

## Lecture 6 – Cooperative R&D

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## Cooperative R&D

# Cooperative R&D: overview

## **i** Object of analysis

R&D cooperation when R&D creates spillovers ( $\beta > 0$ ) or allows cost sharing (RJV).

- ▶ Baseline: each firm chooses R&D privately and internalises only its own costs/benefits
- ▶ This lecture:
  - ▶ R&D spillovers and the incentive to coordinate R&D
  - ▶ Research joint ventures (RJVs) as cost-sharing arrangements
- ▶ Core question:
  - ▶ When does cooperation increase welfare relative to non-cooperative R&D?

# Multi-stage games: reminder

► Two-stage structure:

1. Stage 1: choose  $x_i$  (R&D)
2. Stage 2: choose  $q_i$  (product-market competition)

! Backward induction

Solve Stage 2 for  $q_i^*(x)$ , substitute into Stage 1 payoffs, then solve for  $x^*$ .

R&D spillovers (d'Aspremont–Jacquemin)

## Spillovers model: primitives

- ▶ Duopoly with inverse demand:

$$p(Q) = A - Q, \quad Q = q_1 + q_2$$

- ▶ Cost and spillovers:
  - ▶ Marginal cost of firm  $i$ :  $c_i = c - x_i - \beta x_j$  with  $\beta \in (0, 1)$
  - ▶ Feasibility:  $x_i + \beta x_j \leq c$
- ▶ R&D cost:
  - ▶ Firm  $i$  pays  $\frac{x_i^2}{2}$
- ▶ Objects:
  - ▶ Choice variables:  $x_i$  (stage 1),  $q_i$  (stage 2)
  - ▶ Parameters:  $A, c, \beta$

### **i** Spillover parameter

$\beta \in (0, 1)$  measures how much of firm  $j$ 's R&D reduces firm  $i$ 's marginal cost.

## Spillovers model: stage-2 profit

- ▶ Given  $(x_1, x_2)$ , firm  $i$  chooses  $q_i$  to maximise:

$$\pi_i(q_i; q_j, x_i, x_j) = [A - (q_i + q_j) - c_i]q_i - \frac{x_i^2}{2}$$

- ▶ Interpretation:
  - ▶ R&D shifts marginal cost; output competition determines how much cost reduction is monetised

## Product-market equilibrium (Cournot): quantities

- ▶ Cournot–Nash equilibrium quantities (given  $x_1, x_2$ ):

$$q_i^* = \frac{1}{3} \left[ (A - c) + (2 - \beta)x_i + (2\beta - 1)x_j \right]$$

- ▶ Interpretation:

- ▶ Own R&D raises own output; rival R&D can raise or lower own output depending on spillover strength

### **i** Strategic effect of spillovers

The term  $(2\beta - 1)x_j$  implies rival R&D can be output-increasing or output-reducing depending on whether  $\beta$  is above or below  $\frac{1}{2}$ .



R&D regimes

## Regimes: definition

- ▶ We compare three institutional regimes:
- ▶ Game I:
  - ▶ Non-cooperative R&D and non-cooperative output (Cournot)
- ▶ Game II:
  - ▶ Cooperative R&D, non-cooperative output (Cournot)
- ▶ Game III:
  - ▶ Cooperative R&D and cooperative output (joint profit maximisation)

## Game I: stage-1 problem (non-cooperative R&D)

- Stage 1 objective for firm  $i$ :

$$\max_{x_i} \pi_i^*(x_i, x_j) = [q_i^*(x_i, x_j)]^2 - \frac{x_i^2}{2}$$

- Symmetric equilibrium ( $x_1 = x_2 = x^*$ ):

$$x^* = \frac{(A - c)(2 - \beta)}{4.5 - (2 - \beta)(1 + \beta)}$$

- Interpretation:

- Each firm invests less when spillovers are high because part of the benefit accrues to the rival

## Game II: stage-1 problem (cooperative R&D)

- ▶ Firms choose  $(x_1, x_2)$  to maximise joint profit given Cournot output:

$$\max_{x_1, x_2} \hat{\pi} = \pi_1^* + \pi_2^*$$

- ▶ Symmetric solution ( $x_1 = x_2 = \hat{x}$ ):

$$\hat{x} = \frac{(A - c)(1 + \beta)}{4.5 - (1 + \beta)^2}$$

- ▶ Interpretation:
  - ▶ Internalising spillovers increases R&D relative to Game I (for intermediate  $\beta$ )

## Game III: cooperative R&D and output

- ▶ With full cooperation, firms maximise joint profit over  $(q_1, q_2, x_1, x_2)$
- ▶ Under symmetry ( $x_1 = x_2 = x$ ,  $q_1 = q_2$ ), aggregate output in stage 2 is:

$$\tilde{Q} = \frac{(A - c) + (1 + \beta)x}{2}$$

- ▶ Stage 1 chooses  $x$  to maximise joint profit; solution:

$$\tilde{x} = \frac{(A - c)(1 + \beta)}{4 - (1 + \beta)^2}$$

- ▶ Interpretation:
  - ▶ Output coordination reduces product-market competition; R&D incentives differ because they are evaluated at monopoly output

Welfare

## Welfare benchmark: social planner

Assume symmetry  $x_1 = x_2 = x$ .

- ▶ Welfare function (as stated in the lecture):

$$W(Q) = V(Q) + R(Q) - [c - (1 + \beta)x]Q - x^2$$

- ▶ Stage 2 FOC w.r.t.  $Q$ :

$$Q = A - c + (1 + \beta)x$$

- ▶ Interpretation:
  - ▶ Planner expands output to the efficient level given the cost reduction from total effective R&D

## Social optimum: R&D and output

- Socially optimal R&D:

$$x^{**} = \frac{(A - c)(1 + \beta)}{2 - (1 + \beta)^2}$$

- Socially optimal output:

$$Q^{**} = (A - c) \left[ \frac{2}{2 - (1 + \beta)^2} \right]$$

- Interpretation:

- Relative to market outcomes, the planner internalises both spillovers and the consumer-surplus gain from lower prices



# Comparing regimes: R&D and output rankings

- ▶ R&D expenditure comparison (from the lecture):
  - ▶ Large spillovers:  $x^{**} > \tilde{x} > \hat{x} > x^*$
  - ▶ Small spillovers:  $x^{**} > \tilde{x} \geq x^* > \hat{x}$
- ▶ Output comparison (from the lecture):
  - ▶ Large spillovers:  $Q^{**} > \hat{Q} > Q^* > \tilde{Q}$
  - ▶ Small spillovers:  $Q^{**} > Q^* > \hat{Q} > \tilde{Q}$

## ! Reading the rankings

Higher  $x$  need not imply higher  $Q$  when cooperation also changes the intensity of product-market competition.

Research joint ventures (Combs)

## RJV model: primitives

- ▶ Probability a single lab succeeds:  $p$
- ▶ Product-market profits:
  - ▶ Monopoly:  $\pi^m$
  - ▶ Duopoly:  $\pi^d$
- ▶ Fixed cost of a lab:  $F$
- ▶ Assumptions:
  - ▶ If both succeed, firms compete in the product market (profits  $\pi^d$  each)
  - ▶ If only one succeeds (non-cooperative setting), the innovator earns  $\pi^m$

## RJV: cost-sharing (single lab)

- ▶ Each cooperating firm's expected payoff:

$$V_C = p\pi^d - \frac{F}{2}$$

- ▶ Non-cooperating firm's expected payoff:

$$V_N = p(1-p)\pi^m + p^2\pi^d - F$$

- ▶ Cooperation condition:

$$V_C \geq V_N \quad \Leftrightarrow \quad \frac{F}{2} \geq p(1-p)(\pi^m - \pi^d)$$

- ▶ Interpretation:

- ▶ Cooperation is more attractive when the “winner-takes-all” component  $p(1-p)$  is small

## RJV: duplication (two labs)

- ▶ If the RJV runs two labs (duplication), payoff of each cooperating firm:

$$\tilde{V}_C = 2p\pi^d - F$$

- ▶ Non-cooperating payoff remains  $V_N$
- ▶ Cooperation condition:

$$\tilde{V}_C \geq \tilde{V}_N \quad \Leftrightarrow \quad p \geq \frac{\pi^m - 2\pi^d}{\pi^m - \pi^d} \equiv K$$

- ▶ Interpretation:
  - ▶ With duplication, cooperation depends mainly on success probability  $p$  (not on  $F$ )

# Summary and next week

## Summary

- ▶ Spillovers  $\beta > 0$  create an externality in R&D, so non-cooperative R&D can be inefficiently low
- ▶ Cooperative R&D internalises spillovers and can increase R&D relative to non-cooperative choices
- ▶ Full cooperation may reduce product-market competition, affecting output and welfare
- ▶ RJVs trade off cost sharing against strategic effects from duplication and winning probabilities

## Next week: assessment and feedback

- ▶ Online class test (timing and format)
- ▶ Tutorial: class test feedback and problem solving
- ▶ Transition to subsequent lecture topics as scheduled

## References

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