Lecture 7: Research and Development

Cooperative and Noncooperative R&D in Duopoly with Spillovers


Regulatory policy typically prohibits cooperation among firms (due to concerns that such cooperation will raise prices, limit entry, etc.) This prohibition includes cooperation on R&D as well.

When there are spillovers in R&D, cooperation may actually enhance consumer welfare by restoring research incentives.

1984 U.S. - National Cooperative Research Act (NCRA) – research joint ventures (RJVs) subject to “rule of reason”

Model in d’Aspremont and Jacquemin addresses this issue

Framework

Stage 1: Firms decide how much to invest in research and development

Stage 2: Firms compete in quantities (Cournot competition)

Stage 2 is always non-cooperative, that is firms compete.

The paper compares two possible regimes in stage 1:

(I) non-cooperative interaction (i.e., no cooperation in R&D)

(II) Cooperation at the R&D stage

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The Model

Demand Function: \( P(Q) = a - bQ \)

\( x_1 = \text{R&D progress of firm 1}, \ x_2 = \text{R&D progress of firm 2} \)

\( K_c = \gamma (x_1)^{3/2} \rightarrow \text{Cost of R&D to firm 1 (similar for firm 2)} \)

Marginal Cost of production for firm 1 \( c_1(x_1, x_2) = (A - x_1 - \beta x_2) \)

\( 0 < \beta < 1 \) is the spillover parameter;

Some of the benefits from firm 2’s research spills over to firm 1 (and vice versa).

Technical Assumptions:

\( 0 < A < a \) (If \( A > a \), there will be no market without R&D)

\( x_1 + \beta x_2 \leq A \) (otherwise MC can be negative) \( \rightarrow \) endogenous

\( Q \leq a/b \) (otherwise price will be negative) \( \rightarrow \) endogenous
Solving the Model
By backwards induction – begin with the second stage
In both regimes, there is Cournot competition in the 2nd stage.
Given \((x_1, x_2)\) from the first stage, we can write down the second stage profits for the firms:
\[
\pi_1 = (a-bQ)q_1 - c_1q_1, \quad \text{where} \quad c_1 = A - x_1 - \beta x_2.
\]
\[
\pi_2 = (a-bQ)q_2 - c_2q_2, \quad \text{where} \quad c_2 = A - x_2 - \beta x_1.
\]
We know how to solve Cournot models:
Solution is \(q_1^* = \frac{(a+c_2-2c_1)}{3b}, \quad q_2^* = \frac{(a+c_1-2c_2)}{3b}\).
Hence \(Q^* = q_1^* + q_2^* = \frac{(2(a-A) + (\beta+1)(x_1+x_2))}{3b}\).

Solving the Model (Continued)
First Stage: (Regime 1) no cooperation
\[
\pi_1 = (a-bQ^*)q_1^* - [A - x_1 - \beta x_2] q_1^* - \gamma x_1^2/2.
\]
\[
\pi_2 = (a-bQ^*)q_2^* - [A - x_2 - \beta x_1] q_2^* - \gamma x_2^2/2.
\]
Substituting for \(q_1^* \) & \( q_2^* \) yields:
\[
\pi_1 = \left( \frac{(2-\beta)x_1 + (2\beta-1)x_2}{9b} - \gamma x_1^2 \right) /2.
\]
FOC: \(2(2-\beta)(2\beta-1)x_2/9b - \gamma x_1 = 0\).
SOC: \(2(2-\beta)/9b - \gamma < 0 \) (so SOC hold)
Solution: \(x_1^* = x_2^* = x^* = \frac{(a-A)(2-\beta)(\beta+1)}{4.5b\gamma - (2-\beta)(\beta+1)}\)

Solving the Model (Continued)
First Stage: (Regime 2) cooperation
Second stage is still the same:
\[
q_1^* = \frac{(a+c_2-2c_1)}{3b}, \quad q_2^* = \frac{(a+c_1-2c_2)}{3b}.
\]
Here the firms jointly choose \(x_1 \) & \(x_2\) to maximize \(\pi_1 + \pi_2\)
\[
\Pi = \pi_1 + \pi_2 = (a-bQ^*)q_1^* - [A - x_1 - \beta x_2] q_1^* - \gamma x_1^2/2 + (a-bQ^*)q_2^* - [A - x_2 - \beta x_1] q_2^* - \gamma x_2^2/2.
\]
Substituting for \(q_1^* \) & \( q_2^* \), and maximizing yields:
\[
x_1^* = x_2^* = x^* = \frac{(a-A)(\beta+1)}{4.5b\gamma - (2-\beta)(\beta+1)}.
\]
### Comparing the Outcomes

When $\beta=1/2$, the investments in R&D are the same under both regimes ($x^* = x^\prime$) and hence the output is the same ($q^* = q^\prime$); consumer surplus is the same.

When $\beta<1/2$, so that spillovers are relatively small, both the investment and output in the “R&D cooperation regime” are less than in the “R&D competition regime”, (i.e., $x^* < x^\prime$ and $q^* < q^\prime$); This means a higher price for consumers & lower consumer surplus in “R&D cooperation regime.” (standard result...)

When $\beta>1/2$, so that spillovers are relatively large, both the investment and output in the “R&D cooperation regime” are greater than in the “R&D competition regime”, (i.e., $x^* > x^\prime$ and $q^* > q^\prime$); This means a lower price for consumers & higher consumer surplus in “R&D cooperation regime.”

### Understanding the Intuition Behind the Results

Look at the second stage:

$$q^2* = \frac{(a+c_1-2c_2)/3b. = ([a-A]+[2\beta-1]x_1+[2-\beta]x_2)/3b. \partial q^2* / \partial x_1 = [2\beta-1].}$$

When $\beta>1/2$, an increase in the investment of firm 1 leads to increased production for firm 2. Hence when $\beta>1/2$, sign “$\partial \pi_1/\partial q_2|\partial q_2*/\partial x_1$” is “+”. This leads to “under-investment” in a duopoly without cooperation when spillovers are large.

Investment incentives can be restored by allowing firms to cooperate.

Public Policy Implications: when $\beta>1/2$, allowing cooperative R&D is unambiguously welfare enhancing.

### Taxonomy of Business Strategies

\[
d\pi_1/dx_1 = \partial \pi_1/\partial x_1 + \partial \pi_1/\partial q_1|\partial q_1*/\partial x_1 + \partial \pi_1/\partial q_2|\partial q_2*/\partial x_1
\]

- First Term= Direct Effect
- Second term=0 (Envelope Theorem)
- Third Term=Strategic Effect

When sign of strategic effect is negative: underinvestment. (D&J model $\beta>1/2$) When sign of strategic effect is positive: overinvestment (D&J model $\beta<1/2$).

Example: First Entry model we looked at in lecture 5:

$\pi_1 = (1-K_1-K_2) x_1$, $\partial \pi_1/\partial x_1 = K_1$

$\partial \pi_1/\partial q_1|\partial q_1* / \partial x_1 = 1 - K_1 + K_2$

Since $q_1* = K_2 + K_1$, $\partial \pi_1/\partial q_1|\partial q_1* / \partial x_1 = -1/2$

sign of strategic effect: $[\partial \pi_1/\partial q_1|\partial q_1* / \partial x_1]$ is positive:

Hence, overinvestment (relative to Cournot model)