Cooperation Spillovers and Price Competition in Experimental Markets*

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Abstract
Firms often cooperate explicitly through activities such as research joint ventures, while competing in other markets. Cooperation in research and development can allow firms to internalize the external benefits of knowledge creation and increase the returns from R&D expenditures. Such cooperation may spill over to facilitate collusion in the market, however, potentially lowering welfare and efficiency. This paper uses a laboratory experiment to examine if sellers successfully coordinate to fund a joint research project to reduce their costs, and how this collaboration affects their pricing behavior. The experiment includes control treatments with separate R&D cooperation and markets. Our results show that although participants usually cooperate when given an opportunity, cooperation is observed less frequently when they also compete in the market. Communication improves cooperation in all environments, particularly when the market is present. Nevertheless, the data provide no evidence of seller collusion in the market.

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1. Introduction

Both competition and cooperation are important for the successful functioning of many economic systems. For example, firms compete in markets but they also cooperate with one another through arrangements such as research joint ventures, lobbying, cooperative marketing agreements and strategic alliances.

In this paper we use experiments to examine how competitive interactions affect agents’ propensity to cooperate. We are interested in studying spillovers that may involve cooperation in one domain (such as a research joint venture) and competition in another (such as in a market). Cooperation could weaken competition, perhaps promoting collusion, or market competition could reduce incentives for non-market cooperation. These “behavioral spillovers” could go in either direction. They are distinct from another type of spillover, through knowledge externalities that occur in R&D when the innovator cannot fully appropriate the gains to innovation, leading potentially to a socially inefficient level of research (deBondt, 1996). As discussed below, behavioral spillovers have been shown in experiments to increase cooperation in otherwise competitive environments, for example through establishing cooperative precedents.

A large body of theoretical research has focused on firms cooperating in research joint ventures and how this impacts competition in output markets. For example, Cooper and Ross (2009) examine the mechanism by which agreements to cooperate in one market can have negative effects on competition in other markets, even in situations when these markets are not

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1 Climate change is a prominent example highlighting the need for both cooperation and competition. While cooperation amongst firms and countries is needed to solve this complex international collective action problem, competition between firms is also essential to provide incentives for innovation to reduce the costs of controlling emissions. This complementarity has led to a growing interest in both competition and cooperation, with economists and policy makers endeavoring to find market solutions to social dilemmas, such as markets for emissions permits.

2 Cellini and Lambertini, (2009) however show that irrespective of the amount of R&D spillover, cooperative behavior in R&D would be preferable from both a private and a social point of view. Their dynamic model allows for investment smoothing over time, hence the externality is internalized via the joint profit maximization in the R&D phase and this is socially desirable irrespective of the spillover effects. Amir (2000) compares different earlier models with R&D spillovers and illustrates the sensitivity of the results to small changes in model specifications.
linked via costs or demand. Cabral (2000) shows that product market prices are affected by R&D agreements between firms. Caloghirou et al. (2003), Lambertini et al. (2003) and Poyago-Theotoky (2007) also discuss the impact of forming research joint ventures on product markets and cartel formation.3

Empirical work using field data has provided creative indirect evidence on the collusive potential of research joint ventures by exploiting natural “policy experiments,” although the extent of this evidence is limited. Goeree and Helland (2010), for example, show that research joint ventures facilitate collusion because they became less popular following an enforcement policy change (leniency) that made collusion less attractive. Policy experiments such as these are often required since systematic collusion often goes undetected by authorities. Dusko et al. (2010) also examine the link between research joint ventures and collusion, using data from the US National Cooperation Research Act that granted certain research joint ventures milder antitrust scrutiny. They find that horizontal research joint ventures lead to more collusion than vertical joint ventures. Our work provides complementary and more direct evidence, since in the laboratory we can observe the level and sustainability of tacit and explicit collusion and can therefore circumvent the measurement and endogeneity issues that are often prevalent in field data.

The specific research goals of the present study are the following. First, we wish to examine if agents take advantage of available gains from cooperation in the presence of payoff uncertainties that arise from stochastic innovation success. Second, we are interested in learning if a behavioral spillover of cooperation can lead to collusion in markets, or whether competition in markets reduces non-market cooperation. These notions of cooperation concern contributions

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3 Many of the theoretical models developed in these papers build on the seminal research by d’Aspremont and Jacquemin (1989) and Kamien et al. (1992).
to joint R&D projects or collusion in price setting, and are defined independently of any communication opportunities. Therefore, our third goal is to determine how this interaction between cooperation and competition is affected by the introduction of non-market communication opportunities. Finally, we will measure the externalities from R&D cooperation to non-innovators in the market.4

Subjects in our experiment trade in a computerized double auction market where they make price offers and can accept offers made by others in continuous time. Sellers have the option to contribute voluntarily to a public good, corresponding to a research joint venture, which may (stochastically) reduce their marginal costs. This cost reduction lowers equilibrium prices, so buyers can also potentially benefit from this innovation. Cooperative research is modeled as a threshold (provision point) public goods problem, in which the good (the reduction in costs) is provided if voluntary contributions exceed the required threshold level of contributions and if the research project succeeds. Many collective action scenarios can be represented as such public good games. For example, firms contributing to a research fund may require financing or effort to reach a specific threshold for any chance of successful innovation.

We find that while there are some modest behavioral spillovers, subjects often cooperate in funding the public good even though they also compete aggressively in the market. Although cooperative research occurs less frequently when subjects also compete in the market, research cooperation does not reduce the intensity of market competition. Communication helps subjects coordinate on an efficient choice of public good contributions in all environments, and we also observe significant R&D externalities that benefit non-innovators. The results therefore suggest that R&D collaborations need not diminish robust market competition.

4 These “downstream” benefits through lower market prices are similar to surplus externalities that can motivate vertical R&D collaborations (e.g., Harabi, 2002).
The idea that individuals’ behavior could spill over across different environments or domains has received considerable attention in the recent experimental literature, although theoretically little is understood about the relevant mechanisms (Bednar and Page, 2007). Bednar et al. (2012) document behavioral spillovers for several different types of two-player bimatrix games. Falk et al. (2011) find that behavior does not differ from isolated controls when two coordination or public goods games are played simultaneously with different opponents. Savikhin and Sheremeta (2012) also study simultaneous play, and they find that cooperation in a voluntary contribution game reduces competitive overbidding in contests. Brandts and Cooper (2006) document behavioral spillover due to cooperative precedent established in a high incentive coordination game to a lower incentive coordination game. Cason et al. (2012) show that a behavioral spillover occurs for two different coordination games, but only if they are played sequentially and not when they are played simultaneously. None of the (few) previous experiments that have considered behavioral spillovers have included markets.

In addition, our experiment is novel because few previous studies have used experiments to examine issues in R&D and competition, and even less have considered R&D joint ventures. Issac and Reynolds (1992) report an experiment where sellers compete in prices and in cost reducing R&D. Their sellers competed in a posted offer market (with simulated buyers), and after five periods they could undertake costly innovation, which if successful lowered costs for that seller only. Davis et al. (1995) varied the tax subsidy available to subjects who invest in R&D and also the appropriability of returns to R&D. They find that an equal tax subsidy across investors increases levels of investment in R&D, but not in proportion to the amount of the subsidy. Buckley et al. (2003) examine the effectiveness of alternative subsidy schemes in stimulating R&D, and show that incremental subsidies are less effective than level subsidies.
Unlike all of these experiments, we have added to the market structure a stage where subjects have the opportunity to contribute towards a joint research fund. The “research” is also successful only stochastically, differentiating this threshold public goods game from most of the experimental literature. Deck and Erkal (2011) examine how the decision to form research joint ventures changes in a dynamic environment and find that cooperation can unravel as firms move forward in the R&D process and monopoly rents become more attractive.

Suetens (2005) tests how different levels of appropriability of R&D externalities affects investment, and Suetens (2008) adds competition in the product market and finds that binding R&D cooperation facilitates price collusion in a duopoly context. Both studies employed simulated buyers. In contrast, our experiment employs more sellers in each market (triopolies) and explicitly incorporates markets where sellers compete to make trades with strategic human buyers in a realistic and competitive (double auction) trading institution. Our design also allows us to isolate the impact of behavioral spillovers, separately from R&D externalities that accrue to non-innovating buyers through lower prices.

2. **Design**

The experiment is designed to study the links between market competition and cooperation. It uses a $3 \times 2$ design, summarized in Table 1, employing a total of 264 subjects. We examine two dimensions and conduct three treatments across each dimension. In one treatment subjects participated only in a threshold public goods game, in another they traded only in a market and in the third treatment subjects participated both in a market and in a threshold public goods game. These public good provision and market pricing games require coordination to increase payoffs, and this coordination may further require non-market communication. Therefore, we vary
opportunities for communication along the second dimension and all three treatments included sessions in which sellers were allowed to communicate with each other using typed text in computer-based chat rooms, contrasted with sessions in which all traders made decisions without any communication.

The Public Good Only treatment examines whether subjects coordinate and cooperate with each other when threshold public good returns are uncertain, and studies how communication affects cooperation. The Market Only treatment explores the impact of communication on collusion, prices and trading efficiency. The main motivation for conducting these two treatments is to provide baselines to compare subjects’ cooperative and competitive behavior with the combined Market and PG treatment (Combined), hence allowing identification of behavioral spillovers. The comparison with the Public Good Only baseline reveals how market competition may reduce cooperation, while the comparison with the Market Only baseline indicates how cooperation in providing the public good (which lowers sellers’ costs) affects price competition.

2.1. Treatments

Combined

The Combined treatment includes data from 20 sessions. In all sessions, 6 subjects traded in a computerized double auction market across 27 periods. Our design is motivated in part by recent policy initiatives to mitigate climate change. Emission markets are an ideal environment to study spillovers as trading in carbon markets is being implemented or considered by different countries, while governments are also actively promoting cooperative R&D arrangements between firms to reduce the future costs of emission reductions and the discovery of new
mitigation technologies. Therefore, in our markets all participants have the opportunity to buy and sell units, and they were required to hold a “coupon” to be able to avoid producing a unit. One could interpret this as holding an emissions permit to avoid abating one unit of pollution, but neutral framing was used in the experiment so alternative interpretations are reasonable. Marginal costs rise as subjects increase abatement and they can avoid these cost increases by purchasing permits. As in permit markets in the field, subjects had to compare the price of permits with their individual costs and on that basis decide whether to be permit buyers or sellers. This endogenous buyer/seller role determination exists in many other market contexts, such as in asset, securities and currency markets, and was one reason why the market was organized using double auction rules. Such symmetric trading rules make it transparent for subjects to take either the buying or selling side, unlike posted offer markets where predetermined seller and buyer roles are more natural.

The double auction market is used extensively in experiments and is considered a relatively competitive trading institution, which is another reason for this institutional design choice since a main goal of this study is to determine the influence of market competition on cooperation in a joint R&D task. Even in this market institution, however, traders can exert market power (Muller et al, 2002) and this appears to be a stronger tendency when they are in flexible trader roles (as in the present study) rather than predetermined buyer or seller roles. Nevertheless, super-competitive pricing is observed in some sessions and is completely absent in others, so greater concentration on one side of the market does not often lead to significantly more collusion (Cason et al., 2003). In the present study, we incorporated several design features

5 Jaffe et al (2002) discuss the importance of including innovation and technological change for understanding alternative policy responses to environmental challenges.
6 Ledyard and Szakaly-Moore (1994), Godby (2000) and Muller et al. (2002) are examples of other market experiments using an environmental context that also feature endogenous role determination. Smith et al. (1988) is an early example of an asset market experiment sharing this same feature.
that allow some non-competitive opportunities to emerge in this otherwise competitive double auction institution, such as repeated seller interactions, non-market communication between sellers, and a relatively concentrated (triopoly) market structure.

As shown in Table 2, three of the six subjects had relatively low abatement costs and high permit endowments so that they should be sellers in the market. The other three subjects had higher costs and low permit endowments and so they should be buyers. (Subjects correctly recognized their role as buyers or sellers, since after the initial 6 periods only 0.8% of the trader-periods had a subject trading on the wrong side.) At the start of each period the buyers were endowed with 3 permits each and the sellers with 7 permits each, creating a total supply of 30 permits. The competitive equilibrium price in the market ranged from 500-525 with 4 units traded by each subject, as illustrated in Figure 1. At this equilibrium, the 3 buyers earn a total of approximately 1425 experimental dollars each period and the 3 sellers earn approximately 1500. (The exact amount depends on where prices are in the equilibrium price interval.)

Subjects participated in this market for 6 initial periods and then in blocks of 3 periods. After the first 6 periods and after some of the 3 period blocks, the 3 sellers played in a threshold public goods game.⁷ This public good represents a common project such as a research joint venture, and the sellers chose their level of contribution. We chose a threshold public goods game instead of a linear public goods game as we were interested in research projects that require a particular scale to be successful. If the research project is successful, this cost-reducing innovation lowered the sellers’ marginal abatement costs by 100 experimental dollars for the

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⁷ An alternative design could introduce the public good coordination problem prior to introducing the market. We chose to introduce the market first, since the value of the public good is realized through market trading. It is necessary for subjects to first understand how their costs influence their profit before they can reasonably understand the benefits of investments required to lower those costs.
next block of 3 periods. We left structural cost levels unchanged in 3-period blocks because experimental markets typically require several periods to reliably approach equilibrium.

For the common research project to be successful, two conditions were necessary. First, the total group contributions by the three sellers had to reach a threshold of 1500 or more experimental dollars. Contributions above this threshold are not returned, and contributors receive no refund if total contributions do not reach the threshold. Second, if group contributions reach or exceed this threshold, with a 75 percent probability the research is successful. This stochastic element represents the uncertainty involved in the realization of cost-reducing benefits from R&D projects and can be interpreted as luck. As shown in Figure 1, successful R&D leads to a reduction in the equilibrium price to 450-475, with 5 units being traded by each subject in equilibrium. This leads to predicted total profits for the buyers and the sellers of approximately 2250 and 3000, respectively. With these parameters the sellers’ total return from the innovation is 4500 for each 3-period block. Thus, the expected step return (Croson and Marks, 2000) to this threshold public good, accounting for the 0.75 probability that the good is provided, is $(0.75 \times 4500)/1500=2.25$.\(^8\) Buyers also benefit from a positive externality generated by the successful R&D. In particular, in equilibrium the 3 buyers gain from the innovation by a total of approximately 2250-1425=825 per period through lower permit prices.

If the research project is unsuccessful, sellers have a new opportunity to contribute to the project again after a 3-period block. After every 3-period block in which they have had costs lowered, the costs return to the original, higher level for three periods. At the end of that 3-period block of 3 periods. We left structural cost levels unchanged in 3-period blocks because experimental markets typically require several periods to reliably approach equilibrium.

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8 Multiple Nash equilibria exist in this threshold public goods game. In a Pareto-dominated equilibrium no agent contributes anything and the good is not provided. For the parameters used in the experiment, any total contributions that sum to 1500—as long as no individual (risk neutral) agent contributes more than the expected benefit (1125 per agent)—constitute a Pareto efficient equilibrium. No equilibria exist with only one positive contributor. With three potential contributors and a threshold of 1500, clearly the focal, efficient equilibrium is a contribution of 500 per agent. As documented in the results section, this is the equilibrium that is typically played.
block they have another opportunity to contribute to the project to lower their costs. The design thus features stationary repetition of the cycle of contributions and 3-period blocks of the trading mechanism to allow for learning.

The joint profit-maximizing (optimal collusive) price for the Figure 1 parameters is 550 experimental dollars, with \( Q = 12 \) units traded (4 sold by each seller), regardless of whether sellers have low or high costs. Therefore, if sellers collude optimally they capture all of the benefits of the cost reduction that arise through their research collaboration.\(^9\)

In the 10 sessions where sellers were allowed to communicate, they could send typewritten computer chat messages to each other for 90 seconds before they made their contribution decisions. Chat communication is common in economic laboratories, since it admits rich use of language while still maintaining anonymity, control, and complete observability of the information that is being exchanged. While the sellers chatted, the buyers responded to a questionnaire by typing into their computer some information about their decisions in the market.\(^10\) The buyers did not know that sellers were communicating and were not given any information about the sellers’ public good contribution decision.

Note that the communication opportunity occurs prior to the public good investment choice, rather than immediately before market trading begins for each period. We implemented communication in this way for several reasons. First, communication about a research collaboration is explicitly permitted among firms who have an approved joint venture, whereas explicit communication about prices is, of course, *per se* illegal. Therefore, our setup does not encourage price communication, although we did not implement any communication restrictions

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\(^9\) Individual sellers could withhold one (marginal) unit unilaterally in both cost conditions and benefit sufficiently from higher prices received on other units to make this profitable, but of course this creates another public goods problem with each seller having the incentive to free-ride on others’ quantity restriction.

\(^10\) This buyer activity led all subjects to type during the same time intervals. This was intended to obscure buyer and seller identities and reduce possible suspicions by the buyers that the sellers were communicating with each other.
to prohibit discussions about prices. The second main reason for this design choice is to extend the literature on communication and collusion in experimental markets. In previous research the subjects typically did not have other activities to discuss besides price and quantity choices, which may have made collusion focal, or possibly even an “experimenter demand effect” (Zizzo, 2010). Our Combined treatment includes a cooperative activity which separates the communication period from the market periods, and can determine whether the collusion observed previously is robust to situations in which subjects make both investment and pricing choices rather than just pricing choices alone. We do not suggest any topic of conversation to the subjects, and they can just as naturally discuss prices as contribution levels.\footnote{In the Combined treatment, market trading commenced within 60 seconds of the chat conclusion in 80 percent of the periods, and the median time between chat and trading was 47 seconds. So the contribution and pricing decisions both followed quickly after the communication phase.}

**Market Only**

In the Market Only treatment (16 sessions), subjects traded with each other for 27 periods and did not have an opportunity to lower their costs. In 8 sessions sellers were allowed to communicate, again while buyers filled out questionnaires about their decisions in the experiment. Communication only occurs in the Combined treatment after 3-period blocks that have high costs, and costs (and thus communication periods) were endogenous in that treatment. Therefore, all of the Market Only sessions were conducted after the Combined sessions so that the subjects in both treatments had communication opportunities in exactly the same periods.\footnote{To ensure comparability with the no-communication sessions in the Combined treatment, buyers answered the same within-session questionnaire even in sessions where sellers were not allowed to communicate.}

**Public Good Only**

In the Public Good Only treatment (16 sessions) subjects participated in groups of three for 8 periods. This treatment isolates the sellers’ potential benefits of R&D cooperation in a simple reduced form by immediately translating successful cost reduction to increased profits. Sellers

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12 To ensure comparability with the no-communication sessions in the Combined treatment, buyers answered the same within-session questionnaire even in sessions where sellers were not allowed to communicate.
did not have to realize these profits through market trading. Each subject received at least 1500 experimental dollars every period and in certain periods they had an opportunity to increase this income to 3000 experimental dollars. These amounts correspond to the expected profit the sellers earn in competitive equilibrium for the three period blocks following successful cost reduction in the Combined treatment. Just like the Combined treatment, to increase payoffs the subjects had to reach a total contribution threshold of 1500, and also have an innovation success random draw (again with 0.75 probability). Thus, the set of Nash equilibria of this threshold public goods game (see footnote 7) is exactly the same as in the Combined treatment.

2.2 Procedures

The experiment was conducted using Z-tree (Fischbacher, 2007) and all subjects were students at the University of Melbourne with a variety of academic backgrounds, including economics. We conducted 52 independent sessions, and all 264 subjects were inexperienced in the sense that they had not participated in previous public goods or double auction market experiments. Although subjects interacted anonymously in 3 or 6 person fixed groups (depending on the treatment), multiple sessions were conducted simultaneously in the laboratory using 12 to 24 subjects. Upon arrival at the laboratory, subjects were randomly assigned a computer terminal, which had large partitions to prevent visual contact between subjects. Subjects read the experimental instructions and answered a set of computerized questions that examined and reinforced their understanding of the instructions. The experiment instructions for the Combined treatment are in the Appendix. In the Market Only and the Combined treatments buyers and sellers had different instruction sheets in the communication condition since only the sellers communicated. Before the session began the experimenter read aloud a one page instructions summary to establish common knowledge about the main experimental rules and conditions. At
the end of their session, which lasted about two hours, subjects filled out a demographic survey with questions regarding their age, gender, field of study, and other characteristics. They were paid privately in cash, and earnings averaged AUD 35.13.

3. Experimental Results

3.1 Cooperative Research Funding

We first explore whether individuals can recognize and coordinate to exploit the benefits from cooperation by funding the public good of collaborative research. To determine if this depends on participation in a competitive market stage and to study the impact of communication, we examine data in the Public Good Only and Combined treatments, with and without communication. We state the results and then provide statistical support.

**Result 1**: Even in the presence of payoff uncertainties, subjects frequently cooperate in the provision of the public good.

**Result 2**: Without communication, coordination and cooperation in public good provision is lower when subjects also interact in the competitive market. Allowing communication improves coordination and cooperation in public good provision.

We define two alternative dependent variables that measure cooperation in similar but distinct ways. The first variable is the number of times subjects met the contribution threshold of 1500 experimental dollars as a proportion of the number of times they had an opportunity to contribute. Figure 2 presents these proportions graphically for each of the 36 sessions in the Public Goods Only and Combined treatments. The second variable is the average total contributions made by subjects in the periods when they were given an opportunity to fund the good. Both variables indicate that subjects often cooperate when they are given the opportunity, 13 At the time the experiment was conducted, 10 Australian dollars could be exchanged for about 8.5 U.S. dollars.
even when they face uncertainties in payoffs. This result extends the existing literature on cooperation in the threshold public goods to an environment with uncertain payoffs. Unlike environments with certain payoffs for reaching the threshold and a high return, contributors often fail to reach the threshold without communication.\textsuperscript{14}

To compare behavior across the two treatments, we conduct non-parametric two-sample Wilcoxon rank-sum tests, using exactly one (statistically independent) aggregated measure from each session. To start with, we examine the group contributions in the first possible period in both treatments without communication and this shows that average contributions are approximately double in the Public Goods Only treatment (1388 versus 672), a difference that is highly significant (Wilcoxon $p$-value<0.01). Thus, the initial periods of market competition in the Combined treatment appear to spill over to reduce subjects’ success in their first chance at cooperation.

As reported in Table 3, both the number of times the threshold was met and the total contributions are higher for the Public Good Only treatment than for the Combined treatment. For example, when subjects are not allowed to communicate, they met the threshold 66 percent of the time, compared to 38 percent in Combined. However Figure 2 shows that for many of these across-treatment comparisons there is significant overlap in the distributions of contribution frequencies, so these conservative nonparametric tests do not indicate statistically significant differences.

Allowing communication between subjects, however, has a large and statistically

\textsuperscript{14} Most previous experimental studies on provision point public goods with uncertainty implement threshold uncertainty, in which contributors do not know exactly what level of contribution is necessary to provide the public good. For example, see Dannenberg et al. (2011) for a recent discussion. By contrast, in our design the threshold is known to subjects, but even if the threshold is met it is not certain whether the public good (in our case R&D success resulting in a cost reduction) is provided. This reflects the nature of R&D, where even well-funded projects can be unsuccessful. An interesting extension for future work would make the probability of success a function of how much is invested in R&D, rather than having a constant probability of success whenever the threshold is reached.
significant impact on whether the threshold is met in both of the treatments. The top right column of Table 3 indicates that the data reject the null hypothesis that communication does not increase the frequency that subjects meet the public good provision threshold. Nevertheless, average total contributions are not different across treatments in the sessions where communication is allowed. This indicates substantial miscoordination of contributions without communication. In the communication sessions the total contributions usually meet the threshold of 1500 exactly, as agreed to in the contributors’ chats. In sessions without communication, in contrast, average contributions both exceed and fall short of the threshold point in different periods. For example, in 3 of the 10 Combined sessions without communication, the average total contributions exceed the highest of the contributions in the 10 sessions with communication.

Miscoordination also occurs in the Public Good Only sessions. For this treatment in the communication sessions, despite being allowed to contribute any amount between 0 to 1200, individual contributions take only 2 values: either 0 (6 percent of the cases) or 500 (94 percent of the cases). In contrast, in sessions where subjects cannot communicate, individual contributions vary from 0 to 800, and the focal contribution of 500 occurs only 56 percent of the time. This increased coordination through communication has been observed previously in coordination games (e.g., Blume and Ortmann. 2007; Cason et al., 2011). Although this public good can be provided if only two of the three agents contribute, all three contributed in every instance that the threshold was met. Not only was there no successful free-riding, but “cheap-riding” was also uncommon, since all individuals contributed at least their equal share of 500 in 94 percent of the cases where the threshold was met.

15 The distributions of average total contributions are marginally significantly different in the communication and no communication conditions for the Combined treatment according to a Kolmogorov-Smirnov test ($p$-value=0.055).
Table 4 reports results from panel regressions that examine the interaction between communication and competition in the market on cooperation in public goods provision. We estimate a probit model for the binary outcome of whether the threshold was met, and a tobit model for the total amount contributed. These panel regressions assume a session-specific random effect. The independent variables include a dummy variable for communication opportunities, a dummy variable for the Combined treatment and a treatment interaction term and time (expressed in the commonly used nonlinear form of 1/period). When subjects can communicate with each other, the threshold is met more often but total contributions are significantly greater only in the Combined treatment as indicated by the significant interaction term. Subjects in the Combined treatment contribute significantly less on average when communication is not allowed. These reduced contributions in the Combined treatment could occur because, as documented below in Section 3.4, the cost reduction from the public good provision often leads to a smaller increase in earnings than implemented in the Public Good Only treatment. Earnings depend on market trading, and the exact gains from cost reductions are variable. Behavioral spillovers could also cause subjects to be less cooperative in environments where they also participate in a competitive market stage.

3.2 Market Competition-Transaction Prices and Quantities

The contribution results for the Public Good Only and Combined treatments indicate that communication is important for promoting cooperation in public good provision. Given its

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16 We only examine the data from periods when there is a potential opportunity for the subjects to participate in a common project. There is a maximum of 7 such opportunities per session. The tobit model is appropriate for the model of total contributions, since 17 of the 179 contributions were at the lower threshold of zero.
17 With one minor exception noted below in footnote 22, all of the regression results shown in Tables 4 and 5 are qualitatively unchanged when using cluster-robust standard errors rather than random effects to capture the non-independence of errors within sessions.
18 The impact of communication is also clearly observed in an unreported random effects probit regression of individual contributions, in which the dependent variable is whether the subject has contributed 500 or more in the Public Good Only environment. In this regression we also control for demographic and individual specific characteristics such as gender, course of study, region of origin, academic performance and experience.
significance in this cooperative domain, also documented elsewhere (Ledyard, 1995), it is important to examine communication’s impact in the competitive domain—specifically in the market stages of the Combined treatment and the Market Only treatment.

**Result 3**: Allowing opportunities to cooperate to fund public good provision does not significantly weaken price competition.

**Result 4**: Allowing subjects to communicate does not significantly increase prices in either the Combined or Market Only treatments.

To provide support for the above results we investigate how average price deviates from the competitive equilibrium, because the competitive equilibrium depends on whether sellers face high costs or low costs. As shown in Section 2, in periods that sellers’ costs are high the equilibrium price range is 500-525 and in periods when sellers’ costs are lowered by 100 the equilibrium price range is 450-475. To identify potentially super-competitive pricing relative to this theoretical benchmark, we normalize transaction prices by subtracting the upper endpoint of the equilibrium interval (525 or 475) that is appropriate given the cost realization in each period.

Wilcoxon rank sum tests that employ one (pooled aggregate) average transaction price per session indicate that the price deviation is significantly higher in the Market Only treatment compared to the Combined treatment when there are no communication opportunities available (18.37 vs. -13.59; \( p \text{-value: 0.019} \)). When communication is allowed, however, no significant differences exist between these two treatments. Considering the impact of communication, in the Combined treatment the price deviation is significantly higher in sessions where communication is allowed (18.56 vs. -13.59; \( p \text{-value: 0.034} \)).\(^{19}\) This is consistent with the familiar finding that communication facilitates collusion (e.g., Isaac et al., 1984). Figure 3 shows, however, that in

---

\(^{19}\) All of these results continue to hold when restricting the Combined treatment to just the high-cost periods. The conclusions based on multiple pairwise comparisons that employ the Combined treatment without communication are robust to using an application of the Holm-Bonferroni adjustment.
later period blocks the differences across treatments disappear. Average prices converge to the upper endpoint of the competitive equilibrium price interval in all treatments.

To account for this time trend and other factors that can influence prices, Column (1) of Table 5 presents a random effects regression of the average price deviation from competitive equilibrium during each 3-period block. Explanatory variables include time (1/period), and dummy variables indicating whether sellers communicated at the beginning of the block of three periods and whether the costs they faced were low or not. Recall that costs are endogenous since they are determined based on sellers’ success in (a) reaching the total contribution threshold and (b) obtaining a positive random draw leading to a successful innovation to reduce costs. We therefore use an instrumental variables approach, using the exogenous “luck” random draw for innovation success as the identification variable for low costs.20

The estimates indicate that the deviation of price from the competitive equilibrium is higher in periods when the sellers face lower costs. Buyers are not aware of any seller cost reductions, so this indicates that sellers succeed in maintaining higher prices and reaping a greater share of the benefits of cost reduction. Controlling for these cost reductions and the overall time trend, seller communication opportunities do not have a significant impact on prices. Column (2) of Table 5 indicates that communication does modestly increase transaction quantity, however, contrary to the expectation that sellers would use the chat room to make agreements to restrict their quantity sold. (Transaction quantity is also greater when sellers have low costs, as predicted by the competitive model, but not by the collusive model.) Recall that communication increases the probability of meeting the contribution threshold, as shown in

---

20 Subjects can influence the costs by contributing more to reach the threshold, but cannot influence the random draw (luck) by their decisions. Hence luck is an appropriate instrument, since it is merely the realization of an independent random draw. In the first stage regression where the costs are regressed on the full set of exogenous variables including the instrument, luck, we find that the instrument used is highly significant (p-value = 0.00) in explaining the costs faced by subjects.
Section 3.1 and Table 4, raising the probability that the sellers have lower costs. This provides a direct channel for communication opportunities to have an effect on market outcomes.\textsuperscript{21}

Additional information regarding the relationship between communication and collusion is provided by the sellers’ chat communication. While we do not attempt a detailed content analysis of their chats, a review of the communications data reveals, surprisingly, that sellers often do not discuss restricting quantities or price fixing. In particular, we identified discussions to fix prices in only four of the eight sessions in the Market Only treatment. In one session, for example, the subjects are very conspiratorial from the start of the communication stage and recognize that they are the only sellers in the market. They discuss fixing prices at a specific level and encourage each other to delay accepting offers from buyers.\textsuperscript{22} Even in these cases, however, prices are not often above the competitive equilibrium.

Price fixing discussions were even more uncommon in the Combined treatment. Virtually none of the groups in the ten sessions attempted to conspire, in contrast to the frequent observation in previous price conspiracy experiments (dating back to Isaac and Plott, 1981), where subjects usually recognize conspiratorial opportunities immediately and try to reach collusive agreements. Rather than trying to fix prices, in the Combined treatment subjects often

\textsuperscript{21} Prices do not immediately adjust to their new equilibrium level following a cost change, of course, due to hysteresis effects that are commonly observed in market experiments. To reduce the influence of these effects on our conclusions, we also estimate the price regression after dropping the first period of each three-period block, which is the period that could immediately follow a cost change. The estimation results are qualitatively unchanged, so we do not report this regression result here.

\textsuperscript{22} The entire chat script of the first chat room for this session (which is opened after period 6) is as follows, where different statements (typically made by different subjects) are separated by semicolons: “gday; hi; hello; okay i have a tonne of coupons, ill sell him for around 550 each time, sound good?; me too ill sell; who's buying?; no sell higher; sounds good; sell higher?; ok; what price; keep the price high; 600? 700? lol; 600 is fine; dont spoil market; ok 600; cool; put 750 at start, reduce slowly; ok, min 550; ok; sweet; yeah anything below 540 is a loss lol; lol”
focus instead on solving the coordination problem of funding the cost-reducing public good. They are generally cooperative and usually agree on contributing 500 each to the fund.\textsuperscript{23}

The low rate of conspiracy in both treatments could be due, in part, to our use of the double auction trading institution. This institution is known for its competitive properties even with a small number of traders, and ample evidence exists that collusion is hard to maintain with these trading rules (Isaac et al., 1984; Clauser and Plott, 1993). Alternative design choices, such as a less competitive trading institution or chat rooms that were open during market trading to promote more seller discussion, could have increased the amount of collusion.

### 3.3 Market Competition-Efficiency

A key performance measure that is directly observable in market experiments is efficiency—how well do market transactions exploit the available gains from exchange? Efficiency is the ratio of actual (observed) gains from trade to the maximum possible gains given the underlying cost and value conditions of the traders in the experimental session. Note that these maximum gains from trade are greater in the period blocks where sellers have succeeded in lowering their costs. Figure 4 presents the time series of efficiency across the treatments and shows that efficiency is lower in the Combined treatments than the Market Only treatments.

**Result 5:** Trading efficiency is lower in the Combined treatment, and is unaffected by the availability of communication.

To determine whether trading efficiency is statistically different across treatments we first conduct Wilcoxon rank-sum tests, which show that the Market Only treatment has higher

\textsuperscript{23} The data do not indicate that sellers in the Combined treatment were time constrained in the 90 seconds of chat to discuss a price conspiracy, since they actually exchanged a significantly smaller fraction of their chat messages in the final 30 seconds than sellers did in the Market Only sessions (Wilcoxon p-value<0.05). In other words, more groups tended to finish their chats early in the more complex Combined treatment than the Market Only treatment. In addition, a count of the number of statements per chat shows that sellers in the Combined treatment wrote fewer statements than in the other two treatments (13.0 statements per chat in Combined, 15.4 in Market Only and 18.5 in Public Goods Only treatment).
efficiency levels than the Combined sessions (78 versus 70 percent, \( p \)-value<0.01), for the no communication condition. The efficiency levels were not statistically different in the communication condition and also within the Combined and the Market Only treatments with and without communication. We also present a random effects regression for trading efficiency in column (3) of Table 5. The results also show that trading efficiency is lower in the Combined treatment, and the opportunity to communicate does not impact efficiency.

3.4 R&D Externality

Although trading efficiency declines in the Combined treatment when sellers can collaborate to reduce their costs, this is not because total realized trading surplus declines. Efficiency is lower in this treatment relative to the Market Only treatment because the cost reductions lead to a greater maximum trading surplus. That is, a higher maximum surplus is used in the denominator of the efficiency measure in the low-cost periods. Figure 5 shows that total gains from exchange are usually higher in the Combined treatment than the Market Only treatment. (These figures do not subtract the R&D investments that sellers incur to reduce costs.) The question we address in this subsection is how this increased surplus is divided between the sellers and the buyers in the market.

Result 6: R&D externalities that benefit buyers are positive though smaller than predicted.

Both buyers and sellers earn higher profits in the period blocks in which costs are low. This is documented in random effects regressions shown in Table 5, using buyer profits (column 4) and seller profits (column 5) as dependent variables. While both agent types earn significantly higher profits in the low-cost periods, sellers’ total profit increase is much higher than buyers’
total profit increase.\textsuperscript{24} This indicates that the R&D externalities that benefit buyers are positive but relatively small, and buyers’ indirect benefit from the lower costs is much smaller than the sellers’ direct benefit. For the parameters implemented in the experiment, buyers realize less than half of the R&D externality predicted by a strictly equilibrium analysis. This shortfall reflects the less than 100 percent efficiency realized by the market, and some high prices in a few sessions.

4. Discussion and Conclusion

In this paper we present a novel experiment examining the interactions between competition and cooperation. This link can be difficult to measure empirically as both competitive and cooperative preferences are often hard to isolate in the field. Consequently, only limited evidence on this interaction has been provided by field data.

We find in this experiment that although individuals cooperate to fund a public good when given an opportunity, they cooperate somewhat less frequently in environments where they also compete in a market. These behavioral spillovers could be attributed to the increased cognitive load required to devote attention to both the public good and market trading tasks (e.g., Cason et al., 2012). The lower cooperation rate could also be due to the different mechanisms through which subjects realize the benefits of cooperation. Although we chose a double auction trading institution that usually leads to high efficiency and competitive prices even with small numbers of traders, the relatively low realized trading surplus limited the benefits of cooperation accruing to the subjects. Even though sellers’ profits in period blocks when they face lower costs were on average higher, compared to when costs were high, the difference between the two profit levels is less than the return implemented exogenously in the Public Good Only sessions.

\textsuperscript{24} Moreover, this marginally significant increase in profit (454) for buyers when seller costs are low is not statistically significant in an alternative (unreported) specification of the error structure, using robust-clustering at the session level rather than session random effects.
We observe a spillover from competition that lowers cooperation, this spillover is however only weakly significant and is overcome by the influence of communication among sellers. Whatever the source of these differences in cooperation in the public good and market environments, our results suggest that measures of cooperation in one context may not extend directly to other, external situations.

Allowing participants to communicate substantially improves their ability to coordinate in funding a public good, especially in the Combined treatment. In particular, the threshold was met almost three times more often in the Combined treatment when communication was allowed. This suggests that while communication is important in both the treatments, it has a critical role to play in the market environment, where competitive forces make cooperation more challenging.

We find no significant behavioral spillover from cooperation to weaken competition. This is in spite of the fact that we incorporated several design features that have been shown to increase collusion, such as repeated seller interactions and a concentrated (triopoly) market structure. Given our research emphasis on the impact of competitive market interactions, however, we chose a relatively competitive double auction trading institution so as to isolate the effect of competition. The strong market competition in a double auction could explain the lack of behavioral spillovers from cooperation to weaken competition. Other trading institutions that are less competitive may have increased any potential spillover to reduce price competition.

Allowing communication does not have a substantial impact on prices and efficiency, hence seller communication does not lead to collusion in our experiment. This suggests that previous results supporting collusion, such as Suetens (2008), could be attributed to the choice of trading institutions or how collusion is allowed to emerge in the market structure.
Communication in our experiment nevertheless influences market performance because it leads more frequently to successful R&D collaborations and lower costs. Price deviations are higher when costs are lowered for sellers in the market because successful innovation reduces the competitive equilibrium price. Average actual prices also decrease, so giving sellers the option to cooperate increases the earnings of both sellers and buyers. R&D externalities are therefore observed in our experiment, implying that allowing one side of the market to cooperate can lead to positive benefits. Our findings are therefore in the spirit of results highlighting the social desirability of R&D (Cellini and Lambertini, 2009). In future research it may be useful to allow for communication at different stages of the experiment so as to examine if behavior is invariant to chat timings.

It is always important to be cautious in generalizing from the controlled environment of the laboratory to naturally occurring markets. With that caveat in mind, however, our findings indicate that competitive forces and preferences for cooperation can potentially co-exist. In particular it suggests the importance of encouraging the emergence of trading institutions that are less sensitive to collusive forces, specifically in areas that could gain from cooperation such as R&D into new environmental technologies. In such situations it may be possible to encourage cooperative efforts without endangering competition and efficiency.
### Table 1: Experimental Design (264 Total Subjects)

<table>
<thead>
<tr>
<th></th>
<th>Public Goods Only</th>
<th>Market Only</th>
<th>Market and Public Goods (Combined)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>communication</strong></td>
<td>8 sessions (24 subjects)</td>
<td>8 sessions (48 subjects)</td>
<td>10 sessions (60 subjects)</td>
</tr>
<tr>
<td><strong>Without</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>communication</strong></td>
<td>8 sessions (24 subjects)</td>
<td>8 sessions (48 subjects)</td>
<td>10 sessions (60 subjects)</td>
</tr>
</tbody>
</table>

### Table 2: Marginal Abatement Costs Assigned to Firms

<table>
<thead>
<tr>
<th>Units of Abatement</th>
<th>Buyer 1</th>
<th>Buyer 2</th>
<th>Buyer 3</th>
<th>Seller 1</th>
<th>Seller 2</th>
<th>Seller 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>175 (75)</td>
<td>175 (75)</td>
<td>175 (75)</td>
</tr>
<tr>
<td>2</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>225 (125)</td>
<td>225 (125)</td>
<td>225 (125)</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>275 (175)</td>
<td>275 (175)</td>
<td>275 (175)</td>
</tr>
<tr>
<td>4</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>325 (225)</td>
<td>325 (225)</td>
<td>325 (225)</td>
</tr>
<tr>
<td>5</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>375 (275)</td>
<td>375 (275)</td>
<td>375 (275)</td>
</tr>
<tr>
<td>6</td>
<td>650</td>
<td>650</td>
<td>650</td>
<td>425 (325)</td>
<td>425 (325)</td>
<td>425 (325)</td>
</tr>
<tr>
<td>7</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>475 (375)</td>
<td>475 (375)</td>
<td>475 (375)</td>
</tr>
<tr>
<td>8</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>525 (425)</td>
<td>525 (425)</td>
<td>525 (425)</td>
</tr>
<tr>
<td>9</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td>575 (475)</td>
<td>575 (475)</td>
<td>575 (475)</td>
</tr>
<tr>
<td>10</td>
<td>850</td>
<td>850</td>
<td>850</td>
<td>625 (525)</td>
<td>625 (525)</td>
<td>625 (525)</td>
</tr>
<tr>
<td><strong>Endowment</strong></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total Endowment</strong>= 30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Competitive Equilibrium Price = 500-525; Units Traded: 4 each  
Competitive Equilibrium Price (with cost reduction) = 450-475; Units Traded: 5 each  
Collusive Outcome, Price = 550; Units Traded: 4 each

The permits endowed (pre-trading) allow firms to avoid the abatement costs shown in bold. Costs in periods with successful cost reduction are shown in parentheses.
### Table 3: Summary of results by Communication and Market Treatment

<table>
<thead>
<tr>
<th>Description</th>
<th>No Communication</th>
<th>Communication</th>
<th>Wilcoxon p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fraction of Opportunities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshold is Met</td>
<td>Public Good Only</td>
<td>0.663</td>
<td>0.950</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>0.377</td>
<td>0.935</td>
</tr>
<tr>
<td><strong>Wilcoxon p-value</strong></td>
<td></td>
<td>0.21</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Average Total Contributions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Public Good Only</td>
<td>1423.2</td>
<td>1425.0</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>867.7</td>
<td>1463.6</td>
</tr>
<tr>
<td><strong>Wilcoxon p-value</strong></td>
<td></td>
<td>0.14</td>
<td>0.61</td>
</tr>
</tbody>
</table>

* Significant at 5%; ** Significant at 1%.

### Table 4: Random effects Probit and Tobit regressions of Project Contributions

<table>
<thead>
<tr>
<th>Variables</th>
<th>Threshold is met†</th>
<th>Total contributions¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication Allowed (dummy)</td>
<td>2.485* (1.134)</td>
<td>-0.32 (202.90)</td>
</tr>
<tr>
<td>Combined Treatment (dummy)</td>
<td>-1.547 (0.996)</td>
<td>-598.47*** (190.95)</td>
</tr>
<tr>
<td>Communication × Combined</td>
<td>0.874 (1.586)</td>
<td>642.87** (271.94)</td>
</tr>
<tr>
<td>Interaction (dummy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/Period</td>
<td>-0.263 (0.485)</td>
<td>257.61*** (78.15)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.841 (0.751)</td>
<td>1311.00*** (145.97)</td>
</tr>
<tr>
<td>Probability&gt;chi squared.</td>
<td>0.02</td>
<td>0.0001</td>
</tr>
<tr>
<td>Number of Observations.</td>
<td>179</td>
<td>179</td>
</tr>
</tbody>
</table>

† Random effects probit regression. ¶ Random effects tobit regression.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
The numbers in the parentheses are the standard errors.
Table 5: Random effects Regressions of Market Performance Measures

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IV Regression</td>
<td>IV Regression</td>
<td>IV Regression</td>
<td>IV regression</td>
<td>IV regression</td>
</tr>
<tr>
<td>Price Deviations</td>
<td>41.69***</td>
<td>1.635***</td>
<td>-0.005</td>
<td>454*</td>
<td>3,113***</td>
</tr>
<tr>
<td></td>
<td>(9.23)</td>
<td>(0.616)</td>
<td>(0.024)</td>
<td>(270)</td>
<td>(284)</td>
</tr>
<tr>
<td>1/Period</td>
<td>22.93***</td>
<td>-4.042***</td>
<td>-0.192***</td>
<td>-1,116***</td>
<td>-482**</td>
</tr>
<tr>
<td></td>
<td>(6.79)</td>
<td>(0.451)</td>
<td>(0.017)</td>
<td>(198)</td>
<td>(209)</td>
</tr>
<tr>
<td>Combined Treatment (dummy)</td>
<td>-9.14</td>
<td>-0.540</td>
<td>-0.091***</td>
<td>33</td>
<td>-776**</td>
</tr>
<tr>
<td></td>
<td>(12.54)</td>
<td>(0.736)</td>
<td>(0.022)</td>
<td>(338)</td>
<td>(358)</td>
</tr>
<tr>
<td>Communication Allowed (dummy)</td>
<td>-1.69</td>
<td>1.410*</td>
<td>-0.007</td>
<td>-42</td>
<td>-7</td>
</tr>
<tr>
<td></td>
<td>(12.58)</td>
<td>(0.740)</td>
<td>(0.023)</td>
<td>(340)</td>
<td>(360)</td>
</tr>
<tr>
<td>Sellers Communicated at the beginning of 3 period block (dummy)</td>
<td>-4.83</td>
<td>-0.148</td>
<td>-0.007</td>
<td>40</td>
<td>-130</td>
</tr>
<tr>
<td></td>
<td>(6.55)</td>
<td>(0.436)</td>
<td>(0.017)</td>
<td>(191)</td>
<td>(201)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.21</td>
<td>14.394***</td>
<td>1.007***</td>
<td>3532***</td>
<td>4642***</td>
</tr>
<tr>
<td></td>
<td>(11.26)</td>
<td>(0.660)</td>
<td>(0.020)</td>
<td>(304)</td>
<td>(321.808)</td>
</tr>
<tr>
<td>Observations</td>
<td>288</td>
<td>228</td>
<td>288</td>
<td>288</td>
<td>288</td>
</tr>
<tr>
<td>Number of sessions</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

a: Lowcost is instrumented and the estimates are from an IV regression.
Figure 1:

Supply and Demand Parameters

Competitive Equilibrium Interval for High Cost Periods

Competitive Equilibrium Interval for Low Cost Periods

- Buyer Permit Values
- Seller Permit Values
- Seller Permit Values, with Innovation
Figure 2: Percentage of Threshold Met

Combined Treatment without Communication

Combined Treatment with Communication

Public Good Only Treatment without Communication

Public Good Only Treatment with Communication

(Threshold never met in sessions on 0% axis)
Figure 3: Average Price Deviation Across Treatments

- Price Deviation
- Period Blocks
- Market Only, No Comm
- Combined, No Comm
- Market, Comm
- Combined, Comm
Figure 4: Efficiency Across Treatments

- **Market Only, No Comm**
- **Market, Comm**
- **Combined, No Comm**
- **Combined, Comm**
Figure 5:

Total Gains from Trade Across Treatments

Trading Surplus vs. Period Blocks

- Market Only, No Comm
- Combined, No Comm
- Market, Comm
- Combined, Comm
References:


Instructions Appendix – Combined Treatment with Communication
(Version Distributed to Net Buyers)

General
This is an experiment in the economics of decision making. The instructions are simple and if you follow them carefully and make good decisions you will earn money that will be paid to you privately in cash. All earnings on your computer screens are in Experimental Currency Units (ECUs). These ECUs will be converted to real Dollars at the end of the experiment, at a rate of 400 ECU = $1AUD. Notice that the more ECUs you earn, the more cash you will receive at the end of the experiment. After you have read these instructions, you will be asked to answer some questions on your computer. For each correct answer you will earn 50 cents.

Attached to these instructions you will find a sheet labeled Personal Record Sheet, which will help you keep track of your earnings based on the decisions you might make. You are not to reveal this information to anyone. It is your own private information.

You will interact in a market with the same 5 other participants across 27 separate periods. After some periods, you will be asked to provide some information about your decisions.

Instructions relating to Trading
In the ‘trading stage’ every period you will have the opportunity to sell or buy “coupons” and plan production levels. You will be given a Fixed Period Revenue which allows you to buy coupons and/or pay production costs. This fixed revenue does not depend on any actions you take, and does not change throughout the experiment (in fact, it is already written on your Personal Record Sheet).

Your earnings each period will be determined as follows:

Earnings = Fixed Period Revenue – Total Production Costs + Sale Proceeds from Selling Coupons – Amount Spent when Buying Coupons.

Production Costs
You must pay production costs when you produce units. The cost of each unit produced is typically different from the cost of other units produced, and your costs may or may not be different from the costs of other participants. Your production costs are always shown on the left side of your computer screen, as illustrated in Figure 1 (the numbers on this example screen are different from the actual numbers used in the experiment, and you won’t actually learn your values until the experiment begins).

Everyone can produce up to 10 units, and the cost of each unit is written separately. For example, based on the numbers shown in the example in Figure 1, your first unit produced would cost 25, your second unit produced would cost 35, etc. If, for example, these were your production costs and you produced 3 units, your total costs would be 25+35+47=107. So you must recognize that the costs shown on your screen are the extra costs associated with each additional unit produced.
Figure 1

Coupons

We’ve already explained that your Fixed Period Revenue never changes, but your costs increase when you increase production. So your production will be equal to 10 minus the number of coupons you hold at the end of the period. If you for example, hold 6 coupons, you will pay the production costs for 10-6=4 units. These will be the first 4 units in your list of production costs.

As you can see, you can avoid production (and save on your production costs) by holding coupons. Everyone starts each period with some number of coupons, and anyone can adjust their own holding of coupons by buying and selling them in a market that will operate over the computer network. If you sell coupons your cash increases by the sale amount, and if you buy coupons your cash decreases by the sale amount. Later in these instructions we explain the rules for buying and selling coupons.

Why might you want to buy a coupon? Remember that coupons allow you to avoid production. If you currently hold 2 coupons, for example, and if you had the example production costs shown in Figure 1, then the last unit that you produce is the 8th unit (so that your production of 8 + coupons of 2 = 10). The production cost of this 8th unit is 141. So if you can buy a coupon for less than 141, this might be a good idea since it allows you to save the production cost of 141. For example, if you bought a coupon for 120, you save the production cost of 141 and therefore make a profit (because of the lower costs that you need to incur) of 141-120=21.
Why might you want to sell a coupon? Continuing the illustration based on the example production costs shown in Figure 1, suppose that you currently hold 6 coupons. Then the last unit that you produce is the 4th unit (so that your production of 4 + coupons of 6 = 10). The production cost of your 5th unit is 75. So if you can sell a coupon for more than 75, this might be a good idea since these sales revenues exceed the production costs of this 5th unit. For example, if you sell a coupon for 120, even if you incur the additional (5th unit) production cost of 75 you would still make a profit on this sale of 120-75=45.

**How to Buy and Sell**

In the trading stage you will have the opportunity to buy or sell coupons for 2 minutes. In this stage everyone is free to make an offer to buy a coupon at a price they choose; likewise, everyone is free to make an offer to sell a coupon at a price they choose. Also at any time during the stage, everyone is free to buy at the best offer price specified by someone wishing to sell, and everyone is free to sell at the best offer price specified by someone wishing to buy. (Of course, there are some limits: to sell a unit or make a sales offer, you need to have a coupon to sell. And to buy a unit or make a buy offer, you need to have enough cash to pay.)

You will enter offer prices and accept prices to execute transactions using your computer. Figure 1 shows the market trading screen. The time left in the period is shown on the upper right corner of the trading screen. Participants interested in buying can submit offer prices using the “Buy Offer” box on the right side of the screen, and then clicking on the “Make Offer” button in the bottom right corner. This offer price is immediately displayed on all traders’ computers on the upper right part of the screen, labeled “Buy Offers.” Once this offer price has been submitted, it is binding in the sense that anyone wishing to sell can accept this price offer. Such an acceptance results in an immediate trade at that price. The previous trading prices in the current period are displayed in the “Trading Prices” list in the center of your computer screen.

If there are already Buy Offers displayed in the current period, then new buy offers submitted by anyone wishing to buy must provide better trading terms to the sellers. Sellers prefer higher prices, so any new Buy Offers must be higher than the current highest Buy Offer. Your computer will give you an error message if you try to offer a lower price than the best price currently available.

Anyone wishing to buy can accept the best (that is, lowest Sell Offer price) by simply clicking on the “Buy Coupon” button at the bottom of their computer screen. This results in an immediate trade at that price.

Participants interested in selling can submit offer prices using the “Sell Offer” box on the left side of the screen, and then clicking on the “Make Offer” button below this box. This offer price is immediately displayed on all traders’ computers on the left part of the screen, labelled “Sell Offers.” Once this offer price has been submitted, it is binding in the sense that anyone wishing to buy can accept this price offer. Such an acceptance results in an immediate trade at that price.
If there are already Sell Offers displayed in the current period, then new Sell Offers submitted by anyone wishing to sell must provide better trading terms to the buyers. Buyers prefer lower prices, so any new Sell Offers must be lower than the current lowest Sell Offer. Your computer will give you an error message if you try to offer a higher price than the best price currently available.

Anyone wishing to sell can accept the best (that is, highest offer price) by simply clicking the “Sell Coupon” button on the bottom of their computer screen. This results in an immediate trade at that price.

In the results screen, shown in Figure 2, you will be informed about the costs you incurred from buying coupons or producing units and the profit you made from the trading stage.

**Figure 2:**

<table>
<thead>
<tr>
<th>Marginal production costs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 25</td>
</tr>
<tr>
<td>4. 61</td>
</tr>
<tr>
<td>7. 111</td>
</tr>
<tr>
<td>10. 211</td>
</tr>
</tbody>
</table>

**Period results:**

| The number of coupons you hold is: 6 |
| Your production is: 4 |
| Your fixed period revenue is: 1200 |
| Your remaining cash after the trading is: 1200 |

Cost of units to pay for \((25 \times 35 + 47 \times 61)\): 168

| Your payoff from this period is: 1122.00 |
| Your cumulative payoff from this experiment is: 1122.00 |

After some of the periods, you will be asked to provide some information about your decisions.

After you have read these instructions, you will be asked to answer some questions on your computer. For each right answer you will earn 50 cents.
Instructions Appendix (continued) – Combined Treatment
(Version Distributed to Net Sellers)

General
This is an experiment in the economics of decision making. The instructions are simple and if you follow them carefully and make good decisions you will earn money that will be paid to you privately in cash. All earnings on your computer screens are in Experimental Currency Units (ECUs). These ECUs will be converted to real Dollars at the end of the experiment, at a rate of 400 ECU = $1AUD. Notice that the more ECUs you earn, the more cash you will receive at the end of the experiment. After you have read these instructions, you will be asked to answer some questions on your computer. For each correct answer you will earn 50 cents.

Attached to these instructions you will find a sheet labeled Personal Record Sheet, which will help you keep track of your earnings based on the decisions you might make. You are not to reveal this information to anyone. It is your own private information.

You will interact in a market with the same 5 other participants across 27 separate periods. You are going to participate in this market for 6 periods and then in blocks of 3 periods. After the first six periods and after some of these 3 period blocks, you will participate in a common project where you and 2 other participants will decide how to allocate ECUs to a common project to reduce your costs of production for the next block of 3 periods. The other 3 participants in your 6-person market will be asked to provide some information about their decisions.

Instructions relating to Trading
In the ‘trading stage’ every period you will have the opportunity to sell or buy “coupons” and plan production levels. You will be given a Fixed Period Revenue which allows you to buy coupons and/or pay production costs. This fixed revenue does not depend on any actions you take, and does not change throughout the experiment (in fact, it is already written on your Personal Record Sheet).

Your earnings each period will be determined as follows:

Earnings = Fixed Period Revenue – Total Production Costs + Sale Proceeds from Selling Coupons – Amount Spent when Buying Coupons.

Production Costs
You must pay production costs when you produce units. The cost of each unit produced is typically different from the cost of other units produced, and your costs may or may not be different from the costs of other participants. Your production costs are always shown on the left side of your computer screen, as illustrated in Figure 1 (the numbers on this example screen are different from the actual numbers used in the experiment, and you won’t actually learn your values until the experiment begins). After the first 6 periods and after certain 3-period blocks, you will participate in a task where you will be asked to make decisions regarding contributions to a common project. The outcome of this task will determine your production costs in the next block of 3 periods. If the common project is implemented, your production costs will be lower in
the next 3 periods. If the Project is not implemented, then you will have the same production costs for the next 3 periods as in the previous 3 periods.

Everyone can produce up to 10 units, and the cost of each unit is written separately. For example, based on the numbers shown in the example in Figure 1, your first unit produced would cost 25, your second unit produced would cost 35, etc. If, for example, these were your production costs and you produced 3 units, your total costs would be 25+35+47=107. So you must recognize that the costs shown on your screen are the extra costs associated with each additional unit produced.

**Figure 1:**

<table>
<thead>
<tr>
<th>Period</th>
<th>1 of 24</th>
<th></th>
<th>Remaining time (sec)</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash:</td>
<td>1290</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coupons</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Marginal production costs:
1. 25
2. 35
3. 47
4. 61
5. 76
6. 91
7. 111
8. 141
9. 173
10. 211

**Coupons**
We’ve already explained that your Fixed Period Revenue never changes, but your costs increase when you increase production. Your production will be equal to 10 minus the number of coupons you hold at the end of the period. If you for example, hold 6 coupons, you will pay the production costs for 10-6=4 units. These will be the first 4 units in your list of production costs.

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Anyone wishing to buy can accept the best (that is, lowest Sell Offer price) by simply clicking on the “Buy Coupon” button at the bottom of their computer screen. This results in an immediate trade at that price.

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**Figure 2:**

<table>
<thead>
<tr>
<th>Period</th>
<th>1 of 24</th>
<th>Remaining time [sec]</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal production costs:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1: 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2: 35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3: 47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4: 61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5: 73</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6: 91</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7: 111</td>
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<td></td>
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<td>8: 141</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9: 173</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10: 211</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Period results:**

- The number of coupons you hold: 6
- Your production is: 4
- Your fixed period revenue is: 1200
- Your remaining cash after the trading is: 1290

Cost of units to pay for (25 + 35 + 47 + 61): 100

Your payoff from this period is: 1122.00

Your cumulative payoff from this experiment is: 1122.00
**Instructions relating to contribution to the common project**

After the first six periods and after some blocks of three periods, you and two other participants will be asked to make decisions on whether you want to contribute to a common project that, if successful, reduces your production costs for the next three periods by 100 ECU per unit produced.

When you are asked to participate in the common project, you should know that there is a limit on the amount that you can contribute. This limit is 1200 ECU. Your task is to decide the amount, between 0 - 1200 ECU, you want to contribute to the common project. Your contribution decision can lead to a reduction in your production costs in the next three periods.

Before you make this decision you can communicate with the other two potential contributors to the common project via the computer using a ‘chat-box’ in which each group member will appear with a separate ID (Participant_1, Participant_2, etc.). As shown in Figure 3, you will be able to type your message in the chat box in the middle of the screen and press ‘Enter’ on your keyboard for your message to be displayed. You will have the opportunity to communicate with the other two individuals for 90 seconds. In sending messages back and forth between you and the other two people we request that you follow two simple rules: (1) Be civil to each other and use no profanity and (2) Do not identify yourself.

**Figure 3:**

Please be advised that the Project can only be implemented if group contributions reach a threshold of 1500 ECU.

After group members have made their decisions and if the threshold of 1500 ECU has been met, a random device will determine whether the Project will be implemented with a probability of 75%.

If the Project is implemented, in the next three periods your marginal production costs will be lowered by 100 ECU each.

If the Project is NOT implemented, in the next three periods your marginal production costs will remain the same.

Once all three participants have decided how much to contribute to the project, it will be decided whether the project can be implemented or not.
Conditions for the Project to be implemented:
Please note that in order for the Project to be implemented and for you to benefit from it, the following two conditions have to be met:

1. In order for the Project to be implemented total group contributions by the three participants in the common project have to reach a threshold of 1500 or more ECU. If the total of the contributions falls below this value, the Project cannot be implemented.

2. If group contributions reach or exceed the threshold value of 1500 ECU, the computer will utilize a random device to determine whether the Project will be implemented or not with a probability of 75%. If the device generates a positive value, the Project will be implemented, if it generates a negative value, the Project will not be implemented.

To understand the chances of generating this positive value, imagine an urn or bingo cage containing 4 balls in total: 3 white balls and 1 red ball. One ball is drawn from this imaginary urn if the total contributions reach or exceed 1500 ECU, and if we draw a white ball then the project would be implemented; if we draw a red ball then the project would not be implemented. A different ball draw is conducted for every different group for every different period in which the project might be implemented. In other words, the random draws are all independent.

If the project is implemented, then the production costs of the three group members who decided on contributions to the common project will be reduced by 100 ECU for 3 periods. For example, if the total group contribution in a particular period = 1600 ECU, and the project is implemented with a white ball draw, then the production costs relating to all units of the three members would decrease by 100 ECU for 3 periods.

If the Project is not implemented for any of the two reasons above (either the threshold was not reached or it was reached, but the random device determined a negative outcome), then the production costs will not be lowered and will be the same as before. You will have a new opportunity to chat and contribute to the project after every three-period block in which you have not already lowered your costs by implementing the project. After every three-period block in which you have had costs lowered by 100, you costs will return to the original, higher level for three periods. At the end of that three-period block you will again have a new opportunity to chat and contribute to the project to lower your costs again.

The production costs of the other three participants in your 6-person market who do not participate in attempting to fund a common project always remain the same across all periods.
After the time for communication has expired you will be prompted to enter an amount that you wish to contribute to the Project as in **Figure 4:**

**Figure 4:**

- Period: 0 of 24
- Remaining time [sec]: 24

Please be advised that the Project can only be implemented if group contributions reach a threshold of 1500 ECU.

You can contribute up to 1000 ECU.

After group members have made their decisions and if the threshold of 1500 ECU has been met, a random device will determine whether the Project will be implemented with a probability of 75%.

If the Project is implemented, in the next three periods your marginal production costs will be lowered by 100 ECU each.

If the Project is NOT implemented, in the next three periods your marginal production costs will remain the same.

Your contribution: [ ]

[OK]
You will be then informed about the total group contribution, whether the Project was implemented or not, and your production costs in the next period as shown in Figure 5.

**Figure 5:**

<table>
<thead>
<tr>
<th>Period</th>
<th>Remaining time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 of 24</td>
<td>44</td>
</tr>
</tbody>
</table>

Your payoff from the trading stage was: 1000
Your contribution was: 500
Total contribution of all 3 group members was: 1500

The contribution threshold was met.
The outcome of the random draw was positive.
The Project was implemented.

In the next three periods your marginal production costs will be lowered by 100 ECU each.

Your final payoff from this period is: 590
Your cumulative payoff in this experiment is: 2000

**Summary**

**Trading**
- You will participate in a market for six periods and then in blocks of three periods.
- You will get a fixed period revenue which does not change throughout the experiment.
- Your production costs shown on the left of your computer screen are the extra, additional costs incurred for each unit that you produce.
- Your production will be equal to 10 minus the number of coupons you hold at the end of the period.
- You can avoid production (and save on your production costs) by holding coupons. Depending on the trade price it may be possible to make a profit by buying or selling coupons.

**Common Project**
- You and two other participants in your market will each have an individual contribution limit of 1200 ECU and you can choose how much of it to contribute to the common project. You and these two other group members can use the computer to communicate with each other for 90 seconds before they make this decision.
- If the Project is implemented you will receive a benefit from it in terms of lower production costs in the next block of three periods.
The Project will not be implemented if group contributions do not reach the threshold of 1500 ECU or if the random device generates a negative outcome. The random device generates a negative outcome with a 25% probability.

After you have read these instructions, you will be asked to answer some questions on your computer. For each right answer you will earn 50 cents.

**Summary (read orally by the Experimenter at the conclusion of the instructions)**

- You are in an experiment with 5 other participants.
- You will participate in a market for 27 periods.
- You will get a fixed period revenue which does not change throughout the experiment.
- Your production costs shown on the left of your computer screen are the extra, additional costs incurred for each unit that you produce.
- Your production will be equal to 10 minus the number of coupons you hold at the end of the period.
- You can avoid production (and save on your production costs) by holding coupons. Depending on the trade price it may be possible to make a profit by buying or selling coupons.
- Please record your decisions and earnings in the Personal Record Sheet provided to you.