(3)}{\ln(\rho)} < \infty, \text{ when } \rho \geq 0.5$$

Subsidizing new product development

AIRBUS

BOEING		Produce	Don't produce
	Produce	-10, -10	50,0
	Don't produce	0,50	0,0

EC subsidy for production 15

AIRBUS

BOEING		Produce	Don't produce
	Produce	-10, 5	50,0
	Don't produce	0,65	0,0

Subsiding process innovation (cont')

- Brander and Spencer (1983, 1985)
- Consider two countries denoted by i=1,2
- Assume the world's demand for the product is $p=a-Q$ and the preinnovation unit cost of each firm is c, where $0<c<a$
- x_i denote the amount of R&D sponsored by the government in country i, the unit production cost for the firm producing in country i is reduced to $c-x_i$

Subsiding process innovation

Cournot' result

$$\pi_i = \frac{[a - 2(c - x_i) + c - x_j^{\,*}]^2}{9} = \frac{(a - c + 2x_i - x_j^{\,*})^2}{9}$$

Government i's decision problem

$$\max_{x_i} W_i = \pi_i - TC_i(x_i) = \frac{(a - c + 2x_i - x_j^{\,*})^2}{9} - \frac{x_i^{\,2}}{2}$$

FOC ⇨ $x_i = 4(a - c) - 4x_j$

Symmetric Nash Equilibrium

⇨ $x_1^{\,n} = x_2^{\,n} = \dfrac{4(a - c)}{5}$