January 2022

(Updated version)

Fondazione Eni Enrico Mattei

Working Paper

02.2022

Public subsidies and cooperation in research and development. Evidence from the lab

Antonio Acconcia, Sergio Beraldo, Carlo Capuano, Marco Stimolo

Public subsidies and cooperation in research and development. Evidence from the lab*

By **Antonio Acconcia**,University of Naples 'Federico II' and CSEF
Sergio Beraldo, University of Napoli 'Federico II' & CSEF
Carlo Capuano, University of Napoli 'Federico II' & CSEF
Marco Stimolo, Department of Economic and Social Sciences, Università Politecnica delle Marche

Summary

We implement an experimental design based on a duopoly game in order to analyse the impact of public subsidies on the willingness to cooperate in research and development (R&D) activities. We first implement six experimental markets by exogenously varying the level of knowledge spillovers (low or high) and the intensity of competition in the product market (low, intermediate, or high). We find that the probability of cooperation increases in the level of spillovers and decreases in that of market competition. We then replicate the six experimental markets by subsidising subjects who cooperate. Whenever they are sufficient to change the incentive structure of the game, subsidies substantially increase the probability of cooperation, causing, however, a reduction of R&D investments. Overall, our evidence suggests that, depending on the characteristics of the market, the provision of subsidies is not always desirable. These might be redundant because firms have sufficient private incentives to invest cooperatively in R&D, or even counterproductive, as they might induce firms to significantly reduce R&D investments compared to the noncooperative scenario.

Keywords: Cooperation in R&D; Public subsidies; knowledge spillovers; market competition.

JEL Classification: L24, O3.

Address for correspondence:
Marco Stimolo
Department of Economic and Social Sciences,
Università Politecnica delle Marche, Piazzale R. Martelli, 8, 60121, Ancona, Italy
E-mail address: m.stimolo@staff.univpm.it

**This is the latest version of the paper, submitted in May 2023 after substantial revision carried out by the Authors. The first version appeared in FEEM Working Papers 'Note di Lavoro' in January 2022.*

PUBLIC SUBSIDIES AND COOPERATION IN RESEARCH AND DEVELOPMENT. EVIDENCE FROM THE LAB[*]

Antonio Acconcia[†]

Sergio Beraldo[‡]

Carlo Capuano[*]

Marco Stimolo[§]

Abstract. We implement an experimental design based on a duopoly game in order to analyse the impact of public subsidies on the willingness to cooperate in research and development (R&D) activities. We first implement six experimental markets by exogenously varying the level of knowledge spillovers (low or high) and the intensity of competition in the product market (low, intermediate, or high). We find that the probability of cooperation increases in the level of spillovers and decreases in that of market competition. We then replicate the six experimental markets by subsidising subjects who cooperate. Whenever they are sufficient to change the incentive structure of the game, subsidies substantially increase the probability of cooperation, causing, however, a reduction of R&D investments. Overall, our evidence suggests that, depending on the characteristics of the market, the provision of subsidies is not always desirable. These might be redundant because firms have sufficient private incentives to invest cooperatively in R&D, or even counterproductive, as they might induce firms to significantly reduce R&D investments compared to the noncooperative scenario.

JEL Classification: L24, O3.

Keywords: Cooperation in R&D; Public subsidies; Knowledge spillovers; Market competition.

---

[*] **Acknowledgments**. Funding support by POR Campania – European Social Fund (REPOS Project) – is gratefully acknowledged. This project is part of the activities of the project “Innovation, digitalization and sustainability for the diffused economy in central Italy” research unit of the Università Politecnica delle Marche, Department of Economic and Social Sciences, Ancona (Italy). We are grateful to an anonymous referee and one of the editors-in-chief of this journal for their helpful comments. We thank Alfredo Del Monte for his valuable support and the discussion he provided on the previous draft of this paper. We also thank Guido De Blasio, Valerio Filoso, John H. Kagel, Tommaso Reggiani for comments, as well as all the participants to the workshop “Experiments in Public Management Research” at the Masaryk University of Brno (February 2019), the Conference of the Society for the Advancement of Behavioral Economics (SABE) in Moscow (July 2020), and the Southern Europe Experimental Team’s Workshop in Naples (February 2020). Tomáš Miklánek of the University of Economics of Prague provided us with excellent research assistance and programming. The usual disclaimers apply.

[†] Department of Economics and Statistics, University of Naples ‘Federico II’ and CSEF. Via Cintia Monte Sant’Angelo, 80124, Naples, Italy. e-mail address: antonio.acconcia@unina.it

[‡] Department of Economics and Statistics, University of Napoli ‘Federico II’ and CSEF, Via Cintia Monte Sant’Angelo, 80124, Naples, Italy. e-mail address: s.beraldo@unina.it

[§] *Corresponding author*: Department of Economic and Social Sciences, Università Politecnica delle Marche, Piazzale R. Martelli, 8, 60121, Ancona, Italy. e-mail address: m.stimolo@staff.univpm.it

1. Introduction

Market failures, due to knowledge spillovers (information leakage between firms) and imperfect appropriability of returns, adversely affect private research and development (R&D hereafter) investment decisions and justify the use of public subsidies to incentivize firms' cooperation (e.g., Arrow 1972). This, in turn, by allowing the appropriation and protection of free flows of information, is expected to boost firms' propensity to take on risky investments beneficial to the national economy (López, 2008). Targeting funds to the most *promising beneficiaries* is, however, challenging because problems of asymmetric information might leave room for opportunistic behaviours by subsidised firms. Public policies can, therefore, be inefficient or even backfire; they could prevent further R&D investments or – worse – they could crowd them out (Antonelli and Crespi, 2013). Overall, the efficacy of public subsidies in stimulating cooperation in R&D is an empirical question.

Unfortunately, results based on observational data provide mixed evidence. For example, Czarnitzki et al. (2007) show that incentives for cooperation increase firms' R&D spending, whereas subsidies for individual research activities do not. In the same vein, Pippel (2014) shows that R&D cooperation increases the probability of innovation. Other studies, instead, document that public subsidies aimed at incentivizing firms' cooperation can have a crowding-out effect on their investment rates (e.g., Zúñiga-Vicente et al., 2014; Crescenzi et al., 2020; Cantabene and Grassi, 2018), similar to the one caused by R&D tax credit (Acconcia and Cantabene, 2018). All of these results raise the suspicion – investigated in the present paper – that various market conditions may be at the root of the differential impact of public subsidies on the willingness to cooperate in R&D and the related investment decisions.

Our investigation considers duopoly markets characterized by different levels of knowledge spillovers and product market competition (for an extensive review, see Suetens, 2004). The presence of spillovers and the strength of competition in the product market are two opposing forces in determining the extent of market failure and the desirability of public intervention. Indeed, higher spillovers induce firms to cooperate in an attempt to internalize externalities and reduce fixed costs duplication (e.g., D'Aspremont and Jacquemin, 1988; Kamien et al., 1992; Cassiman and Veugelers, 2002; Suetens, 2005; Capuano and Grassi, 2019). More intense market competition instead reduces firms' willingness to cooperate by lowering duopoly expected profits (e.g., Silipo and Weiss, 2005; Wu, 2012).[5]

---

[5] Importantly, compared to the case of knowledge spillover, the effect of product market competition on firms' willingness to cooperate is more complex. Indeed, studies focusing on market settings different from a duopoly document that the strength of product market competition and firms' cooperation rate in R&D are linked in a nonmonotonic fashion (e.g., Cassiman and Veugelers, 2002; Belderbos et al., 2004; Aghion et al., 2005).

In tackling the issues at hand, lab experiments are a suitable way to complement – if not improve upon – the econometric analysis of observational data. Specifically, they provide a straightforward method to test how changes in the background market circumstances affect subjects' R&D cooperation and investment rates, with or without the provision of public subsidies. Furthermore, they allow researchers to properly address two endogeneity issues possibly biasing econometric results. These are related with self-selection and reverse causality problems. As for the former, because the success of applications for public funds may depend on the characteristics of the applicants, these may self-select in the sample of beneficiaries. This issue, commonly addressed through an instrumental variable approach (for reviews, see Zúñiga-Vicente et al., 2012; Becker, 2015), is tackled by the experimental method through a randomization – determining control and treatment groups – that can easily lead to an identification strategy based on a difference-in-differences design. For what concerns the latter, notice that R&D investments affect the probability of being imitated (i.e., spillovers), as well as the degree of market competition (e.g., Ioannou et al., 2021; Roelof et al., 2017). One way to address this problem of reverse causality with the experimental method is to implement – as in our case – markets that differ in their level of knowledge spillovers and in the strength of competition. Thus, the comparison *between* them allows for measuring the effect of the exogenous change of these structural parameters on cooperation and investment rates.
So far, the experimental literature has mainly investigated the effect of market competition (e.g., Reynolds, 1988; Darai et al., 2010; Aghion et al., 2018; Silipo, 2005; Østbye and Roelofs, 2013) and knowledge spillovers (e.g., Isaac and Reynolds, 1988; Suetens, 2005; Halbheer et al., 2009; Roelofs et al., 2017) on subjects' investments and cooperation in R&D. Moreover, some experiments have investigated the optimal allocation of public subsidies among innovating firms, with a view to design incentive–compatible mechanisms able to induce them to truthfully reveal their funding needs (e.g., Russo et al., 2007; Giebe et al., 2006). In this paper, we extend Suetens's (2005) design to make it adaptable to a setting in which the invention process is stochastic, different levels of market competition and spillovers are possible, and subsidies to cooperating firms might be provided. To the best of our knowledge, no experimental investigation has so far assessed the effect of public subsidies on firms' cooperation and investment rates in market settings with different levels of knowledge spillovers and product market competition.

Our experiment is based on a simplified version of the theoretical setting proposed by Capuano and Grassi (2019). In line with a huge theoretical literature, they consider a duopoly game where cooperation in R&D may emerge as a subgame perfect Nash equilibrium (SPNE). In the first stage, firms declare their potential interest in R&D cooperation; in the second, they decide whether to jointly invest in R&D or not; and in the third, they face Cournot competition in the product market. An important feature of the model is that it considers a breakthrough innovation that involves a technological jump so as to create a new market with a demand independent of existing goods.[6] The model identifies *i*) cases where – depending on the intensity of spillovers, the level of R&D costs, the probability of successful innovation, and the intensity of market competition – the provision of public subsidies is necessary to induce firms to invest cooperatively in R&D; and *ii*) cases where cooperation spontaneously emerges as an equilibrium outcome.

The framework we present in Section 2 below takes all of these elements into consideration, delivering two clear predictions: *i*) given the level of market competition, higher spillovers favour cooperation among firms (as in D'Aspremont and Jacquemin, 1988) but induce lower R&D investments if firms decide not to cooperate; and *ii*) given spillovers, cooperation reduces R&D investment levels when market competition intensifies. From these predictions, two consequences directly follow. First, in a market characterized by high spillovers, the provision of subsidies to foster cooperation might be useless, as cooperation would emerge anyway. Second, in highly competitive markets, public subsidies, by encouraging cooperation, may favour a reduction of the overall level of R&D investments, which might be inconsistent with the goals pursued by public authorities. In a word, alongside market failures, government failures also emerge in these cases.

Subjects play a duopoly game for 25 rounds with random and anonymous matching to avoid reputation effects and preserve the one-shot nature of the strategic interaction. As control groups, we build six experimental markets by exogenously varying the level of knowledge spillovers (low or high) and the intensity of competition in the product market (low, intermediate, or high). Then, in the treatment groups, we replicate the six experimental markets incentivizing cooperation by means of lump sum subsidies. Hence, for any combination of knowledge spillovers and competition level, we can assess the impact of public subsidies on cooperation and investment rates by comparing subjects' behaviour in treatment (subsidies are provided) and control (no subsidies are provided) markets.

In the six markets in the control, consistent with the theoretical predictions, we find that the probability that a subject is willing to cooperate in R&D increases in the level of knowledge spillovers (by 10 percentage points, on average); it instead decreases as market competition increases (by 20 percentage points, on average). As far as investment rates are concerned, we find that these decrease in the level of knowledge spillovers (24 percentage points, on average) and in the level of market

---

[6] Capuano and Grassi (2019: 198) discuss the findings of the Eurostat's Community Innovation Survey (CIS, 2012) documenting that the percentage of firms investing in product innovation in most European countries is equal or superior to the percentage of firms investing in process innovation (e.g., technological innovation reducing marginal costs of production).

competition (11 percentage points).

In *focus* markets (i.e., in markets in which the provision of incentives is expected to induce a shift in the equilibrium strategies, from non-cooperation to cooperation) the probability that a subject is willing to cooperate in R&D increases on average by 36 percentage points compared to the control: hence, subsidies prove effective in boosting R&D cooperation. However, there is evidence that when subjects cooperate *because* of the provision of subsidies, the average investment rate declines (up to 6 percentage points in focus markets). This supports the strand of literature (e.g., Fölster, 1995; Griliches, 1998; Belderbos et al., 2004; Colombo et al., 2006; Czarnitzki and Hottenrott, 2012; Cantabene and Grassi, 2018; Crescenzi et al., 2020), according to which public intervention aimed at boosting cooperation in R&D might be counterproductive if the ultimate goal is to promote a higher level of investment in R&D.

Overall, our results suggest that the use of public subsidies is not to be indiscriminate. Contingent on market conditions, subsidies can be redundant – as firms would cooperate anyway – or even counterproductive because, by inducing a higher rate of cooperation, they can indirectly stimulate lower R&D investments. All of this might translate into a waste of public funds. The government should be aware of this when designing incentives to promote R&D cooperation.

The remaining of the paper is organized as follows. Section 2 sketches the theoretical setting. Section 3 illustrates the experimental design in detail, whereas Section 4 delivers our results. Section 6 concludes.

2. Theoretical Setting

Our experiment is based on the theoretical framework proposed by Capuano and Grassi (2019), which focuses on duopoly markets. Firms in a duopoly have a larger capacity to undertake innovation because they are more able to deal with externalities since there are less competitors who can imitate them. Larger firms are also more qualified to exploit increasing returns in R&D, and are more internally diversified, which usually implies greater willingness – and ability – to undertake the intrinsic risk of innovation (Belleflamme and Peitz, 2015).

The theoretical framework proposed by Capuano and Grassi (2019) has the following characteristics. Two firms, (i, j), have the chance to rely on binding contracts to share the cost of R&D activities aimed at developing a new product. Coordination allows firms to fully internalize knowledge spillovers and partially reduce fixed costs duplication.

There are two phases in the model: an *investment* phase and a *production* phase. The *investment* phase contemplates two mutually exclusive scenarios, depending on whether firms decide to coordinate their R&D activities (cooperative scenario) or not (noncooperative scenario). In the first scenario, firms jointly decide on the investment level, sharing the associated cost; if the investment is successful, both firms will be able to produce and sell the innovative good.

Importantly, when firms agree to coordinate their R&D investments, they receive a lump sum subsidy $S \geq 0$ from the government. Subsidies for cooperation are meant as a remedy to tackle the problems of knowledge spillovers and imperfect appropriability of returns, deemed as the main market failures justifying public intervention. Indeed, subsidies increase firms' private incentive to cooperate in the investment phase.[7]

In the second scenario, each firm acts independently, bearing the whole cost of the investment and being aware that the rival may be able to imitate due to the presence of knowledge spillovers. When firms decide not to cooperate, they may realize either duopoly profits (D) (i.e., the profits that the two firms in the duopoly realize when they both innovate) or monopolistic (M) profits (i.e., the profits that only one firm realizes as it is the only one that innovates).

The production phase is characterized by Cournot quantity competition in any scenario. This assumption is in line with the most relevant literature on R&D activities in duopoly markets, inspired by the seminal contributions by d'Apremont and Jaquemin (1988) and Kamien et al. (1992). In our framework, it is motivated by the fact that we consider breakthrough product innovation like IT companies competing to produce and sell new software, pharmaceutical firms developing new drugs, and companies in the automotive sector investing in new engine technology. In these cases, it is more realistic to assume that firms stick to the produced quantity and adjust the price accordingly in the spirit of Cournot competition. For example, in sectors such as aircraft and spacecraft, electrical machinery, and motor vehicles, it can be difficult to adjust quantities; therefore, firms fix capacities at the outset and then adjust prices to sell the available quantities (Belleflamme and Peitz, 2015).

The strength of competition is measured by an index of product differentiation, $\alpha \in [0,1]$, computed as the ratio between the noncooperative duopoly (D) and monopoly (M) profits (i.e., $\alpha = D/M$). Hence, when α is larger, the difference between monopoly and duopoly profits is lower; that is, the competitive pressures in the product market are lower.

As shown in Figure 1, the interaction between firms is modelled as a non-repeated game with complete information.

---

[7] Of course, the provision of subsidies is not the only type of public intervention theoretically possible. Patent protection also reduces information leakages. Patent protection, however, is a less flexible policy and one more difficult to implement with respect to the provision of incentives for research joint ventures (on this, see Capuano and Grassi, 2019).

Figure 1. Timing of the game

$t = 0$	$t = 1$	$t = 2$	$t = 3$
Public subsidies announced	Firms agree to cooperate or not	Firms set R&D investments	Competition in the product market

At time $t = 0$, the government announces the level of the lump sum public subsidy ($S \geq 0$) that firms get if they cooperate in R&D; at time $t = 1$, firms simultaneously decide whether to create a research joint venture (RJV) or not; at time $t = 2$, firms choose the investment levels, jointly (if both opt for an RJV) or independently (otherwise); and at $t = 3$, once R&D outcomes and spillovers are observed, each firm independently decides the production level (Cournot competition is assumed).

The innovation process is stochastic. The probability of innovation, $\rho(.) \in [0,1]$, is assumed to be increasing in the investment level, with investments being characterized by diminishing marginal returns: $\rho' > 0, \rho'' < 0$.

As a matter of notation, in what follows, k will denote a generic firm (either i or j), and $-k$ will denote k's opponent.

If at time $t = 1$ an agreement is not reached (noncooperative scenario), each firm independently decides the level of R&D investments. In this case, firm $k = (i, j)$'s probability of innovating, $\rho(k) \in [0,1]$, is assumed to be independent of the following: *i*) the R&D investment brought about by its rival (i.e., x_{-k}); and *ii*) the probability, $\rho(x_{-k}) \in [0,1]$, that the rival is successful at innovating given its investment decisions (non-tournament approach).

Each firm is aware that, in case no agreement is reached, its competitor might imitate its innovation, with a probability β that, consistent with the main literature (e.g., D'Aspremont and Jacquemin 1988; Kamien et al., 1992), can take up a continuum of values from 0 to 1 (i.e., $\beta \in [0,1]$ indicates the presence of spillovers effects).[8] In this case, given the probability of successful innovation, ρ, the spillover effects, β, and the differentiation index, $\alpha = D/M$, firm k's expected profits can be written as follows:

$$E\Pi_k^{NC} = r_k^d \cdot D + r_k^m \cdot M - x_k^{NC} \tag{1}$$

where

[8] As in Capuano and Grassi (2019), knowledge spillovers are ex-post, measured as the probability to be imitated.

- $r_k^d = \rho_k\rho_{-k} + \rho_k(1-\rho_{-k})\beta + (1-\rho_k)(\rho_{-k})\beta$ is the probability that firm k = (i, j) is engaged in duopolistic competition in the production phase: this occurs when both firms innovate or one innovates and the other is successful at imitating; and
- $r_k^m = \rho_k(1-\rho_{-k})(1-\beta)$ is the probability that firm k = (i, j) enjoys monopoly profits in the production phase: this occurs when the firm k innovates and the rival neither innovates nor is successful at imitating.

If at time t = 1 an agreement is reached (cooperative scenario), firms jointly invest in R&D and equally share the whole cost of the investment. The expected profit of firm k = (i, j) will be

$$E\Pi_k^C = r_k^c \cdot D - x_k^C + S \tag{2}$$

where S is the level of public subsidy, and $r_k^c = \rho(2x_k)$ is the probability of innovating induced by the overall R&D expenditure, given that $x_k^C = x_{-k}^C$.

The market for a new product is created when at least one competitor innovates. If none innovates, no revenues are obtained by firms; that is, profits are negative because of R&D expenditures. If one firm innovates and the other does not, the innovator gains monopoly profits, M > 0. If either of the two firms innovates or one innovates and the other imitates, each firm obtains duopoly profits D, where D = αM with α ∈ [0,1].

In any subgame, firms – independently or jointly – set a level of R&D expenditure such that expected profits are maximized. Hence, cooperation in R&D emerges as a SPNE of the game if and only if the difference between $E\Pi_k^C$ and $E\Pi_k^{NC}$ is nonnegative for any firm k = (i, j) whose investment decisions are optimal in any subgame. By construction, the difference $E\Pi_k^C - E\Pi_k^{NC}$ is increasing in both the level of the public subsidy and the probability of knowledge spillovers, whereas it is decreasing in market differentiation.

Although very simple, the model is able to stress the relevant incentive structure faced by firms. On the one hand, cooperation, by fully internalizing spillovers, increases the probability of successful innovation for any given pair of balanced investment levels: this stimulates cooperation. On the other hand, due to the assumption of joint patenting, the probability of becoming a monopolist in the production phase is zero. Thus, when the duopolistic competition is tougher, the per-firm expected profits and the incentives to cooperate are lower. For the same reasons, aggregate investment levels may decrease with cooperation. Indeed, when competition in the product market is tough (i.e., differentiation between final goods is low), expected returns for additional R&D investments decrease, and this has a negative impact on the overall investment level. Therefore, even if public subsidies *mechanically* encourage cooperation, they cannot, in general, be advocated on the grounds that they increase the overall investment level in R&D.

In equilibrium (SPNE), the private incentive to cooperate in R&D is positively affected by the level of spillovers and negatively affected by the intensity of market competition.

The analysis above suggests the following theoretical predictions:

- Given the level of market competition, higher spillovers favour cooperation among firms[9] but induce R&D investments lower than the noncooperative ones.

- Given spillovers, cooperation reduces R&D investment levels in the presence of strong market competition.

The theoretical model sketched above clarifies that when the policymaker is not exclusively concerned with implementing cooperation *per se* but rather, for example, with increasing the overall investment level to favour the emergence of innovations, providing subsidies does not necessarily qualify as an efficient use of public resources. This observation applies also to cases in which firms have sufficiently high private incentives to spontaneously cooperate and jointly invest in R&D (as it is the case with high spillovers and high product differentiation).

3. Materials and Methods

In this section, we illustrate our experimental design. It extends Suetens's (2005) experimental setting along two key dimensions. First, it introduces the level of product differentiation as a structural parameter affecting subjects' R&D investments. Second, it introduces uncertainty in the innovation process, in the spirit of the stochastic invention model that Isaac and Reynolds (1988) first tested in the lab.

3.1 *The Setting*

We recruited a gender-balanced sample of 120 undergraduate, master and PhD students in economics from the University of Economics (VSE) and Charles University of Prague that we assumed to be more familiar with strategic interactions. They took part in the experiment run at the Laboratory of

---

[9] This result has been shown to hold in the more general model of Kamien et al. (1992) considering also Bertrand price competition in the product market.

Experimental Economics (LEE, VSE) in March 2016. Participation granted a show-up fee of 100 CZK (3.7 euros). Potential subjects were randomly selected from the database of the LEE and formally invited by e-mail to sign up for ORSEE – Online Recruitment System for Economic Experiments (Greiner, 2004).

Once recruited, subjects were randomly assigned to one of 12 experimental sessions, six for the control and six for the treatment. Each session comprised a group of 10 subjects. The trial was designed as a computer-based experiment managed by a z-tree script (Fischbacher, 2007). Subjects were randomly assigned to computer slots that were completely isolated to guarantee full anonymity. They were not allowed to talk during the session, and lab assistants checked for compliance (instructions are reported in the Supplementary material).

The experimental design was based on the duopoly game described in Section 2. Each subject knew that they would play the game for 25 rounds, with random and anonymous matching in any round. These features of the matching process preserve the one-shot nature of the strategic interaction. Thus, for each experimental market, we have 250 observations that form the results of our analysis, particularly the effect of the change in the spillover level on cooperation, comparable to Suetens (2005).

Participants were informed at the beginning of the experiment about the circumstances characterizing the interaction between subjects: the level of knowledge spillovers (β) and the degree of product differentiation (α).

Experimentally, we consider three possible levels of product differentiation, $\alpha \in \{0.10, 0.45, 0.70\}$. The higher the level of differentiation, the lower the competitive constraint in a duopoly (in our theoretical setting, the parameter α plays the role of an inverse index of market competition). By differentiating their products from competitors, firms can create a monopolistic market in which they enjoy price-making power.

Following Suetens (2005), we considered only two possible levels of knowledge spillovers, $\beta \in \{0.20, 0.80\}$, for the sake of simplicity and to sharpen the expected difference in participants' behaviour.

By combining the possible values taken up by parameters α and β, six experimental markets can be conceived, each of which characterizes one of the six control sessions and one of the six treatment sessions. In some of these markets, public subsidies (S) are necessary for cooperation to occur; that is, without subsidies, cooperation does not emerge as an SPNE of the game.

3.2 *Interaction*

Each session in the control was characterized by a specific (α, β) pair and involved a group of 10 subjects. We decided to vary the level of product differentiation and spillovers between and not within markets for the sake of simplicity. Indeed, a within-subject design would have increased the complexity of the game, making it hard for participants to understand the related changes in the incentive structure of the strategic interaction. Additionally, it would have entailed exposing participants to multiple treatments (i.e., changes in α, β, and S), thereby increasing the risk of confounders biasing the estimated effects (Charness et al., 2012).[10]

Preliminarily, we repeated the game for two rounds just for practice; at the end of these rounds, subjects were allowed to ask clarifying questions, following the rules illustrated at the beginning of the experiment. The choices made by subjects in the first two rounds are excluded from the analysis. The game was then repeated for 25 rounds. This number of game iterations can be considered sufficient to ensure familiarity with the changes in the incentives structure brought about by the introduction and removal of public subsidies. Subjects were aware of the random and anonymous matching process at each round.

In every round, each participant was endowed with 200 monetary units (MUs) and could invest any amount of this endowment in R&D. MUs not invested in a given round could be converted to CZK crowns at the end of the experiment.[11]

At the end of each round, subjects were informed about their own round-specific profit; they were aware of opponents' choices only in the case of cooperation.

The game was implemented in the lab through three phases: *information*, *investment*, and *production*.

Information Phase. At the beginning of each session, subjects observed a printed graphic with the probability of innovation, $\rho \in (0, 0.45)$, depicted as an increasing concave function of the investment level (see Fig 1).

[Figure 1, near here]

They could thus recognize the intrinsic uncertainty of the innovation process. Subjects could also observe two matrices displaying the expected payoffs associated with specific investment levels (see the Supplementary material). These matrices conveyed information both for the noncooperative

[10] Additionally, between-subject designs have less statistical power than within-subject ones, because the latter reduce the variance due to the (unobserved) difference between subjects. Therefore, we provide a more conservative test of the hypotheses on the effect of spillovers and competition on cooperation and investment rates (Charness, 2012; Moffat, 2020).

[11] Given the exchange rate, the gain for a subject who abstained from investing throughout the experiment was about 12 euro: 200 MU × 25 = 5000 MU = 300 CZK ~ 12 EUR. The exchange rate was set at 0.06 CZK for any MU.

scenario – in which participants invested autonomously in R&D – and for the cooperative one, in which agreements upon a joint investment level in R&D were allowed (see Tables A1NC/A1C-A6NC/A6C in the Supplementary material). These matrices were printed on two separate sheets of paper and were built by computing expected profits for various (α, β) pairs and combinations of investment levels.

We assumed throughout that monopoly profits M equal 1000 MUs.

Investment Phase. Given the information set, subjects had to decide in any round whether to coordinate their R&D decisions. As specified above, two scenarios could arise.

A cooperative scenario came about whenever both subjects in the duopoly were willing to coordinate their R&D investments, in which case they were given the chance to bargain on the joint investment level.

The use of a profit calculator to simulate the expected payoffs for any possible joint level of investment and formulate a proposal to the counterpart was allowed during the experiment. No restrictions were imposed on the number of proposals. As soon as subjects agreed on a joint investment level, a *symmetric* binding contract entailing each subject to bear half of the cost of the investment was automatically made.

A noncooperative scenario came about when one of the two subjects was not willing to coordinate R&D investments or the subjects failed to reach an agreement in the contracting phase. In this scenario, subjects were free to decide on their investment level autonomously, being aware of the possibility of being copied by the competitor.

Production Phase. According to the experimental rules, monopoly profits (equal to 1000 MUs) could be obtained only in the noncooperative scenario, if only one subject was able to produce and sell the innovative good. Otherwise, subjects got duopoly profits, with production *fixed* at the Cournot-Nash equilibrium. Collusion in the product market was not allowed.

3.3 *Treatment*

Each session in the treatment was characterized by a triplet (α, β, S). The six control markets were replicated by providing S = 30 MUs (the lump sum public subsidy) to those who managed to sign a symmetric binding agreement on a joint R&D investment. Subsidies were announced at the beginning of the session. They were only provided from round 7 to 21, which was publicly known. Subsidies were then removed in rounds 22-25. This design feature allowed measuring subjects' reactions to changes in the incentive structure *within* the treatment. Specifically, we announced subsidies at the outset to test whether subjects' willingness to cooperate was prone to a psychological announcement effect. Similarly, we removed subsidies in the last rounds (22-25) to investigate the existence of a persistence effect of public subsidies' provision on cooperation rates.

Notice that, due to the random and anonymous matching, the finitely repeated duopoly game implemented in the lab had a unique SPNE outcome that corresponded to the equilibrium outcome of the one-shot game. On these grounds, in Table 1, we summarize the theoretically predicted outcomes in terms of cooperative (C) and noncooperative (NC) investment behaviour for each triplet (α, β, S), both in the control ($S = 0$ MUs) and treatment groups ($S = 30$ MUs), given the shape of the innovation function and the other parameter values.

Table 1 illustrates the choices (i.e., C or NC in R&D activities) that subjects were expected to make for each combination of the parameters α and β. The table includes both the control (left panel) and the treatment groups (right panel).

[Table 1, near here]

In the control groups, subjects were expected to cooperate in Cases IV to VI in equilibrium. In these cases, the provision of 30 MUs was clearly not expected to alter subjects' incentives, hence their equilibrium strategies. For Case I, providing subjects 30 MUs was not enough to incentivize cooperation. Table 1 also clarifies that in Cases II ($\alpha = 0.10$, $\beta = 0.80$) and III ($\alpha = 0.45$, $\beta = 0.80$), the provision of subsidies changed the incentives of the game compared to the control group, thereby supporting cooperation in R&D as an SPNE.

3.4 *Testable Hypotheses*

Grounded in the theoretical model sketched in Section 3, we formed the following experimental hypotheses:

HP1. *In the control, the willingness to coordinate R&D investments increases in α and β.*

The rationale behind HP1 goes as follows: For given levels of product differentiation (α), the higher the level of knowledge spillovers (β), the lower the appropriability of returns deriving from noncooperative investments. Hence, subjects in a duopoly market with higher β have a stronger incentive to coordinate R&D investments to internalize spillovers, reduce fixed-cost duplication, and increase the probability of innovating for balanced investment levels.

As for market competition, remember that when subjects sign a symmetric binding agreement, the probability of getting monopoly profits is zero. Thus, for given levels of spillover, when the level of product differentiation is lower (i.e., α is lower), the expected profits of cooperative investments are lower compared to noncooperative ones. Conversely, when final products are strongly differentiated, firms' profits are weakly affected by the presence of a competitor (i.e., duopolistic profits tend to shift to monopolistic ones as α increases). At the same time, cooperation reduces fixed-cost duplication. Hence, when products are strongly differentiated (i.e., the level of market competition is low), subjects' expected profits of cooperation are higher.

HP2. *In the control, the investment levels in the noncooperative scenario decrease in* β.
The rationale behind this hypothesis follows from the previous argument. For a given level of market differentiation, if subjects do not cooperate, the higher the probability of being imitated, the lower the incentive to invest in R&D.

HP3. *In the control, the average investment level increases in* α.
For a given level of knowledge spillovers, the duopolistic profits approximate the monopolistic ones as the level of market differentiation increases. Hence, subjects have a stronger incentive to invest in R&D, both in the cooperative and noncooperative scenarios.

We now turn to the effect of public subsidies. Therefore, we focus on Cases II ($\alpha = 0.10$, $\beta = 0.80$) and III ($\alpha = 0.45$, $\beta = 0.20$), in which the provision of additional MUs was expected to induce a change in subjects' investment behaviour.

HP4. *In Cases II (α = 0.10, β = 0.80) and III (α = 0.45, β = 0.20), the provision of 30 additional MUs increases the average willingness to cooperate in R&D investments compared to the control.*
This hypothesis follows directly from the assumption that subjects react rationally to the change in the incentive structure of the game, converging to the SPNE outcome. Indeed, the provision of public subsidies increases the expected profits of cooperation, inducing subjects to coordinate their R&D investments.

HP5. *In Cases II (α = 0.10, β = 0.80) and III (α = 0.45, β = 0.20), cooperation induced by public subsidies is associated with lower investments in R&D.*
The rationale behind HP5 is the following. In these market settings, the relatively high level of competition lowers subjects' expected profits from cooperation, compared to the expected profits of noncooperative investments. Whenever subjects choose to cooperate, they invest less compared to the noncooperative scenario. Hence, if public subsidies encourage cooperation, then they indirectly

induce a lower level of investments in R&D.

4. Results

In this section, we present the results of the analysis of subjects' cooperation and investment rates. Specifically, our findings concerning the effect of spillovers and market competition on cooperation and investments are reported in 4.1. In 4.2, we illustrate the effect of the treatment (i.e., the provision of 30 MUs simulating public subsidies) on cooperation and investment rates.

4.1. *Effects of Spillovers and Competition on Cooperation and Investments in R&D*

Here, we test hypotheses HP1-HP3, providing evidence on how subjects reacted at baseline to changes in incentives due to the exogenous variation in the level of both knowledge spillovers (β) and product differentiation (α). To this end, consistently with a relevant branch of literature in experimental economics (Struwe et al., 2022; Cox et al., 2023), we estimate a panel multiple-level linear model (MLM) and a panel multiple-level probit model with round fixed effects and random effects on the session and subject level:

$$Y_{ijt} = \gamma_0 + \gamma_1 SP_{high} + \gamma_2 PD_{med} + \gamma_3 PD_{high} + \delta_t + u_i + v_j + \eta_{ijt} \quad (3)$$

where Y_{ijt} is, alternatively, either a dummy taking value 1 if subject *i* is willing to cooperate in session j at round t, or subject i's investment rate (i.e., the ratio between the investment level and the endowment) in session j at round *t*; SP_{high} is a variable taking value 1 for the highest level of spillovers (SP_{low} dropped category); and PD_{med} and PD_{high} are dummies taking value 1 for an intermediate to high level of product differentiation respectively (PD_{low} dropped category).

We control for rounds' fixed effects (δ_t); u_i and v_j are the subject and session-specific random effects, respectively, and η_{ijt} is the error term. To assess whether participants' (lack of) understanding of the game rules affected our results, we control for their degree in economics meant as a reliable proxy of their math skills.[12] Since this control does not substantially affect the coefficients of the variables of interest, the related estimates are not reported. Standard errors (in parentheses) are clustered at the session level.

[12] We control for subjects' degree with two dummies: degree2 for master and degree3 for PhD students, with degree1 (undergraduate students) as baseline.

As a robustness check, we also check our results by bootstrapping standard errors (reported in brackets). We employ a block bootstrap procedure that accounts for the serial correlation of our observations through randomly selecting samples with replacement by panel and not by individuals (Moffat, 2020, 2021). We do this because in small samples used in lab experiments, statistically significant results and statistical inference, can be misleading. In these cases, the appropriate bootstrap procedure provides a more reliable inference by approximating the distribution of the estimator without any assumption on the shape of the distribution of the data (MacKinnon, 2006; Horowitz, 2019; Ersoy, 2021).

Results are in Table 2, where the reported significance levels are based on standard errors clustered at the session level. As for the effect of exogenous changes in α and β on subjects' average willingness to cooperate, the results (first four columns) are consistent with our theoretical expectations. Indeed, the probability that subjects were willing to cooperate in R&D significantly increased by 10 percentage points moving from a low to a high level of knowledge spillovers. Moreover, an increase of 35 percentage points in the level of product differentiation induced an increase in individuals' willingness to cooperate of 16 percentage points, while an increase of 60 percentage points in the degree of product differentiation induced an increase of 40 percentage points in individuals' willingness to cooperate in R&D. This entails that a change from a low to a medium level of product differentiation, as well as a change from a medium to a high level of product differentiation, induced an *average* increase in individuals' willingness to cooperate in R&D of about 20 percentage points. These results are qualitatively confirmed by the estimation of the multiple-level probit model. Bootstrapped standard errors confirm or increase estimate precision. Therefore, we summarize the results of the experimental investigation as follows:

Result 1. *On average, the probability of cooperation increases with both knowledge spillovers and product differentiation*.

[Table 2, near here]

We now turn to the effect of a change in the value of the structural parameters on investment behaviour (HP2-HP3) by estimating a panel MLM, as in equation (3), with the investment rate as the dependent variable. Table 2 (Columns 5 and 6) shows that an increase in the level of knowledge spillovers significantly reduces the average investment rate by 25 percentage points on average. This is compatible with HP2. Moreover, in line with HP3, an increase in product differentiation induces an average increase in the individual investment rate of approximately 11 percentage points. Bootstrapped standard errors confirm or increase estimates precision. This leads us to our second finding:

Result 2. *On average, investment rate decreases with the level of knowledge spillovers and increases with the degree of product differentiation*.

4.2 *Results: Effect of Subsidies on Cooperation and Investment Rates*

In this section, we report the results on the causal effect of the provision of 30 MUs on cooperation rate in the treatment group compared to the control (4.2.1). We also analyse the impact of 30 MUs on investment rates within the control and treatment groups (4.2.2).

4.2.1 The effect of subsidies on cooperation

In this section, we analyse the effect of subsidizing cooperation in R&D. For our purposes, we first restricted our analysis to Cases II (α = 0.10, β = 0.80) and III (α = 0.20, β = 0.45). Indeed, these are the only cases in which the provision of public subsidies is expected to induce a shift from non-cooperation to cooperation. We also examine all the other cases (i.e., Cases I and IV-VI), where equilibrium strategies dictate either 'never cooperate' (Case I) or 'always cooperate' (Cases IV-VI), independent of the provision of subsidies.

Here, we tested whether *the provision of additional monetary units increases the average willingness to cooperate in R&D investments* (HP4). As detailed in Section 3, we partitioned the 25 rounds played by treated subjects into three time periods, depending on whether subsidies are only announced (rounds 1-6), provided (rounds 7-21), or removed (rounds 22-25). This design feature allowed us to exploit both within and between-subject behavioural variations, and therefore to implement a difference-in-differences analysis.

As a preliminary step, in Figure 2, we plotted the dynamics of the subjects' average willingness to coordinate R&D investments in both treatment and control by jointly considering Cases II and III.

[Figure 2, near here]

We observed that in the control groups, individuals' willingness to cooperate is approximately stable through rounds. Conversely, in treatment groups, it significantly increases when additional monetary units are provided (rounds 7-21) and then falls when subsidies are removed. Thus, *the provision of public subsidies does not induce any announcement or persistence effect* influencing the average willingness to cooperate in R&D, as subjects simply respond to changes in the material incentives of the game.

To provide support for this evidence, we implemented a difference-in-differences analysis between treatment and control group by estimating a panel MLM and a panel multiple-level probit model with round fixed effects and random effects on the subject level[13]:

$$C_{it} = \pi_0 + \pi_1 S + \pi_2 DID + \delta_t + u_i + \varepsilon_{it} \quad (5)$$

where C_{it} is a dummy capturing the individual willingness to cooperate in R&D and ε_{it} is the error term. As S is the dummy denoting the treatment group, π_1 measures the average difference in the individual willingness to cooperate in R&D between treatment and control groups when subsidies *are not* provided (i.e., in rounds 1-6 and 22-25). DID stands for the usual difference-in-differences interaction term between S and a dummy (*time*) that is equal to one in rounds 7-21 when subsidies are provided in the treatment group. Hence, π_2 measures the difference in the average willingness to cooperate between treatment and control before and after the provision of subsidies in rounds 7-21.

We controlled for round fixed effects (δ_t) and subject-specific random effects (u_i). We also controlled for participants' degree. Standard errors (in parentheses) are clustered at the subject level and ground the reported significance levels. As before, we estimated equation (5) by bootstrapping standard errors (reported in brackets).

We first analysed Cases II and III, where the provision of public subsidies is expected to boost subjects' cooperation. Estimated results in Table 3 support HP4, as the provision of subsidies significantly increases the probability of cooperation in R&D.

[Table 3, near here]

Specifically, looking at the coefficient associated with *S*, no difference between the treatment and control group is recorded when public subsidies are not provided. Hence, the significant increase in the willingness to cooperate measured by the positive coefficient associated with the difference-in-differences interaction term can be attributed to the actual provision of subsidies. More specifically, in Cases II and III, when public subsidies are provided (rounds 7-21), the probability that a subject is willing to cooperate in R&D increases, on average, by 36 percentage points compared to the control.

[13] We report the estimates of the two-level model with random effects on the subject level because it does not significantly differ from a three-level model with random effects on the session and subject level according to the likelihood ratio test.

In other words, public subsidies increase individuals' average willingness to cooperate in R&D by 80% of its actual mean (i.e., 0.45). These results are qualitatively confirmed by the estimation of the multiple-level probit model. Bootstrapped standard errors confirm or increase the precision of estimates.

Result 3. *When public subsidies induce a change from a noncooperative to a cooperative strategy, they substantially increase the average willingness to cooperate in R&D.*

Now we consider all the market settings in which subsidies do not change the incentive structure of the duopoly game. Thus, in Figure 3, we plotted the average willingness to cooperate in R&D over rounds. We separately considered Cases IV to VI (panel a), where subjects were expected to cooperate in both treatment and control[14] and Case I (panel b), where subjects should never cooperate.

In panel *a*, we observed that the willingness to cooperate tends to overlap between treatment and control, suggesting that the provision of public subsidies does not impact the subjects' behaviour. Although in the treatment group the average willingness to cooperate is 60% in the first round and 70% in the last one, there is no significant trend in the data. Instead, there are wide fluctuations in the first rounds that decrease through game iterations. More precisely, when subsidies are only announced in rounds 1-7, the variance of the individual willingness to cooperate is 0.23 on average, while it decreases to 0.18 in subsequent rounds ($p < 0.050$ according to the variance ratio test). Interestingly, in the control group the variance remains approximately stable through rounds (0.22 on average). This descriptive analysis suggests that the provision of public subsidies in the treatment group facilitates a more stable pattern of cooperative behaviour compared to the control.

We also notice that in Cases IV to VI (Fig 3, panel a), the average willingness to cooperate is about 75%. It is likely that subjects initially fail to understand the incentive structure of the game and erroneously start to play a dominated noncooperative strategy. This mistake can be self-supporting because of the stochastic nature of the innovation process. Indeed, individuals erroneously playing a noncooperative strategy in a given round can still be the only one at innovating, thus realizing monopoly profits. Analogously, noncooperative subjects may be successful at imitating their opponents. These circumstances may reduce the subjects' willingness to cooperate in subsequent rounds.

To shed some light on this issue, we created a variable counting the number of successful innovations

[14] The pattern of the average willingness to cooperate in each case singularly taken from 4 to 6 is analogous to the aggregated one presented in panel a of Figure 1. Graphics are in Figure 6 available in the Supplementary material.

from a noncooperative strategy in the previous rounds, and we estimated its (unconditional) correlation with the probability of cooperation in the subsequent rounds. Results showed that the cumulative success at innovating noncooperatively in the previous rounds stands in significantly negative correlation with the probability of cooperation in the subsequent rounds in each case from IV to VI, with an average negative correlation of –0.218 ($p < 0.001$). We took this as suggestive evidence possibly contributing to the interpretation of the fact that participants' willingness to cooperate in Cases IV to VI fluctuates around a mean of about 75% through rounds.[15]

In Case I (Fig 3, panel b), the pattern is less clear. During the pre-treatment period (i.e., rounds 1-6), the average willingness to cooperate in R&D is lower in the treatment group. However, in rounds 7-21 it increases, remaining stably higher than in the control group up to the end of the treatment period (round 21). This seems to suggest that the provision of public subsidies, though not affecting the incentive structure of the game, may induce subjects in this case to display a higher willingness to cooperate.

Nonetheless, the induced pattern of behaviour is unstable. Indeed, in the control, we observed an average variance of 0.25 in participants' willingness to cooperate in the first eight rounds that substantially decreases to 0.16 in the subsequent rounds, reaching a minimum of 0.13 in the last four rounds ($p < 0.050$ according to the variance ratio test). In addition, the probability of subjects' cooperation substantially decreases starting from round 9, reaching a minimum in the last four rounds. Overall, this descriptive evidence suggests that subjects learn through rounds that cooperation is not their best strategy. In the treatment, instead, the variance in the cooperation rate is lower when subsidies are only announced (0.20 on average, rounds 1-7) or removed (0.13 on average, rounds 22-25), compared to rounds 7-21 – when subsidies are actually provided – where the average variance is 0.25 (the difference is statistically significant with a $p < 0.100$). Thus, the provision of subsidies seems to lead subjects to play an out-of-equilibrium strategy that is much harder to establish as a consistent pattern of behaviour.

[Figure 3, near here]

Estimating equation (5) for Case I and, separately, for Cases IV to VI, delivers results coherent with

[15] Of course, this evidence cannot be taken as conclusive since the two variables at stake are possibly endogenous as both are strongly correlated with the exogenous variables (i.e., the spillovers level, the degree of competition and public subsidies). That is why we do not include the cumulative success at innovating noncooperatively in the previous rounds as a control in regression analysis (see Angrist and Pischke, 2009: 47).

the graphical analysis.[16] In Cases IV to VI, the coefficient associated with the interaction term (*DID*) is not significantly different from zero; that is, because the provision of public subsidies in these market settings does not affect the incentives of the game, no difference is recorded in the subjects' willingness to cooperate in R&D.

However, the results are at odds with our expectations in Case I (Column 1), where subjects should not be conditioned by the provision of subsidies. Indeed, the coefficient associated with the difference-in-differences interaction term (*DID*) is significantly positive, documenting that subjects in the treatment group tend to increase their willingness to cooperate in rounds 7-21 compared to the control. This result is confirmed when we consider bootstrapped standard errors (reported in brackets) and when we estimate the multiple-level probit model (Column 2).

[Table 4, near here]

A plausible explanation is related with the well-known framing effect (Kahnemann and Tversky, 2013). In an environment in which the incentive structure obviously dictates non-cooperation, the provision of subsidies might change the way the game is perceived. Considering the computational difficulties that subjects face in comparing the two different scenarios to determine the profit-maximizing choice, the provision of subsidies might be meant by subjects as a *cue* that the right *scenario* – the one whose selection gives rise to a *right* to be rewarded – is the cooperative one. Indeed, this kind of effect is not observed in Cases IV to VI, where public subsidies do not change the perception of the game; it was and still is, after the provision of subsidies, a game which must be played cooperatively.

Although puzzling, this result is in line with previous studies showing how individuals' willingness to cooperate is particularly prone to framing effects in oligopoly experiments, especially when the tasks are demanding on the computational level (e.g., Davis and Holt, 1998, Cason, 1995). Most relevantly for our study, the results in Case I are in line with the results of the cheap-talk treatment in Suetens (2005), where it is shown that the possibility of sending nonbinding messages (cheap talk) on the level of investments in R&D in a similar duopoly game significantly increases the cooperation rate in R&D compared to a contract treatment where participants could instead sign binding agreements for cooperation. This evidence shows that irrelevant signals (i.e., signals not affecting the

[16] As robustness, for all cases (I to VI), we re-estimate equation 5 with a Panel model with round fixed effects and random effect on the subject level by clustering standard errors at the level of treatment and control group in each round. Our results are confirmed and reported in Table 6 available in the Supplementary material.

incentive structure of the game) may affect subjects' choices by framing cooperation as the right thing to do. In our setting, the provision of public subsidies works as an irrelevant signal that encourages participants to cooperate in R&D through a framing effect.

This result is particularly relevant for real world interactions between firms. Indeed, we provided evidence compatible with a framing effect in a duopoly game implemented in the lab where subjects have complete information on the opponent's payoff function. This is a more severe environment for a framing effect to emerge compared to real-world circumstances where firms lack complete knowledge. Several studies show that when economic agents are short of relevant information, they tend to adopt cognitive short-cuts (i.e., heuristics) to cope with computationally difficult decision tasks in a variety of domains (e.g., Gigerenzer and Gaissmaier, 2011). Therefore, it is legitimate to think that, given the high level of uncertainty for the R&D process in the real world, the disbursement of public subsidies can be a strong cue triggering the heuristic choice of cooperation as a satisficing solution for a complex decision problem even in cases where a cooperative strategy is not strictly rational.

4.2.2 The effect of subsidies on investment rates

In this section, we perform a within-control and a within-treatment analysis for more details on subjects' investment behaviours.

Preliminarily, in Figure 4, we plotted the dynamics of cooperative and noncooperative investment rates – in the control and treatment groups for Cases II and III – together with the theoretically predicted rates for noncooperative (i.e., the horizontal grey line) and cooperative (i.e., the horizontal dashed black line) investments.

[Figure 4, near here]

In the control, we observed that in both cases the dynamics of the average rate of cooperative and noncooperative investments do not follow a clear pattern and tend to overlap, providing graphical evidence of no significant differences between them.

As for the treatment groups, in both cases the average of cooperative investment rates exhibits a clearer pattern. In Case II, when subsidies are provided, cooperating subjects invest 10% of their endowment on average, a significantly larger share than the theoretically predicted rate of 4%. In Case III, instead, cooperating subjects invest on average 43% of their endowment when subsidies are provided, slightly lower than the theoretically predicted rate of 48%.

In Case II, the dynamics of cooperative and noncooperative investment rates tend to overlap, due to the small difference between the respective theoretically predicted rates. Nonetheless, in line with our theoretical predictions, noncooperative investment rates are slightly higher than cooperative ones when public subsidies are provided, even though the difference is economically insignificant.

In Case III, we observed that in the first six rounds – when subsidies are only announced – the dynamics of the average cooperative investment rate is highly variable, while it is more stable across rounds when subsidies are provided. Overall, the average noncooperative investment rate exhibits an increasing trend in rounds 7-21 when subsidies are provided, and they are on average higher than the cooperative ones.

In Figure 5, we plotted the dynamics of the average cooperative and noncooperative investment rates in the remaining cases for both the control (left panel) and treatment (right panel).

[Figure 5, near here]

In Cases IV to VI, we did not observe substantial differences between the control and treatment groups, with the exception of Case VI, where the dynamics of the average cooperative and noncooperative investment rates in the treatment are more clearly separated than in the control.

For Case I, instead, we observed some differences. In the control group, the dynamics of cooperative and noncooperative investment rates tend to overlap. In the treatment, the average cooperative investment rate exhibits a declining trend from round 11 onward. As a consequence, cooperative investment rates are on average lower than noncooperative ones.

We deepened the graphical analysis by performing a difference-in-differences estimation within the control and within the treatment group, focusing on Cases II and III only. We estimated a panel MLM with round fixed effects and random effects on the subject level:

$$IR_{it} = \theta_0 + \theta_1 CI_{it} + \theta_2 DID + \delta_t + u_i + e_{it} \tag{6}$$

where IR_{it} is i's investment rate at round t; CI_{it} is a dummy taking value one if subjects invest cooperatively in R&D at time t. Hence, θ_1 measures the average difference between cooperative and noncooperative investment rates when subsidies are not provided (i.e., in rounds 1-6 and 22-25); *DID* is the difference-in-differences interaction term between cooperative investments (CI_{it}), and a dummy (*time*) that equals one in rounds 7-21 when subsidies are provided; therefore, θ_2 compares cooperative and noncooperative investment rates before and after the provision of public subsidies in rounds 7-21.

We controlled for the fixed effects of rounds (δ_t) and the subject-specific random effect (u_i); e_{it} is the error term. We also controlled for participants' degree. Standard errors are clustered at the subject level (in parentheses). As a robustness test, we estimated equation (6) by bootstrapping standard errors (reported in brackets). Results are reported in Table 5.

[Table 5, near here]

Considering within control estimates (first four columns), regression results record no significant differences between cooperative and noncooperative investment rates. The picture changes if one considers within treatment estimates (last four columns). Table 5 documents that, in line with our theoretical expectations, cooperative investment rates are systematically lower than noncooperative ones. Specifically, in both cases the negative coefficient associated with the dummy variable CI_i shows that cooperative investment rates are significantly lower than noncooperative ones in rounds where subsidies are not provided (i.e., rounds 1-6 and 22-25), even though the coefficients lose significance in Case III (last column) when we control for the participants' degree. This result holds in both Cases II and III when we consider bootstrapped standard errors.

In Case II, the insignificant coefficient associated with the difference-in-differences interaction term documents that, on average, cooperative investment rates do not significantly vary when public subsidies are provided compared to noncooperative investment rates.

In Case III, the coefficient associated with the difference-in-differences interaction term gauges a negative and statistically significant difference of six percentage points between cooperative and noncooperative investment rates when subsidies are provided. Overall, regression analysis shows that, in competitive markets:

Result 4. *Cooperation induced by public subsidies entails a lower than average investment rate compared to the noncooperative scenario*.

This result is consistent with the strand of literature pointing to a crowding-out effect of public subsidies for cooperation in R&D on firms' investment rates (e.g., Zúñiga-Vicente et al., 2014; Crescenzi et al., 2020; Cantabene and Grassi, 2018; Acconcia and Cantabene, 2018).

5. Discussion and Concluding Remarks

In this paper, we have analysed the impact of public subsidies on firms' R&D activities in markets characterized by varying degrees of competition and spillover. With the theoretical predictions, we have consistently found that the probability of cooperation increases with the level of knowledge spillover and with the level of product differentiation. We have also found that, on average, investment rates decrease in the level of knowledge spillover and increase in the level of product differentiation.

To assess the impact of public subsidies on cooperation rates, we first focused on cases in which the provision of additional monetary units is expected to induce a shift from a noncooperative to a cooperative strategy. Our difference-in-differences analysis has documented a significant and substantial positive effect of public subsidies on cooperation rates. We have also analysed cases in which the provision of additional monetary units does not affect the incentives of the duopoly game and is not expected to have an impact on subjects' choices. Specifically, we have found that in those cases where subjects have sufficient private incentives to cooperate, the provision of public subsidies does not alter their choices. However, where public subsidies are not enough to incentivise cooperation, we have found that they still increase subjects' willingness to invest cooperatively in R&D. We have interpreted this result in terms of the well-known framing effect as the provision of subsidies might be meant by subjects as a *cue* that the right *scenario* – the one whose selection gives rise to a *right* to be rewarded – is the cooperative one.

We have also analysed the impact of public subsidies on investment rates. We have found that in competitive markets the provision of additional monetary units encourages cooperation but may reduce the average investment rate. Hence, consistent with the relevant literature on the subject (e.g., Cerulli, 2010; Zúñiga-Vicente et al., 2014; Fölster, 1995; Griliches, 1998; Belderbos et al., 2004; Colombo et al., 2006; Czarnitzki and Hottenrott, 2012; Crescenzi et al., 2020; Cantabene and Grassi, 2018), we showed that, even in those cases in which public subsidies *mechanically* encourage cooperation, they cannot in general be advocated on the grounds that they increase the overall investment level in R&D.

Overall, our results suggest the relevant policy implication that the use of public subsidies should not be indiscriminate. Contingent on market conditions, subsidies can be redundant as firms have sufficient private incentives to cooperate spontaneously – that is, either when competition in the product market is low or when the level of knowledge spillover is high. Public subsidies can also be counterproductive because, by inducing a higher cooperation rate, they can indirectly stimulate lower R&D investments. This translates into a warning for public policies aimed at designing incentives to promote R&D cooperation. In specific circumstances, this would entail a waste of public resources.

References

Acconcia, A., & Cantabene, C. (2018). Liquidity and firms' response to fiscal stimulus. *The Economic Journal*, *128*(613), 1759-1785.

Aghion, P., Bechtold, S., Cassar, L., & Herz, H. (2018). "The causal effects of competition on innovation: Experimental evidence." *The Journal of Law, Economics, and Organization*, *34*(2), 162-195.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt (2005), "Competition and innovation: An inverted-U relationship". *Quarterly Journal of Economics* 120(2), 701–728.

Angrist, J. D., & Pischke, J. S. (2009). *Mostly harmless econometrics: An empiricist's companion*. Princeton university press.

Angrist, Joshua D., and Jörn-Steffen Pischke. 2010. "The Credibility Revolution in Empirical Economics: How Better Research Design Is Taking the Con out of Econometrics." *Journal of Economic Perspectives*, 24(2): 3-30.

Antonelli, C., & Crespi, F. (2013). The" Matthew effect" in R&D public subsidies: The Italian evidence. *Technological forecasting and social change*, *80*(8), 1523-1534.

Aristei, D., Sterlacchini, A., & Venturini, F. (2017). Effectiveness of R&D subsidies during the crisis: firm-level evidence across EU countries. Economics of Innovation and new Technology, 26(6), 554-573.

Arrow, K. J. (1972). *Economic welfare and the allocation of resources for invention* (pp. 219-236). Macmillan Education UK.

d'Aspremont, C. and A. Jacquemin (1988), 'Cooperative and noncooperative R&D in duopoly with spillovers'. *American Economic Review* 78, 1133–1137.

Belderbos, R., Carree, M., & Lokshin, B. (2004). Cooperative R&D and firm performance. *Research policy*, *33*(10), 1477-1492.

Belderbos, R., M. Carree, B. Diederen, B. Lokshin, and R. Veugelers. 2004. Heterogeneity in R&D Cooperation Strategies. *International Journal of Industrial Organization* 22 (8–9): 1237–1263.

Belleflamme, P., and Peitz, M. (2015). *Industrial organization: markets and strategies*. Cambridge University Press.

Becker, B. (2015). Public R&D policies and private R&D investment: A survey of the empirical evidence. *Journal of economic surveys*, *29*(5), 917-942.

Bianchini, S., Llerena, P., & Martino, R. (2019). The impact of R&D subsidies under different institutional frameworks. *Structural Change and Economic Dynamics*, 50, 65-78.

Bloom, N., Griffith, R., & Van Reenen, J. (2002). Do R&D tax credits work? Evidence from a panel of countries 1979–1997. *Journal of Public Economics*, *85*(1), 1-31.

Bronzini, R., & Piselli, P. (2016). The impact of R&D subsidies on firm innovation. *Research Policy*, *45*(2), 442-457.

Cantabene, C., & Grassi, I. (2019). Public and private incentives to R&D cooperation in Italy. *Economics of Innovation and New Technology*, *28*(3), 217-242.

Capuano, C., & Grassi, I. (2019). Spillovers, product innovation and R&D cooperation: a theoretical model. *Economics of Innovation and New Technology*, *28*(2), 197-216.

Cason, T. N. (1995). An experimental investigation of the seller incentives in the EPA's emission trading auction. *The American Economic Review*, 905-922.

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

Cerulli, G. (2010) Modelling and measuring the effect of public subsidies on business R&D: a critical review of the econometric literature. *The Economic Record*, 86(274): 421–449.

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of economic behavior & organization*, *81*(1), 1-8.

Colombo, M. G., L. Grilli, and E. Piva. (2006). In Search of Complementary Assets: The Determinants of Alliance Formation of High-Tech Start-ups. *Research Policy*, 35 (8): 1166–1199.

Cox, J. C., Sadiraj, V., & Tang, S. X. (2023). Morally monotonic choice in public good games. *Experimental Economics*, 1-29.

Crescenzi, R., de Blasio, G., & Giua, M. (2020). Cohesion Policy incentives for collaborative industrial research: evaluation of a Smart Specialisation forerunner programme. *Regional Studies*, *54*(10), 1341-1353.

Czarnitzki, D., & Hottenrott, H. (2012). Collaborative R&D as a strategy to attenuate financing constraints. *ZEW-Centre for European Economic Research Discussion Paper*, (12-049).

Czarnitzki, D., Ebersberger, B., & Fier, A. (2007). The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany. *Journal of applied econometrics*, *22*(7), 1347-1366.

Czarnitzki, D., & Hussinger, K. (2004). The link between R&D subsidies, R&D spending and technological performance. *ZEW-Centre for European Economic Research Discussion Paper*, (04-056).

Darai, D., Sacco, D., & Schmutzler, A. (2010). Competition and innovation: an experimental investigation. *Experimental Economics*, *13*(4), 439-460.

Davis, D. D., & Holt, C. A. (1998). Conspiracies and secret discounts in laboratory markets. *The Economic Journal*, *108*(448), 736-756.

Ersoy, F. (2021). Returns to effort: experimental evidence from an online language platform. *Experimental Economics*, *24*(3), 1047-1073.

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

Fölster, S. (1995). Do subsidies to cooperative R & D actually stimulate R&D investment and cooperation?. *Research Policy*, *24*(3), 403-417.

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

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic decision making. *Annual review of psychology*, *62*, 451-482.

Greiner, B. (2004). An online recruitment system for economic experiments.

Griliches, Z. (1998). R&D and productivity: The unfinished business. In *R&D and Productivity: The Econometric Evidence* (pp. 269-283). University of Chicago Press.

Halbheer, D., Fehr, E., Goette, L., & Schmutzler, A. (2009). Self-reinforcing market dominance. *Games and Economic Behavior*, *67*(2), 481-502.

Horowitz, J. L. (2019). Bootstrap methods in econometrics. *Annual Review of Economics*, *11*, 193-224

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

Ioannou, C. A., Makris, M., & Ornaghi, C. (2021). R&D productivity and the nexus between product substitutability and innovation: Theory and experimental evidence. *Journal of Economic Behavior & Organization*, *186*, 135-151.

Kagel, J. H. (2009). Laboratory Experiments: The Lab in Relationship to Field Experiments, Field Data and Economic Theory. in *The Methods of Modern Experimental Economics*, Oxford University Press.

Kahneman, D., & Tversky, A. (2013). Choices, values, and frames. In *Handbook of the fundamentals of financial decision making: Part I* (pp. 269-278).

Kamien, M. I., Muller, E., & Zang, I. (1992). Research joint ventures and R&D cartels. *The American Economic Review*, 1293-1306.

López, A. (2008). Determinants of R&D cooperation: Evidence from Spanish manufacturing firms. *International Journal of Industrial Organization*, *26*(1), 113-136.

MacKinnon, J. G. (2006). Bootstrap methods in econometrics. *Economic Record*, *82*, S2-S18.

Moffatt, P. (2020). *Experimetrics: Econometrics for experimental economics*. Bloomsbury Publishing.

Moffatt, P. G. (2021). Experimetrics: a survey. *Foundations and Trends® in Econometrics*, *11*(1–2), 1-152.

Pippel, G. (2014). R&D cooperation for non-technological innovations. *Economics of Innovation and New Technology*, *23*(7), 611-630.

Østbye, S. E., & Roelofs, M. R. (2013). The competition–innovation debate: is R&D cooperation the answer?. *Economics of Innovation and New Technology*, *22*(2), 153-176.

Roelofs, M. R., Østbye, S. E., & Heen, E. E. (2017). Asymmetric firms, technology sharing and R&D investment. *Experimental Economics*, *20*(3), 574-600.

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

Russo, A., Catalano, M., Gaffeo, E., Gallegati, M., & Napoletano, M. (2007). Industrial dynamics, fiscal policy and R&D: Evidence from a computational experiment. *Journal of Economic Behavior & Organization*, *64*(3), 426-447.

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

Silipo, D. B., & Weiss, A. (2005). Cooperation and competition in an R&D market with spillovers. *Research in Economics*, *59*(1), 41-57.

Sørensen, F., Mattsson, J., & Sundbo, J. (2010). Experimental methods in innovation research. *Research Policy*, *39*(3), 313-322.

Struwe, N., Blanco, E., & Walker, J. M. (2022). Competition among public good providers for donor rewards. *Experimental Economics*, 1-29.

Suetens, S. (2004). Literature review: R&D cooperation in oligopoly with spillovers: An experimental economics approach. *Mimeo*.

Suetens, S. (2005). Cooperative and noncooperative R&D in experimental duopoly markets. *International Journal of Industrial Organization*, *23*(1), 63-82.

Szücs, F. (2020). Do research subsidies crowd out private R&D of large firms? Evidence from European Framework Programmes. *Research Policy*, *49*(3), 103923.

Wu, J. (2012). Technological collaboration in product innovation: The role of market competition and sectoral technological intensity. *Research Policy*, *41*(2), 489-496.

Zúñiga-Vicente, J. Á., Alonso-Borrego, C., Forcadell, F. J., & Galán, J. I. (2014). Assessing the effect of public subsidies on firm R&D investment: a survey. *Journal of Economic Surveys*, *28*(1), 36-67.

Appendix

Figure 1. Probability of successful innovation as a function of the investment level.

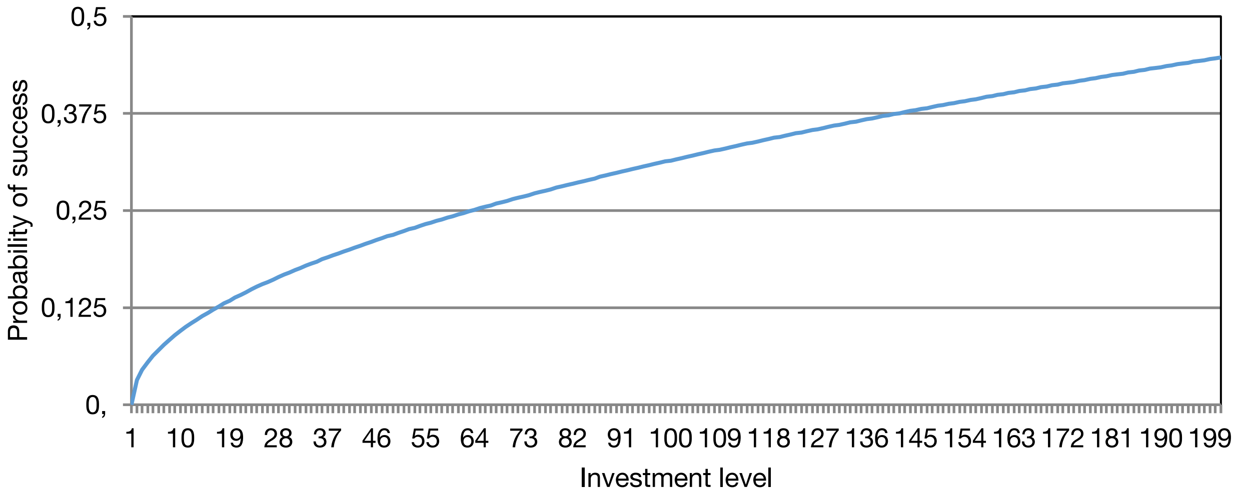


Figure 2. Dynamics of the average willingness to cooperate (cases II and III)

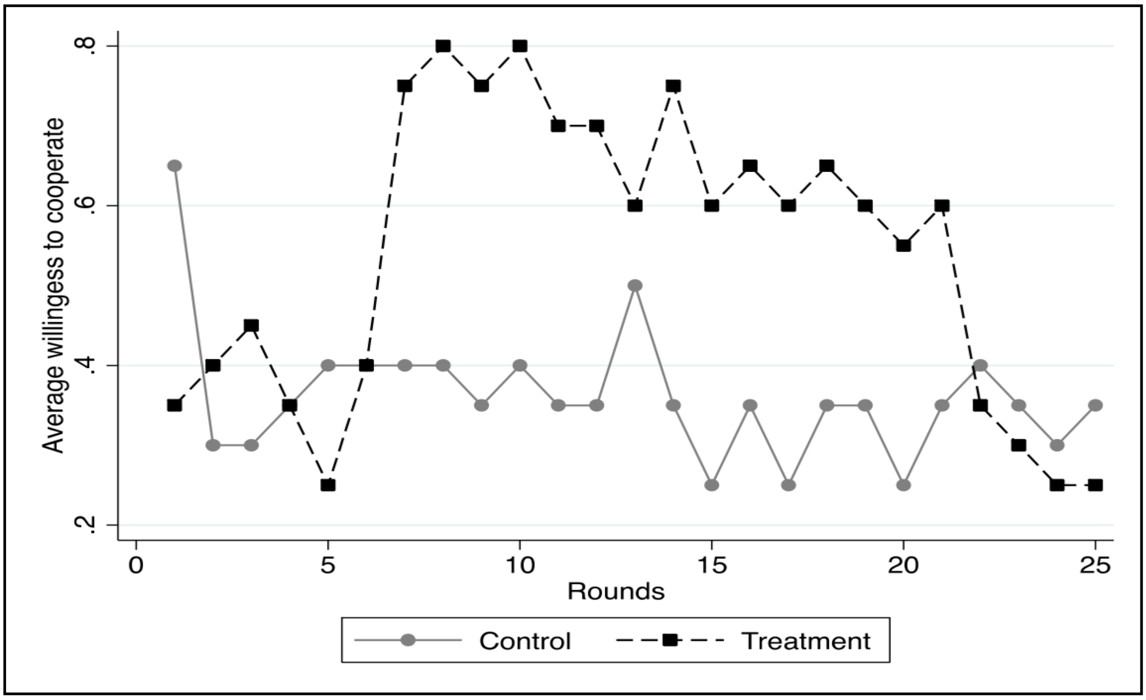
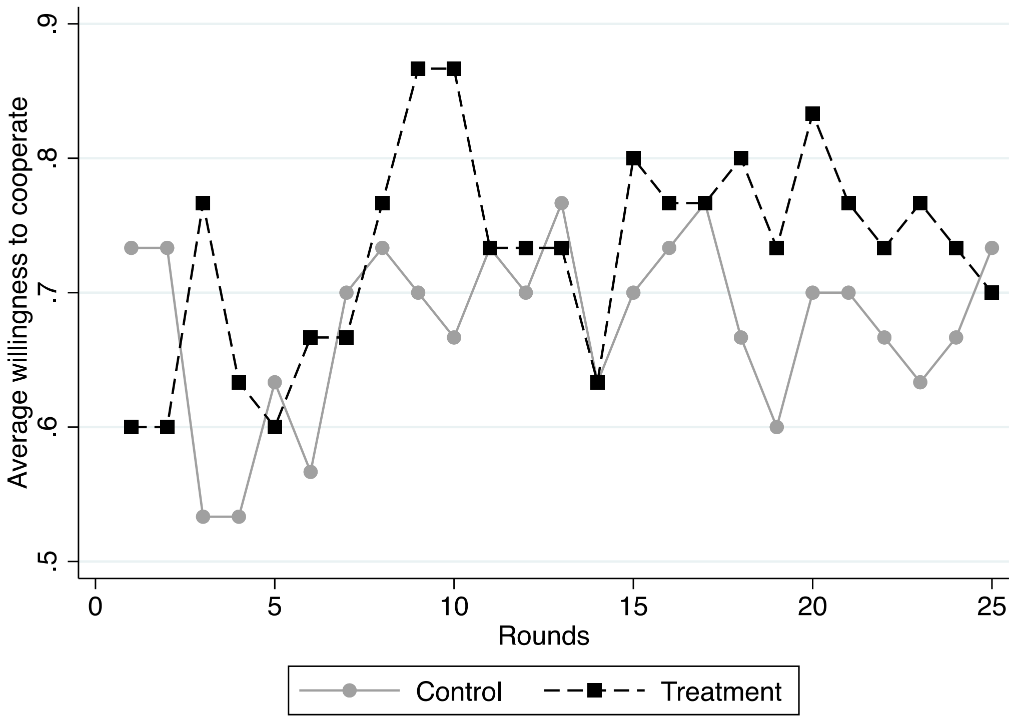


Figure 3. Dynamics of the average willingness to cooperate (cases IV-VI and Case I)

a) Cases IV-VI



b) Case I

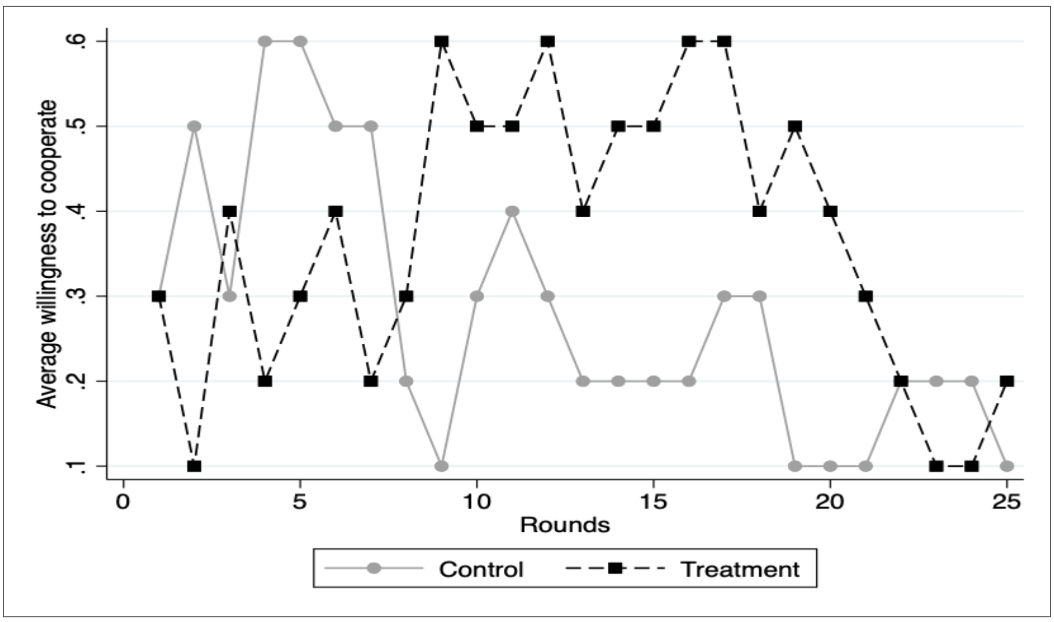


Figure 4. Dynamics of average investment rate in cases II and III (Control and Treatment)

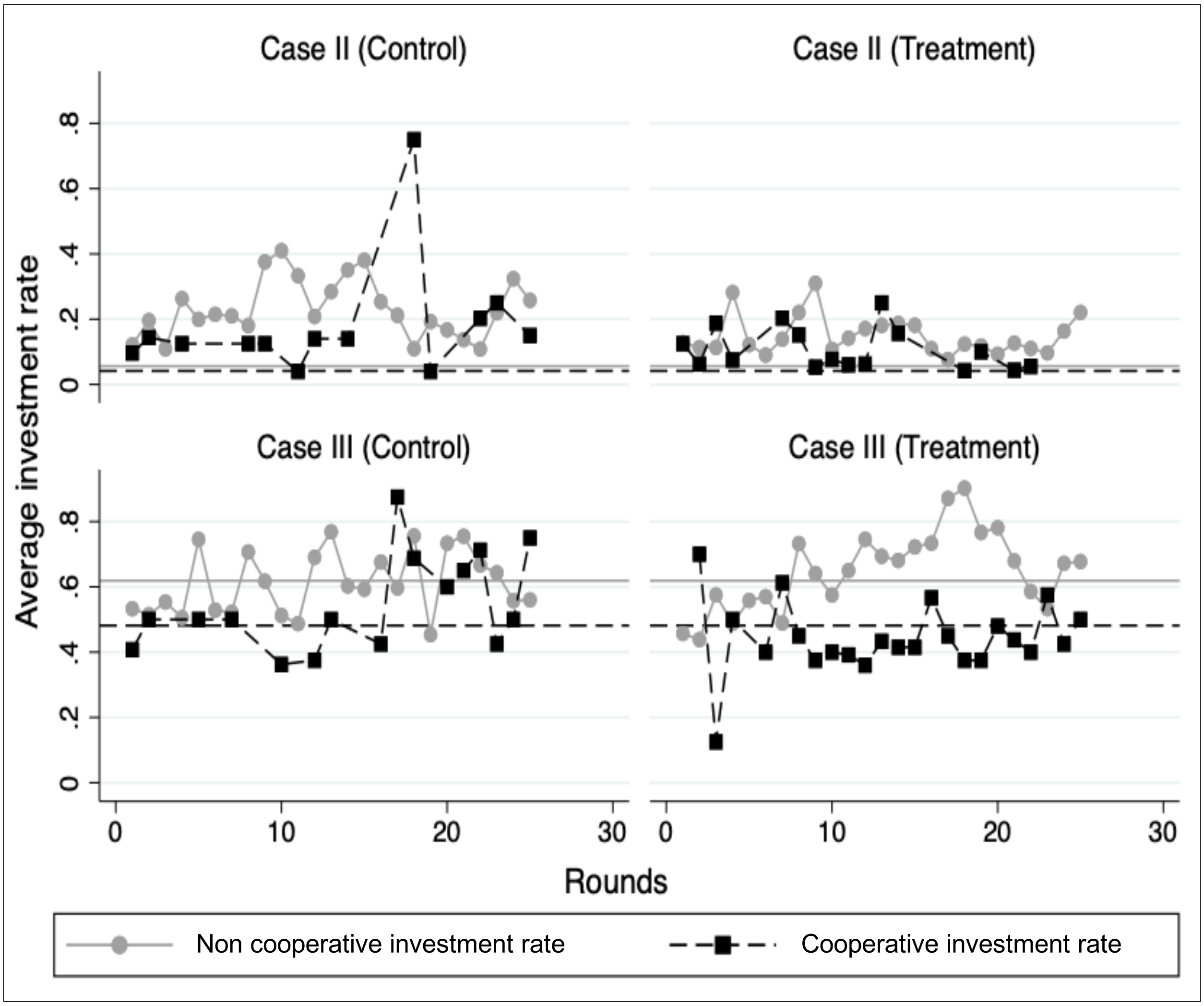


Figure 5. Dynamics of average investment rate in cases I, IV, V, VI (Control & Treatment)

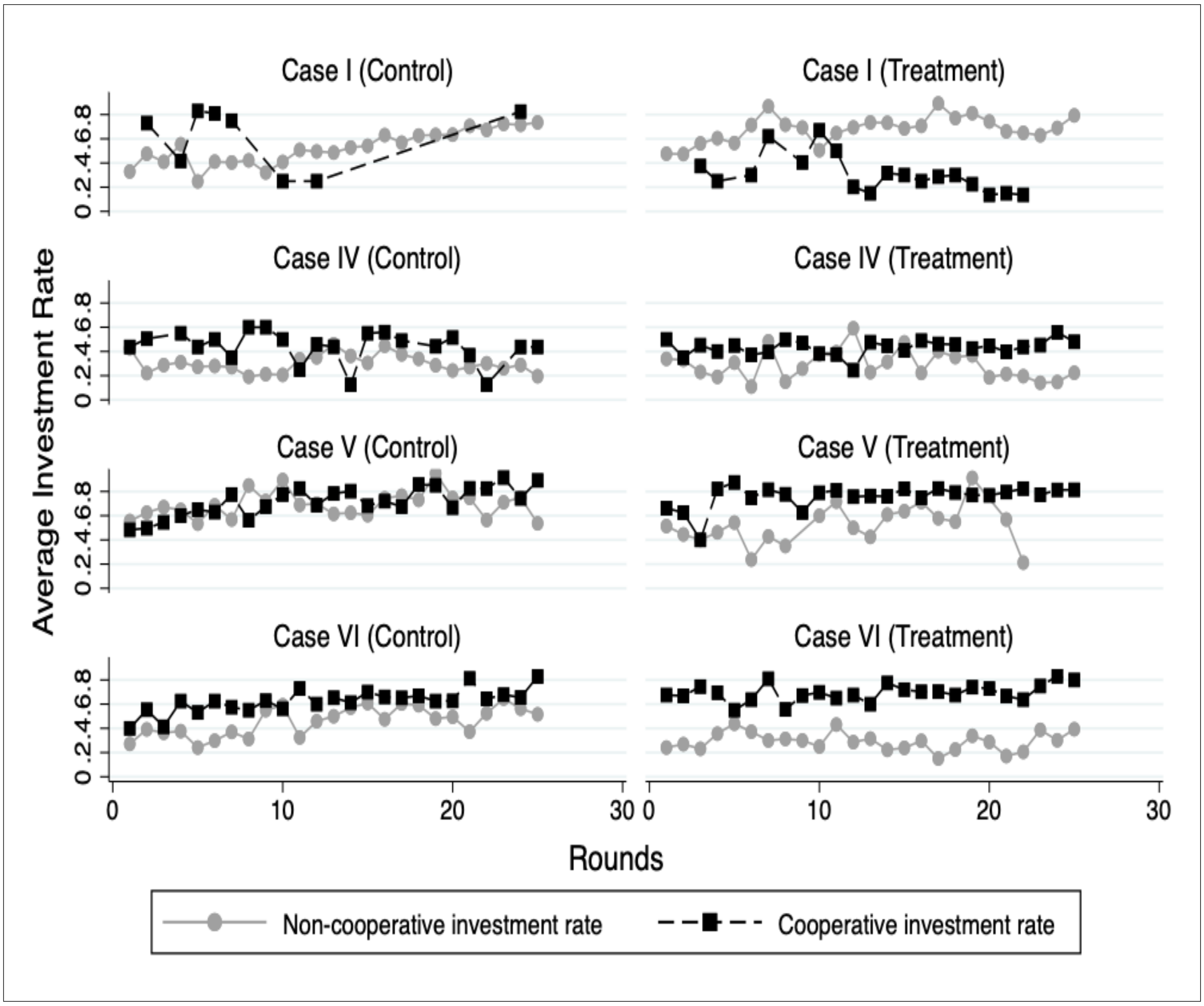


Table 1. Predicted outcomes in Control and Treatment groups

	Control Groups S=0 MUs		*Treatment Groups* S=30 MUs	
	β=0.20	**β=0.80**	**β=0.20**	**β=0.80**
α=0.10	NC (I)	**NC (II)**	NC (I)	**C (II)**
α=0.45	**NC (III)**	C (IV)	**C (III)**	C (IV)
α=0.70	C (V)	C (VI)	C (V)	C (VI)

Note. *The parameter α is a measure of product differentiation. The parameter β is a measure of knowledge spillovers. Subsidies are 30 monetary units provided to cooperating subjects in the treatment groups during rounds 7-21.*

Table 2. Effect of Spillovers and Competition on Cooperation and Investment Rate in R&D

	Willingness to Cooperate in R&D				Investment Rate in R&D	
	MLM		Probit		MLM	
SP_{high}	0.100** (0.043) [0.019]	0.112*** (0.023) [0.021]	0.326* (0.187) [0.094]	0.409*** (0.104) [0.102]	–0.247*** (0.026) [0.010]	–0.242*** (0.023) [0.008]
PD_{med}	0.164*** (0.050) [0.023]	0.160*** (0.027) [0.024]	0.514** (0.220) [0.108]	0.518*** (0.121) [0.103]	0.083*** (0.025) [0.011]	0.088*** (0.020) [0.011]
PD_{high}	0.400*** (0.041) [0.022]	0.444*** (0.037) [0.022]	1.637*** (0.190) [0.123]	1.870*** (0.174) [0.127]	0.236*** (0.039) [0.012]	0.239*** (0.026) [0.013]
Degree	No	Yes	No	Yes	No	Yes
Rounds F.E.	Yes					
N	1500					

Note: In the first four columns, the dependent variable is a dummy taking value one if subjects are willing to cooperate. In the first two columns, we estimate a panel Multi-Level Model (MLM) with random effects on the session and subject level. In the subsequent two columns, we estimate a panel Multiple-level Probit model with random effects on the session and subject level, taking into account errors correlations. In the last two columns, we estimate a Multi-Level Model with random effects on the session and subject level, where the dependent variable is subjects' investment rate. SP_{high} is a dummy taking value one for high levels of spillovers. The PD_{med} and PD_{high} are dummies taking value one for intermediate and high levels of product differentiation respectively. SP_{low} (i.e., low spillover level) and PD_{low} (i.e., low level of product differentiation) are the baseline dropped categories. All estimates control for period fixed effects. We control for subjects degree with two dummies: degree2 for master and degree3 for PhD students, with degree1 (undergraduate students) as baseline. Since this control does not substantially affect the coefficients of the variables of interest, the related estimates are not reported. In parentheses and square brackets we report *robust* and *bootstrapped* standard errors clustered at session level. Reported significance levels (*** 1%, ** 5%, * 10%) are based on robust standard errors.

Table 3. Treatment Effect of Subsidies on Cooperation in R&D (cases II and III)

	Case II				Case III			
	MLM		Probit		MLM		Probit	
Subsidies	–0.060 (0.145) [0.053]	0.012 (0.122) [0.059]	–0.069 (0.728) [0.298]	0.230 (0.613) [0.340]	–0.030 (0.167) [0.058]	–0.073 (0.167) [0.064]	0.068 (0.708) [0.354]	–0.163 (0.729) [0.268]
DID	0.326** (0.134) [0.058]	0.326** (0.134) [0.060]	1.264** (0.502) [0.400]	1.266** (0.504) [0.423]	0.410*** (0.155) [0.065]	0.410*** (0.155) [0.070]	1.631** (0.647) [0.367]	1.635** (0.646) [0.346]
Degree	No	Yes	No	Yes	No	Yes	No	Yes
Rounds F.E.	Yes							
N	500							

Note: The dependent variable is a dummy taking value one if subjects are willing to cooperate. We estimate both a panel Multi-level Model with random effects on the subject level, and a panel Multiple-Level Probit model. The variable Subsidies is a dummy equal to one for the treatment group. DID is the difference-in-differences interaction term between Subsidies and a dummy (*time*), taking value one for those rounds (7-21) in the treatment groups where 30 MUs are provided to cooperating subjects. All estimates control for rounds fixed effects. We control for subjects degree with two dummies: degree2 for master and degree3 for PhD students, with degree1 (undergraduate students) as baseline. Since subjects degree affects neither the size nor the significance of the relevant coefficients, we do not report estimates results. In parentheses and square brackets we report respectively *robust* and *bootstrapped* standard errors clustered at subject. Reported significance levels (*** 1%, ** 5%, * 10%) are based on robust standard errors.

Table 4. Treatment Effect of Subsidies on Cooperation in R&D (cases I, IV, V, VI)

	Case I		Case IV		Case V		Case VI	
	MLM	Probit	MLM	Probit	MLM	Probit	MLM	Probit
Subsidies	–0.119 (0.102) [0.063]	–0.753 (0.607) [0.307]	0.197 (0.135) [0.066]	0.859 (0.574) [0.667]	0.089 (0.091) [0.053]	0.284 (0.458) [0.661]	–0.104 (0.129) [0.062]	–0.582 (0.596) [0.615]
DID	0.346*** (0.095) [0.071]	1.506*** (0.378) [0.385]	–0.016 (0.116) [0.078]	–0.007 (0.430) [0.444]	0.006 (0.075) [0.073]	–0.010 (0.335) [0.402]	0.093 (0.111) [0.074]	0.320 (0.455) [0.597]
Degree	Yes							
Rounds F.E.	Yes							
N	500							

Note: The dependent variable is a dummy taking value one if subjects are willing to cooperate. For all cases we estimate both a panel Multi-level Model with random effects on the subject level, and a panel Multiple-Level Probit model with random effects on the subject level. The variable Subsidies is a dummy equal to one for the treatment groups. DID is the difference-in-differences interaction term between Subsidies and a dummy (*time*), taking value one for those rounds (7-21) in the treatment groups where 30 MUs are provided to cooperating subjects. All estimates control for rounds fixed effects. We control for subjects' degree with two dummies: degree2 for master and degree2 for PhD students, with degree1 (undergraduate students) as baseline. In parentheses and square brackets we report respectively *robust* and *bootstrapped* standard errors clustered at subject level for the variables of interest (constant excluded). Reported significance levels (*** 1%, ** 5%, * 10%) are based on robust standard errors.

Table 5. Effect of Subsidies on the Difference between Cooperative and Non-cooperative Investment Rates (cases II and III)

	Within Control				Within Treatment			
	Case II		Case III		Case II		Case III	
C.I.	–0.035 (0.052) [0.044]	–0.034 (0.056) [0.044]	–0.039 (0.039) [0.037]	–0.039 (0.038) [0.069]	–0.027** (0.012) [0.020]	–0.031*** (0.011) [0.017]	–0.056* (0.033) [0.035]	–0.053 (0.033) [0.029]
DID	0.019 (0.100) [0.103]	0.021 (0.101) [0.107]	–0.018 (0.040) [0.040]	–0.018 (0.040) [0.050]	0.014 (0.034) [0.035]	0.019 (0.036) [0.040]	–0.060** (0.029) [0.035]	–0.059** (0.028) [0.033]
Degree	No	Yes	No	Yes	No	Yes	No	Yes
Rounds F.E.	Yes							
N	250							

Note: The dependent variable is the subjects' investment rate. We estimate a panel Multi-Level Model with random effects on the subject level. The variable CI is a dummy equal to one for those subjects that invest cooperatively in R&D. DID1 is the difference-in-differences interaction term between CI and a dummy (*time*) taking value one for those rounds (7-21) in the treatment group where 30 MUs are provided to cooperating subjects. All estimates control for rounds fixed effects. We control for subjects degree with two dummies: degree2 for master and degree3 for PhD students, with degree1 (undergraduate students) as baseline. Since subjects degree affects neither the size nor the significance of the relevant coefficients, we do not report estimates results. In parentheses and square brackets we report respectively *robust* and *bootstrapped* standard errors clustered at subject. Reported significance levels (*** 1%, ** 5%, * 10%) are based on robust standard errors.

FONDAZIONE ENI ENRICO MATTEI WORKING PAPER SERIES
"NOTE DI LAVORO"
Our Working Papers are available on the Internet at the following address:
http://www.feem.it/getpage.aspx?id=73&sez=Publications&padre=20&tab=1

"NOTE DI LAVORO" PUBLISHED IN 2022

1. 2022, Daniele Crotti, Elena Maggi, Evangelia Pantelaki, Urban cycling tourism. How can bikes and public transport ride together for sustainability?
2. 2022, Antonio Acconcia, Sergio Beraldo, Carlo Capuano, Marco Stimolo, Public subsidies and cooperation in research and development. Evidence from the lab.

Fondazione Eni Enrico Mattei
Corso Magenta 63, Milano – Italia

Tel. +39 02.520.36934
Fax. +39.02.520.36946

E-mail: letter@feem.it
www.feem.it

Fondazione Eni Enrico Mattei