The effect of payoff tables on experimental oligopoly behavior

Gürerk, Özgür and Selten, Reinhard

University of Erfurt, CEREB

29 April 2010

The Effect of Payoff Tables on Experimental Oligopoly Behavior

Özgür Gürerk · Reinhard Selten

Abstract We explore the effects of the provision of an information-processing instrument – payoff tables – on behavior in experimental oligopolies. In one experimental setting, subjects have access to payoff tables whereas in the other setting they have not. It turns out that this minor variation in presentation has non-negligible effects on participants' behavior, particularly in the initial phase of the experiment. In the presence of payoff tables, subjects tend to be more cooperative. As a consequence, collusive behavior is more likely and quickly to occur.

Ö. Gürerk
University of Erfurt, Laboratory for Experimental Economics
Tel.: +49-361-7374561
Fax: +49-361-7374529
E-mail: oezguer.guererk@uni-erfurt.de
Nordhäuser Str. 63, 99089 Erfurt

R. Selten
University of Bonn, *BonnEconLab*
Tel.: +49-228-739192
Fax: +49-361-739193
E-mail: rselten@uni-bonn.de
Adenauerallee 24-42, 53113 Bonn

1 Introduction

Payoff tables[1] are widely used as an informational aid in experimental economics since its beginnings. Some of the pioneering studies on oligopolies adopt payoff tables (Fouraker and Siegel 1963; Sauermann and Selten 1967; Dolbear et al. 1968) as well as recent ones (e.g., Abbink and Brandts 2008, the majority of the studies reviewed in Huck et al. 2004). The influence of this device on subjects' behavior, however, has not yet been explored systematically. With this study, we try to fill this gap.

We conduct a series of Cournot market experiments with two presentational settings that differ slightly. In one setting named *TAB*, subjects are provided with payoff tables whereas they are not in the other setting (*noTAB*). Our main research interest concerns whether subjects in the two settings behave differently. In the context of an oligopoly, we may re-formulate our research question: Do competitors with an information processing aid tend to be more collusive than competitors without such an aid? To check whether the possible effects of payoff tables are robust with respect to market size, we conduct experiments with two, three, and four competitors.[2]

Previous studies show that slight differences in information presentation may indeed have effects on subject's behavior. Pruitt (1967), for instance, reports more cooperation in the prisoner's dilemma game if the payoff structure of the game is presented to subjects in the decomposed form. In a public goods experiment, Saijo and Nakamura (1995) provide subjects either with a "rough" table containing basic payoff information or a "detailed" table that is comparable to the payoff table we provide. They find, if the marginal capita per return is high (and resp. low), average contributions to the public goods are higher with detailed tables (resp. lower) than the investments with rough tables. Huck et al. (1999) find that markets tend to become less competitive if more information about demand and cost conditions are present, while more information about competitors' quantities and profits yields more competitive behavior. Bosch-Domènech and Vriend (2003) investigate imitation behavior in Cournot markets by varying the presentation of market information. They observe that the imitation frequency does not increase when the information retrieval gets more complex. In a gift-exchange experiment, Charness et al. (2004) find significant reductions in both wages and worker effort when subjects are provided with payoff tables compared to the baseline treatment without payoff tables. Requate and Waichman (2011) report no differences in behavior in Cournot duopoly experiments whether subjects are provided with payoff tables or use a payoff calculator. The studies of Charness et al. (2004)

---

[1] A payoff table is a matrix that depicts the payoff of player i for all possible combinations of i's and the opponent's actions. For example, in a Cournot market, the payoff table displays player i's payoff for all combinations of i's production choice and the competitors' total production.

[2] See Huck et al. (2004) for a general discussion of number effects in quantity setting oligopolies.

and especially, Requate and Waichman (2011) are closely related to ours.[3] In the last section of the paper, we will discuss and compare the findings of these studies to our results.

The payoff table we use in our study (see Appendix) reduces the complexity of the payoff structure by presenting all possible payoffs in a crystal clear way. This may help subjects to realize better what alternatives they have and what the consequences of these alternatives are. In particular, subjects may identify collusive quantities more easily. Hence, we conjecture that payoff tables should lead to more collusive behavior. On the other hand, one can think of an alternative conjecture: with payoff tables, subjects could also easily identify best-replies. This could drive the results more in the direction of Nash-equilibrium.

Our results show for all market sizes, average total quantities are lower when subjects are provided with payoff tables, i.e., in *TAB*, the markets are more collusive. In the initial phase of the experiment, the differences between both settings are most pronounced. Subjects provided with payoff tables choose more often collusive quantities. Over time, however, the differences between both settings get smaller.

The next section presents the model. Section 3 describes the experimental design and procedure. Section 4 is dedicated to the results. Section 5 concludes.

2 The model

Since we focus on the impact of payoff tables we use a very simple Cournot model. In a Cournot oligopoly, N symmetric firms compete in a market where a homogenous good is sold. By x_i we denote the single quantity produced by the firm i (production is limited to 60 units per period). The total market production, i.e., the sum of x_i is represented by X. To simplify the problem without changing its nature we set the cost of production to zero. Furthermore, we assume a linear market demand where the computer "buys" the total production. The resulting price is denoted with p and the inverse demand function then is $p = \max\{60 - X, 0\}$. The firms decide simultaneously on x_i. The profit of firm i is given by $\pi_i = (60 - X)x_i$ for $X \leq 60$ and $\pi_i = 0$ for $X > 60$.

For each market size, one can easily calculate the Cournot-equilibrium, which is the only pure Nash-equilibrium of the stage game yielding positive profits for each player. We refer to this equilibrium as the Cournot-Nash-equilibrium (henceforth CNE).[4] The CNE is the first theoretical benchmark to which we will compare the experimental results. The second benchmark to which we refer is collusion where all competitors act as if they were a single monopolist to maximize their joint profits. The third benchmark is the competitive outcome where firms maximize their profits given the market clearing

---

[3] The two main differences between the study of Requate and Waichman and ours are: first we investigate the effect of an informational aid (payoff table) to no aid at all. Second we investigate the possible effect not only for duopolies but for three different market sizes.

[4] The stage game also has other pure equilibria, e.g., $x_i = 60$ for $i = 1...n$.

price. Many experimental studies refer to these three benchmarks of quantity-setting oligopoly (see e.g., Offerman et al. 2002). Table 1 depicts the total quantities and prices in markets with two, three, and four competitors for the respective benchmarks.

Table 1 Total quantity and prices at benchmark outcomes

	Collusion		CNE		Competition	
Market size	X	p	X	p	X	p
$N = 2$	30	30	40	20	60	0
$N = 3$	30	30	45	15	60	0
$N = 4$	30	30	48	12	60	0

3 Experimental design

Our experimental design contains two informational settings (*noTAB*, *TAB*) and three market sizes, i.e., we have six experimental treatments. We conducted 10 independent observations per treatment; in total 180 students participated in ten experimental sessions. [5]After the participants had entered the laboratory, the instructor read aloud the instructions[6] to make sure that every participant heard the information at least once and to create common knowledge. The subjects' assignment to different markets was random but fixed for the duration of the experiment. Communication was not allowed. A market period consisted of a decision and a feedback phase. After the subjects made their quantity decisions, all competitors received feedback about all single quantities and profits in their market. The participants played 100 experimental periods that lasted two and half hours on average including the introduction. The average payoff was about 18 Euros. The experiments were programmed with the experimental programming toolbox RatImage (Abbink and Sadrieh 1995).

4 Results

4.1 Aggregate Behavior

On the aggregate level, there is a clear difference between both settings. Figure 1 depicts for each treatment average total quantities in blocks of ten periods.

---

[5] We had 2+2=4 sessions with 20 subjects each for the quadropoly treatments; 2+2=4 sessions with 15 subjects each for the triopolies; and 1+1=2 sessions with 20 subjects each for the duopoly treatments. Most of the participants were students who were recruited from economics, law, and social sciences departments.

[6] For an English translation of the instructions, see the Appendix. The original instructions in German are available upon request from the authors.
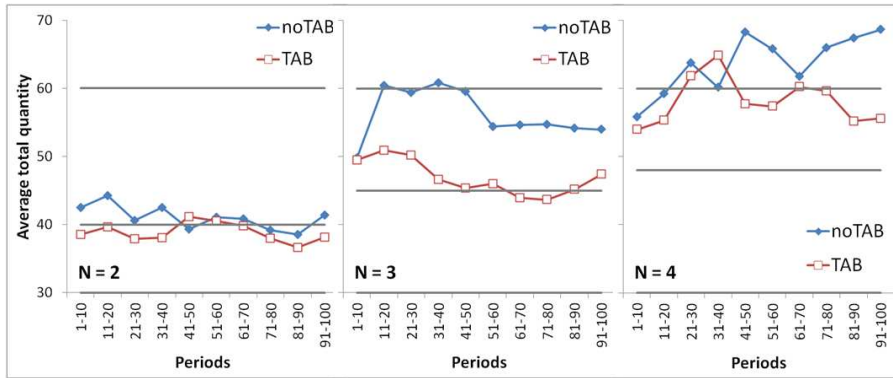
Fig. 1 Average numbers in different phases

For all market sizes and for almost all blocks, the average total quantity is lower in *TAB* than in *noTAB*.

The effect of payoff tables emerges early in the experiment. Averaged over the first five periods, in *TAB*-markets subjects choose significantly more often (U-Test, $p = 0.007$) single collusive quantities[7] (49% of all decisions) than subjects in *noTAB* (29% of all decisions).[8]

How do average quantities evolve during the experiment? In order to study this issue we compare data from periods 1-30 to the averages of periods 61-90.[9] In *noTAB*-duopolies, average quantities significantly decrease in later periods (Wilcoxon matched pairs test, $p = 0.059$). In *TAB*-duopolies, there is no significant decrease since subjects here – in contrast to their counterparts in *noTAB* – choose low production levels already in the initial phase of the experiment. For $N = 3$ and $N = 4$, in *TAB*, over time, we observe a trend to more collusive quantities when subjects are provided with payoff tables. The average total quantity in the later periods is lower ($N = 3 : p = 0.093$, $N = 4 : p = 0.114$) than in the early periods 1-30.[10] In contrast, in these markets in *noTAB* setting, there is no decrease of quantities.

A closer look on the three figures reveals a non-monotonicity of the effect of payoff tables, i.e., for $N = 3$ the differences between *TAB* and *noTAB* are more pronounced than the differences for $N = 2$ and $N = 4$. In duopolies,

---

[7] Single collusive quantities are closer to the symmetric collusive benchmark than to other benchmarks. For example, in duopolies, the symmetric collusive benchmark quantity is 15 while the single quantity in CNE is 20. Hence, all single quantities closer to 15 than to 20 are counted as collusive single quantities.

[8] The reported non-parametric statistical tests use the session averages of independent observations and report two-sided p-values.

[9] We do not consider the last 10 periods to exclude possible end game effects.

[10] Compared to other studies (e.g., reported in Huck et al., 2004) the average quantity in *TAB*-quadropolies could be considered as somewhat high. However, if we exclude one strong outlier market with 142.3(!) units, the average market quantity in periods 61-90 is only 53.5 (and not 58.2). Without that extreme outlier, the decrease in quantity in the last 30 periods, in *TAB*-quadropolies gets even highly significant ($p = 0.015$)

the impact of payoff table is immediate, in the first ten periods, subjects with payoff table produce -10.3% less than subjects without payoff table (N=3: -0.6%, N=4: -3.5%). Over the course of the experiment, however, this difference declines, since duopolists in *noTAB* also learn to collude successfully. In triopolies, payoff tables seem to be most effective by helping subjects to cooperate. On average, in subjects *TAB* produce -20.1% less than their counterparts in *noTAB*. For $N = 4$, the payoff table is apparently not so effective in decreasing contributions although the average difference between both treatments is higher than for $N = 2$ (-9.8% for $N = 4$, -5.7% for $N = 2$). Moreover, play in $N = 4$ is often dominated by punishment actions directing the averages in both treatments to a similar level. These observations are in line with the finding of Huck et al. (2004) that collusion is rare for markets with $N = 4$ or higher.

Table 2 depicts a classification of markets based on average quantities in periods 61-90. It shows that over all market sizes, there are more collusive markets in *TAB* (11 markets, 37% of all markets) than in *noTAB* (8 markets, 27%). [11] We define a market as collusive (abbrev. COL) if this market's average total quantity is closer to the collusive benchmark than to other two benchmarks introduced in Section 2; i.e., a duopoly market is classified as collusive if this market's average total quantity is below 35 while the same market is classified as a "CNE-market" (CNE) if this market's average total quantity lies between 35 and 50. [12]

Table 2 Classification of markets according their average quantities in periods 61-90

Market size	*noTAB*			*TAB*		
	COL	CNE	COM	COL	CNE	COM
$N = 2$	5	2	3	5	3	2
$N = 3$	2	3	5	4	3	3
$N = 4$	1	5	4	2	2	6
Total	8	10	12	11	8	11

In total, in *noTAB*, there are 10 markets with average total quantities around the CNE (8 in *TAB*). In *noTAB*, we classify 12 markets as competitive while there are 11 COM markets in *TAB*.

The above classification reveals that many markets succeed to collude. Interestingly, oligopolies in *TAB* establish collusion in significantly earlier periods than markets in *noTAB*. Figure 2 shows the evolution of collusive markets for each treatment in blocks of ten periods. As can be seen from the figures, in the beginning phase (periods 1-20), for all market sizes, in *TAB* there are more collusive markets then in *noTAB*. Aggregated over all market sizes, the

---

[11] Previous studies use similar classifications, see e.g., Fouraker and Siegel (1963) or Huck et al. (2004).

[12] Applying the same logic we label duopoly markets with average quantities above 50 as competitive (COM).

difference between both settings is highly significant (U-Test, $p = 0.022$). The markets in *noTAB*, however, catch up during the experiment with the markets in *TAB*. Similar to the evolution of average quantities, for $N = 3$, the differences between both settings remain stable while they diminish for $N = 2$ and $N = 4$.
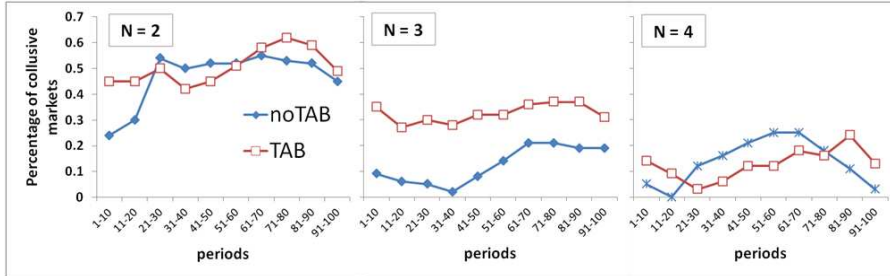

Fig. 2 Relative frequency of collusive markets

4.2 Individual Behavior

How do payoff tables influence the individual behavior? Since in our experiment subjects receive detailed feedback about each of the competitors' quantities and profits, they were able to apply a variety of decision rules. We focus on rules to which it is often referred in previous studies on quantity setting markets: Best-reply, collusive response, and imitation. In our game, each competitor is able to unilaterally force the market price to zero by choosing $x_i = 60$. This choice can be interpreted as a punishment act since in this case the player who chooses 60 as well as all other competitors obtain zero profits for sure. For this reason, we consider punishment as a fourth decision rule. In the following, we define the four rules more precisely. Then we look whether and how often subjects did choose these rules in the experiment.

Best-Reply (BR): A player i playing a (myopic) best-reply assumes that the sum of competitors' quantities will be the same in period t as in period $t-1$ and sets her actual quantity in period t according to the best-reply function $x_i^t = 30 - (X_{-i}^{t-1}/2)$ with X_{-i}^{t-1} being the sum of other competitors' last period quantities.

Collusive Response (CR): A player i who applies a collusive response wants to maximize the joint profits in the market. Thus she chooses x_i according to the formula: $x_i^t = 30 - X_{-i}^{t-1}$, i.e., the total quantity including player i's quantity equals the monopoly quantity.

Imitate the successful (IM): An imitator i sets the own quantity to $x_i^t = x_j^{t-1}$, where i being the imitator and j the most successful competitor in the previous period, with total quantity $X^{t-1} < 60$ and $x_j^{t-1} > x_i^{t-1}$.[13]

Punishment (PUN): A punisher i chooses $x_i = 60$ to set the market price to zero.

Which of the rules described above do subjects follow? Are subjects in *TAB* more inclined to apply BR than subjects in *noTAB* since the payoff table presents them the best-replies in a clear way? Do subjects with payoff tables choose more often CR which were easily identifiable? On the other hand, because of the clarity, one could expect less IM-behavior with payoff tables. Punishment could be observed more often in *noTAB*, e.g. as a signaling/disciplining device, if quantities in *noTAB* are indeed higher (less cooperative) than in *TAB* where probably there is less need for punishment.

In this study, we are interested in the differences between both information settings and not in learning behavior. Hence, we focus on exact applications of the above mentioned rules. Table 3 depicts the absolute and the relative frequencies of exact applications of the decision rules we observed in our experiments. Relative frequencies refer to the cases in which a decision rule was *applicable* which means that a player indeed was able to choose a particular rule. The percentage of applicable cases are also depicted in Table 3.[14]

BR was applicable in 87.6% of the cases in *noTAB* and in 92.4% cases in *TAB*. In both settings, however, only less than 10% of the decisions are actually BR. This is surprising since subjects had all necessary information to calculate the BR. In *TAB*, subjects could even read the best-reply directly from the payoff table. Despite this, subjects in *TAB* (8.2%) do not choose significantly more often BR than subjects in *noTAB* (7.1%).

In *noTAB*, CR was applicable in 47.1% of all cases (in *TAB*: 50.8%). Of these cases, 28.6% were actually CR (in *TAB*: 37.4%). Hence, in both settings, CR is the most frequent observed decision rule, in relative as well as in absolute terms. Subjects in *TAB* choose more often CR than subjects in *noTAB*. The difference between both settings is highest for $N = 3$. In both settings, the amount of CR declines with N.

In *noTAB*, imitation was applicable in 36.9% of all possible cases (37.8% in *TAB*). However, subjects applied imitation only in 10.1% of the these cases (10.9% in *TAB*). In duopolies imitation is more frequent (20.0% in *noTAB*, 16.3% in *TAB*) whereas it is rare in quadropolies (8.3% in *noTAB*, 7.8% in *TAB*). The discrepancy between the imitation numbers in duopolies and in quadropolies could be due to the ambiguity of the intention of imitational

---

[13] We exclude cases where the total quantity in the market was 60 or higher since in these case the profits of all competitors were zero, i.e., all competitors were equally successful (or equally unsuccesful). We also exclude cases where the player i him/herself was (one of) the most successful competitor(s) in period $t-1$. In such cases, for player i there is no successful competitor to copy in period t.

[14] Not all the rules were applicable in each period. For example, CR is only applicable if the total quantity in a market is less than or equal to 30. If the total quantity is greater than 30, there is no reasonable CR.

Table 3 Observed decisions in percent

		noTAB					TAB				
		BR	IM	CR	PUN	Total	BR	IM	CR	PUN	Total
$N = 2$	relative	3.4	20.0	37.8	1.0		8.0	16.3	39.3	1.6	
	app. cases	99.0	24.2	93.4	99.0		98.4	24.9	93.3	99.0	
	absolute	3.4	4.8	35.3	1.0	44.5	7.9	4.1	36.7	1.6	50.2
$N = 3$	relative	9.8	8.6	21.6	5.3		6.7	13.2	40.2	2.3	
	app. cases	89.3	41.5	37.5	99.0		95.4	36.1	55.7	99.0	
	absolute	8.8	3.6	8.1	5.2	25.7	6.4	4.8	22.4	2.3	35.8
$N = 4$	relative	7.0	8.3	21.1	7.1		9.6	7.8	29.3	4.7	
	app. cases	80.5	39.7	30.9	99.0		87.2	45.6	27.7	99.0	
	absolute	5.6	3.3	6.5	7.0	22.5	8.4	3.6	8.1	4.7	24.7
Total	relative	7.1	10.1	28.6	5.2		8.2	10.9	37.4	3.2	
	app. cases	87.6	36.9	47.1	99.0		92.4	37.8	50.8	99.0	
	absolute	6.2	3.7	13.5	5.1	28.6	7.6	4.1	19.0	3.2	33.9

decisions. First, subjects may imitate the most succesful competitor if they do not know what else to do. Sometimes, however, imitation may also occur in order to send a "message" to others. For example, some subjects choose the symmetric collusive quantity and that of the (most succesful) competitor with the highest quantity alternately to signal that the competitor with the highest quantity also should choose the collusive quantity. It is clear, that this kind of "signaling" is observed more often if the addressee of the signal can identify that he or she is the addressee - as in the case of a duopoly.

PUN was applicable with the exception of the first period, i.e., in 99.0% of possible cases. In $noTAB$, subjects punish in 5.2% of these cases while in TAB this percentage decreases to 3.2%. In both settings, the use of punishment increases with N (Jonckheere-Terpstra-Test, $p = 0.052$ for $noTAB$; $p = 0.032$ for TAB). This reflects the increasing difficulties to collude when the market size grows.[15]

Huck et al. (1999) and Offerman et al. (2002) investigate different learning theories in a Cournot quadropoly and triopoly setting respectively, in different treatments with different feedback mechanisms. Huck et al. (1999) find overall, imitation seems the better explanation for the adjustment of quantities. The number of perfect hits of imitation behavior, however, is relatively low throughout the treatments. In particular, in FULL, the only comparable treatment to our design, 7.9% of the decisions are actually imitate the best, 0.6% imitate the average, and 1.4% are BR. Huck et al. (1999) do not count CR. In Offerman et al. (2002) $Qq\pi$ is the comparable treatment to our settings. In this treatment, collusion is found roughly as frequent as the competitive (Walrasian) outcome. Additionally, the more complicated demand and cost functions could be a reason that in the latter study one observes more imita-

---

[15] A multinomial logistic regression analysis which we report in the Appendix brings out similar results with respect to individual choice behavior of the considered decision rules.

tion than in our extremely simple setting where cognitive costs of finding the collusive response may be lower, especially in *TAB*.

5 Conclusion

In this study, we systemically investigate the effect of payoff tables on subjects' behavior in Cournot markets with two, three, and four competitors. The only variation between our two informational settings is the provision of a payoff table - all other things remaining equal. Hence, any differences between the both settings of our study can be unambiguously traced back to the presence (or the absence) of payoff tables. Overall results show that subjects provided with payoff tables choose more often collusive quantities. Moreover, subjects with payoff tables manage to collude earlier than subjects without payoff tables. Towards the end of the experiment, however, the differences between both settings get smaller. Thus, the length of the experiment seems to be an important determinant: in experiments with a small number of periods, payoff tables are more likely to make significant differences. For all market sizes, the number of collusive markets are higher with payoff tables.

Both ours and the study of Charness et al. (2004) show that payoff tables have an effect on behavior. In contrast to Charness et al. (2004), however, we find that payoff tables seem to make behavior more cooperative. Charness et al. (2004) observe significant reductions of average wages and effort levels in a gift-exchange game when subjects are provided with payoff tables. One major difference between our setting and the study of Charness et al. (2004) is that they investigate an asymmetric game while our setting has a symmetric structure. In a symmetric game, the payoff table possibly makes subjects more clear that there are gains from cooperation if all competitors would choose similar quantities. In contrast, in an asymmetric environment as in the gift-exchange game, the payoff table may let subjects focus on the inequality of the situation leading to less gift-exchange than observed normally without payoff tables. One explanation provided by Charness et al. is that payoff tables possibly made subjects more clear that in a gift-exchange experiment firms' marginal benefits from worker's effort decrease when effort increases. Subjects realizing this "inefficiency of gifts" at higher wages may provide less effort, i.e., they may cooperate less than subjects without payoff tables.

The study by Requate and Waichman (2011) and ours complement each other well in understanding the effect of informational aids in Cournot experiments. While they show that there is no significant differences in behavior whether subjects use payoff tables or a payoff calculator, we show that the use of an informational aid at all can make (significant) differences. Requate and Waichman (2011) investigate only duopolies. Our results with respect to duopolies are roughly in line with their findings: in the long-run, the duopolies in *noTAB* are similarly collusive as duopolies in *TAB*. We find, however, significant differences between our settings for triopolies. The question remains open

whether for $N > 2$ there would be (significant) differences between settings with payoff tables and settings with a payoff calculator.

In the theoretical literature, we find many results on the presence and absence of information but very little on the significance of information processing instruments. This study clearly shows that information-processing aids have non-negligible effects. Our results show that payoff tables indeed have an impact on subjects behavior even in a very simple setting. Hence, they might have even stronger effects in more complicated environments which possibly demand subjects' cognitive abilities even more. Thus, from a methodological point of view, the provision of subjects with payoff tables may be useful and recommended, especially in complex experimental studies.

References

1. Abbink, K. and Brandts, J. (2008). 24. Pricing in Bertrand competition with increasing marginal costs. *Games and Economic Behavior*, 63(1), 1-31.
2. Abbink, K. and Sadrieh, A. (1995). RatImage - Research assistance toolbox for computer aided human behavior experiments. Discussion Paper B-325, University of Bonn.
3. Bosch-Domènech, A. and Vriend, N. (2003). Imitation of successful behavior in Cournot markets. *Economic Journal*, April.
4. Charness, G., Frechette G.R., and Kagel, J.H. (2004). How robust is laboratory gift exchange? *Experimental Economics*, 7, 189-205.
5. Dolbear F.T., Lave, L.B., Bowman, G., Lieberman, A., Prescott, E., Rueter, F. and Sherman, R. (1968). Collusion in Oligopoly: An experiment on the effect of number and information. *Quarterly Journal of Economics*, 82, 240-259.
6. Fouraker, L. and Siegel, S. (1963): Bargaining behavior. New York: McGraw-Hill.
7. Huck, S., Normann, H., and Oechssler, J. (1999). Learning in Cournot oligopoly - An Experiment. *Economic Journal*, 109, C80-C95.
8. Huck, S., Normann, H., and Oechssler, J. (2004). Two are few and four are many: Number Effects in Experimental Oligopolies. *Journal of Economic Behavior and Organization*, 53, 435-446.
9. Offerman, T., Potters J., and Sonnemans, J. (2002). Imitation and belief learning in an oligopoly experiment. *Review of Economic Studies*, 69(241), 973-998.
10. Pruitt, D. G. (1967). Reward structure of cooperation: The decomposed prisoner's dilemma game. *Journal of Personality and Social Psychology*, 7, 21-37.
11. Requate, T., and Waichman, I. (2011) A profit table or a profit calculator? A note on the design of Cournot oligopoly experiments. *Experimental Economics*, 14, 36-46.
12. Saijo, T., and Nakamura, H. (1995) The "Spite" Dilemma in Voluntary Contribution Mechanism Experiments. *Journal of Conflict Resolution*, 39, 535-560.
13. Sauermann, H. and Selten, R. (1967). Ein Oligopolexperiment. In: H. Sauermann (ed.), Beiträge zur Experimentellen Wirtschaftsforschung, Vol. I, Tübingen, 9-59.

6 Appendix

6.1 Additional Analysis

A comparison of the constant terms reveals that the decision rule CR is chosen more frequently than the all other decision rules and the remaining category

Table 4 Multinomial logistic regression

Decision rule		Coefficient	Rob. Std. Error	z	p
Other		(base outcome)			
Best-reply (BR)	n	-0.101	0.130	-0.78	0.435
	treat	0.271	0.228	1.19	0.234
	cons	-2.228	0.481	-4.62	0.000
Imitation (IM)	n	-0.364	0.097	-3.72	0.000
	treat	0.179	0.150	1.19	0.233
	cons	-1.836	0.306	-6.00	0.000
Collusive response (CR)	n	-1.702	0.353	-4.83	0.000
	treat	0.528	0.601	0.88	0.380
	cons	2.871	1.017	2.82	0.005
Punishment (P)	n	0.451	0.314	1.44	0.150
	treat	-0.430	0.520	-0.83	0.409
	cons	-4.237	1.043	-4.06	0.000

Std. Err. adjusted for 60 clusters (markets). Number of obs = 18000. Pseudo $R^2 = 0.0955$, Wald chi2(8) = 40.55, log pseudolikelihood = -15207.035.

"others". All decision rules but CR are chosen less frequently than the remaining category as the negative signs of the constant terms and the significant p-values show. For any decision rule, there are no significant differences between treatments, i.e., the respective rules are chosen in similar percentages in both treatments. If we look at number effects, we see that the probability to choose CR and IM decreases with N whereas the probability to choose BR or P does not change significantly when N incraeses.

6.2 Translation of the Instructions to the Experiment

The Structure of the Experiment. The experiment consists of 100 periods. You will be randomly assigned to different groups. There are 2 to 4 participants in each group. The composition of each group does not change throughout the experiment. The members of a group are competitors on a market for a specific good. At the beginning of the experiment you will be informed, how many competitors you have.

The Structure of a Period. You determine your supply x, by choosing a number out of $\{0..60\}$. There are no costs, i.e., the good is produced and supplied without costs. Depending on your supply and the supply of your competitors, the total supply X on this market is determined as follows: $X = \sum_i x_i$, where x_i denotes the single supply of the supplier i on the market. The price p depends on the total supply X as follows:

$$p = \begin{cases} 60 - X & \text{if } X \leq 60 \\ 0 & \text{if } X > 60 \end{cases}$$

Your profit G is calculated as follows: $G = p \cdot x$. Your earnings depend on your final profit.

Feedback at the end of each Period. At the end of each round, each participant is informed about his profit G and the supplies and profits of his competitors. The profits of your competitors are determined in the same way as your own profit. Depending on the profit, every participant is paid a certain amount in the fictitious currency "Thaler". The screen shows the profit of the last period and the cumulated profit (sum of all profits obtained so far).

End of the Experiment and Total Payoffs. From the beginning, the exchange rate is displayed on the computer screen. At the end of the experiment your cumulated profit will be multiplied with the exchange rate. After the experiment you will be paid this amount.

Additional instructions for the setting "TAB". You will be provided with a payoff table. The lines on this table correspond to your possible supplies out of {0..60}. The columns correspond to the competitors' supplies (i.e., sum of the supplies of your competitors). In the respective fields of the table, you will find your corresponding profit.

6.3 The Payoff Table

Fig. 3 Excerpt from the Payoff Table