PUBLIC SUBSIDIES AND COOPERATION IN R&D ACTIVITIES. WHAT DOES THE EXPERIMENTAL EVIDENCE TELL US?

Antonio Acconcia
University of Napoli "Federico II"& CSEF

Sergio Beraldo
University of Napoli "Federico II"& CSEF

Carlo Capuano
University of Napoli "Federico II"

Marco Stimolo
University of Salerno

Abstract. In this paper we examine the factors that foster firms' willingness to carry on R&D activities in a cooperative fashion, the way to efficiently target public subsidies to support such activities in markets characterized by varying degrees of competition and spillovers. We first review some key studies of a growing literature which applies the typical techniques of behavioural economics to the study of issues in the traditional domain of Industrial Organization. We then present the main findings of an experiment we have conducted at the University of Prague. Our main findings are the following. For certain spillovers-market competition combinations, the provision of public subsidies is not necessary to support cooperation, for firms would have cooperated anyway. As firms spontaneously cooperate even in the absence of public incentives - either when competition in the product market is low or when the level of spillovers is not low - any subsidy to support cooperation represents a waste of public funds.

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1. Introduction.

During the last decades, regional systems for innovation grounded in an extensive interaction between companies, universities and local governments have shown better than average results as far as both the generation of knowledge and the diffusion of innovations are concerned.

In many countries, public policies have therefore been aimed at smoothing the interaction between the relevant actors by supporting the foundation of technological districts.

A recurrent theme of many (EU) official reports surveying such policies is that innovation-enhancing programmes should be better designed to induce agents to behave cooperatively rather than strategically.[1]This means that the features of the environment in which firms interact must be taken into consideration, for firms' willingness to cooperate in R&D activities notably vary with both the market structure and the *quality* of the relationships among them.

In less developed areas, for example, where social trust is weak and small firms are not incline to cooperation, networks of large firms could be more effective. Similarly, in high trust environment characterized by trustworthy relationships, networks of small firms and local authorities may be associated with good performances.

Among all the factors that may have a relevant effect on firms' willingness to cooperate (by forming for example research joint ventures, RJV), the economic literature on the subject has mainly focused on: the presence of externalities, spreading out from R&D activities (spillovers); the level of competition in the product market.

The level of spillovers negatively affects, in principle, firms' incentive to invest in R&D,for market profits shrink alongside with the innovator's ability to catch the fruits of innovation. Hence, for high level of spillovers (i.e. above a critical value) firms might have an incentive to carry on joint R&D activities.

[1] It is well known that Article 101 of the TFEU prohibits horizontal agreements that could disrupt free competition. Regulation (EEC) No 2821/71 provides however an exemption of application in case of R&D agreements which contain provisions related to the assignment or licensing of intellectual property rights in order to carry out a joint R&D, paid-for R&D or joint exploitation. Indeed, the European Commission considers cooperation in R&D a cornerstone of economic growth. The Innovation Union, an action-packed initiative for an innovation-friendly Europe, is part of the Europe 2020 strategy whose aim is to create smart, sustainable and inclusive growth (European Commission, 2014).

The effect of market competition on firms' incentive to invest and/or cooperate in R&D is far less clear from a theoretical point of view, for such an effect depends upon many factors, including the characteristics of the invention and the extent of competition in the product market. Recent literature on the subject suggests that market competition and cooperation in R&D activities might be linked in an anti-monotone fashion[2].

In this paper we survey the laboratory evidence on the determinants of firms' R&D activities by focusing on two main issues; one related to the identification of the factors fostering firms' willingness to carry on such activities in a cooperative fashion; the other related to devising an efficient system of public subsidies to support R&D activities in markets characterized by varying degrees of competition and spillovers. As far as the first issue is concerned, we mainly review some key studies of a growing literature which applies the typical techniques of behavioural economics to investigate subjects in the traditional domain of Industrial Organization. As far as the second issue is concerned, we briefly survey the main findings of an experiment the authors of the present paper conducted at the University of Prague in 2014. A more comprehensive analysis of these findings will be available in a forthcoming paper.

The standard method to study the determinants of firms' investment behavior in R&D is based on the econometric analysis of real data.

For many issues of interest, as for instance the effects of spillovers on firms' willingness to cooperate in R&D, the available econometric evidence seems unable to provide clear-cut results (e.g. Cassiman and Veugelers, 2002). Other than that, in many situations the use of econometric techniques is simply prevented by the absence of available data, as it happens whenever a newly devised policy measure is under scrutiny.

In this case, recourse to Lab experiments can be particularly fruitful, for the effects of the policy measure can be simulated under a great variety of circumstances, and useful evidence can be collected to improve the policy design.

The one just discussed, *ex-ante policy evaluation*, is our main justification for the use of experimental techniques to investigate issues in the traditional domain of Industrial Organization. Another plausible justification however, the one most popular, is that the use of laboratory experimental is in many cases very useful to implement a first test of

[2] For empirical surveys see Griliches (1998), Cassiman and Veugelers (2002), Belderbos et al. (2004), Marinucci (2012), Ruble and Versaevel (2014).

whether available theoretical predictions are confirmed whenever subjects in the Lab are confronted with the same set of incentives that firms face in real markets.

Indeed, as perfectly controlled experiments make possible to get rid of disturbing factors, they permit to isolate the effect of any theoretically relevant determinants of firms' behavior.

Obviously, experimentalists devise worlds that are as similar as possible to the world described in the theoretical model, and are generally willing to argue in favor of the external validity of their results. In other words, they consider experimental results informative of firms' behavior *outside* the lab, an hypothesis that cannot be conclusively affirmed (on this see Guala 2005).

In this paper we take the different perspective of ex-ante policy evaluation as the main justification for the recourse to the Lab. We revise the results of an experiment conducted at the University of Prague whose aim was that of identifying the impact of public policies on R&D cooperation and investments.

By virtue of this, our experiment provides a working prototype (Plott 1996), that might be employed to enhance the efficacy of public policies aimed at increasing firms' cooperation rate in R&D in the real world.

The remainder of this chapter is organized as follows. In section 2, we survey the main theoretical results on firms' investment behavior in R&D. In this Section, we basically introduce the framework on which the experimental literature we subsequently review is based. In Section 3, we propose a description of three paradigmatic experiments on the causal relevance of spillovers and market competition on firms' investments in R&D. As far as these papers are concerned, recourse to the Lab is justified by the need of confirming clear-cut theoretical predictions. In section 4, we survey the result of our experiment on the impact of public policy on firms' cooperation rate (and investment levels) in R&D, making clear that our perspective is one of ex-ante policy evaluation. Section 5 concludes.

2. Cooperation in R&D activities: the theoretical framework.

Much of the focus of industrial organization models examining cooperation in R&D activities, concerned the way market competition alters the incentives of collaborative partnerships. The impact of knowledge spillovers has also been considered in theoretical analyses.

Knowledge or incoming spillovers are forms of "information leaks" that allow firms to obtain costless advantages from competitors' R&D activities. In *product R&D models* with a multiplicity of firms as potential investors, knowledge spillovers can be measured as the probability that one or more competitors can imitate the only innovating firm, so to have the possibility of selling a substitute of the innovative product. In *cost-reducing or process R&D models*, knowledge spillovers are considered as a sort of production externality, positively affecting the efficiency of the other firms in the same industry.

As Cassiman and Veugelers point out (2002), a significant distinction is between *incoming spillovers*, positively affecting the rate of innovation of the relevant firm, and *imperfect appropriability*, negatively affecting the ability of firms to reap the benefits from innovation.

On one hand, *imperfect appropriability* increases the benefits from R&D agreements among firms: when spillovers are high enough, i.e. above a critical level, firms that cooperate are expected to invest more on R&D activities (earning higher profits) compared to firms which act autonomously. On the other hand, however, imperfect appropriability increases the incentives to free ride on other firms' R&D investments. Clearly, imperfect appropriability represents a source of inefficiency whenever it is such as discouraging the overall R&D activity by the firms.

The paradigmatic framework for analyzing R&D investment decisions in presence of spillovers is the one provided by D'Aspremont and Jacquemin (1988) who analyze the case of duopolistic competition within a homogeneous good industry. As this model has structured the way the subsequent literature on the subject (especially the experimental literature) has dealt with the problem, we briefly sketch here its main characteristics.

The model by D'Aspremont and Jacquemin (1988) has the following two-stage game structure: in the first stage firms invest in cost reducing R&D activities (precompetitive stage); in the second stage firms compete by choosing the level of production (competitive stage).

This simple two-stage game can be conceived as played in three different scenarios. In the first one, firms act non-cooperatively in both output and R&D. In the second scenario, cooperation in R&D comes about alongside with competition in the product market. The third scenario corresponds to a cartel in which firms cooperate/collude in both stages of the game.

The model at issue delivers two key results. First, the presence of spillovers decreases R&D efforts by non-cooperative firms. Second, for high levels of spillovers, cooperation in R&D increases investments in R&D with respect to the non-cooperative scenario.

The large majority of models dealing with R&D cooperation and spillovers shares the same basic structure of the framework just illustrated. Indeed, it is usually assumed that any firm first chooses the level of R&D activity, either coordinating its choice with that of its opponent(s) or not, and then it competes with its rivals (where the choice variable is either the price or the quantity to be offered)[3].

To sum up, what the standard analysis suggests is that imperfect appropriability may reduce private incentives to innovate well beyond a socially optimal level. This opens the room to public intervention.

Despite many authors claim that public intervention is necessary to boost socially beneficial cooperation in R&D, work on the characteristics that a suitable intervention should possess remain scarce, as well as work on the features that a suitable policy should have according with key environmental factors such as the presence of spillovers and the strength of market competition. As emphasized above, the present article constitutes a step to fill this gap in the literature, analyzing the determinants of firms' R&D activities.

3. **Experimental approach to R&D Cooperation in presence of spillovers.**

In this section we survey three paradigmatic experiments that identify spillovers and the level of competition in the product market as crucial causes to explain the dynamics of firms' investments in R&D. Moreover, the experiments at issue clarify how these parameters affect firms' willingness to cooperate in R&D.

How it will become clear later, experimental analyses, in line with the theoretical literature, generally identify: a negative relationship between firms' willingness to

[3] In examining the class of models whose main characteristics have just been outlined, two things are worth noticing. First, even though it is not possible to exclude that, in principle, R&D cooperation may facilitate coordination in the product market, it is broadly accepted the conclusion that R&D cooperation does not necessarily lead to collusion. Second, the class of models at hand usually assumes that firms compete by choosing the production level of an homogenous good. However, it is fairly clear that differentiation in the product market makes appropriability more effective. As Bondt and Veugelers (1991) have argued, high product differentiation, i.e. imperfect product substitution, moderates the disincentive to invest in R&D. Notice that the idea that the presence of spillovers (imperfect appropriability) lowers the incentives to engage in R&D activities is supported also if stochastic R&D processes are assumed (e.g. Choi, 1993).

autonomously invest in R&D and the level of spillovers (e.g. Isaac and Reynolds 1988); stronger incentives to subscribe *symmetric* binding contracts to invest cooperatively in R&D whenever higher spillovers are present (Suetens 2005).

Besides this, experimental analyses also show that firms' willingness to cooperate in R&D depends negatively on the level of competition they face in the product market. This occurs because with low levels of competition, R&D cooperation reduces production costs without reducing firms' market profits.

A natural extension of these experiments would be to test the impact of public policies on firms' cooperation in R&D given both the presence of spillovers and the strength of market competition . This is the kind of extension we discuss in the next Section.

3.1 *The effect of spillovers and market structure on R&D investments when cooperation in not allowed*

In their paper, Isaac and Reynolds (1988) tackled the issue of the impact of spillovers and market structure (i.e. the size of the industry) on firms' R&D investment, by considering a single-period non-cooperative game. In their setting, each subject (firm) decides the R&D activity level being aware that success in innovation (a new marketable product) is stochastic and that the higher the level of R&D activity is, the higher the probability of innovation (if more firms succeed in innovating, then they will share the market profits).

The experiment by Isaac and Reynolds (1988) tested two theoretical hypotheses. First, lower appropriability leads to lower investment in R&D. Second, an increase in the number of market competitors raises the *aggregate* level of R&D investment, but lowers the *individual* R&D activity level[4].

Experimental results were consistent with the prior that individual effort in R&D activities increases along with appropriability. It is noteworthy that evidence was found

[4]Isaac and Reynold (1988) operationalized the R&D investment decisions by letting the experimental subjects to draw, at a fixed per unit cost, balls from a container. At any round, subjects could decide how many balls to draw, bearing the relative cost of their choice. The balls were numbered from 1 to 10 and any number indicated the probability (ρ) of innovation, with number 10 indicating that the subject was successful at innovating (i.e. $\rho = 1$).

on the influence of the market structure on firms' investment behavior (the mean number of draws *per person* resulted greater in smaller groups, see footnote 4).

3.2 *The effect of spillovers on firms' cooperation in R&D*

In a non-cooperative environment, the reduction of investment in R&D when the level of appropriability is insufficient is a rational strategy. However, the possibility of subscribing binding contracts where firms commit to share an agreed level of R&D investment, significantly changes the payoffs of the game because firms can internalize spillovers. This is the crucial result of d'Aspremont and and Jacquemin (1988)'s model tested by Sigrid Suetens in her 2005 paper.

Suetens aimed at measuring the impact of spillovers on firms' cooperation rate in R&D through an experimental design where subjects played a duopolistic two-stage game: at the first stage, firms had to make their investment decisions in R&D, while at the second stage production quantities were fixed at their Cournot-Nash equilibrium. R&D decisions were repeated for 27 rounds to allow for learning.

The author run two non-cooperative treatments (baseline and cheap-talk treatment) and a contract treatment. Each treatment was replicated for the most separated levels of spillover: i.e. no or full spillover.

In the baseline treatment subjects played a non-cooperative R&D game. In the cheap-talk treatment each subject could send to the other player non-binding signals communicating the intended level of investment in R&D. The possibility of subscribing symmetric binding contracts was instead given to subjects in the contract treatment (they could commit to equally share an agreed level of investment in R&D).

This design aimed at testing two main hypotheses: 1) Spillovers negatively affect non-cooperative investments in R&D; 2) Spillovers positively affect cooperative investments in R&D.

In the baseline treatment, the investment levels in the zero-spillover scenario higher than in the full-spillover scenario. This result confirmed the theoretical prior that in presence of spillovers firms have incentive to reduce their R&D investment. In the contract treatment with full-spillover investment levels in R&D were at the cooperative level and

systematically higher than the investment levels in the baseline treatment. This evidence suggests it was profitable to internalize spillovers through symmetric binding contracts[5].

3.3*The effect of market competition on firms' cooperation in R&D.*

The level of competition is an additional factor that might influence firms' cooperation rate. Silipo (2005) tackled this issue by means of both theoretical analysis and experimental investigation.

The author provided a deterministic patent-race model with the following characteristics. Two firms invest in R&D for a number of periods, until they accumulate the relevant amount of knowledge necessary for an innovation to occur. During this race, the two firms can build a research joint venture (RJV) and share the costs of R&D. Nevertheless, in each period firms are free to breach the agreement, autonomously investing in R&D. If just one firm is successful in the discovering process then it realizes monopoly profits. If both firms are successful, a random mechanism selects the (only) winner. Finally, if both firms innovate through cooperative investments in R&D (i.e. they *jointly* discover the innovation), then they share market profits.

Given the incentive structure of the game, Silipo's tested two theoretical priors for two exogenously fixed levels of competition. If the level of market competition is high, then firms will cooperate at the very beginning, but will break up the RJV at the end of the race. The rationale of this hypothesis is a trade-off between the incentive to reduce the cost of innovation through cooperation at the beginning of the race, and the incentive to get monopoly profits in the product market. It is reasonable to assume that the incentive to get monopoly profits outweighs the incentive to reduce production costs when the end of the race is approaching. If market competition is low, then firms will cooperate throughout the patent race up to the joint discovery of the innovation because this will *certainly* provide market profits close to monopoly profits.

[5] An anomalous result of Suetens's experiment was that in the cheap-talk treatment, R&D investments were close to the cooperative level in the full-spillover scenario, and to the Nash-equilibrium in the zero-spillover scenario. The result is anomalous for the Nash-equilibrium of the cheap-talk treatment is equivalent to the one of the non-cooperative game of the baseline treatment. By virtue of that, in the cheap-talk treatment with full spillovers, R&D investments should not be at the cooperative level. Suetens explained this anomaly as a framing effect. More precisely, firms started to cooperate in the cheap-talk treatment because the signals, though not binding, framed the strategic interaction as a cooperative game. Therefore, given the framing effect, the full-spillover scenario provided incentives to cooperate.

Silipo tested these predictions through an experimental design that exactly mimics the theoretical model. The level of competition was exogenously varied by awarding the winners with either a low or a high market prize (high prize indicates low competition).

Experimental results were supportive of the theoretical predictions. First, Silipo observed a higher rate of joint discoveries in patent races with a high prize than in patent races with a low prize. This finding supported the hypothesis of a negative relation between firms' willingness to cooperate and the level of competition in the product market. Furthermore, the author found that the probability of cooperating throughout the race was higher in the high-prize scenario than in the low-prize scenario. This evidence supported the theoretical prior that cooperation is a persistent strategy when market competition is expected to be low.

4.**Experimental economic policy**

The experiments described in the previous Section are silent on the relevance of public policy on firms' investment behaviour in R&D[6]. In particular, nothing has been said on how the information on the degree of appropriability and the strength of market competition can be used to discriminate between cases where socially beneficial cooperation emerges spontaneously from cases in which public intervention is necessarily required. Next section briefly survey the main features and some of the key results of an experiment the authors of the present paper conducted at the University of Prague. This experiment shows how spillovers and market competitions are crucial to efficiently target public subsidies to R&D activities. As discussed above, what motivates the use of experimental techniques is, in our case, the need of *ex-ante policy evaluation*, rather than the will of testing a particular theoretical prediction.

As it will become clear shortly, the case we analyze (the provision of subsidies to firms which decide to cooperate in R&D activities) is one in which recourse to the Lab is particularly fruitful, for the effects of the policy measure can be simulated under a great variety of circumstances, and remarkable evidence can be collected to improve the policy design.

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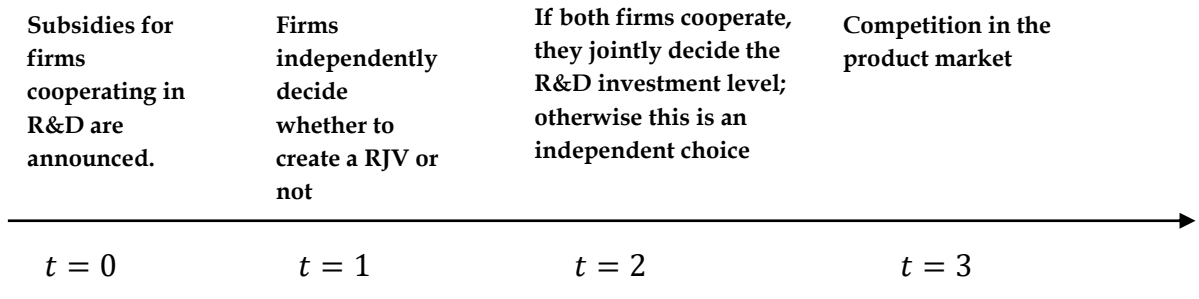
[6]The experimental literature on policy issues has mainly analyzed the inefficiencies of subsidies allocations viewed from the angle of the right incentives for firms to reveal truthfully the necessary funding for R&D (Giebe *et al.*, 2006).

4.1.*Targeting transfers to firms to support R&D activities: from the theoretical framework to the experimental evidence.*

The experiment whose results we briefly review in this Section is inspired by a theoretical framework proposed by Capuano (2014). This framework has the following characteristics: duopolistic firms may agree (with binding contracts) to coordinate their R&D activities for developing a new product. The innovation process is stochastic and R&D investments are characterized by decreasing returns to scale. Firms can create a RJV allowing them to fully internalize knowledge spillovers and share the cost of R&D investments (it helps also in avoiding fixed costs duplication). If no agreement is being reached (the non cooperative option), each firm independently decides its R&D expenditure level, being aware that its competitor will be able, with a given probability, to get advantage from the product innovation (possibly) made available by its investment (presence of spillover effects).

The model setting considers as exogenous the level of spillovers and product differentiation in the final market. As shown in Figure 1, Capuano (2014) models firms' interaction as a non-repeated four-stage game with complete information. At time $t = 0$, the decision maker announces the lump-sum subsidy firms can get if they cooperate in R&D; at time $t = 1$, firms simultaneously decide whether to create a RJV or not; at time $t = 2$, firms decide investment levels, jointly or independently, depending on the history of the game; finally, at $t = 3$, once R&D outcomes and spillovers are observed, each firm independently decides the production level.

Figure 1. Timing of the game.



The proposed theoretical framework suggests that in equilibrium (SPNE) the private incentive to cooperate in R&D is positively affected by the level of knowledge spillovers and negatively conditioned by the level of product differentiation. Moreover, since cooperation increases appropriability of R&D returns and avoids duplication of fixed costs, the level of per firm investment can either increase or decrease when subsidies induce firms to cooperate.

Focusing on the theoretical relation between cooperation and subsidies, policy implications are twofold. On the one hand, when the decision maker is not concerned in implementing cooperation *per se*, but rather in increasing expected welfare, providing subsidies not contingent to market conditions does not qualify as an efficient use of public resources. This occurs, for example, whenever firms have sufficiently high private incentives to spontaneously cooperate and jointly invest in R&D (as it is in presence of high spillovers and high product differentiation).

Moreover, in all the cases in which subsidies are necessary for cooperation to occur, they should vary according to the structural characteristics of the markets. In particular, optimal subsidies have to be designed as a decreasing function of both the level of knowledge spillovers and the level of product differentiation in the final market.

In terms of input-additionality, it is important to highlight that a reduction of the average investment level after the introduction of subsidies is not an unambiguous measure of public policy ineffectiveness.

The experiment we discuss shortly aimed primarily at checking how private incentives to invest in R&D perhaps cooperatively are affected by some key structural characteristics of the market (presence of knowledge spillovers and product differentiation) and by a system of public subsidies.

4.2. *Experimental design*

In this section we illustrate our experimental design. It extends Sueten's (2005) experimental setting by inducing uncertainty on the outcome of the innovation process, in the spirit of the stochastic invention model that Isaac and Reynolds (1988) first tested in the lab.

Our experimental setting uses two key parameters: β, a stochastic measure of knowledge spillovers, and α, the ratio between duopolistic and monopolistic profit which

we interpret as an inverse measure of competitiveness in the product market[7]. The combination of specific values of these parameters can be used to single out cases where socially beneficial cooperation emerges spontaneously and cases where public intervention is needed to induce firms to coordinate their R&D investments.

We run an experiment with the following characteristics. At any period subjects are randomly matched to play a static three-stage game[8]. In the first stage any pair must agree on whether to carry on a joint R&D activity or not; in the second stage, investment decisions are taken, being aware that, in the third stage of the game, production is fixed at the Cournot-Nash equilibrium.

Subjects played the three-stage game 25 times (rounds). At any repetition, participants were endowed with 200 monetary units and they could invest any amount of it, possibly keeping the remaining units for themselves. The probability of success in innovation was set as an increasing function of the investment levels (however, the highest possible investment level granted success with a probability of about 0.5).

In the first stage of the game subjects had to decide whether to coordinate their investments in R&D or not. Before deciding that, participants were informed about the expected payoff associated to any combination of investment levels both for the cooperative and the non-cooperative scenario. If subjects decided to coordinate their actions, they could jointly choose the level of investment by subscribing a symmetric (binding) contract. In this case, if at least one subject was successful at innovating, both individuals could internalize spillovers and get duopoly profits.

Subjects could use a profit calculator to simulate the expected payoffs for any possible joint level of investment in such a way as to formulate a (consistent) proposal to the other player.

In this experimental setting the non-cooperative scenario occurs either because subjects decide not to coordinate their investments at the outset, or because they fail to subscribe an agreement in the contracting phase.

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[7]When final products are strongly differentiated firms profits are weakly affected by the presence of competitors, so duopolistic profits are very close to monopolistic ones, we have high appropriability of R&D investment and α tends to be close to 1. Conversely, when we consider homogenous final goods, monopolistic profits are significantly higher than duopolistic ones, the latter tend to zero when we assume Bertrand competition and α tends to zero.

[8] As emphasized above, the theoretical model considers a fourth stage in which the decision-maker sets the level of subsidies granted to cooperative firms. During the experiment, subjects obviously receive the relevant information about the decision-maker's choice.

In the non-cooperative scenario subjects are free to decide their investment in R&D autonomously[9].

The experimental markets differed along two dimensions: the strength of competition, defined as the level of market differentiation, and the level of spillovers, i.e. the probability that full appropriability does not occur.

Given the payoff functions, we varied the values of α and β in such a way as to single out the cases in which public subsidies are necessary for cooperation to come about.

The experiment tested the following theoretical hypotheses, corresponding to the sub-perfect Nash equilibrium of the game:

- given market competition, higher level of spillovers induce lower levels of autonomous R&D investments and greater cooperation among firms;
- given spillovers, stronger market competition induces lower R&D investments and greater cooperation among firms;
- given spillovers, cooperation reduces R&D investment levels in presence of strong market competition (the reverse occurs for low levels of market competition).

The rationale behind these hypotheses is to be found in the fact that in markets with high spillovers and weakly differentiated products the appropriability of returns deriving from R&D is severely reduced. Indeed, in these markets, the expected duopolistic profits tend to zero even though firms innovate. The grounding intuition behind the last hypothesis is based on the tradeoff between two distinct effects. On one hand, cooperation, by fully internalizing spillovers, increases the probability that firms obtain non-zero profits and this stimulates cooperating firms to invest more. On the other hand, cooperating firms never become monopolistic; this reduces the incentives to invest, in particular when market competition, decreasing duopolistic profits, significantly reduces the expected payoff of cooperation. In other words, when competition is strong, the mirage to become monopolistic induces non-cooperative firms to invest more.[10]

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[9]In the non-cooperative scenario, if both subjects innovate they get (Cournot) duopoly profits (equal to a proportion α of the monopoly profits, the latter being equal to 1000 monetary units). Moreover, if only one subject innovates the other can imitate its competitor without bearing any cost with probability β; in this latter case both subjects get duopoly profits.

[10] This result is well-established in literature, in particular dealing with (tournament) patent races where in absence of spillovers we never observe oligopolistic competition after innovation but "the winner takes all". In this context, Mortensen (1982) explains that the non-cooperative solution to this kind of games has the

To study the impact of public policies on investment decisions, we replicated the six (α,β) combinations in six treatment groups where we provided a public subsidy of 30 monetary units to firms that chose to cooperate[11]. To avoid sequence effects, we provided public subsidies to cooperating firms only from the 7th to the 21th round.

We tested the hypothesis that subsidies increase the willingness to cooperate in R&D activities, although they can discourage, at least in some cases, the levels of individual and aggregate R&D investments.

Table 2 illustrates the cases in which the sub-game perfect Nash equilibrium of the game induces cooperation in R&D activities, given the payoff function of the players.

Table 2. α-β combination and expected decisions about cooperation in R&D activities (Control and Treatment Groups).

	Control groups (without subsidies)		**Treatment groups (with subsidies)**	
	β_{Low}	β_{high}	β_{Low}	β_{high}
α_{Low}	Non-cooperation	Non-cooperation	Non-cooperation	Cooperation
α_{Medium}	Non-cooperation	Cooperation	Cooperation	Cooperation
α_{High}	Cooperation	Cooperation	Cooperation	Cooperation

4.3Implementation

The experiment was conducted at the University of Economics of Prague (Vysoka Skola Ekonomicka) from the 27/10/2015 to the 4/11/2015, and it was programmed with the Ztree software (Fischbacher 2007). A sample of 120 students of economics from the University of Economics and Charles University of Prague were randomly selected from the database of the Laboratory of Experimental Economics (LEE) and formally recruited via e-mail. We organized 12 experimental sessions: i.e. 6 sessions for the control groups and 6 sessions for the treatment groups. Each session comprised a group of 10 subjects.
Participation granted a show-up fee of 100 CZK (3.7 Euros). Furthermore, the amount of monetary units that subjects gained at the end of the experiment was converted in CZK at

property that all firms invest "too much" in R&D in a Pareto sense; a sort of Prisoner's dilemma occurs and ex ante agreement of cooperation is one way to resolve the dilemma.

[11] Subsidies are set at a fixed level, and are independent from the values of □ and □.

an exchange rate that varied in accordance with the characteristics of each experimental market. Once assigned to their slot position, subjects found on their desk the instructions of the experiment and two tables with the classes of expected payoffs both for the cooperative and the non-cooperative scenario. Subjects were asked to stay in their slots without talking to each other to preserve the anonymity of the game. At the beginning of the experiment, subjects had to read carefully the instructions of the game, which were also publicly illustrated. Afterwards, they were required to answer to a questionnaire, aimed at testing their comprehension of the rules of the experiment.

We established that the first round of the experiment was just for practice, while the remaining 26 rounds were all payoff relevant.

4.4 Results

We briefly survey the main results of the experiment in Tables 3-6. In Table 3, we report the probability of cooperation in R&D for different combinations of the parameters α and β. It is easy to check that both in the control and in the treatment group the probability of cooperation increases with spillovers. Moreover, it increases, given spillovers, along with the strength of market competition. As expected, the introduction of subsidies generally increases the individual's willingness to cooperate for any given (α,β)-pair. The observed average willingness to cooperate indeed varies between 62 and 80% whenever cooperation was expected. Notice that, without subsidies, firms spontaneously cooperate either when α is high (i.e. low competition in the final market) or when α is high but β is not low (high spillovers with moderate or low competition in the market). In terms of policy assessment, these are cases with high appropriability of investment in R&D, in which, as expected, any subsidy to support cooperation represents a waste of public funds.

Table 3.Average willingness to cooperate in control and treatment groups (rounds 7-21)

	Control (S=0)		**Treatment (S=30)**	
	β_{Low}	β_{high}	β_{Low}	β_{high}
α_{Low}	0.23	0.35	0.46	0.62
α_{Medium}	0.34	0.64	0.72	0.75
α_{High}	0.71	0.74	0.80	0.74

Table 4 reports the levels of investment in R&D when firms do not cooperate, for different combinations of the parameters α and β, in the control and treatment groups; while Table 5 reports the correspondent values when firms cooperate.

Table 4. Average investment levels when firms do not cooperateas a share of the endowment (rounds 7-21).

	Control (S=0)		**Treatment (S=30)**	
	β_{Low}	β_{high}	β_{Low}	β_{high}
α_{Low}	0,53	0,25	0,72	0,14
α_{Medium}	0,63	0,30	0,70	0,34
α_{High}	0,73	0,48	0,57	0,28

A glance to Tables 4 and 5 makes clear that both in the control and in the treatment groups the average level of investment in R&D decreases when spillover increase; given the level of spillovers, the average level of investment in R&D generally increases with market competition.

Table 6 reports the differences between the levels of investments when firms cooperate and when firms do not. With respect to the non-cooperative case, cooperation decreases the level of investments in R&D for low values of α and any values of β, while the reverse occurs for high values of α. Moreover, for medium values of α cooperation decreases investments in R&D only in presence of low values of β. This is true both in the control and in the treatment groups.

Table 4. Average investment levels when firms cooperate, as a share of the endowment (rounds 7-21).

	Control (S=0)		**Treatment (S=30)**	
	β_{Low}	β_{high}	β_{Low}	β_{high}
α_{Low}	0,42	0,19	0,32	0,11
α_{Medium}	0,53	0,46	0,44	0,43
α_{High}	0,75	0,64	0,76	0,68

Table 5. Differences between average cooperative investment levels and non-cooperative ones (as a share of the players' endowment)(rounds 7-21).

	Control (S=0)		Treatment (S=30)	
	β_{Low}	β_{high}	β_{Low}	β_{high}
α_{Low}	-0,11	-0,06	-0,40	-0,03
α_{Medium}	-0,09	0,16	-0,27	0,09
α_{High}	0,02	0,16	0,19	0,41

Other than confirming the above mentioned sub-perfect Nash hypotheses concerning the effects of market competition and spillovers on firms' R&D activities, the preliminary descriptive analysis of data accruing from the Lab provided a clear support to the expectation of a positive impact of public subsidies on firms' cooperation rate in R&D.

More importantly, they clearly indicated that for certain spillovers-market competition combinations, i.e. for certain combination of *structural* characteristics of the market, the provision of public subsidies is not necessary to support cooperation, for firms would have cooperated anyway.

Indeed, as expected, the introduction of subsidies generally increases the individual's willingness to cooperate for any given (α,β)-pair.

However, firms cooperate even in the absence of public incentives, either when α is high (i.e. low competition in the final mark set) or when α is high but β is not low (high spillovers with moderate or low competition in the market). In terms of policy assessment, these are cases with high appropriability of investment in R&D, in which, any subsidy to support cooperation represents a waste of public funds.

Conclusive remarks

In this paper we surveyed the laboratory evidence on the determinants of firms' R&D activities by focusing on two main issues: the factors that foster firms' willingness to carry on R&D activities in a cooperative fashion; the way to efficiently target public subsidies to support R&D activities in markets characterized by varying degrees of competition and spillovers.

As far as the first issue is concerned, we mainly reviewed some key studies of a growing literature which applies the typical techniques of behavioural economics to the study of issues in the traditional domain of Industrial Organization. As far as the second issue is concerned, we briefly surveyed the main findings of an experiment the authors of the present paper conducted at the University of Prague in 2014.

As emphasized at length above, the standard method to study the determinants of firms' investment behavior in R&D is based on the econometric analysis of real data. However, in many situations, the use of econometric techniques is simply prevented by the absence of available data, as it happens whenever a newly devised policy measure is under scrutiny. We believe that, in cases like this, recourse to the Lab can be particularly fruitful, for the effects of the policy measure can be simulated under a great variety of circumstances and useful evidence can be collected to improve the policy design.

The one just discussed, *ex-ante policy evaluation*, is the motivation we propose for the use of experimental techniques to investigate issues such as the effects of public subsidies on firms' R&D activities.

The simple analysis provided in this paper supports the prior that public subsidies exert a positive impact on firms' cooperation rate in R&D.

As far as the policy design is concerned, the most interesting result is that for certain spillovers-market competition combinations, the provision of public subsidies is not necessary to support cooperation, for firms would have cooperated anyway.

As firms spontaneously cooperate even in the absence of public incentives - either when competition in the product market is low or when the level of spillovers is not low - any subsidy to support cooperation represents a waste of public funds.

This suggests that the decision maker should pay more attention to the characteristics of the environment in which agents interact, in such a way as to improve the targeting of transfers and, in so doing, the allocation of societal resources.

As the use of experimental techniques constitutes an useful support to simulate the effects of a policy measure under a great variety of circumstances, it constitutes a valid instrument to improve the quality of public decision making.

References

Belderbos, R.; Carree,M. and Lokshin,B. (2004). Cooperative R&D and firm performance. Research Policy. 33 (10), 14771492.

Bondt, R. and R. Veugelers, 1991, "Strategic investments with spillovers," European Journal of Political Economy, 7, 345--366.

Capuano, C., 2014, "Spillovers di conoscenza e innovazione di prodotto: è sempreefficientesussidiare le imprese?", working paper prepared for the 53th Annual Scientific Conference of the Italian Economic Society (SIE), Trento, 23-25 October 2014 [available at: http://www.siecon.org/online/wp-content/uploads/2014/10/Capuano-346.pdf]

Cassiman, B. and R. Veugelers, 2002, "R&D cooperation and spillovers: some empirical evidence from Belgium", American Economic Review 92(4), 1169 - 1184.

Choi, J.P., 1993, "Cooperative R&D with Product Market Competition", International Journal of Industrial Organization 11, 553-71.

d'Aspremont, C. and Jacquemine A., 1988, "Cooperative and noncooperative R&D in duopoly with spillovers", The American Economic Review, 78(5), 1133-37.

De Bondt, R. and J. Vandekerckhove, 2012, "Reflections on the relation between competition and innovation". Journal of Industry, Competition and Trade 12 (1): 7-19.

European Commission (2014). "State of the Innovation Union, Taking Stock 2010 – 2014", Staff Working Document, available at http://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2013/state_of_the_innovation_union_report_2013.pdf.

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. Experimental economics, 10(2), 171-178.

Giebe, T., Grebe, T. and Wolfstetter, E., 2006. How to allocate R&D (and other) subsidies: An experimentally tested policy recommendation. Research Policy, 35(9), 1261-1272.

Griliches, Z., 1998. Issues in Assessing the Contribution of Research and Development to 22 Productivity Growth. R&D and Productivity: The Econometric Evidence. National Bureau of Economic Research, Inc.

Guala F. (2005), *Methodology of Experimental Economics*. Cambridge University Press.

Isaac, R. M., and Reynolds, S. S., 1988. Appropriability and market structure in a stochastic invention model. The Quarterly Journal of Economics, 647-671.

Jaffe, A., 1989, "The Real Effects of Academic Research.", American Economic Review 79: 957-970.

Marinucci, M., 2012. "A primer on R&D cooperation among firms," Questioni di Economia e Finanza (Occasional Papers) 130, Bank of Italy, Economic Research and International Relations Area

Mortensen, D., 1982, "Property Rights and Efficiency in Mating, Racing, and Related Games," American Economic Review, LXXII, 968-79.

Plott, C. R. (1997), "Laboratory and experimental testbed: Application to the PCS auction," Journal of Economics and Management Strategy 6, 605-638.

Ruble R, B. Versaevel, 2014, "Market shares, R&D agreements, and the EU block exemption", International Review of Law and Economics 37:15-25.

Silipo, D. B., 2005. The evolution of cooperation in patent races: Theory and experimental evidence. Journal of Economics, 85(1), 1-38.

Suetens, S., 2005. Cooperative and noncooperative R&D in experimental duopoly markets. *International Journal ofIndustrial Organization* 23, 63–82.