Strategic interaction, externalities and cooperation in social dilemmas: experimental evidence

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Abstract

Results are reported of an experiment aimed at disentangling the effects of the type of strategic interaction (strategic substitutes versus strategic complements) and the type of externalities (negative versus positive) on the tendency to cooperate in general dominance-solvable games with a Pareto-inefficient Nash equilibrium (so-called social dilemmas). We find that there is significantly more cooperation when actions exhibit strategic complementarities in the sense of Bulow et al. (1985) than with strategic substitutes. The sign of externalities has no significant impact on the tendency to cooperate.

Keywords: strategic substitutes and complements, negative and positive externalities, cooperation, experiment.

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1 Introduction

Holt (1995) remarks in his survey on industrial organisation experiments that it seems to be easier to collude in price-choice than in quantity-choice experiments: "if tacit collusion causes prices to be above noncooperative levels in price-choice environments, then why do quantities tend to be above noncooperative, Cournot levels; that is, why do we often see the reverse of tacit collusion in quantity-choice environments with more than two or three sellers?" (Holt, 1995, pages 423–424). We are not aware of laboratory studies that *explicitly* examine whether tacit collusion is more likely in quantity-choice (Cournot) or price-choice (Bertrand) games, but there exist a number of studies examining the impact of information on outcomes in both type of games (see Fouraker and Siegel, 1963; Huck et al., 2000; Davis, 2002; Altavilla et al., 2003). In these experiments, there is often more tacit collusion in Bertrand than in Cournot treatments.

Furthermore, experimental results based on a noncooperative R&D game of the type of d'Aspremont and Jacquemin (1988), with properties similar to those of Cournot and Bertrand games[1], indicate that the tendency to cooperate in R&D—measured as deviations from Nash play towards joint profit maximising play—are higher when R&D has technological spillovers than when R&D has no spillovers (see Suetens, 2004, 2005). Indeed, cheap-talk possibilities only increase the degree of R&D cooperation significantly when R&D has spillovers.

An important similarity across the above games is the following. Actions in typical Cournot games and R&D games without spillovers are strategic *substitutes* in the sense of Bulow et al. (1985), and have *negative* externalities, while actions in typical Bertrand games and R&D games with high enough spillovers are strategic *complements* and have *positive* externalities. In games with a negative (positive) externality, an action of a player reduces (increases) utility of the other players. Games of strategic substitutes (complements) have the property that an action of a player reduces (increases) *marginal* utility of the other players yielding a negatively (positively) sloped reaction curve.

A relevant question is whether the higher cooperation in these social dilemma games of strategic complements and positive externalities is due to the type of strategic interaction or to the sign of the externality, or to both. In this paper we discuss the results of an experiment where strategic properties and the sign of the externality are disentangled.

[1] Both are dominance-solvable games with a Pareto-inefficient Nash equilibrium, i.e. social dilemmas with a unique Nash equilibrium.

In the experiment we implement social dilemma games of strategic substitutes and of strategic complements, characterised by either positive or negative externalities. So as to solely consider the effect of the type of strategic interaction and the sign of externalities on the tendency to cooperate, all games have the same (unique) Nash equilibrium, which is Pareto-inefficient, and, given the externalities' sign, the same symmetric joint profit maximising optimum, both yielding the same profit. Moreover, in order to guarantee the same speed of convergence of out-of-equilibrium play towards the Nash equilibrium, the absolute values of the reaction curves' slopes are the same. It has further been guaranteed that incentives to cooperate in infinite repetitions of the games, measured as suggested by Friedman (1971), are also the same in both games. For both settings of strategic interaction, treatments have been run based on games with a negative and games with a positive externality.

There exists some theoretical evidence for the hypothesis that cooperative preferences depend on whether actions are strategic substitutes or complements[2]. Rotemberg (1994) shows that rational players can choose to become cooperative in a first stage (referred to as rational altruism), if second-stage actions are strategic complements[3]. Bester and Güth (1998) develop an evolutionary model and provide evidence for the hypothesis that some degree of cooperation (called altruism by the authors) is only evolutionarily stable when actions exhibit strategic complementarities.

As for the type of externalities, a number of experimental papers examine effects on cooperation in a public good context. Andreoni (1995) came to the idea of examining whether cooperation is easier when actions have positive externalities than when actions have negative externalities on the basis of previous experimental findings that in typical public good experiments subjects are more cooperative than predicted while in oligopoly and common-resource experiments Nash predictions perform well[4]. He suggested that the behavioural asymmetry may be caused by the fact that in public good games, actions have positive externalities and in oligopoly and common-resource games actions have negative externalities and finds support for this intuition

[2]Another line of research examines the effects of strategic complementarity in a macroeconomic context (Haltiwanger and Waldman, 1985, 1989; Fehr and Tyran, 2002). Adjustment of behaviour after a macro-economic shock seems to be slower with strategic substitutes than with strategic complements.

[3]This approach is closely related to the concept of strategic delegation (see Vickers, 1985; Sklivas, 1987; Eaton, 2004). Dufwenberg and Güth (1999) provide a comparison between strategic delegation and indirect evolution.

[4]Note that not all actions in oligopoly experiments have negative externalities. Think e.g. of typical Bertrand price-choice experiments.

based on an experiment where the same game is implemented under a positive and a negative frame (see also Sonnemans et al., 1998; Willinger and Ziegelmeyer, 1999; Park, 2000; Zelmer, 2003, for similar results). Recently, Brandts and Schwieren (2004) put these results somewhat into perspective and find that decisions in public good/bad games are much influenced by other parameters chosen, such as e.g. the incentive structure. Parameters may even be chosen in a way such that the direction of the framing effect is opposite to Andreoni's original results (see also Brewer and Kramer, 1986). Our experiment contributes to this literature by examining the effect of the sign of externalities on cooperation in a context without framing.

There exists a large social psychology literature on the determinants of cooperation rates in social dilemma games (see Sally, 1995; Kollock, 1998, for overviews) but our experiment is the first that examines the effect of the type of strategic interaction on the tendency to cooperate, and the first that disentangles the effects of the type of strategic interaction and the sign of externalities on the tendency to cooperate.

Whether behaviour in a social dilemma game depends on the type of externalities or on the type of strategic interaction is a relevant research topic with applications in IO and many other disciplines, such as, for instance, international economics, the economics of intellectual property rights and the economics of environmental pollution (see also Eaton, 2004). Examples of social dilemmas in the field of public economics that follow the above taxonomy are public good and bad games with de- or increasing marginal utility of the public good (bad). A public good game with decreasing marginal utility of the public good, for instance, is an example of a game of strategic substitutes and positive externalities (this game is implemented by Andreoni, 1993; Chan et al., 1997).

The paper proceeds as follows. In section 2 we examine differences in incentives to tacitly collude between Cournot and Bertrand experimental settings based on data that are available from previous experiments. Section 3 contains the general framework that serves as a basis for the experiment in this chapter and section 4 the experimental procedure. The experimental data are described in section 5 and the final section concludes.

2 Cournot versus Bertrand experiments

In this section we have a closer look at behavioural differences between Cournot and Bertrand treatments based on the experimental data used in Fouraker and Siegel (1963); Huck et al. (2000); Davis (2002) and Altavilla et al. (2003)[5] (henceforth referred to as FS, HNO, Davis and ALS, respectively). FS, HNO, Davis and ALS examine the impact of information on outcomes in experimental Cournot and Bertrand oligopolies. The main finding of FS is that under incomplete information, Cournot and Bertrand predictions perform well[6]. Under complete information, actions exhibit greater variability in both types of markets and range between the competitive and the cooperative level. HNO, Davis and ALS find that in Cournot markets competition significantly increases under a full information scenario compared to an incomplete information scenario. In Bertrand markets the additional information does not make behaviour more competitive.

All experiments are based on a repetition of Cournot and Bertrand games and have similar BASIC and EXTRA treatments. Under BASIC, subjects only get aggregate information on their competitors' actions after each round. Under EXTRA, they get detailed information on their competitors' actions and profit.

In order to have one measure for the degree of cooperation across different experiments, the degree of cooperation of duopoly k in round t is defined as follows:

$$\rho_{kt} = \frac{\bar{p}_{kt} - p_{\text{Nash}}}{p_{\text{JPM}} - p_{\text{Nash}}}, \tag{1}$$

where $\bar{p}_{kt}$ is the average price of oligopoly k in round t[7]. If $\rho_{kt} = 0$, duopoly k makes Nash choices in round t and if $\rho_{kt} = 1$, duopoly k makes joint profit maximising (JPM) choices in round t. Table 1 provides averages and standard deviations referring to cross-sectional variability of the degree of cooperation for the different experiments[8]. Also included in the table are p-values of Mann-Whitney tests of $H_0 : \bar{\rho}_{\text{COURNOT}} = \bar{\rho}_{\text{BERTRAND}}$.

Table 1 shows that overall, average degrees of cooperation are higher in Bertrand than in Cournot treatments. Only under the BASIC information condition in the experiment of Davis, there is on average more cooperation in the Cournot setting, but the difference is not significant. Under the BASIC information condition in the experiment of HNO, the difference is in the 'right' direction but is neither significant. Under EXTRA information

[5]We gratefully acknowledge Luigi Luini, Hans Normann, Jörg Oechssler and Patrizia Sbriglia for providing us their data and Doug Davis for providing his data on his website.

[6]Given the assumption of homogenous goods maintained by FS, the Bertrand price equals the competitive price.

[7]With respect to the Cournot treatments, the price of each oligopoly member is calculated on the basis of the inverse demand function taking into account that $p_i \geq 0$.

[8]Note that only pre-merger data from Davis are used for our purposes since post-merger data are *ex ante* asymmetric. From ALS we only used data from the ED1 and ED3 treatments.

	BASIC		EXTRA	
	$\bar{\rho}_{1\text{ to }T}$	N	$\bar{\rho}_{1\text{ to }T}$	N
FS duopoly				
Cournot	-0.12 (0.16)	16	-0.24 (0.70)	11
Bertrand	0.24 (0.15)	17	0.52 (0.26)	10
p-value	0.000	33	0.002	21
FS triopoly				
Cournot	-0.24 (0.18)	16	-0.25 (0.19)	11
Bertrand	0.09 (0.07)	17	0.18 (0.06)	10
p-value	0.000	33	0.000	21
HNO				
Cournot	0.01 (0.03)	6	-0.23 (0.15)	6
Bertrand	0.04 (0.07)	6	0.04 (0.06)	6
p-value	0.394	12	0.004	12
Davis				
Cournot	0.14 (0.54)	5	-0.50 (0.09)	5
Bertrand	-0.10 (0.02)	5	-0.05 (0.03)	5
p-value	0.151	10	0.008	10
ALS				
Cournot1	-0.70 (0.82)	18	-1.50 (0.48)	20
Cournot2	-1.30 (0.47)	18	-2.19 (0.57)	22
Bertrand	0.75 (0.43)	18	-0.14 (0.19)	22
p-value1	0.000	36	0.000	42
p-value2	0.000	36	0.000	44

Standard deviations are in brackets.
N = number of independent observations for FS, HNO and Davis and number of players for ALS.

Table 1: Average degrees of cooperation in Cournot/Bertrand experiments

conditions, differences between Cournot and Bertrand settings are for all experiments highly significant.

One may argue that under EXTRA information conditions, where detailed information is provided on the success of competitors, the force of the imitation equilibrium drives the difference between Cournot and Bertrand settings. Indeed, Bertrand-Nash equilibria are much closer to imitation equilibria than Cournot-Nash equilibria implying that degrees of cooperation calculated in imitation equilibria are *a priori* higher in Bertrand games (see HNO, Davis and ALS for the imitation equilibria). This may have played a role in the HNO and Davis experiments, where groups consisted of four players. But the argument is not valid under BASIC information conditions, because subjects are then unable to identify which competitor is most successful. In the FS and ALS experiments there is also significantly more cooperation under BASIC. Moreover, imitation is most likely more important when groups have more than two players. In duopolies, subjects may influence their opponent's behaviour, rather than adjust to it (see e.g. Selten et al., 1997).

As to show that none of the experiments provides a 'clean' comparison between a Bertrand and a Cournot scenario, we refer to table 2, which summarises theoretical predictions and other important features of the four sets of experiments distinguishing between Cournot (C) and Bertrand (B) markets[9]. A 'clean' comparison requires that both scenarios have the same theoretical benchmarks such as the same equilibria, the same JPM actions, the same profits in these benchmarks, the same absolute value of the reaction curves' slopes and the same incentive to cooperate in the infinitely repeated static game (measured by the *Friedman* index of equation 14 discussed in appendix A)[10].

In the FS, HNO and Davis experiments, most theoretical benchmarks differ across treatments. Take e.g. HNO, where only JPM price and profit are the same across the Cournot and Bertrand treatments. And under the BASIC condition of Davis e.g., only the Nash actions are the same. The ALS experiments are better suitable for comparisons between Cournot and Bertrand settings because either only the slopes of the reaction curves differ in absolute value, or the Nash profit (and consequently any variable related to the relation between π_{Nash} and π_{JPM}, including the *Friedman* index). Nevertheless, the experimental data provide an idea on whether differences in behaviour occur between Cournot and Bertrand markets. Given that in the FS, HNO and Davis experiments the *Friedman* index is higher in the Cournot markets than in the Bertrand markets, one would expect the tendency to cooperate to be higher in Cournot markets than in Bertrand markets if infinitely repeated game strategies are followed. In the FS triopoly experiments, the index is somewhat higher in the Bertrand than in the Cournot treatments but the difference is small.

In this paper, our aim is not only to disentangle the effects of the type of strategic interaction and the externalities' sign on the degree of cooperation, but also to provide a 'clean' comparison between different treatments.

[9]In the FS, HNO and ALS experiments, theoretical benchmarks are the same across both information treatments.

[10]Experimental evidence of e.g. Selten and Stoecker (1986) and Normann and Wallace (2004) suggests that similar strategies are followed in finitely and infinitely repeated games.

	FS duopoly		FS triopoly		HNO		Davis		ALS		
	C	B	C	B	C	B	C	B	C1	C2	B
# players	2	2	3	3	4	4	4	4	2	2	2
# rounds	22	15	22	15	40	40	40	40	20	20	20
matching	fixed		fixed		fixed		fixed		random		
$p_{\text{Nash}}^{\text{BASIC}}$	0.8	0.5	0.6	0.5	76.5	39.25	57	57	8	9.6	8
$q_{\text{Nash}}^{\text{BASIC}}$	20	26	15	17.33	74.5	86.92	56	56	16	14.4	16
$\pi_{\text{Nash}}^{\text{BASIC}}$	16	0	9	0	5550	3238	3136	1344	128	138.2	128
$p_{\text{JPM}}^{\text{BASIC}}$	1.2	3.5	1.2	3.5	151	151	113.1	129	12	12	12
$q_{\text{JPM}}^{\text{BASIC}}$	15	14	10	9.33	49.67	49.67	37.3	32	12	12	12
$\pi_{\text{JPM}}^{\text{BASIC}}$	18	36	12	20	7400	7400	4181	3072	144	144	144
$p_{\text{Nash}}^{\text{EXTRA}}$							81	57			
$q_{\text{Nash}}^{\text{EXTRA}}$							48	56			
$\pi_{\text{Nash}}^{\text{EXTRA}}$							2304	1344			
$p_{\text{JPM}}^{\text{EXTRA}}$							129	129			
$q_{\text{JPM}}^{\text{EXTRA}}$							32	32			
$\pi_{\text{JPM}}^{\text{EXTRA}}$							3072	3072			
slope	1/2	1	1/2	1	-1/3	1/7	-1/3	1/7	-1/2	-1/4	1/4
$\frac{\pi_{\text{JPM}}}{\pi_{\text{Nash}}}$	1.13	∞	1.33	∞	1.33	2.29	1.33	2.29	1.13	1.04	1.13
Friedman	1	0.77	0.23	0.32	0.75	0.44	0.75	0.44	0.89	0.96	0.89

JPM = joint profit maximising

Table 2: Summary of features of Cournot/Bertrand experiments

3 A general framework

In the experiment social dilemma games with two players are implemented. A social dilemma game is a dominance-solvable game where the JPM choice is Pareto-superior to the unique Nash equilibrium. In such a game, individually rational behaviour leads to a situation in which all players are worse off than they might have been when coordinating their actions. A typical example of such a game is a prisoner's dilemma. The action space in the games in the experiment is, unlike the prisoner's dilemma, continuous. Eaton (2004) provides a useful taxonomy of social dilemmas with a continuous action space based on the sign of externalities (referred to as plain substitutes and complements) and the type of strategic interaction (strategic substitutes and complements).

Since we want to examine differences in the tendency to cooperate between games with strategic substitutes and games with strategic complements on the one hand, and between games with positive externalities and games with negative externalities on the other hand, when comparing scenarios of different strategic interactions, the type of externalities should be controlled for and *vice versa*.

A 'clean' comparison between the four scenarios further requires that standard theoretical benchmarks are the same. More specifically,

- the Nash prediction should be the same in the four scenarios,
- profit calculated in the Nash equilibrium should be the same in the four scenarios,
- the symmetric JPM level should be the same for strategic complements and substitutes given the type of externalities[11],
- profit calculated in the cooperative optimum should be the same in the four scenarios.

Subjects participating in experiments do not always play according to the Nash equilibrium. Therefore we also require that convergence from out-of-equilibrium play to the Nash equilibrium is at the same speed in the four scenarios. This implies that the *absolute values of the reaction curves' slopes should be the same* in the four scenarios.

Furthermore, since the experiment is based on a finite repetition of a static one-shot game, it is possible that trigger strategies are played that are viable in an infinitely-repeated-game context (see e.g. Selten and Stoecker, 1986; Normann and Wallace, 2004). We require that incentives to play a trigger strategy are the same in the four scenarios, or in other words, that the *Friedman index is the same* (see appendix A). This implies that—given that profits calculated in the Nash equilibrium and in the symmetric JPM level are the same in the four scenarios—profit when deviating from cooperative play should be the same in the four scenarios.

As to guarantee these restrictions, a flexible profit function defined in terms of the actions of the players is required for the four scenarios. Define profit of player i in a game of two players each making a choice $x_i \geq 0$ with $i = 1, 2$ as follows:

$$\pi_i = a + bx_i + cx_j - dx_i^2 + ex_j^2 + fx_ix_j, \tag{2}$$

[11]With a negative (positive) externality, the JPM choice will be below (above) the Nash equilibrium.

with $b, c, d, f > 0$, $e \geq 0$ $j = 1, 2$ and $j \neq i$. The game has a positive externality since $\frac{\partial \pi_i}{\partial x_j} > 0$. The game is one of strategic complements since $\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} = f > 0$. If player i maximises her own profit, she has the following reaction curve[12]:

$$x_i = \frac{b}{2d} + \frac{f}{2d} x_j \qquad i, j = 1, 2, j \neq i, \tag{3}$$

where the slope is strictly positive since $f, d > 0$. The Nash equilibrium that results is unique and symmetric and equal to

$$x^{\text{Nash}} = \frac{b}{2d - f}, \tag{4}$$

where $2d > f$ for x^{Nash} to be strictly positive.

Joint-profit maximising actions are unique and symmetric and equal to

$$x^{\text{JPM}} = \frac{b + c}{2(d - e - f)}, \tag{5}$$

where $d > e + f$ for x^{JPM} to be strictly positive.

Define profit of player i with $i = 1, 2$ in a scenario with strategic substitutes and positive externalities as follows:

$$\pi_i = \alpha + \beta x_i + \gamma x_j - \delta x_i^2 + \epsilon x_j^2 - \zeta x_i x_j, \tag{6}$$

with $\beta, \gamma, \delta, \zeta > 0$,$\epsilon \geq 0$, $j = 1, 2$ and $j \neq i$. For the game to generate a positive externality, the condition $\gamma + 2\epsilon x_j - \zeta x_i > 0$ should be satisfied. The game is one of strategic substitutes since $\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} = -\zeta < 0$. Maximising profit of player i yields the following reaction curve for i[13]:

$$x_i = \frac{\beta}{2\delta} - \frac{\zeta}{2\delta} x_j \qquad i, j = 1, 2, j \neq i, \tag{7}$$

where the slope is strictly negative since $\delta, \zeta > 0$. The Nash equilibrium that results is unique and symmetric and equal to

$$x^{\text{Nash}} = \frac{\beta}{2\delta + \zeta}. \tag{8}$$

[12]Note that the profit function is strictly concave since $\frac{\partial^2 \pi_i}{\partial \bar{x}_i^{\,2}} = -2d < 0$.

[13]The profit function is strictly concave since $\frac{\partial^2 \pi_i}{\partial \bar{x}_i^{\,2}} = -2\delta < 0$.

Symmetric joint profit maximising actions are equal to

$$x^{\mathrm{JPM}} = \frac{\beta + \gamma}{2(\delta - \epsilon + \zeta)}, \tag{9}$$

where $\delta > \epsilon - \zeta$ for x^{JPM} to be strictly positive. For JPM actions to be symmetric, the condition $\delta > \epsilon + \zeta$ should hold.

For the six requirements for a 'clean' comparison (see page 9) to be valid, the parameters $\alpha, \beta, \gamma, \delta, \epsilon$ and ζ should be defined in terms of a, b, c, d, e and f in the following way:

$$\begin{cases} \alpha &= a \\ \beta &= \dfrac{b(2d-f)}{2d+f} \\ \gamma &= c + \dfrac{2bf}{2d+f} \\ \delta &= \dfrac{d(2d-f)^2}{(2d+f)^2} \\ \epsilon &= e + \dfrac{2f^3}{(2d+f)^2} \\ \zeta &= \dfrac{f(2d-f)^2}{(2d+f)^2}. \end{cases} \tag{10}$$

Note that for the above parameterisations, not only profit calculated in the Nash equilibria is the same as in the scenario with strategic complements and positive externalities, but also profit on the entire reaction curve. Profit calculated in reaction curves (3) or (7) is equal to

$$\pi_i = a + \frac{b^2 + 2(bf + 2cd)x_j + (4de + f^2)x_j^2}{4d} \qquad i, j = 1, 2, j \neq i. \tag{11}$$

Transformations of the above games with positive externalities into games with negative externalities are straightforward by replacing x_i in equations (2) and (6) by $m - y_i$ for $i = 1, 2$. y_i is the choice variable of player i and m represents a sort of initial endowment. It comes down on assuming that x_i and y_i are bounded from above by m and transforming the games with a positive externality in a way that is comparable to the transformation of a public good game into a public bad game. Nash equilibria are the same in the transformed games if $m = \dfrac{2b}{2d-f}$, implying that the Nash equilibrium should be in the middle of the choice set. The symmetric JPM action in the negative externality games is equal to

$$y^{\mathrm{JPM}} = \frac{b(2d - 4e - 3f)}{2(d-e-f)(2d-f)} - \frac{c}{2(d-e-f)}. \tag{12}$$

	strategic substitutes		strategic complements	
	negative extern.	**positive extern.**	**negative extern.**	**positive extern.**
$x^{\text{Nash}} = y^{\text{Nash}}$	$\frac{b}{2d-f}$	$\frac{b}{2d-f}$	$\frac{b}{2d-f}$	$\frac{b}{2d-f}$
π^{Nash}	$a + \frac{bc}{2d-f} + \frac{b^2(d+e)}{(2d-f)^2}$	$a + \frac{bc}{2d-f} + \frac{b^2(d+e)}{(2d-f)^2}$	$a + \frac{bc}{2d-f} + \frac{b^2(d+e)}{(2d-f)^2}$	$a + \frac{bc}{2d-f} + \frac{b^2(d+e)}{(2d-f)^2}$
x^{JPM}	-	$\frac{b+c}{2(d-e-f)}$	-	$\frac{b+c}{2(d-e-f)}$
y^{JPM}	$\frac{b(2d-4e-3f)-c(2d-f)}{2(d-e-f)(2d-f)}$	-	$\frac{b(2d-4e-3f)-c(2d-f)}{2(d-e-f)(2d-f)}$	-
π^{JPM}	$a + \frac{(b+c)^2}{4(d-e-f)}$	$a + \frac{(b+c)^2}{4(d-e-f)}$	$a + \frac{(b+c)^2}{4(d-e-f)}$	$a + \frac{(b+c)^2}{4(d-e-f)}$
slope	$-\frac{f}{2d}$	$-\frac{f}{2d}$	$\frac{f}{2d}$	$\frac{f}{2d}$
Friedman	$\frac{4d(d-e-f)}{(2d-f)^2}$	$\frac{4d(d-e-f)}{(2d-f)^2}$	$\frac{4d(d-e-f)}{(2d-f)^2}$	$\frac{4d(d-e-f)}{(2d-f)^2}$

Table 3: Theoretical benchmarks: general expressions

To summarise, table 3 provides an overview of the theoretical benchmarks in the four scenarios in terms of the parameters of the scenario with strategic complements and positive externalities.

Figure 1 provides graphs of the best-response curves of the players and the Nash and JPM choices in the four scenarios.

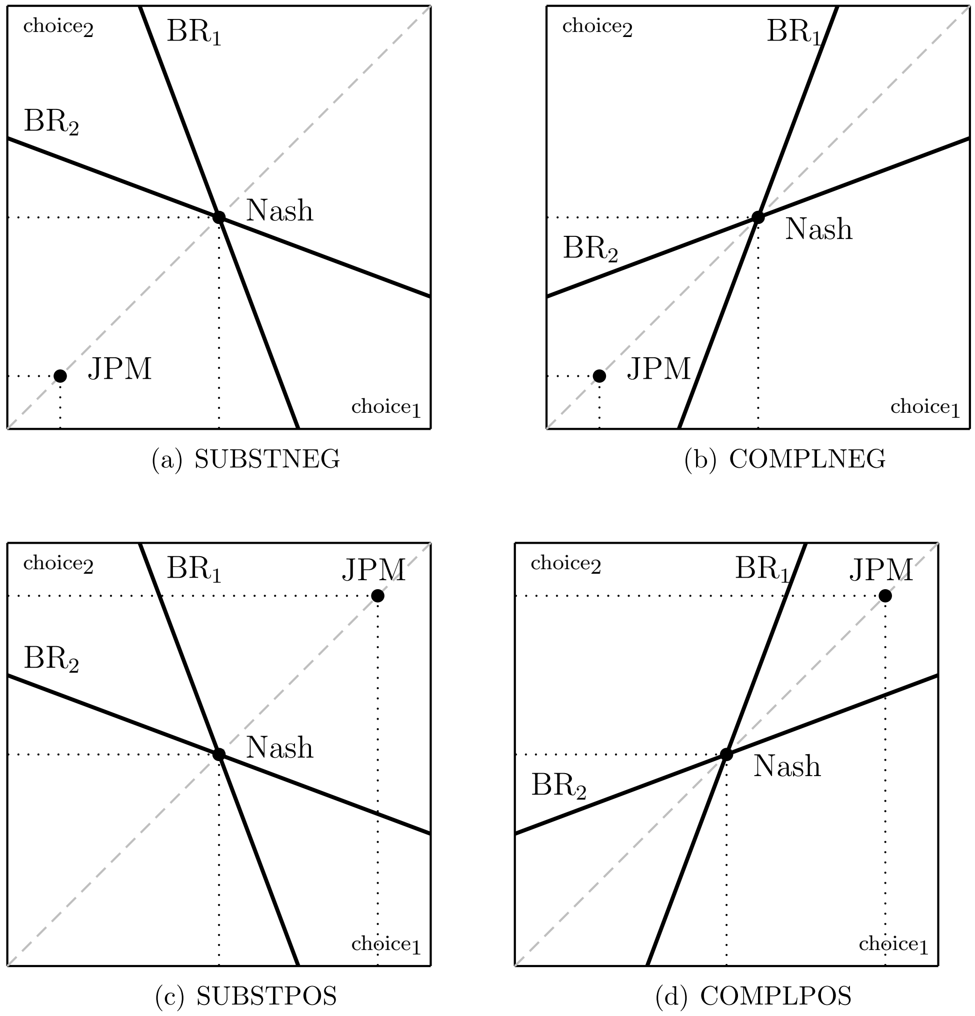

Figure 1: Best-response curves, Nash and JPM choices in social dilemmas

4 Experimental design

The following four treatments based on the games with two players discussed in the previous section have been run:

1. strategic substitutes and negative externalities (SUBSTNEG),
2. strategic substitutes and positive externalities (SUBSTPOS),
3. strategic complements and negative externalities (COMPLNEG),
4. strategic complements and positive externalities (COMPLPOS).

Six computerised sessions have been conducted in CentERlab at Tilburg University in November 2004[14]. In each of the first four sessions, one of the four treatments has been run and in the final two sessions, mixes of all treatments have been run in order to balance the number of observations across the four treatments. 110 students participated in the experiment and were recruited through e-mail lists of students interested in participating in experiments. Each treatment has 14 independent observations (pairs) except treatment SUBSTNEG which has 13 independent observations.

All participants received the same instructions[15]. The treatments only differed with respect to the profit function. Participants were told that their earnings depended on their own choices and on the choices of one other participant in the session, which remained the same during the entire experiment. They were asked to choose a number between 0.0 and 28.0 in each round[16]. Their earnings in points could be calculated by means of a profit table for combinations of hypothetical choices that are multiples of two, and by means of an earnings calculator on the computer screen for any combination of hypothetical choices[17]. They were explicitly told that choices were not restricted to be multiples of two.

The same static game was repeated 31 times including a trial round which did not count to calculate earnings in EUR. Subjects were informed on the number of rounds which implies that the static game-theoretic Nash predictions of the one-shot game are strictly speaking valid in each round. We

[14]We used the experimental software toolkit *z-Tree* to program the experiment (see Fischbacher, 1999).

[15]See appendix B for the instructions.

[16]Choices could have one decimal point.

[17]Profit tables are in appendix B. As to show the difference in slopes of reaction curves between strategic substitutes and complements, reaction curves for multiples of two are marked in grey (which was not the case in the experiment). Note that profits on the 'real' reaction curves, when choices are not restricted to multiples of two, are exactly the same for both scenarios of strategic interaction.

know from previous experimental evidence on finitely repeated games that it is highly unlikely that Nash behaviour occurs in each round, due to, for instance, learning and strategic play (see Selten and Stoecker, 1986). Based on standard game theory, we hypothesise that there should not be any difference in behaviour between the four treatments. The sessions lasted between 50 and 55 minutes and average earnings were 9.30 EUR.

Parameter choices are $a = 28, b = 5.474, c = 0.01, d = 0.278, e = 0.0055$ and $f = 0.165$ which gives $m = 28$. Theoretical benchmarks are in table 4[18]. As table 4 shows, static Nash predictions are the same for all treatments and so are the absolute values of the reaction curves' slopes[19] and equilibrium and cooperative profits. Cooperative decisions in the scenarios with negative externalities are the mirror image of cooperative decisions in the scenarios with positive externalities. Moreover, incentives to cooperate in an infinitely repeated version of the game are the same across the treatments as the *Friedman* index is the same.

5 Experimental results

5.1 General

Table 5 contains an overview of descriptive statistics for the pair choices based on all rounds. The standard deviations only refer to cross-sectional variability and not to variability in time. The degree of cooperation of pair k in round t is defined as in section 2:

$$\rho_{kt} = \frac{\text{average choice}_{kt} - \text{choice}^{\text{Nash}}}{\text{choice}^{\text{JPM}} - \text{choice}^{\text{Nash}}}.$$

[18]In the experiment earnings in points were rounded at two decimals.

[19]Note that we tried to maximise the absolute value of the reaction curves' slope as to sharpen possible contrasts between strategic substitutes and complements. But in doing this we are constraint by the requirement that $y^{\text{JPM}} \geq 0$. Assume that c is very small such that it becomes negligible; $c \approx 0$. In that case expression (12) reduces to

$$y^{\text{JPM}} = \frac{b(2d - 4e - 3f)}{2(d - e - f)(2d - f)}, \tag{13}$$

and the condition $y^{\text{JPM}} \geq 0$ reduces to $2d \geq 4e + 3f$ since $d > e + f$ and $2d > f$. If we also assume that $e \approx 0$ the condition $y^{\text{JPM}} \geq 0$ reduces to $2d \geq 3f$, or $\frac{f}{2d} \leq \frac{1}{3}$. In other words, the slope of the reaction function (see equation (3)) cannot exceed 1/3. If $c > 0$ or $e > 0$ the condition becomes $\frac{f}{2d} < \frac{1}{3}$ and the absolute value of the slope will always be strictly smaller than 1/3.

	SUBST		COMPL	
	SUBSTNEG	SUBSTPOS	COMPLNEG	COMPLPOS
$\text{choice}^{\text{Nash}}$	14.0	14.0	14.0	14.0
π^{Nash}	27.71	27.71	27.71	27.71
$\text{choice}^{\text{JPM}}$	2.5	25.5	2.5	25.5
π^{JPM}	41.94	41.94	41.94	41.94
slope	-0.30	-0.30	0.30	0.30
$\frac{\pi^{\text{JPM}}}{\pi^{\text{Nash}}}$	1.51	1.51	1.51	1.51
Friedman	0.78	0.78	0.78	0.78
choice_{min}	0.0	0.0	0.0	0.0
choice_{max}	28.0	28.0	28.0	28.0

Table 4: Theoretical benchmarks in the experiment

	Nash	JPM	mean (s.d.)	median	ρ_{mean} (s.d.)	ρ_{median}
SUBSTNEG	14.0	2.5	11.3 (4.84)	12.1	0.24 (0.42)	0.17
COMPLNEG	14.0	2.5	8.4 (4.81)	7.0	0.49 (0.42)	0.61
SUBSTPOS	14.0	25.5	15.9 (4.70)	13.8	0.17 (0.41)	-0.02
COMPLPOS	14.0	25.5	18.8 (4.09)	18.5	0.42 (0.36)	0.39

Table 5: Average choices

When pair k chose on average to maximize individual profit in round t then $\rho_{kt} = 0$, while with joint profit maximization, $\rho_{kt} = 1$.

From the table we learn that both for negative and positive externalities, the tendency to cooperate is higher with strategic complements than with substitutes. Furthermore, there is overall more cooperation with negative than with positive externalities, given the type of strategic interaction.

We further have a look at averages based on different subsets of rounds and Mann-Whitney-U tests of treatment effects[20]. Table 6 provides test results of $H_0 : \bar{\rho}_{\text{NEG}} = \bar{\rho}_{\text{POS}}$ for SUBST and COMPL based on different subsets of rounds. The tests indicate that the degree of cooperation is generally not significantly different between treatments with negative and treatments with positive externalities. This goes for both scenarios of strategic interaction. With strategic substitutes, there is a marginally significant difference

[20]All tests have been performed in *SPSS 12.0*.

rounds	1-30		1-10		11-20		21-30		30	
	NEG	POS	NEG	POS	NEG	POS	NEG	POS	NEG	POS
SUBST										
$\bar{\rho}$	0.24	0.17	0.22	0.00	0.26	0.25	0.24	0.25	-0.32	-0.21
N	13	14	13	14	13	14	13	14	13	14
2-tailed sig.	0.519		0.094		0.756		0.616		0.450	
COMPL										
$\bar{\rho}$	0.49	0.42	0.38	0.31	0.60	0.45	0.48	0.49	0.07	0.16
N	14	14	14	14	14	14	14	14	14	14
2-tailed sig.	0.667		0.982		0.454		0.874		0.151	

2-tailed sig. of Mann-Whitney tests of $H_0 : \bar{\rho}_{\text{NEG}} = \bar{\rho}_{\text{POS}}$

Table 6: Effects of sign of externalities on the degree of cooperation

in degree of cooperation in the first ten rounds in favour of the negative externalities scenario, but the significance disappears after the first ten rounds. Thus, we do not find evidence for the idea launched by Andreoni (1995) that there is more cooperation when actions have positive externalities compared to when actions have negative externalities.

Table 7 provides results of Mann-Whitney-U tests of differences between strategic substitutes and strategic complements. Given that no significant difference in degree of cooperation exists between negative and positive externalities, results without distinguishing on the basis of the type of externalities are included. The tests confirm previous experimental evidence because the degree of cooperation is overall higher with strategic complements than with strategic substitutes with a two-tailed significance level of 2.5%. The difference is significant in the first ten rounds. The significance of the difference reduces somewhat in the final ten rounds, but the p-value does not fall beyond 9.2%. Moreover, the difference is strongly significant in the final round.

When analysing the data separately for the scenarios of negative and positive externalities, the test statistics based on all rounds point in the same direction provided that for negative externalities a one-tailed test is used. This may be justified given that most previous experimental evidence seems to indicate that cooperation is easier or better sustained with strategic complements than with substitutes. With negative externalities, the difference between complements and substitutes based on one-tailed tests only becomes significant after the first ten rounds. With positive externalities, on the other hand, the significance of the difference that exists in the first ten rounds disappears afterwards. But both for negative and positive externalities, in the final round there is significantly more cooperation with complements.

rounds	1-30		1-10		11-20		21-30		30	
	S	C	S	C	S	C	S	C	S	C
ALL										
$\bar{\rho}$	0.20	0.45	0.11	0.34	0.25	0.53	0.24	0.49	-0.26	0.12
N	27	28	27	28	27	28	27	28	27	28
2-tailed sig.	0.025		0.016		0.067		0.092		0.000	
NEG										
$\bar{\rho}$	0.24	0.49	0.22	0.38	0.26	0.60	0.24	0.48	-0.32	0.07
N	13	14	13	14	13	14	13	14	13	14
2-tailed sig.	0.185		0.480		0.173		0.155		0.000	
POS										
$\bar{\rho}$	0.17	0.42	0.00	0.31	0.25	0.45	0.25	0.49	-0.21	0.16
N	14	14	14	14	14	14	14	14	14	14
2-tailed sig.	0.085		0.016		0.246		0.210		0.002	

S = SUBST; C = COMPL

2-tailed sig. of Mann-Whitney tests of $H_0 : \bar{\rho}_{\text{SUBST}} = \bar{\rho}_{\text{COMPL}}$

Table 7: Effects of strategic interaction on the degree of cooperation

5.2 JPM and non-JPM choices

A thorough study of subject- and round-specific choices indicates that in all treatments, there are some outspoken cooperative pairs. Moreover, it can be observed that once pairs succeed in making choices close to the JPM choice, these choices are mostly repeated until almost the end of the experiment. Typically, in the final round(s) cooperation breaks down, often referred to as an end-effect in the experimental literature. This end-effect suggests that cooperation is strategic. In what follows we examine behaviour of these cooperative pairs and other pairs separately. We define a pair's choice to be a JPM choice in round t if the average choice of the pair in round t is in interval $[24.0, 28.0]$ when externalities are positive, and in $[0.0, 4.0]$ when externalities are negative[21].

Table 8 presents total number of JPM choices in different subsets of rounds and Mann-Whitney-U test results based on average pairs' choices of the null hypothesis that there is no difference in number of JPM choices between complements and substitutes[22]. With substitutes, 23% of the choices are in the JPM interval (188 out of 810) while with complements, 31% (260

[21] The degree of cooperation when a JPM choice is made is between 0.8696 and 1.2174.

[22] We do not distinguish on the basis the sign of externalities given that there exist no significant differences in variables we examine in what follows between positive and negative externalities. Only in the middle ten rounds, there are significantly more JPM choices in COMPLNEG than in COMPLPOS with a two-tailed p-value of 0.068.

rounds	1-30		1-10		11-20		21-30	
	S	C	S	C	S	C	S	C
# JPM choices	188	260	29	58	68	111	91	91
N	27	28	27	28	27	28	27	28
2-tailed sig.	0.530		0.066		0.303		0.955	

S=SUBST; C=COMPL

2-tailed sig. of Mann-Whitney tests of $H_0 : \#_{\text{SUBST}} = \#_{\text{COMPL}}$

Table 8: Effects of strategic interaction on number of JPM choices

rounds	1-30		1-10		11-20		21-30	
	S	C	S	C	S	C	S	C
$\bar{\rho}$	-0.01	0.27	0.00	0.22	0.02	0.28	0.06	0.29
N	27	28	25	25	23	20	27	28
2-tailed sig.	0.000		0.008		0.021		0.000	

S=SUBST; C=COMPL

2-tailed sig. of Mann-Whitney tests of $H_0 : \bar{\rho}_{\text{COMPL}} = \bar{\rho}_{\text{SUBST}}$.

Table 9: Effects of strategic interaction on cooperation based on non-JPM choices

out of 840). The table points out that overall, choices in the JPM interval were as often made with substitutes as with complements. In the first ten rounds, significantly more JPM choices were made with complements. These results may indicate that pairs succeed sooner in making JPM choices when actions exhibit strategic complementarities. Yet, once players succeed in making JPM choices, they stick to JPM behaviour, irrespective of whether actions are strategic substitutes or complements.

Given these findings, differences in degree of cooperation between the two strategic settings after the first ten rounds are most likely not driven by differences in number of JPM choices. Table 9 only takes into account non-JPM choices and provides degrees of cooperation based on choices lower than 24 and related Mann-Whitney-U test results of $H_0 : \bar{\rho}_{\text{COMPL}} = \bar{\rho}_{\text{SUBST}}$. The test results point out that when concentrating on choices that are not in the JPM interval, the difference in degree of cooperation between substitutes and complements is highly significant in all subsets of rounds. These results give even more support to the finding that cooperation is easier with complements than with substitutes. JPM choices have clearly blurred the significance in the non-parametric test results of table 7.

6 Conclusion

The experimental evidence that under Bertrand competition the degree of cooperation is often higher than under Cournot competition, that with high spillovers the tendency to cooperate in R&D is higher than without spillovers and that in a number of public good games there is more cooperation than in the equivalent public bad game, may be summarised as follows: When actions in a dominance-solvable game with a Pareto-inefficient Nash equilibrium are strategic complements and/or have positive externalities, it is easier to reach optima that are Pareto-superior to the Nash equilibrium than when actions are strategic substitutes and/or have negative externalities.

Motivated by these experimental findings, in this chapter we set up a general experiment based on this type of game, with the aim to disentangle the effects of the type of strategic interaction and of the type of externalities on the tendency to cooperate. We find that the type of strategic interaction is decisive in influencing the degree of cooperation compared to the sign of the externalities. Moreover, we find that cooperation is easier when actions exhibit strategic complementarities.

Appendix A: The *Friedman* index

Incentives to cooperate in an infinitely repeated non-cooperative R&D game, can be measured by incentives to follow a trigger strategy as explained in Martin (2001) at page 299 (based on Friedman, 1971). Under a trigger strategy players start to cooperate and keep cooperating as long as the other does. Once a player defects, the other defects in all subsequent periods which implies that both play the SPN equilibrium from the subsequent period onwards. As shown by Martin, a trigger strategy is a non-cooperative equilibrium if the discount rate α

$$\alpha \geq \frac{\pi^{\text{DEF}} - \pi^{\text{JPM}}}{\pi^{\text{DEF}} - \pi^{\text{Nash}}},$$

where π^{JPM} and π^{DEF} stand for profit under joint profit maximisation (JPM) and profit from defecting from JPM play, respectively. In terms of the interest rate r, using $\alpha = 1/(1+r)$ the condition becomes

$$r \leq \frac{\pi^{\text{JPM}} - \pi^{\text{Nash}}}{\pi^{\text{DEF}} - \pi^{\text{JPM}}}, \tag{14}$$

and is always satisfied if r is close to zero (Martin, 2001). We call the right-hand side of equation 14 the *Friedman* index. The higher the *Friedman* index, the more probable that r is below it and thus the higher the possibility that the above trigger strategy is a non-cooperative equilibrium.

Appendix B: Instructions

You are participating in an experiment on economic decision-making and will be asked to make a number of decisions. If you follow the instructions carefully, you can earn a considerable amount of money. At the end of the experiment, you will be paid your earnings in private and in cash.

During the experiment you are not allowed to talk to other participants. If something is not clear, please raise your hand and one of us will help you.

Your earnings depend on your own decisions and on the decisions of one other participant. The identity of the other participant will not be revealed. The other participant remains the same during the entire experiment and will be referred to by 'the other' in what follows.

The experiment consists of 30 periods. In each period you have to choose a number between 0.0 and 28.0. The other also chooses a number between 0.0 and 28.0. Your earnings in points depend on your choice and the other's choice. The table attached to these instructions gives information about your earnings for some combinations of your choice and the other's choice. The other gets the same table.

You can calculate your and the other's earnings in more detail (for choices that are no multiples of 2 for instance) by using the EARNINGS CALCULATOR on your screen. By filling in a hypothetical value for your own choice and a hypothetical value for the other's choice you can calculate your and the other's earnings for this combination of choices.

You enter your decision under DECISION ENTRY by clicking on 'Enter'.

In each period you have about 1 minute to enter your decision.

After each period you are informed about the other's choice and your and the other's earnings in that period. A history of your and the other's past choices and earnings is available at the bottom right of your computer screen.

The first period is a trial period and does not count when calculating your earnings. Your total earnings in points are the sum of your earnings in points over the 30 periods. Your earnings in points will be converted into EUR according to the following rate: 100 points = 1 EUR.

		The other's choice →														
		0.0	**2.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**16.0**	**18.0**	**20.0**	**22.0**	**24.0**	**26.0**	**28.0**
Your choice ↓	**0.0**	41.27	36.50	31.91	27.50	23.27	19.22	15.36	11.68	8.18	4.87	1.73	-1.22	-3.99	-6.57	-8.98
	2.0	46.88	41.91	37.13	32.52	28.10	23.86	19.81	15.93	12.24	8.73	5.40	2.26	-0.71	-3.49	-6.09
	4.0	51.84	46.68	41.70	36.90	32.28	27.85	23.60	19.53	15.64	11.94	8.42	5.08	1.92	-1.05	-3.85
	6.0	56.14	50.78	45.61	40.62	35.81	31.18	26.74	22.47	18.39	14.49	10.78	7.25	3.89	0.72	-2.26
	8.0	59.79	54.24	48.87	43.68	38.68	33.86	29.22	24.76	20.49	16.40	12.49	8.76	5.21	1.85	-1.33
	10.0	62.78	57.04	51.48	46.10	40.90	35.88	31.05	26.40	21.93	17.64	13.54	9.62	5.88	2.32	-1.06
	12.0	65.12	59.18	53.43	47.85	42.46	37.25	32.22	27.38	22.72	18.24	13.94	9.82	5.89	2.14	-1.43
	14.0	66.81	60.67	54.72	48.96	43.37	37.97	32.75	27.71	22.85	18.17	13.68	9.37	5.24	1.30	-2.46
	16.0	67.84	61.51	55.37	49.41	43.63	38.03	32.61	27.38	22.33	17.46	12.77	8.27	3.95	-0.19	-4.15
	18.0	68.22	61.70	55.36	49.20	43.23	37.43	31.83	26.40	21.15	16.09	11.21	6.51	2.00	-2.34	-6.49
	20.0	67.94	61.23	54.69	48.34	42.17	36.19	30.38	24.76	19.32	14.07	8.99	4.10	-0.61	-5.14	-9.48
	22.0	67.01	60.10	53.37	46.83	40.47	34.29	28.29	22.47	16.84	11.39	6.12	1.03	-3.87	-8.59	-13.13
	24.0	65.43	58.32	51.40	44.66	38.11	31.73	25.54	19.53	13.70	8.06	2.59	-2.69	-7.78	-12.70	-17.43
	26.0	63.19	55.89	48.77	41.84	35.09	28.52	22.14	15.93	9.91	4.07	-1.58	-7.06	-12.35	-17.46	-22.39
	28.0	60.29	52.80	45.49	38.37	31.42	24.66	18.08	11.68	5.47	-0.57	-6.42	-12.09	-17.57	-22.88	-28.00

Figure 2: Profit table for SUBSTNEG

		The other's choice →														
		0.0	**2.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**16.0**	**18.0**	**20.0**	**22.0**	**24.0**	**26.0**	**28.0**
	0.0	-28.00	-22.88	-17.57	-12.09	-6.42	-0.57	5.47	11.68	18.08	24.66	31.42	38.37	45.49	52.80	60.29
	2.0	-22.39	-17.46	-12.35	-7.06	-1.58	4.07	9.91	15.93	22.14	28.52	35.09	41.84	48.77	55.89	63.19
	4.0	-17.43	-12.70	-7.78	-2.69	2.59	8.06	13.70	19.53	25.54	31.73	38.11	44.66	51.40	58.32	65.43
	6.0	-13.13	-8.59	-3.87	1.03	6.12	11.39	16.84	22.47	28.29	34.29	40.47	46.83	53.37	60.10	67.01
	8.0	-9.48	-5.14	-0.61	4.10	8.99	14.07	19.32	24.76	30.38	36.19	42.17	48.34	54.69	61.23	67.94
	10.0	-6.49	-2.34	2.00	6.51	11.21	16.09	21.15	26.40	31.83	37.43	43.23	49.20	55.36	61.70	68.22
Your	**12.0**	-4.15	-0.19	3.95	8.27	12.77	17.46	22.33	27.38	32.61	38.03	43.63	49.41	55.37	61.51	67.84
choice	**14.0**	-2.46	1.30	5.24	9.37	13.68	18.17	22.85	27.71	32.75	37.97	43.37	48.96	54.72	60.67	66.81
	16.0	-1.43	2.14	5.89	9.82	13.94	18.24	22.72	27.38	32.22	37.25	42.46	47.85	53.43	59.18	65.12
↓	**18.0**	-1.06	2.32	5.88	9.62	13.54	17.64	21.93	26.40	31.05	35.88	40.90	46.10	51.48	57.04	62.78
	20.0	-1.33	1.85	5.21	8.76	12.49	16.40	20.49	24.76	29.22	33.86	38.68	43.68	48.87	54.24	59.79
	22.0	-2.26	0.72	3.89	7.25	10.78	14.49	18.39	22.47	26.74	31.18	35.81	40.62	45.61	50.78	56.14
	24.0	-3.85	-1.05	1.92	5.08	8.42	11.94	15.64	19.53	23.60	27.85	32.28	36.90	41.70	46.68	51.84
	26.0	-6.09	-3.49	-0.71	2.26	5.40	8.73	12.24	15.93	19.81	23.86	28.10	32.52	37.13	41.91	46.88
	28.0	-8.98	-6.57	-3.99	-1.22	1.73	4.87	8.18	11.68	15.36	19.22	23.27	27.50	31.91	36.50	41.27

Figure 3: Profit table for SUBSTPOS

		The other's choice →														
		0.0	**2.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**16.0**	**18.0**	**20.0**	**22.0**	**24.0**	**26.0**	**28.0**
Your choice ↓	**0.0**	41.27	31.42	21.61	11.84	2.12	-7.56	-17.19	-26.78	-36.33	-45.83	-55.29	-64.70	-74.07	-83.40	-92.68
	2.0	51.11	41.91	32.76	23.66	14.60	5.58	-3.40	-12.33	-21.21	-30.05	-38.85	-47.61	-56.32	-64.98	-73.60
	4.0	58.72	50.19	41.70	33.25	24.85	16.49	8.18	-0.09	-8.32	-16.50	-24.64	-32.73	-40.78	-48.79	-56.75
	6.0	64.11	56.23	48.40	40.62	32.88	25.18	17.52	9.91	2.35	-5.17	-12.65	-20.09	-27.48	-34.82	-42.12
	8.0	67.27	60.06	52.89	45.76	38.68	31.64	24.65	17.70	10.79	3.93	-2.89	-9.66	-16.39	-23.08	-29.72
	10.0	68.21	61.66	55.15	48.68	42.26	35.88	29.55	23.26	17.01	10.81	4.65	-1.46	-7.53	-13.56	-19.54
	12.0	66.93	61.03	55.18	49.38	43.62	37.90	32.22	26.59	21.01	15.47	9.97	4.51	-0.90	-6.26	-11.58
	14.0	63.42	58.19	53.00	47.85	42.75	37.69	32.68	27.71	22.78	17.90	13.06	8.27	3.52	-1.19	-5.85
	16.0	57.69	53.11	48.58	44.10	39.66	35.26	30.90	26.59	22.33	18.11	13.93	9.79	5.70	1.66	-2.34
	18.0	49.73	45.82	41.95	38.12	34.34	30.60	26.91	23.26	19.65	16.09	12.57	9.10	5.67	2.28	-1.06
	20.0	39.55	36.30	33.09	29.92	26.80	23.72	20.69	17.70	14.75	11.85	8.99	6.18	3.41	0.68	-2.00
	22.0	27.15	24.55	22.00	19.50	17.04	14.62	12.24	9.91	7.63	5.39	3.19	1.03	-1.08	-3.14	-5.16
	24.0	12.52	10.59	8.70	6.85	5.05	3.29	1.58	-0.09	-1.72	-3.30	-4.84	-6.33	-7.78	-9.19	-10.55
	26.0	-4.33	-5.61	-6.84	-8.02	-9.16	-10.26	-11.32	-12.33	-13.29	-14.21	-15.09	-15.93	-16.72	-17.46	-18.16
	28.0	-23.41	-24.02	-24.59	-25.12	-25.60	-26.04	-26.43	-26.78	-27.09	-27.35	-27.57	-27.74	-27.87	-27.96	-28.00

Figure 4: Profit table for COMPLNEG

		The other's choice →														
		0.0	**2.0**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**16.0**	**18.0**	**20.0**	**22.0**	**24.0**	**26.0**	**28.0**
	0.0	-28.00	-27.96	-27.87	-27.74	-27.57	-27.35	-27.09	-26.78	-26.43	-26.04	-25.60	-25.12	-24.59	-24.02	-23.41
	2.0	-18.16	-17.46	-16.72	-15.93	-15.09	-14.21	-13.29	-12.33	-11.32	-10.26	-9.16	-8.02	-6.84	-5.61	-4.33
	4.0	-10.55	-9.19	-7.78	-6.33	-4.84	-3.30	-1.72	-0.09	1.58	3.29	5.05	6.85	8.70	10.59	12.52
	6.0	-5.16	-3.14	-1.08	1.03	3.19	5.39	7.63	9.91	12.24	14.62	17.04	19.50	22.00	24.55	27.15
	8.0	-2.00	0.68	3.41	6.18	8.99	11.85	14.75	17.70	20.69	23.72	26.80	29.92	33.09	36.30	39.55
	10.0	-1.06	2.28	5.67	9.10	12.57	16.09	19.65	23.26	26.91	30.60	34.34	38.12	41.95	45.82	49.73
Your choice ↓	**12.0**	-2.34	1.66	5.70	9.79	13.93	18.11	22.33	26.59	30.90	35.26	39.66	44.10	48.58	53.11	57.69
	14.0	-5.85	-1.19	3.52	8.27	13.06	17.90	22.78	27.71	32.68	37.69	42.75	47.85	53.00	58.19	63.42
	16.0	-11.58	-6.26	-0.90	4.51	9.97	15.47	21.01	26.59	32.22	37.90	43.62	49.38	55.18	61.03	66.93
	18.0	-19.54	-13.56	-7.53	-1.46	4.65	10.81	17.01	23.26	29.55	35.88	42.26	48.68	55.15	61.66	68.21
	20.0	-29.72	-23.08	-16.39	-9.66	-2.89	3.93	10.79	17.70	24.65	31.64	38.68	45.76	52.89	60.06	67.27
	22.0	-42.12	-34.82	-27.48	-20.09	-12.65	-5.17	2.35	9.91	17.52	25.18	32.88	40.62	48.40	56.23	64.11
	24.0	-56.75	-48.79	-40.78	-32.73	-24.64	-16.50	-8.32	-0.09	8.18	16.49	24.85	33.25	41.70	50.19	58.72
	26.0	-73.60	-64.98	-56.32	-47.61	-38.85	-30.05	-21.21	-12.33	-3.40	5.58	14.60	23.66	32.76	41.91	51.11
	28.0	-92.68	-83.40	-74.07	-64.70	-55.29	-45.83	-36.33	-26.78	-17.19	-7.56	2.12	11.84	21.61	31.42	41.27

Figure 5: Profit table for COMPLPOS

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