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Cooperation in the Classroom: Experimenting with Research Joint Ventures

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Cooperation in the Classroom: Experimenting with Research Joint Ventures

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Abstract

This paper describes a classroom exercise that illustrates the investment incentives facing firms when technological spillovers are present. The game involves two stages in which student "sellers" first make investment decisions then production decisions. The classroom game can be used to motivate discussions of research joint ventures, the free-rider problem, collusion, and antitrust policy regarding research and development.
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"Innovation is an activity in which "dry holes" and "blind alleys" are the rule, not the exception."
Jorde and Teece (1990)

1 Introduction

In 2002, firms in the U.S. spent over $300 billion on research and development (R&D)– nearly 3% of GDP.[1] The U.S. is far from unique in this dimension, in fact many countries spend substantial amounts on R&D each year. Understanding firms' incentives to invest and the role for governmental policy is an important part of any course in Industrial Organization, and is discussed in many applied courses including regulation, antitrust, game theory, and law and economics.

Investment in R&D is distinct from capital investments along two dimensions. First, there is a public good aspect associated with R&D investments. That is, the use of an innovation does not diminish its availability to other firms. This suggests it may be welfare improving to make the innovation available to other firms. In addition, the understanding obtained from investment spills over freely to others. These technological "spillovers" reduce firms' incentives to invest since rivals may benefit from their costly innovation.[2]

The literature has proposed several solutions to remedy the public good and externality problems associated with R&D. One proposed solution is to allow cooperation in investment decisions, research joint ventures (RJV).[3] The coordination of R&D decisions improves incentives to invest when spillovers are high. However, RJVs may increase the likelihood of coordination in the final goods market by member firms.

In the 1980's governmental authorities responded to these theoretical find-

[1] Source: www.nsf.gov/sbe/srs/

[2] For more on this topic see Spence (1984), d'Aspremont and Jacquemin (1988), Kamien *et al.*(1992), and Hinloopen (1997).

[3] According to the National Cooperative Research Act, a RJV is defined as "any group of activities, including attempting to make, making or performing a contract, by two or more persons for the purposes of – (a) theoretical analysis, experimentation, or systematic study of phenomena or observable facts, (b) the development or testing of basic engineering techniques, (c) the extension of investigative finding or theory of a scientific or technical nature into practical application for experimental and demonstration purposes..., (d) the collection, exchange, and analysis of research information, or (e) any combination of the [above]."

ings by relaxing antitrust and competition policy as it pertains to cooperation in R&D. Currently, RJVs are permitted in Europe, the US, and Japan. However, the US legal system makes a distinction between joint R&D decisions and joint production decisions, where the latter is illegal (Jorde and Teece, 1990).

In this paper we present a classroom game that illustrates the investment incentives facing firms, particularly in markets where there are high technological spillovers. It involves a two-stage game in which student "sellers" make investment decisions in the first stage and quantity decisions in the second stage. R&D investments reduce the seller's second stage costs of production.

We present various treatments, which can be implemented individually or together, depending upon classroom time constraints. The treatments demonstrate the free-rider problem in investment decisions when technological spillovers are present, how RJVs can be used to alleviate incentive problems, and the temptation to coordinate on final good production. The observed decisions in this experiment can be used to stimulate discussions of spillovers, research joint ventures, tacit (or explicit) collusion, and competition policy regarding investment in innovations.

2 Overview

The experiment is a two-stage game in which sellers choose quantity to invest and quantity to produce. There are three variations of this classroom experiment and the decisions sheets for each treatment are provided in Appendix B. Each of the treatments can be conducted alone or in combination with any other treatment, depending upon classroom time constraints and the economic concepts you wish to emphasize.

In the baseline treatment (treatment 1) cooperation among sellers in R&D investment decisions is not permitted and a seller's own investment decision determines her costs of production (*ie.* there are no investment spillovers). Treatments 2 through 4 are best used in combination with the baseline treatment and can be divided into two groups: those which permit coordination in R&D decisions, and those which do not. For a summary see Table 1 below.

		Cooperation in R&D	
		Not Permitted	Permitted
Investment	Not present	Baseline Treatment 1	Treatment 2
Spillovers	Present	Treatment 3	Treatment 4

Table 1: Treatment Summary

In the second treatment sellers are permitted to discuss investment decisions (but not final goods production). However, as in the baseline treatment, the seller's investment decision alone determines her costs. The second treatment illustrates the effects of research joint ventures when investment spillovers are not present. You may observe ("illegal") collusion in quantity decisions arising from the contact sellers make during R&D decisions, which provides an opportunity to discuss anti-trust policy with regard to collusion and RJVs.

In the third treatment sellers are not permitted to cooperate in R&D decisions, but a seller's cost is determined by the total amount of investment undergone by both sellers (*i.e.* there are full investment spillovers). In this way Treatment 3 illustrates the free-rider problem in investment decisions arising from investment spillovers.

The final treatment allows for cooperation in R&D investments under full spillovers. This treatment illustrates both the benefits of RJVs in that they alleviate the free-rider problem and the drawbacks of RJVs in that they provide the potential to (illegally) collude in quantity decisions which arises from an occasion to discuss strategies with the competition while in the "research lab".

While each of the treatments can be conducted individually, it is most informative to discuss results relative to the baseline treatment case. Since the time necessary to perform all treatments exceeds a typical classroom allotment we provide a summary of some of the possible treatment combinations, related economic concepts, and time allocation (which includes time for discussion) recommendations in Table 2 below.

Treatments	Economic Concepts	Time
1	two-stage game	30 minutes
1 and 4	spillovers efficiency of RJVs collusion	treatment 1 - 20 minutes treatment 4 - 40 minutes
1 and 3	spillovers free-rider problem inefficiency in R&D investment	treatment 1 - 20 minutes treatment 3 - 30 minutes
1 and 2	RJVs collusion	treatment 1- 20 minutes treatment 2 - 30 minutes

Table 2: Treatment Recommendations

3 Procedures

In preparation for the experiment you will need to make copies of the instructions, copies of the decision sheets in the appendices, and set up a record table on an overhead transparency. The record table should contain one column for the investment decision and one for the quantity decision with enough rows for about five periods. In each cell you will record the decision made by each seller in each period. You will need two assistants, one to help gather decision sheets and the other to help record results. If you plan to conduct treatments 3 or 4 you should make copies of the table in Appendix C, which gives cost reductions for large total R&D investments.

Prior to beginning the experiment ask two or three students to assist with the experiment. Ask the assistants to distribute the instructions, and, while they are doing so, count the students and determine how many markets and sellers you wish to have. We found that three markets with two sellers in each works well, for a total of six sellers. Rather than increasing the number of sellers for larger classes, we've found that allowing students to work in pairs, where two (or three) students represent one seller, decreases the amount of time necessary to conduct the experiment and enhances understanding. Number the decision sheets accordingly, with a different number for each seller. To prevent sellers in the same market from interacting, the groups of sellers should be seated in separate areas of the room. For example, for an experiment with six sellers, arrange three on one side of the room (say sellers numbers 1-3) and the remaining (numbers 4-6) on the other. Once the sellers are arranged, distribute the decision sheets and read the instructions outloud. The students may have questions at this point, but try to keep discussion to a minimum.

After the first round of decisions, ask an assistant to collect the decision sheets. At this time the sellers in each group are randomly assigned to a market. To assign sellers randomly to a market for an experiment involving 3 markets with 2 sellers, for example. Shuffle the decision sheets for the first three sellers then randomly choose one of the sheets – the chosen seller is assigned to the first market, the second seller drawn is assigned to the second market, etc. Shuffle the decision sheets for the other three sellers (numbers 4-6) and assign markets analogously.

4 Discussion of Results

Table 3 gives a summary of results from a number of classroom experiments conducted in Industrial Organization courses at the University of Amsterdam[4]. Comparing treatment 3 to treatment 1, we see that when spillovers are present but sellers are not permitted to cooperate in R&D decisions, R&D investment levels fall relative to the benchmark treatment. You can begin a discussion involving these treatments by asking students if they choose different investment levels in the different treatments and why. They may not immediately realize that spillovers in investment decisions result in a free-rider problem, but a way to reach this understanding is to ask some leading questions. For instance, you

[4] An excel file with which the Nash equilibrium values can be calculated for the various treatments is available upon request.

could ask those students who invested less in the final periods why they reduced their investment levels. Typically the students were either responding to low investment levels of their rival (due to the rival free-riding) or trying to free-ride off the rivals investments. The students should reach this understanding quite naturally, and if they have had some game theory courses may relate the situation to that of the prisoners in the prisoners dilemma game.

	R&D Investment		**Production**	
	Average Outcome	Nash	Average Outcome	Nash
Treatment 1 No cooperation, no spillovers	13.30	18	6.25	6
Treatment 2 Cooperation, no spillovers	11.56	4	5.84	6
Treatment 3 No cooperation, spillovers	6.91	2	5.84	6
Treatment 4 Cooperation, spillovers	18.42	9	5.58	6

Table 3: Results from Classroom Experiment

Students may be interested to discuss if this is really an issue in R&D, that is, are there spillovers in reality and how would they arise? This type of discussion leads naturally into a lecture on R&D incentives. You can then ask students if they could think of ways to alleviate this problem. Is there a role for the government? Should collusion in R&D be legal under certain circumstances? The classroom discussion can then progress to the benefits of RJVs and the prevalence of them in various industries such as the semiconductor industry and the mining and manufacturing industry.[5]

Treatment 4 allows sellers to form RJVs, as can be seen from Table 3, investment decisions increase since the free-rider problem is eliminated. However, these levels are lower than those with no spillovers since each seller can benefit

[5] See Link (1996) for an overview research joint venture filings.

from the rival's investment decisions. Discussion can again begin by asking sellers if they choose different investment levels in treatment 4 and why. You could also focus on a seller who invested less than in the baseline treatment and ask why they choose to do so. Since cooperation is permitted each seller can reduce her own investment and benefit from the others investment decision. If you had the time to conduct treatment 3 prior to 4, then the benefits of RJVs will be evident. This is illustrated in Figure 1 where the average per-period R&D investment levels are shown for treatments 1, 3 and 4 as they emerged during experiments conducted during a summer school of the Economics Network for COmpetition and REgulation (ENCORE)[6].

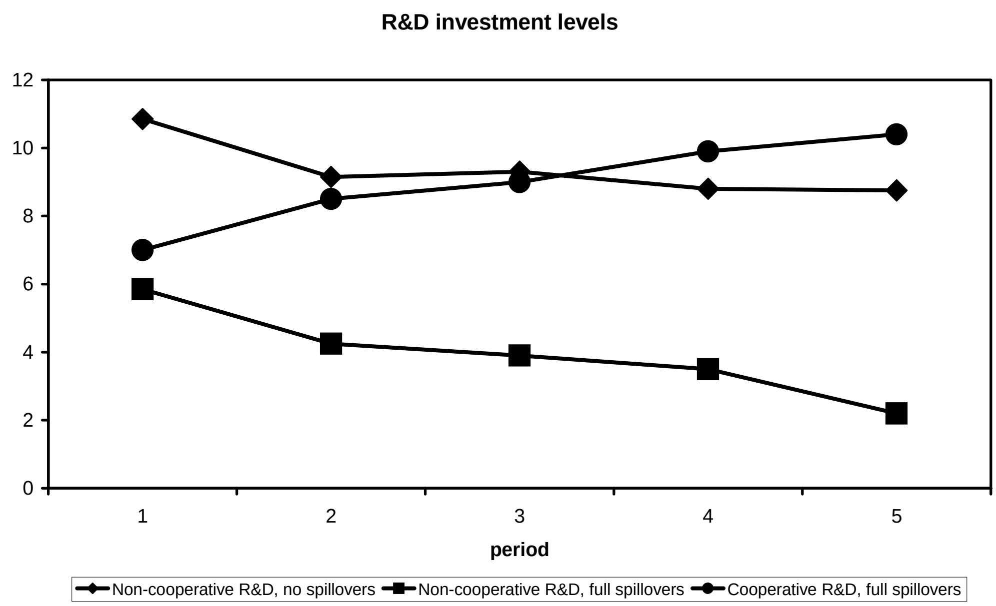

Figure 1: R&D Results from ENCORE summer school

But even if there was no time to conduct treatment 3, you can ask students if they would have invested the same amount if they didn't know what their rival was doing. If the free-rider problem isn't evident, you could single out a student and ask her what she would do if her rival invested 25 and why. Regardless of her answer, you can ask the class if anyone would have made a different decision.

[6] Participants in the ENCORE summer school were mostly government officials of the Dutch antitrust authority or the Dutch Ministry of Economic Affairs.

Once you have finished discussion surrounding the benefits of RJVs, you can discuss potential drawbacks. You may have observed ("illegal") cooperation in production levels. Students will typically respond honestly to the question, "were any of you deciding jointly how much to produce?" You may consider telling the students before you run the final round of the experiment. If output is set jointly then some students may "defect" by increasing their final round output level. We observed final round defection in the form of increased outputs in the majority of the experiments we conducted. Figure 2 contains the average per-period output decisions corresponding to the results in Figure 1. It suggests indeed that in treatment 4 in some markets production levels were jointly set.

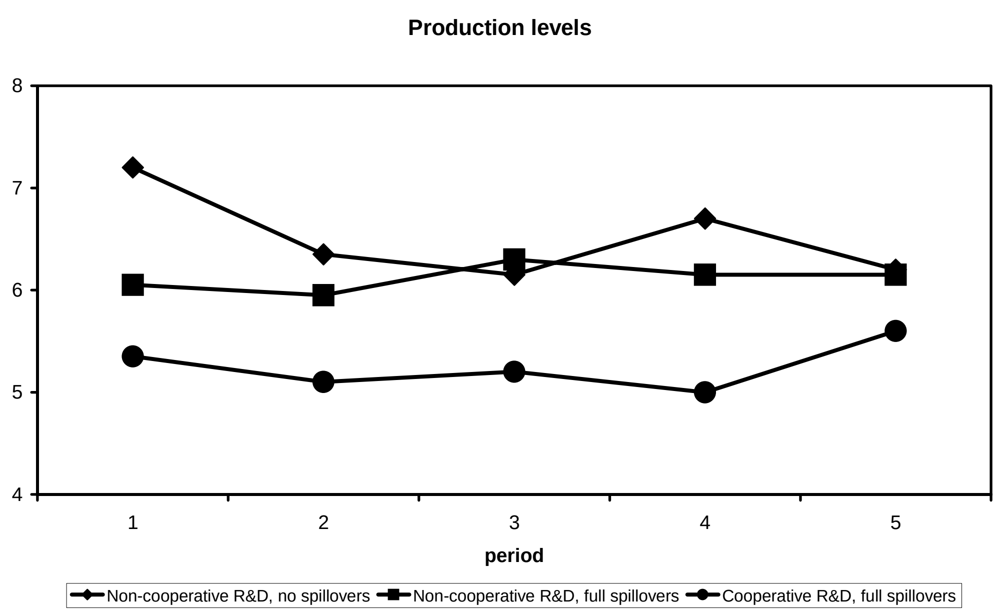

Figure 2: Output results from ENCORE summer school.

These results can motivate discussion of anti-trust policy and the fine line between encouraging investment while prohibiting collusion on output. To illustrate this trade-off you can discuss total welfare results under different treatments, as in Table 4.

	Consumer Surplus		Total Surplus	
	Average Outcome	Nash	Average Outcome	Nash
Treatment 1 No cooperation, no spillovers	78.13	82.65	128.36	128.57
Treatment 2 Cooperation, no spillovers	68.30	63.28	123.63	119.53
Treatment 3 No cooperation, spillovers	68.30	63.28	136.64	123.05
Treatment 4 Cooperation, spillovers	62.35	82.65	136.09	146.94
Control setting: cooperative output Cooperation, spillovers		50.00		125.00

Table 4: Results from a classroom experiment.

5 Further Reading

This paper describes an experimental game designed for use in undergraduate classrooms. The experiment can be used to teach concepts related to research joint ventures, spillovers, collusion, and government antitrust policy regarding investment in innovation. Our classroom paper is in the spirit of many others used as an aid in teaching topics common to industrial organization such as predatory pricing behavior, asymmetric information, rent seeking behavior, and auctions.[7] Wells (1991) and Williams and Walker (1993) provide surveys of the classroom experimental literature.

In addition to classroom experiments, numerous laboratory experiments explore issues related to industrial organization. Suetens (2004) investigates whether R&D cooperation leads to product market collusion for different levels of spillovers. She finds that the degree of price collusion in the final goods market is higher when research joint ventures are permitted. For a survey of

[7] See, for instance, Bergstrom and Miller (1997), Goeree and Holt (1999), Holt and Sherman (1999), and Capra *et al.* (2000) as well as the ongoing Classroom Games column in the *Journal of Economic Perspectives* edited by Holt.

the experimental industrial organization literature see Holt (1995) and Chapter 7 of Davis and Holt (1993).

A Instructions

In this experiment there are many independent markets in which the same good is exchanged. Each of you is a seller in one of the markets for a series of periods. You will be randomly paired with another seller, so in each market there will be two sellers. Each of you has 10 widgets to sell. For each widget that you sell you will incur a cost of 25. In each period, you can decide to make an investment which will lower your costs for that period. Every unit investment results in a cost reduction of the square root of the number of units invested. So if you decide to invest 4 units your production costs will be reduced by $\sqrt{4} = 2$. Each unit you invest costs 1. You can invest at most 25 units and your investment decision must be positive and an integer (*i.e.* you cannot invest half a unit). The following table illustrates the cost reduction (and resulting cost incurred from producing one widget) from each investment level.

invested	reduction	cost	invested	reduction	cost	invested	reduction	cost
1	1.0	24.0	10	3.2	21.8	19	4.4	20.6
2	1.4	23.6	11	3.3	21.7	20	4.5	20.5
3	1.7	23.3	12	3.5	21.5	21	4.6	20.4
4	2.0	23.0	13	3.6	21.4	22	4.7	20.3
5	2.2	22.8	14	3.7	21.3	23	4.8	20.2
6	2.4	22.6	15	3.9	21.1	24	4.9	20.1
7	2.6	22.4	16	4.0	21.0	25	5.0	20.0
8	2.8	22.2	17	4.1	20.9			
9	3.0	22.0	18	4.2	20.8			

The costs you pay per widget sold are determined in the following manner:

$$\text{cost } = 25 - \text{cost reduction} = 25 - \sqrt{\text{units invested}}$$

Once you have made your investment decision, write the number of units you wish to invest on your decision sheet, in the appropriate column for the current period. After all sellers have made their investment decisions we will collect your decision sheets and write the investment decisions on the blackboard.

When all of the decisions have been recorded on the blackboard we will return the decision sheets to you. You will then be asked to choose the number of widgets you wish to sell. All widgets that you sell will be sold at the same price. You can sell at most 10 widgets and the number of widgets offered must be positive and an integer. You must write the number of widgets you selected on your seller decision sheet, in the appropriate column for the current period. After all sellers have chosen the number of widgets to sell, the decision sheets will be collected and the quantity decisions will be written on the blackboard.

When all of the production decisions have been recorded on the blackboard we will return the decision sheets to you. The price you earn for each widget sold is 40 minus the total number of widgets sold by all sellers in your market. So if you decide to sell 4 widgets and the other seller in your group decides to sell 3 widgets then the sales price is: sales price$= 40 - 4 - 3 = 33$. When all sellers have made their quantity decisions the trading period ends and you can calculate your earnings for the period. Your earnings are determined in the following manner:

$$\text{earnings} = (\text{sales price} \times \text{quantity sold}) - (\text{unit cost} \times \text{quanity sold}) - \text{units invested}$$

You can use the attached table to calculate your earnings. Any questions? We will begin by having each seller choose an investment level, which you should record on your decision sheet.

B Decision Sheets

Seller Number : ___________________

		Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
1)	units you invest (max 25)						
2)	cost reduction (from table)						
3)	cost per widget (from table)						
4)	quantity widgets you offer (max 10)						
5)	total widgets offered in your market						
6)	price = 40 - (5)						
7)	price x quantity = (6) x (4)						
8)	cost x quantity = (3) x (4)						
9)	profit = (7) - (8) - (1)						
10)	cummulative profit						

Decision Sheets for Treatments without Investment Spillovers (1 and 3)

Seller number: _____________

		Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
1)	units you invested (max 25)						
2)	total units invested in market						
3)	cost reduction (from table)						
4)	cost per widget (from table)						
5)	quantity widgets you offer						
6)	total widgets offered in your market						
7)	price = 40 - (6)						
8)	price x quantity = (7) x(5)						
9)	unit cost x quantity = (4) x (5)						
10)	profit: (8) - (9) - (1)						
11)	cummulative profit						

Decision Sheets for Treatments with Investment Spillovers (2 and 4)

C Large R&D investments

units invested	cost reduction	cost	units invested	cost reduction	cost
1	1.0	24.0	26	5.1	19.9
2	1.4	23.6	27	5.2	19.8
3	1.7	23.3	28	5.3	19.7
4	2.0	23.0	29	5.4	19.6
5	2.2	22.8	30	5.5	19.5
6	2.4	22.6	31	5.6	19.4
7	2.6	22.4	32	5.7	19.3
8	2.8	22.2	33	5.7	19.3
9	3.0	22.0	34	5.8	19.2
10	3.2	21.8	35	5.9	19.1
11	3.3	21.7	36	6.0	19.0
12	3.5	21.5	37	6.1	18.9
13	3.6	21.4	38	6.2	18.8
14	3.7	21.3	39	6.2	18.8
15	3.9	21.1	40	6.3	18.7
16	4.0	21.0	41	6.4	18.6
17	4.1	20.9	42	6.5	18.5
18	4.2	20.8	43	6.6	18.4
19	4.4	20.6	44	6.6	18.4
20	4.5	20.5	45	6.7	18.3
21	4.6	20.4	46	6.8	18.2
22	4.7	20.3	47	6.9	18.1
23	4.8	20.2	48	6.9	18.1
24	4.9	20.1	49	7.0	18.0
25	5.0	20.0	50	7.1	17.9

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