

Lecture 6 – Cooperative R&D

Gerhard Riener

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, β

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 β 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 β)

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

- ▶ d'Aspremont, C., & Jacquemin, A. (1988). Cooperative and Noncooperative R&D in Duopoly with Spillovers. *American Economic Review*, 78(5), 1133–1137.
- ▶ Combs, K. L. (1992). Cost sharing vs. multiple research projects in cooperative R&D. *Economics Letters*, 39(3), 353–357.
- ▶ Belleflamme, P., & Peitz, M. (2015). *Industrial Organization: Markets and Strategies* (2nd ed.). Cambridge University Press. Chapter 18.3.
- ▶ Shy, O. (1996). *Industrial Organization: Theory and Applications*. MIT Press. Chapter 9.