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pre-play communication in cournot competition: an experiment with students and managers

by Israel Waichman, Till Requate, and Ch'ng Kean Siang

Pre-play Communication in Cournot Competition: An Experiment with Students and Managers*

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Abstract

This study investigates the impact of pre-play communication on the outcomes in Cournot duopoly and triopoly experiments, using both students and managers as subjects. Communication is implemented by two different devices, a 'standardized-communication' and a free-communication device. We find that the effect of communication on collusion is larger in duopoly than in triopoly. Moreover, managers behave in a similar way under the two communication devices, while students are more influenced by the free-communication than by the standardized-communication device. In addition, managers select lower aggregate quantities than students, and communication enhances the difference between the subject pools in duopoly but reduces this difference in triopoly. Inspecting individual behavior, in all treatments the output adjustment is significantly correlated with the previous round's best response strategy. In the treatments with communication, the effect of imitation becomes larger and crowds out the effect of myopic best response. Finally, in all treatments duopoly results in more collusion than triopoly.

JEL Classification: L13, C93, C72, D43, D21

Keywords: artefactual field experiment, subject pools, Cournot oligopoly, managers, cheap talk

*We are grateful to Jörg Oechssler, Steffen Huck, and Hans-Theo Normann for providing us with the computer program used in Huck et al. (2004).

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1 Introduction

The classical quantity-setting (Cournot) oligopoly describes a situation of competition between firms that strategically decide how much to produce. Its elegance and simplicity has inspired a broad range of theoretical models with applications in industrial organization, public finance, environmental economics, trade theory, etc. So it is hardly surprising that the Cournot model has also spawned a constant stream of experimental literature beginning with the studies by Hoggatt (1959) and Selten and Sauermann (1959) and continuing until today. A stylized result of these experiments is that subjects in oligopolies with three or more firms hardly collude. More precisely, in all these "large" oligopolies subjects select quantities close to the Cournot-Nash outcome. In duopolies, some collusion is observed, but even then the average quantities selected by the subjects are closer to the Cournot-Nash outcome than to the symmetric joint profit-maximizing outcome (see, for example, the meta-analysis by Huck et al., 2004). In reality, however, collusion is sometimes observed even when a dozen entities or more are involved. For instance, the Organization of the Petroleum Exporting Countries (OPEC) is a cartel of 12 countries that has been operating since the 1960s. Motta (2007) reports on a legal procedure against a cartel of 40 wood-pulp producers from seven countries. Although there is doubt whether all 40 firms actually colluded, there is strong evidence that two sub-groups of these 40 firms, consisting of 9 and 25 firms, respectively, have indeed engaged in long-term collusion. Additionally, Genesove and Mullin (2001) report on the Sugar Institute, a cartel that consisted of 14 cane sugar refining capacity firms. This cartel operated from 1927 until 1936, when the U.S Supreme Court ruled its activities illegal.

Obviously, we cannot directly compare real-business cartels with the outcomes observed in the laboratory, mainly because in the business world we only observe successful cartels (or those detected by the anti-trust law), and also

because in the business world the coordination of quantities (or prices) is usually forbidden.[1] But it is still true that we observe too little collusion in the laboratory compared with what we should expect. How can we explain the fact that two-firm industries sometimes sustain collusion in the lab, while three-firm and larger industries are almost never able to do so? One possible argument is that people behave differently in the laboratory from when they are making real business decisions (see, for instance, Haan et al., 2009). Another possible explanation is that Cournot experiments do not allow for communication between firms, whereas in the business world, coordination of quantities through communication between managers is possible (although, in most instances, illegal). In fact, evidence from the Sugar Institute[2] (Genesove and Mullin, 2001) highlights the crucial role of explicit communication between the firms in establishing collusion.

The aim of this paper is therefore to investigate the influence of pre-play communication ("cheap talk") in Cournot oligopoly experiments. Since the borderline between collusion and Cournot play is, loosely speaking, between two and three firms, we specifically investigate pre-play communication in duopoly and triopoly. Moreover, besides the usual subject pool of students we have also enlisted managers as subjects. Accordingly, this study investigates how (i) communication, (ii) subject pool, and (iii) oligopoly size, impact on the outcomes. The experimental design is sketched in Figure 1.

- Figure 1 about here -

Exploring the relevant literature on communication in economic experiments, we find an important distinction regarding the communication device in use.

[1] Regarding this last point, Bryant and Eckard (1991) find that the probability of getting caught in a given year in the USA between 1961-1988 was at most between 0.13 and 0.17.

[2] The evidence is based on detailed notes of the Board of Directors, Executive Committee, and Enforcement Committee meetings from January 1929 to mid 1930.

Crawford (1998) distinguishes between "a preexisting common language that ties down the literal meanings of cheap talk messages" (Crawford, 1998, p.289) and non-common language devices. He claims that common language "reduces the multiplicity of equilibria by restricting the plausible interpretation of out-of-equilibrium messages" (Crawford, 1998, p.289). In our design we therefore implement two types of communication devices, a standardized one, only allowing subjects to coordinate on quantities, and a open language device allowing free communication between subjects.

Although the effect of communication on performance has been experimentally investigated in the context of price-setting oligopoly with both homogeneous and differentiated products (Hinloopen and Soetevent, 2008 and Friedman, 1967, respectively), and also in other experiments in the field of industrial organization (see Holt, 1995 for a review), it has not yet been investigated in the context of classic Cournot competition[3].

In economic theory (non-binding) communication is referred to as "cheap talk", since it does not directly affect the subjects' payoffs. In particular, Aumann (1990) claims that communication cannot affect the outcome of a game if a signaler has a strict preference over the other players' strategy choice. This is precisely the case with Cournot oligopoly, since a firm prefers its competitor to select the lowest possible quantity. By contrast, Brown-Kruse and Schenk (2000) claim that communication may facilitate collusion by reducing the time it takes for firms to "learn to collude". They argue that even if one player is able to identify the optimal solution without communication and tries to signal it to the other player, it is in the interest of the other player to be a slow learner.[4] In addition, Crawford (1998) conjectures that communication plays an important

[3]In fact, communication was allowed in a Cournot experiment by Daughety and Forsythe (1987a) and Daughety and Forsythe (1987b). However, these authors were interested in the performance of regulated markets and the effect of communication alone was not isolated in their design.

[4]Brown-Kruse and Schenks' (2000) argument refers to the prisoners' dilemma, but it can equally be applied to the Cournot competition game.

"reassurance" role that facilitates collusion by reducing the uncertainty about the others' actions. The bottom line is that the impact of non-binding communication on behavior is rather ambiguous. It seems that although pre-play communication is considered as "cheap-talk" it could still considerably affect subjects' performance. Section 2 presents a brief review of the literature on oligopoly experiments with communication.

Regarding the subject pool effect, the external validity of Cournot experiments conducted with students has hardly been challenged, despite the focus on firms' behavior and the large number of experimental studies carried out so far. Recently, Waichman et al. (2010a) have shown that managers are slightly (but significantly!) less competitive than students in a Cournot triopoly. These authors later show that this result extends also for the duopoly case (Waichman et al., 2010b). An interesting question arises regarding whether or not managers make use of communication devices in a more effective way than students. For this reason, we have recruited managers, mainly from the manufacturing industry and students, both from Penang, West Malaysia.

We can summarize our results as follows: First, the effect of communication on collusion is larger in duopoly than in triopoly, all other conditions being equal. In fact, communication has no effect on the behavior of managers in triopoly. Second, managers behave in a similar way under both communication devices, while students are more influenced by the free communication than by the standardized-communication device. More precisely, managers select, on average, lower quantities than students, and communication increases the difference between the subject pools in duopoly but reduces this difference in triopoly. Third, in all treatments best response strategies explain output adjustment. In the treatments with communication, however, the effect of imitation becomes larger and crowds out the effect of myopic best response. Fourth, for both subject pools, we observe lower aggregate quantities and more collusion in duopoly

than in triopoly. Finally, we establish that the Cournot-Nash equilibrium quantity describes the performance of the duopoly markets without communication quite accurately, while the performance of these markets is more collusive when communication is allowed. In triopoly, however, the Cournot-Nash equilibrium quantity accurately describes the behavior in almost all treatments. In other words, communication does hardly increase collusion in triopoly.

The paper is organized as follows: In the next section we review the experimental literature on pre-play communication in oligopolies and social dilemmas. Section 3 describes the experimental design and procedure. Section 4 sketches the hypotheses. In section 5 we describe the results, and finally section 6 concludes.

2 Related Literature

Since the early study by Loomis (1959), who finds that pre-play communication (exchange of notes between subjects) enhances cooperation in a prisoners' dilemma (PD) experiment, numerous other PD experiments have been conducted. Sally (1995) summarizes these studies in a meta-analysis including results from social dilemmas (especially PD experiments) between 1958 and 1992. In contrast to Loomis (1959), but in line with economic theory, Sally finds that communication by sending messages to each other does not significantly affect cooperation. On the other hand, face-to-face communication does positively affect cooperation. In a more recent meta-analysis of communication and cooperation in social dilemmas, Balliet (2010), like Sally (1995), finds that face-to-face communication has a stronger positive effect on collusion than written messages. In contrast to Sally (1995), Balliet finds that written messages positively impact collusion. He also observes that in social dilemmas the communication-collusion relationship is stronger in larger than in smaller

groups.

In the area of oligopoly, pre-play communication has been tested experimentally in various contexts: in a price competition context with both homogeneous and differentiated products, in a spatial competition oligopoly à la Hotelling, and also in different types of auctions. The only Cournot experiments allowing explicit communication between the subjects were conducted by Daughety and Forsythe (1987a,b).[5] These authors report on two Cournot duopoly experiments (and also a triopoly treatment) where communication takes place in the form of sending messages. They find that, when firms are able to communicate, they collude much more than without communication. However, since these experiments were designed to investigate the impact of price ceilings on the industries, the effect of communication is not isolated by comparing treatments with and without communication (under a similar condition of no regulation).

Regarding the impact of communication in a price competition game with homogeneous products (à la Bertrand), a series of experiments has been conducted to test the effectiveness of anti-trust policies (especially the effectiveness of leniency programs). In these experiments, conducted by Apesteguia et al. (2007), Andersson and Wengström (2007), Hinloopen and Soetevent (2008), and Bigoni et al. (2009), subjects were allowed to communicate with each other and coordinate prices. However, only the triopoly study by Hinloopen and Soetevent (2008) directly tests the effect of pre-play communication on collusion, whereas the other studies focus on comparison between the different anti-trust policies. Hinloopen and Soetevent (2008) find that communication alone does not affect the average price (nor even its evolution over time). Andersson and Wengström (2007) find that in a duopoly with random-matching costly communication enhances the stability of collusive agreement in comparison with free

[5]Holt (1995) reports on another experiment by Binger et al. (1990). The working paper version is no longer available, and at least the part including the pre-play communication has not been published elsewhere.

communication. Friedman (1967) investigates the effect of communication on a price competition duopoly with a high degree of product differentiation. His design allows written communication and reply from one subject to the other. Friedman finds that in over three-fourths of the rounds the proposal submitted was accepted (and in 90% of the cases honored) and over three-fourths of these agreements were Pareto-optimal.

Regarding the impact of communication in a spatial competition game, Brown-Kruse et al. (1993) and Brown-Kruse and Schenk (2000) report experimental results from repeated spatial competition with free-form communication via written messages between the subjects. They find that the introduction of communication turns the predominant outcome from the Nash outcome to the joint profit-maximizing outcome.

A series of experiments aiming at investigating the effect of face-to-face communication on different market institutions (e.g. double auction, posted-offer, and sealed bid auction) show that communication does not result in sustainable performance around the collusive level. In particular, Isaac and Plott (1981) and Isaac et al. (1984) test the impact of communication on performance in a double auction with four sellers and four buyers. They do not find that communication is sufficient to maintain collusion. Isaac et al. (1984) test the impact of communication on performance in posted-offer markets (with four sellers and four buyers), finding that, although the observed prices exceed the competitive equilibrium prices (and also exceed the prices resulting from a double auction), they do not show a clear tendency to converge to the collusive level. Finally, Isaac and Walker (1985) conduct a similar experiment with a sealed-bid auction (four bidders) and also find that, overall, collusion is not sustainable. In addition, Holt and Davis (1990) and Cason (1995) investigate the effect of communication via written messages on posted-offer triopoly and duopoly markets, respectively. They both find that, although communication has some temporary

effect on collusion, this influence vanishes over time.

In summary, the literature provides rather mixed evidence regarding the influence of pre-play communication on the outcome of oligopoly markets. It appears that the influence of communication depends on the specific institution and the experimental design. The effect of communication on different oligopoly sizes and on non-standard subject populations has not yet been examined in quantity, price, or location-setting oligopolies.

3 Experimental Design and Procedure

We adopt the design proposed by Huck et al. (2004) for the duopoly and triopoly cases. Overall, we test the effect of no communication, the so-called 'standardized-communication' device allowing firms to coordinate quantities, and a device that allows firms to communicate freely. We use two subject populations, Malaysian students and Malaysian managers.

3.1 Underlying model and design

The basic set-up is a fixed-matching symmetric quantity-setting (Cournot) game, where each subject represents a single firm producing a homogeneous good. The experiment lasts 17 rounds[6], and the feedback received by the subjects after each round contains only aggregate information about their competitors' performance. We restricted ourselves to 17 rounds because the high opportunity cost of managers made it impossible to run an experiment longer than 1.5 hours.[7] Within each duopoly (triopoly), firms were identified as either firm '1'

[6]The triopoly control treatments (without communication) lasts 25 rounds. For comparability we report here the result of the first 17 rounds.

[7]This should not considerably affect the results since evidence from long experiments (with 40 rounds) yield either no differences or very small differences between the first and last rounds (see, for instance, Huck et al., 2000). Specifically, we draw our design from Huck et al. (2004), an experiment consisting of 25 rounds. Huck et al. (2004) find that after the first 3-4 periods there is no time trend. Finally, there are several contemporary studies of Cournot oligopoly conducted with about 20 (or fewer) rounds (e.g, Holcomb and Nelson, 1997, Huck et al., 2001,

or firm '2' (firm '3'). In the treatments with communication, subjects enter the 'communication stage' at the beginning of each round. They then have two minutes to communicate with each other via written messages (they can only communicate within their industry and have no interaction with firms in other industries). After this, subjects enter the 'decision stage', where they have two minutes to select their quantities. During this stage subjects could not communicate with their competitors, but on their screens they could still see the exchange that had taken place at the communication-stage.

In the standardized-communication treatments, subjects can coordinate quantities by stating "I suggest that I will produce A units, firm 2 will produce B units, and firm 3 will produce C units" (where A, B, and C are any numbers from the choice set). Subjects can also click on "I agree" and "I do not agree" to express their satisfaction or frustration with the exchange. It is not obligatory to send messages or to suggest positive quantities for any of the subjects. This means that a firm could use, for example, a technique of "leading by example" by omitting quantities B and C. In the free-communication treatments, firms can communicate with each other using a chat box. However, they are not allowed to identify themselves.[8]

Throughout both stages of the experiment, subjects are allowed to use a profit calculator to simulate the result of their choices, given their own and a hypothetical quantity selected by the other firms. Moreover, in both stages subjects are informed about the outcome of the previous round. The computer screenings of the communication and the decision stages are provided in the Appendix (Figures A.1-A.5). The control treatment (without communication) is identical to what has been described here but without the communication stage.

Fonseca et al., 2005, Altavilla et al., 2006, etc.).

[8]We stressed that participants who tries to disclose their identity would not be paid for the experiment.

The firms act in a market with the following demand function:

$$P(Q) = max\left\{100 - Q, 0\right\}, \tag{1}$$

where $Q = \sum_{i=1}^{n} q_i$, $n = 2, 3$. The cost function for each seller is

$$C\left(q_i\right) = q_i \tag{2}$$

Subjects can select quantities between 0 and 100 in steps of 0.01. Under this setting, the benchmark market quantities are given in Table 1. One way to evaluate the propensity of sellers to tacitly collude is to follow the convention adopted by Fouraker and Siegel (1963) and divide the aggregate output space into three ranges associated with the three types of strategies.[9]

- Table 1 about here -

3.2 Subject recruitment and control

We recruited a total of 182 undergraduate students (58% women, 55% of Chinese ethnicity[10]) from Universiti Sains Malaysia in Penang Island, West Malaysia. Most of them were attending economics and business courses, but some of them were students of anthropology, mathematics, physics, social work, and sociology. Additionally, we recruited a total of 164 Malaysian managers (48% women, 92% of Chinese ethnicity[11]) from small and medium-sized firms (companies em-

[9]The midpoint of the ranges between collusive and Cournot, and Cournot and competitive demarcates the range boundaries.

[10]There are three major ethnic groups in Malaysia. The first and largest includes the Malay population (Muslims by constitutional definition). The second-largest group includes Malaysians of Chinese descent (for short "Chinese"). The smallest of the three major groups includes Malaysians of Indian descent ("Indians" for short). Penang is the only non-Malay-dominated state in Malaysia. 43.4% of the population are Chinese, 40.2% are Malay, and 9.9% are Indian.

[11]The proportions of Chinese in the manager sample is considerably larger than in the student sample. The reason for this is that most Chinese work in the private sector while Malays have better chances of being employed in the public sector.

ploying at least 50 staff). Most of these were from the manufacturing industry (plastics, cable assemblers, chip manufacturers, and computer-parts manufacturers), some from financial institutions and other industries in Penang. Target companies were sourced from the Federation of Malaysian Manufacturers (FMM) directory, which lists all the small and medium-sized firms (SME) in Penang state. A letter of invitation was sent to the company secretary[12], asking him/her to forward it to the relevant person in the company (we only approached managers with at least five staff members working under their supervision). In total, about 50% of the managers who received our invitation letters signed up for the experiment. Manager ages ranged between 25 and 54 (average age 35.1), and all of them had at least a Bachelor's degree (five of them were PhDs). The estimated earnings of the selected group ranged between 4000 RM (Malaysian Ringgit) and 9000 RM per month, with an estimated average of 5000-6000 RM (≈1500-1900$). The subjects had not previously participated in an experiment. Table 2 shows the characteristics of the subjects in each treatment (and the abbreviations of the different treatments).[13]

- Table 2 about here -

The Cournot model describes a very simplistic, strategic decision taken simultaneously by firms. In reality, a corresponding decision is taken by the company CEOs (or by the boards of executives). It is, however, almost impossible to get companies' CEOs to participate in an economic experiment due to their high opportunity costs. Therefore, as an alternative or proxy, researchers in experimental economics recruit high-level decision-makers in charge of employees to play the role of firms. Although these high-level decision-makers are usually not CEOs, they are, nevertheless, more representative than university students in

[12]We did not reveal the nature of the experiment, merely that it was a computer-based experiment designed to analyze decision-making. We also disclosed the expected payoff range.

[13]A list of the individual characteristics of the managers can be obtained from the authors upon request.

playing the role of firms in experiments on industrial organization.[14]

The experiment was programmed and conducted using the z-Tree experimental program (Fischbacher, 2007). It was explained and conducted in English. The exchange rate between the experimental currency units (ECU) and the Malaysian Ringgit was calculated to provide sufficient saliency so that a Malaysian student choosing the Nash-equilibrium quantity throughout the experiment (given that his or her competitors also decide on the Nash equilibrium quantity) earns about 3.5$ (9.5 Malaysian Ringgit), while a Malaysian manager earns about 60$.

4 Hypotheses

The experimental design and the unique set of subjects enable us to focus on three research questions. First, does communication facilitate collusion? Second, do mangers behave differently than students? Third, does oligopoly size affect the outcome?

Although the evidence on the influence of communication in facilitating collusion is rather ambiguous (see Section 2), the studies by Friedman (1967) on price competition with differentiated products (using a profit table that resembles Cournot experiments) and on regulated Cournot markets by Daughety and Forsythe (1987a,b) strongly indicate that communication fosters and sustains collusion. Accordingly, we formulate our first hypothesis as follows:

Hypothesis 1: *In the treatments with communication, we expect to observe lower aggregate quantities and more collusion compared to the control treat-*

[14]Other experimental studies in industrial organization also recruit different levels of managers. For example, Cooper (2006), recruited managers from an Executive MBA program, while Cooper et al. (1999) recruited managers and white-collar workers in state enterprises in China. Montmarquette et al. (2004) use managers from the headquarters of a large French-German pharmaceutical company. Finally, Fehr and List (2004) and Alpízar et al. (2004) recruited coffee-mill CEOs from Costa Rica.

ment without communication.

Evidence from experiments without communication (Waichman et al., 2010a,b) show that managers selects lower aggregate quantities and collude more than students. We, therefore, expect to observe such differences also with communication.

Hypothesis 2: *In the treatments with managers, we expect to observe lower aggregate quantities and more collusion compared to the treatment using student subjects.*

The early study by Fouraker and Siegel (1963) (with two-and three-firm industries) identifies more collusion and, on average, lower quantities in duopoly than triopoly. Moreover, in a meta-analysis aiming to identify the effect of the number of firms on Cournot oligopoly, Huck et al. (2004) find that collusion is sometimes observed in duopoly but almost never in triopoly. Accordingly, we formulate our last hypothesis as follows:

Hypothesis 3: *We expect to observe more collusion (and lower aggregate quantities) in duopoly than in triopoly even when communication is allowed.*

5 Results

While our analysis focuses mainly on aggregate (market) performance, we also investigate the individual (firm) data in order to learn about behavioral regularities manifesting themselves in the experiment. A common testing procedure (used, for example, in Huck et al., 2004) is to average the quantities of each market and then compare these independent (average) quantities. In the fol-

lowing, we use this method for comparison between treatments (either between the quantities or between the incidence of collusion).

Table 3 presents the aggregate quantities of each market averaged (i) over all rounds, (ii) over the first 15 rounds, and (iii) over rounds 3 to 15 (to exclude beginning and end effects). From this table it appears that the average quantities selected by the subjects are lower when communication is allowed. It also appears that, all other conditions being equal, students select higher aggregate quantities on average than managers. Recall that the quantities are classified as collusive (M), Cournot-Nash (N), or competitive (C), depending on their distance from the respective benchmark quantities. Looking into the data, we find that between 91% and 100% (or between 61% and 90%) of the markets in the duopoly (triopoly) treatments are able to achieve collusion in at least one round. Figure 2 displays, for each treatment, the percentage of markets that are classified as collusive during a total of 0 rounds, 1 round, 2 rounds, and so on. This figure shows that, by and large, there is a higher incidence of collusion when communication is allowed.

- Table 3 around here -

- Figure 2 around here -

5.1 The effect of communication

We begin our formal analysis by comparing the performance with and without communication, while fixing the other conditions (subject pool, oligopoly size). We employ a (two-sided) robust rank-order test (F-P test, after Fligner and Policello, 1981) to compare the independent market quantities (and also the incidence of collusion (see Figure 2)) in each pair of treatments. The results are

presented in Table 4.

- Table 4 around here -

Accordingly, we can summarize as follows:

Result 1a (students, duopoly): *The control treatment results in higher aggregate quantities (and a lower incidence of collusion) than the two treatments with communication. We do not observe any difference in performance between the two treatments with communication.*

Result 1b (students, triopoly): *The control treatment results in higher aggregate quantities than the free-communication treatment. We do not observe any significant difference in performance between the two treatments with communication. In addition, we find that the control treatment yields a considerably lower incidence of collusion than the two treatments with communication.*

Result 1c (managers, duopoly): *The control treatment results in higher aggregate quantities (and a lower incidence of collusion) than the two treatments with communication. We do not observe any difference in performance between the two treatments with communication.*

Result 1d (managers, triopoly): *We do not observe significant differences in performance (regarding both quantities and incidence of collusion) between the three treatments.*

The results presented so far imply that communication fosters collusion in duopoly but has a moderate impact in triopoly. This aspect is illustrated

by the rows denoting "% change" in Table 3, which describe the percentage change in average performance from the corresponding control treatment. In particular, this table shows that in comparison with the corresponding control treatments, the percentage reductions in output are, on average, higher (or at least not lower) for duopoly than for triopoly. For instance, the student free-communication treatment in duopoly ($\bar{Q}_{1-17}$) achieves 12.29% reduction in quantity in comparison with the control treatment, while in triopoly, the free-communication treatment achieves 10.93% reduction. In the extreme case, the manager free-communication treatment yields a reduction of 14.86% from the control treatment in duopoly, but only a 4.83% reduction in the corresponding triopoly treatment. Using a Kruskal-Wallis test comparing the median quantities of the three communication conditions in duopoly, we formally reject the null hypothesis of equal median quantities between the treatments for both students and managers (P-value 0.00 for each). However, we cannot reject the null hypothesis for students (P-value 0.19) or managers (P-value 0.36) in a triopoly.

Result 1e: *Communication has a stronger impact on collusion in duopoly than in triopoly.*

This result is in contrast to the meta-analysis by Balliet (2010), who finds that the effect of communication on collusion in social dilemmas is larger when the group is larger.[15]

5.2 The effect of the subject pool

After investigating the effect of communication on the performance of the two subject pools, we now compare performance across subject pools. Table 5 presents the results of F-P tests comparing independent market quantities (and

[15]The meta-analysis by Balliet (2010) includes mainly the prisoners' dilemma, give-some (public good), and take-some (common pool resources) games.

also incidence of collusion) in each pair of treatments .

- Table 5 around here -

We can formalize the results as follows:

Result 2a (duopoly): *In the two treatments with communication, managers select lower aggregate quantities (and have a considerably higher incidence of collusion) than students. We do not observe any considerable difference in performance between the control treatments without communication.*

Result 2b (triopoly): *In the control treatments without communication, managers select lower aggregate quantities than students, but we do not observe any difference in performance regarding the incidence of collusion. Nor do we observe any difference in performance between the two treatments where communication is allowed.*

5.3 The effect of oligopoly size

When comparing duopoly and triopoly treatments, we have to take into account the discontinuity between a two-firm industry and industries with more than two firms. In duopoly, once a firm receives feedback about its payoff, it can easily deduce its competitor quantity and payoff. This is however not the case with industries with more than two firms, where the individual quantities and payoffs cannot be deduced from the average quantity. Therefore, in a design providing only aggregate information about the competitors, it is impossible to isolate the size effect from the information effect. In addition, Holt (1995) highlights the fact that even when subjects receive full information about their competitors'

actions and profits (and can thus monitor the competitors' actions), it is impossible in an industry with more than two firms to punish one competitor without hurting the others.

Using an F-P test to compare the quantities selected in the duopoly and triopoly treatments, we reject the null hypothesis of no difference between the quantities selected in the respective duopoly and triopoly treatments (P-values 0.00 in all comparisons, both for students and managers). This result indicates that both students and managers select higher quantities in triopoly than in duopoly, which is not surprising considering that the theorized Cournot-Nash aggregate output is lower in duopoly than in triopoly (the other two benchmark quantities do not depend on industry size). However, we find that there is a considerably higher incidence of collusion in the duopoly than in the triopoly treatment (comparison between Figure 2(a) and 2(c) and between Figure 2(b) and 2(d)). Given that the range of collusive outcomes is smaller in duopoly than in triopoly, this is a remarkable result.

Result 3 (students, managers): *Duopoly results in a higher incidence of collusion (and lower aggregate quantity) than triopoly.*

5.4 Characterizing the markets

Our next move is to investigate whether the benchmark outcomes (collusive, Cournot-Nash, or competitive quantities) describe the market performance accurately. Figure 3 shows the performance in the duopoly and triopoly treatment for each independent market and also how close/far the average quantities of each market are to/from the benchmark quantities.

- Figure 3 about here -

It appears from this figure that in duopoly quantities are spread between the collusive and Cournot-Nash outcomes, whereas in triopoly they are spread around the Cournot-Nash outcome. We employ a one-sample Kolmogorov-Smirnov test[16] and also a one-sample sign-rank test[17] to investigate whether the average quantities selected in the three treatments are different from the collusive and Cournot-Nash outcomes. We find that the collusive outcome does not describe the performance in any of the treatments for both duopoly and triopoly (P-values are 0.00 in all treatments in the two tests). Regarding the Cournot-Nash outcome, we find, for the duopoly case, that the control treatments with no communication and also the student standardized-communication treatment do not yield significantly different quantities than the Cournot outcome. The other treatments, however, yield lower aggregate quantities than the Cournot outcome.

Result 4a (duopoly): *Market performance without communication (and when students communicate through the standardized-communication device) is identified quite accurately by the Cournot outcome, while communication leads to lower aggregate quantities (although still larger than the collusive outcome).*

We repeat the procedure for the triopoly treatments, now finding that in all treatments except the student control treatment, the quantities are not significantly different from the Cournot-Nash outcome.[18] The quantities selected in the student control treatment are larger than the Cournot-Nash outcome.[19]

[16]Following Raab and Schipper (2009), we test whether the distributions of the average quantities in each treatment are different from the normal distribution with a mean equal to the corresponding benchmark quantity.

[17]This test checks whether the median quantity is different from the respective benchmark outcome.

[18]P-values ranging between 0.31 and 0.78 in the Kolmogorov-Smirnov test and between 0.18 and 0.65 in the sign-rank test.

[19]P-value of less than 0.02 in both tests.

Thus, we can formulate our next result.

Result 4b (triopoly): *The Cournot outcome describes market performance quite accurately (except when students are playing and communication is not allowed).*

5.5 Individual (firm) behavior

The analysis of market quantities reveals differences in performance between the treatments diverging with respect to the communication device, the subject pool, and oligopoly size. Examining the individual data may reveal the behavioral regularities leading to the differences in aggregate output levels. Taking into account that subjects were provided with a profit calculator and also received information about performance in the previous round, they could easily calculate their best response to their competitors' quantity. Beside 'best response' a subject could also play an 'imitation' strategy. In duopoly, subjects can imitate their competitors, but in triopoly they could only identify the average quantity of their competitors since the subjects only receive aggregate information about their competitors' quantities. Accordingly, and following Huck et al. (1999), we estimate the following model:

$$q_i^t - q_i^{t-1} = \beta_0 + \beta_1(r_i^{t-1} - q_i^{t-1}) + \beta_2(i_i^{t-1} - q_i^{t-1}) + \beta_3\, Chinese + \beta_4\, Male, \tag{3}$$

where q_i^t is the quantity selected by subject i in round t. r_i^{t-1} denotes subject i's best response to the quantity in the previous round selected by the competitor (or competitors in triopoly), and i_i^{t-1} denotes the quantity in the previous round selected by the competitor in duopoly (or average quantity of competitors in triopoly). *Chinese* is a dummy variable that takes the value of 1 for a

Malaysian of Chinese ethnicity and 0 otherwise (since different ethnic groups may have different "propensities to cooperate"). Finally, $Male$ is a dummy variable that takes the value of 1 for a male and 0 for a female (Mason et al., 1991 find that females collude more than males in the first rounds of a duopoly experiment). Note that a subject who strictly plays a myopic best response ('imitation') should have $\beta_1 = 1$ ($\beta_2 = 1$), while the other coefficients should be equal to zero. However, we do not expect to observe strict best response or imitation strategies, but rather coefficients which are smaller than 1. In contrast to Huck et al. (1999), we did not find that variances changed over time,[20] so it is sensible to estimate the model (employing the pooled data of all subjects in each treatment) by using OLS (clustering the standard errors within each market). The estimation results are given in Table 6.

- Table 6 about here -

Table 6 indicates that Cournot play (best response) significantly explains output adjustments in all treatments, but when communication is allowed, the magnitude of this coefficient is reduced. On the other hand, the influence of imitation becomes larger (and sometimes even turns significant) with communication. In other words, communication results in more imitation and less Cournot play (best response). Even though we sometimes find that ethnicity or gender significantly affect the outcome, these two factors do not have a consistent effect across treatments. Moreover, these factors are hardly significant in the triopoly treatments.

Result 5: *In all treatments, the outcome adjustment is explained by the previous round's best response strategy. In the treatments with communication, the effect of imitation becomes larger and crowds out the effect of myopic best*

[20] Like Huck et al. (1999), we performed Goldfeld-Quandt tests for all treatments, but we could not reject the null hypothesis of homoscedasticity.

response.

Although imitation of the most successful firm leads to the competitive outcome (Vega-Redondo, 1997), our results indicate that in duopoly imitation is used rather as a way of coordinating collusion. By selecting a smaller (more collusive) quantity, a firm "leads" its competitor (by example) to collusion.

6 Concluding Remarks

This experimental study of Cournot oligopoly investigates the impact of pre-play communication on firms' (subjects') performance. For this purpose, we allow subjects to communicate either by using pre-defined expressions (so-called "standardized communication ") or by using a chat box for free communication. Moreover, we investigate the effect of communication in duopoly and triopoly on two subject pools: students and managers. Regarding the effect of pre-play communication, we find first that the effect of communication on collusion is larger in duopoly than in triopoly, all other conditions being equal. In fact, communication does not affect managers in triopoly. Second, managers behave in a similar way under both communication devices, while students are more influenced by the free-communication than by the standardized-communication device. Finally, inspecting the individual data, we find that in all treatments output adjustment is explained to some extent by the previous round's best response strategy. In the treatments with communication, the effect of imitation becomes larger and crowds out the effect of myopic best response.

Regarding the effect of the subject pool on performance, we extend the results reported in Waichman et al. (2010a,b) for the case where communication is allowed. We find that managers select lower aggregate quantities than students in all duopoly treatments. In triopoly, on the other hand, managers only select

lower aggregate quantities than students when communication is not allowed. In other words, communication increases the difference between the subject pools in duopoly but reduces this difference in triopoly.

Regarding the effect of industry size, we find that there are lower aggregate quantities and notably a higher incidence of collusion in duopoly than in triopoly. Finally, we establish that the Cournot-Nash equilibrium quantity quite accurately describes the performance of the markets without communication in duopoly, but when communication is allowed, the performance of the markets is more collusive than this quantity suggests. In triopoly, however, the Cournot-Nash equilibrium quantity accurately describes the behavior of almost all markets.

In sum, our main observation is that even in duopoly with communication, subjects in general do not manage to maintain collusion. This result implies that although computer-mediated communication results in lower aggregate quantities, this is still not enough to ensure collusion, even in duopoly. Bicchieri and Lev-On (2007) identify two conditions for the establishment of collusion: the capability to coordinate mutual promising and the credibility of promises. Regarding the former, face-to-face communication is more likely than computer-mediated communication (or exchange of notes) to foster leaderships which positively impact collusion (see, for example, Orbell et al., 1988). In addition, face-to-face communication allows subjects to use visual, verbal, and social cues to form expectations that may make their mutual promises credible. Accordingly, it seems promising for further research to relax the condition of anonymity and allow for face-to-face communication.

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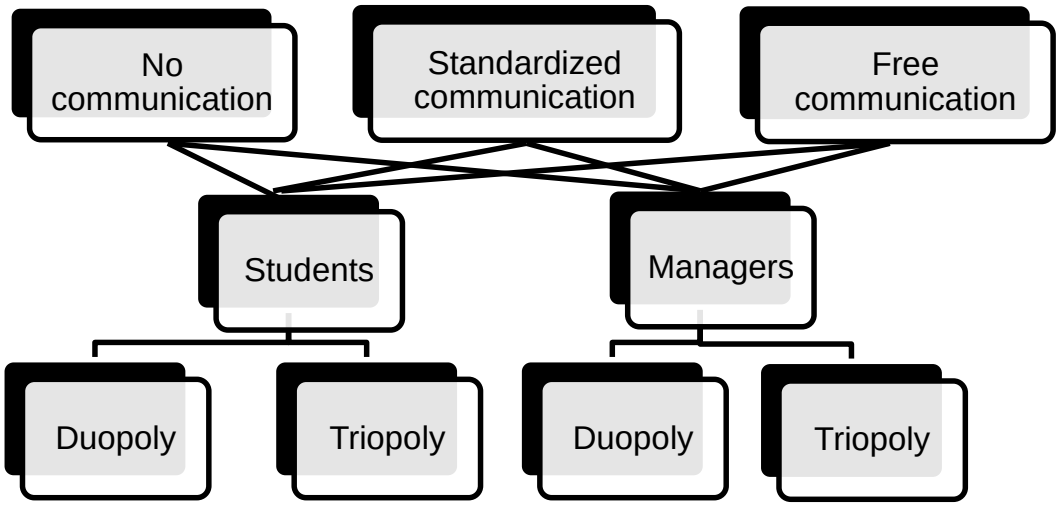


Figure 1: The 2x2x3 experimental design

	Collusive outcomes (Q^M)	Cournot-Nash outcomes (Q_n^N)	Competitive outcomes (Q^C)
Duopoly ($n = 2$)	49.5	66	99
(range)	$\{0, ..., 57.75\}$	$\{57.75, ..., 82.5\}$	$\{82.5, ..., 200\}$
Triopoly ($n = 3$)	49.5	74.25	99
(range)	$\{0, ..., 61.87\}$	$\{61.87, ..., 86.62\}$	$\{86.62, ..., 300\}$

Table 1: The three benchmark market outcomes and their corresponding ranges

Market	No communication	Standardized communication	Free communication
		Students	
	SNC	**SSC**	**SFC**
Markets (Subjects)	12 (24)	11 (22)	17 (34)
% Females	54	72	59
% Chinese	25	40	59
		Managers	
	MNC	**MSC**	**MFC**
Markets (Subjects)	10 (20)	12 (24)	12 (24)
% Females	42	54	50
% Chinese	90	100	100
Average age	34.1	29.8	34.0

(a) Characteristics of subjects in the *duopoly* treatments

Market	No communication	Standardized communication	Free communication
		Students	
	SNC	**SSC**	**SFC**
Markets (Subjects)	13 (39)	10 (30)	11 (33)
% Females	53	53	63
% Chinese	82	86	24
		Managers	
	MNC	**MSC**	**MFC**
Markets (Subjects)	11 (33)	11 (33)	10 (30)
% Females	42	42	53
% Chinese	90	84	90
Average age	38.2	36.9	35.4

(b) Characteristics of subjects in the *triopoly* treatments

Table 2: Characteristics of the different treatments (abbreviations are given in bold letters).

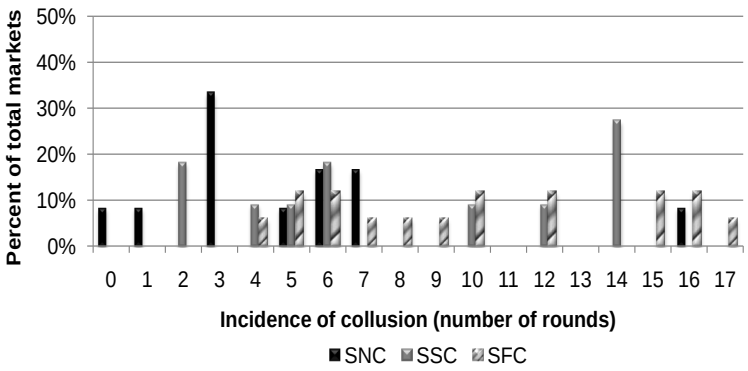
Market	No communication			Standardized communication			Free-communication		
	$\bar{Q}_{1-17}$	$\bar{Q}_{1-15}$	$\bar{Q}_{3-15}$	$\bar{Q}_{1-17}$	$\bar{Q}_{1-15}$	$\bar{Q}_{3-15}$	$\bar{Q}_{1-17}$	$\bar{Q}_{1-15}$	$\bar{Q}_{3-15}$
Students									
Average	68.26	67.97	68.54	63.50	63.01	63.94	59.44	59.40	59.17
median	67.82	67.76	67.57	62.76	61	61.53	58.64	57.86	58.61
SD	6.00	6.51	6.45	9.53	9.19	11.13	5.62	5.58	5.52
% change				6.98	7.29	6.70	12.29	12.61	13.67
Managers									
Average	65.53	65.35	66.76	56.25	56.01	56.31	55.79	56.14	55.67
median	62.85	62.63	63.80	55.02	54.43	55.15	55.17	55.30	55.38
SD	9.75	10.29	10.38	4.29	4.42	4.45	6.43	6.48	6.77
% change				14.15	14.29	15.65	14.86	14.04	16.61

(a) Descriptive statistics of the *duopoly* treatments

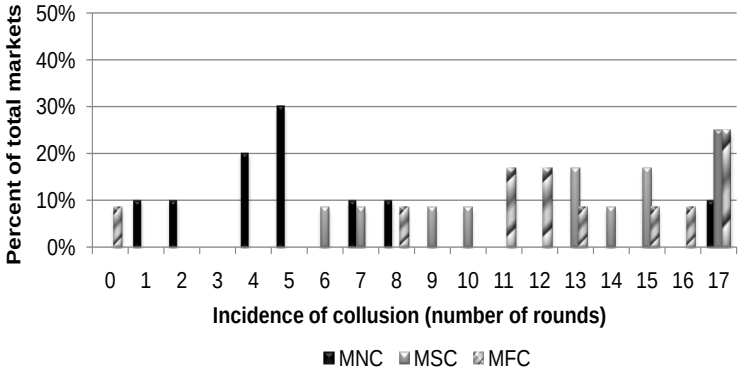
Market	No communication			Standardized communication			Free-communication		
	$\bar{Q}_{1-17}$	$\bar{Q}_{1-15}$	$\bar{Q}_{3-15}$	$\bar{Q}_{1-17}$	$\bar{Q}_{1-15}$	$\bar{Q}_{3-15}$	$\bar{Q}_{1-17}$	$\bar{Q}_{1-15}$	$\bar{Q}_{3-15}$
Students									
Average	80.81	81.04	80.81	75.81	76.50	75.99	71.98	71.77	71.62
median	78.64	79.06	78.53	76.58	77.15	75.93	71.52	72.06	72.76
SD	10.08	10.94	10.22	10.36	11.25	11.57	9.88	9.72	9.40
% change				6.19	5.59	5.95	10.93	11.43	11.37
Managers									
Average	75.63	75.66	75.78	70.93	70.52	70.67	71.97	72.42	70.71
median	74.05	74.40	73.69	73.35	72.60	73.38	71.80	71.80	69.88
SD	5.82	6.31	6.69	6.61	6.94	6.58	13.48	14.05	14.76
% change				6.21	6.78	6.73	4.83	4.28	6.66

(b) Descriptive statistics of the *triopoly* treatments

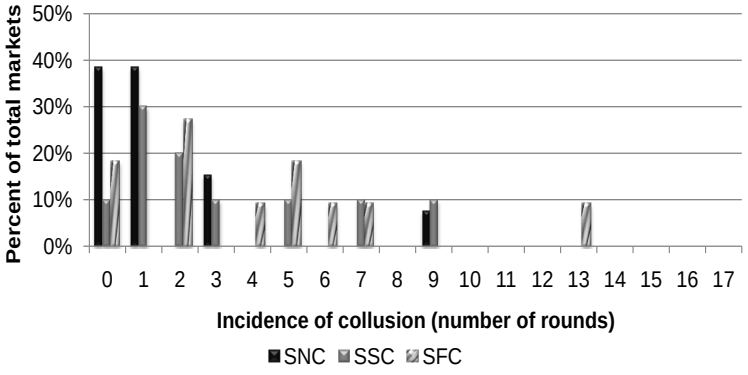
Table 3: Descriptive statistics of the average aggregate quantities selected in the different *duopoly* and *triopoly* treatments. The quantities are averaged over all rounds ($\bar{Q}_{1-17}$), over the first 15 rounds ($\bar{Q}_{1-15}$), and over rounds 3 to 15 ($\bar{Q}_{3-15}$). "% change" describes the percentage change of average performance from the (average performance in the) corresponding control (no communication) treatment.



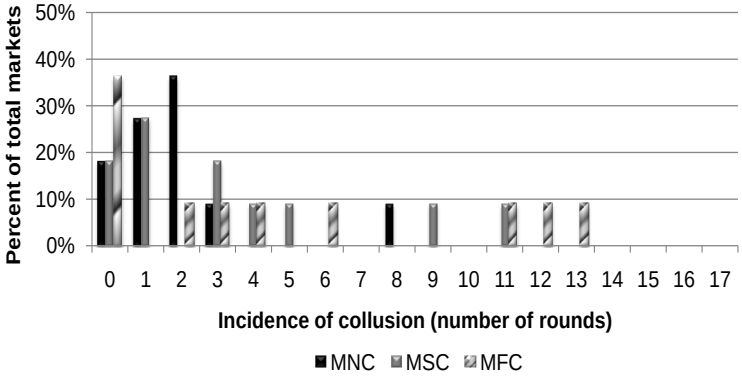
(a) Duopoly: The student sample



(b) Duopoly: The manager sample



(c) Triopoly: The student sample



(d) Triopoly: The manager sample

Figure 2: Percentage of total markets in each treatment colluding for 0, 1, 2 rounds, etc. For example, the incidence of collusion of a market that does not even achieve collusion in a single round is denoted by 0. The collusion incidence of a market maintaining collusion for a total of 10 rounds is denoted by 10, etc.

Subject pool	Oligopoly size	Difference between treatments		
Students	n=2	SNC $>^{***}$ SFC	SNC $>^{*}$ SSC	SSC = SFC
Students	n=3	SNC $>^{***}$ SFC	SNC = SSC	SSC = SFC
Managers	n=2	SNC $>^{***}$ SFC	SNC $>^{***}$ SSC	SSC = SFC
Managers	n=3	SNC = SFC	SNC = SSC	SSC = SFC

(a) Comparison between market quantities

Subject pool	Oligopoly size	Differences between treatments		
Students	n=2	SNC $>^{***}$ SFC	SNC $>^{**}$ SSC	SSC = SFC
Students	n=3	SNC $>^{***}$ SFC	SNC $>^{**}$ SSC	SSC = SFC
Managers	n=2	SNC $>^{***}$ SFC	SNC $>^{***}$ SSC	SSC = SFC
Managers	n=3	SNC = SFC	SNC = SSC	SSC = SFC

(b) Comparison between incidence of collusion

Table 4: Communication effect: Results of a two-sided F-P test between each pair of treatments. *,**, and *** denote significance at the 10%, 5%, and 1% levels.

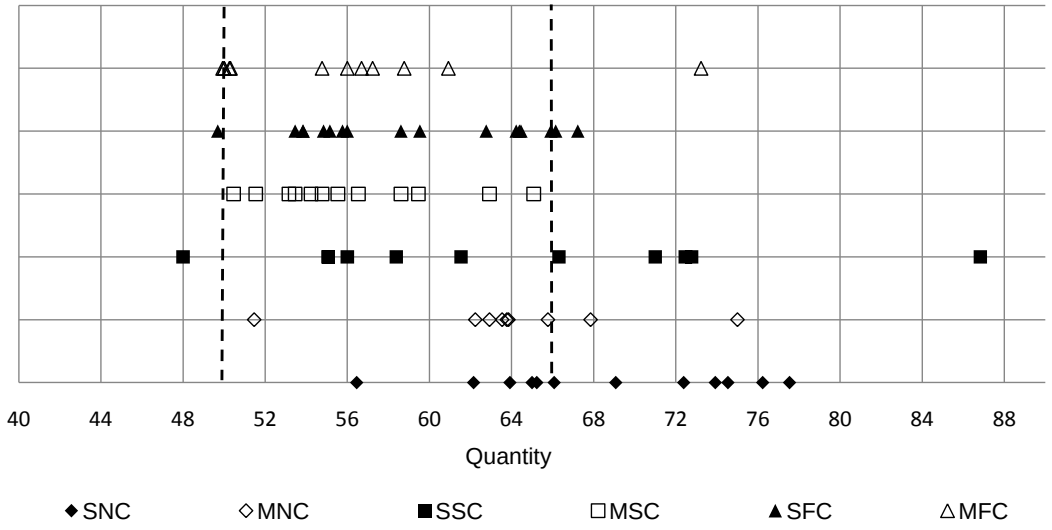
Communication	Oligopoly size	Difference between treatments
No communication	n=2	Students $>^{*}$ Managers
Standardized communication	n=2	Students $>^{***}$ Managers
Free communication	n=2	Students $>^{**}$ Managers
No communication	n=3	Students $>^{*}$ Managers
Standardized communication	n=3	Students = Managers
Free communication	n=3	Students = Managers

(a) Comparison between market quantities

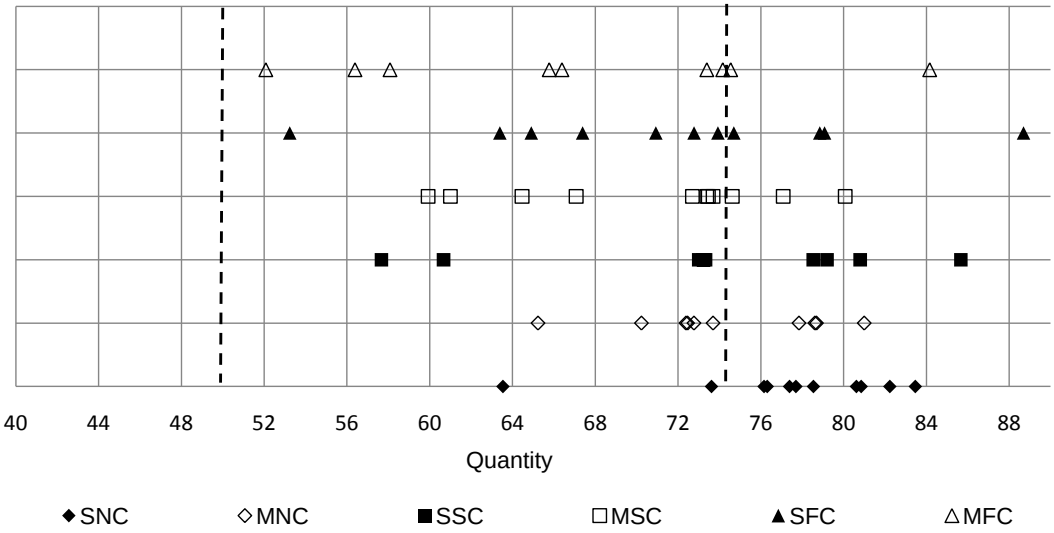
Communication	Oligopoly size	Differences between treatments
No communication	n=2	Students = Managers
Standardized communication	n=2	Students $>^{***}$ Managers
Free communication	n=2	Students $>^{*}$ Managers
No communication	n=3	Students = Managers
Standardized communication	n=3	Students = Managers
Free communication	n=3	Students = Managers

(b) Comparison between incidence of collusion

Table 5: Subject-pool effect: Results of a two-sided F-P test between each pair of treatments. *,**, and *** denote significance at the 10%, 5%, and 1% levels.



(a) The duopoly treatments



(b) The triopoly treatments

Figure 3: Independent average quantities (over the middle periods, 3-15) across duopoly and triopoly treatments. The vertical dashed lines denote the collusive and Cournot outcomes.

	SNC	SSC	SFC	MNC	MSC	MFC
β_1	0.64***	0.31***	0.41***	0.42***	0.35***	0.31***
	(0.05)	(0.05)	(0.05)	(0.03)	(0.06)	(0.12)
β_2	0.09	0.22***	0.72***	0.22*	0.33***	0.30***
	(0.06)	(0.05)	(0.05)	(0.10)	(0.03)	(0.04)
β_3	-0.54	-2.29*	3.51**	1.06	-	-
	(1.16)	(1.19)	(1.55)	(1.57)		
β_4	-4,94***	-0.21	-2.03	-2.23	0.857**	0.05
	(1.42)	(1.12)	(1.58)	(2.02)	(0.03)	(0.62)
β_0	3.71**	0.56	3.53***	0.35	-2.96***	-2.61*
	(1.21)	(1.16)	(0.84)	(1.70)	(0.68)	(1.45)
Obs	384	352	544	320	384	384
$F-test$	41***	31***	151***	36***	70***	14***
R^2	0.40	0.28	0.78	0.35	0.35	0.35

(a) OLS estimation of individual behavior in *duopoly*

	SNC	SSC	SFC	MNC	MSC	MFC
β_1	0.34***	0.29***	0.32***	0.32***	0.37***	0.24***
	(0.05)	(0.03)	(0.03)	(0.05)	(0.08)	(0.06)
β_2	0.11**	0.36***	0.32***	0.17	0.28***	0.26***
	(0.05)	(0.07)	(0.05)	(0.10)	(0.05)	(0.04)
β_3	1.53*	-0.57	-3.03**	0.93	0.99	1.59
	(0.86)	(2.72)	(1.42)	(1.57)	(0.98)	(1.97)
β_4	-1.64	-0.96	0.32	-0.41	0.37	-0.72
	(0.68)	(1.07)	(1.04)	(1.57)	(0.73)	(1.02)
β_0	1.09	1.32	0.09	0.29	-1.18	1.04
	(0.82)	(2.47)	(0.76)	(1.64)	(1.11)	(2.22)
Obs	624	480	528	528	528	480
$F-test$	144***	38***	134***	40***	11***	92***
R^2	0.26	0.35	0.38	0.26	0.38	0.29

(b) OLS estimation of individual behavior in *triopoly*

Table 6: OLS estimations of individual behavior. *,**, and *** denote significance at the 10%, 5%, and 1% levels.

A Instructions and Screens

A.1 Instructions: Triopoly

- Welcome to our experiment. Please read these instructions carefully! From now until the end of the experiment you are not allowed to communicate with the other participants. If you have any question, please raise your hand, and we will answer them individually.

- At the beginning of the experiment, each one of you will be assigned a number. From then on, you and the other participants will be identified by this number. Please keep it until you receive your payment. In addition, there are two empty sheets of paper that you can use during the experiment.

- In this experiment you will repeatedly be asked to make decisions that can earn you a reasonable amount of money. How much you earn depends not only on your decisions but also on the decisions of the other participants.

- All participants receive the same instructions.

- In this experiment you represent a firm, the same as two other firms, that produces and sells the same product on the market. You will be matched with the same two firms during the whole experiment.

- You will stay anonymous from the other firms, both during and after the experiment.

- In each period all firms have to make one decision, namely what quantity they wish to produce.

- The cost of production is 1 ECU (Experimental Currency Unit) per unit (this holds for all firms).

- The following important rule holds: The higher the total (aggregate) quantity produced by all firms, the lower the price in the market. Moreover, from a certain amount of total output upwards the price will be zero.

- Your profit per unit of output will be the difference between the market price and the unit cost of 1 ECU. Note that you will incur a loss if the market price is below the unit cost. Your profit per period is thus equal to the profit per unit multiplied by the number of units you sell.

- [**The standardized communication treatment:**] This experiment is a two-stage experiment. In the first stage (called chat-phase) for two minutes you will have the opportunity to communicate with the other firms in the market by suggesting your quantity to sell and the other firms' quantities to sell. You also have a button "I agree" and "I do not agree"). You are not limited in the number of messages you can write. Recall that the others will never know your personal identity. In the

second stage (called real-decision phase) you will make your real decision of quantity. In this stage you cannot communicate with the others but you can still see the chat window.

- [**The free-communication treatment:**] This experiment is a two-stage experiment. In the first stage (called chat-phase) for two minutes you will have the opportunity to communicate freely with the other firms in the market using a chat window (you send your chat using Enter). You are not limited in the number of messages you can write. However, you are not allowed to identify yourself in any way. You are only allowed to write messages in English. In the second stage (called real-decision phase) you will make your real decision of quantity. In this stage you cannot chat with the others but you can still see the chat window.

- [**The common and free-communication treatments:**] During the experiment (both in the 'chat-phase' and in the 'decision-phase') you can use a 'profit calculator' before you decide on the quantity to produce. This profit calculator helps you simulate the possible outcomes in the markets. You enter your quantity and the total (aggregate) quantity of the other two firms and the 'profit calculator' will calculate your earnings.

- [**No communication treatment:**] During the experiment you can use a 'profit calculator' before you decide on the quantity to produce. This profit calculator helps you simulate the possible outcomes in the markets. You enter your quantity and the total (aggregate) quantity of the other two firms and the 'profit calculator' will calculate your earnings.

- In each period, the output decisions of the other two firms will be registered, the corresponding price determined, and the profits computed.

- After each period, you will receive information about the quantity chosen by you, the aggregate quantity chosen by the other two firms, your profit in the current period, and your commutative profit starting from the first period.

- The experiment consists of exactly 17 periods.

- During the experiment, all payoffs are given in ECU. Each participant starts with an initial amount of 500 ECU.

- After the experiment we will convert your profit to RM. The exchange rate is 81.5 ECU/RM, that is, 81.5 ECU is equal to 1 RM.[21]

- Your total profit in the experiment is the total amount you earned in the 17 periods of the experiment (plus the initial amount of 500 ECU).

- At the end of the experiment we will calculate your money payoff reward. This will be done in a way that ensures that the other participants will

[21] The currencies and the exchange rates differed across treatments.

not see how much you earned, and you will not see how much they earned. You will receive your money immediately in cash.

A.2 Computer screens

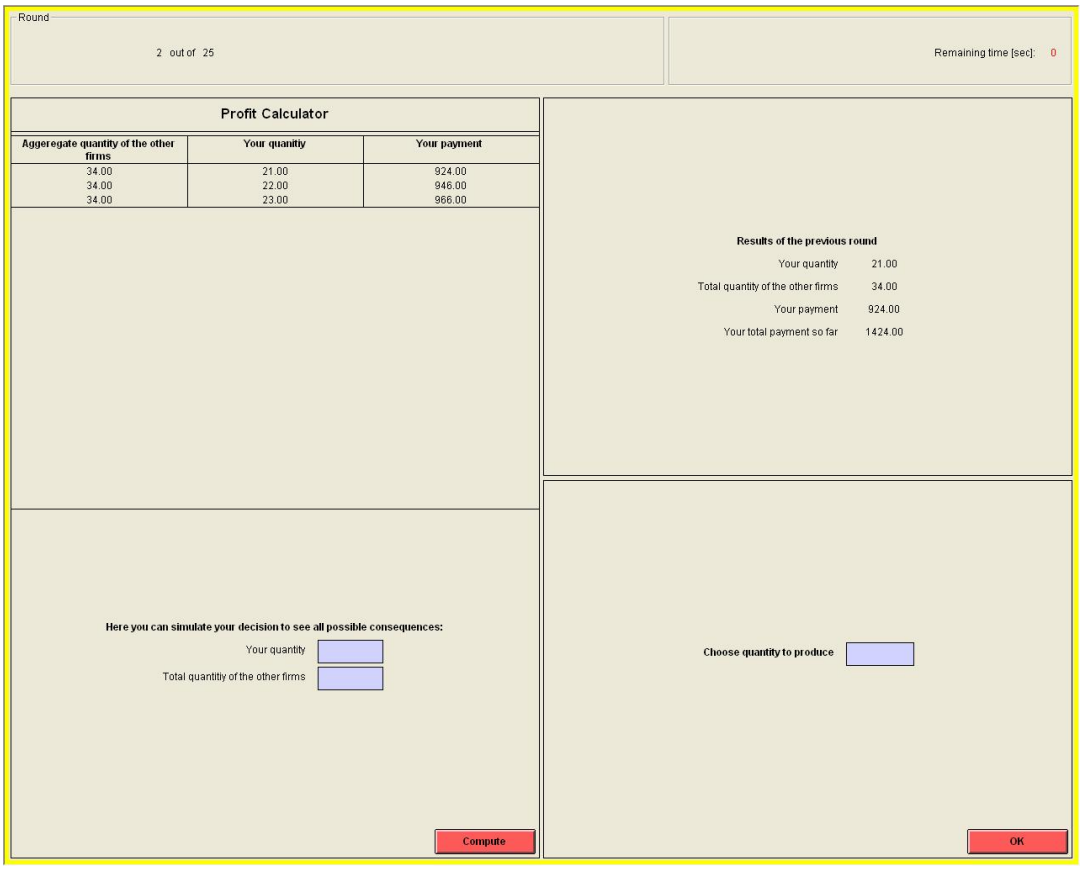


Figure A.1: The computer screens in rounds 2-25 of the experiment (no communication treatment). The profit calculator is located on the left-hand side of the screen. The results of the previous round are shown on the upper right-hand side of the screen, while the output decision is taken on its bottom right-hand side.

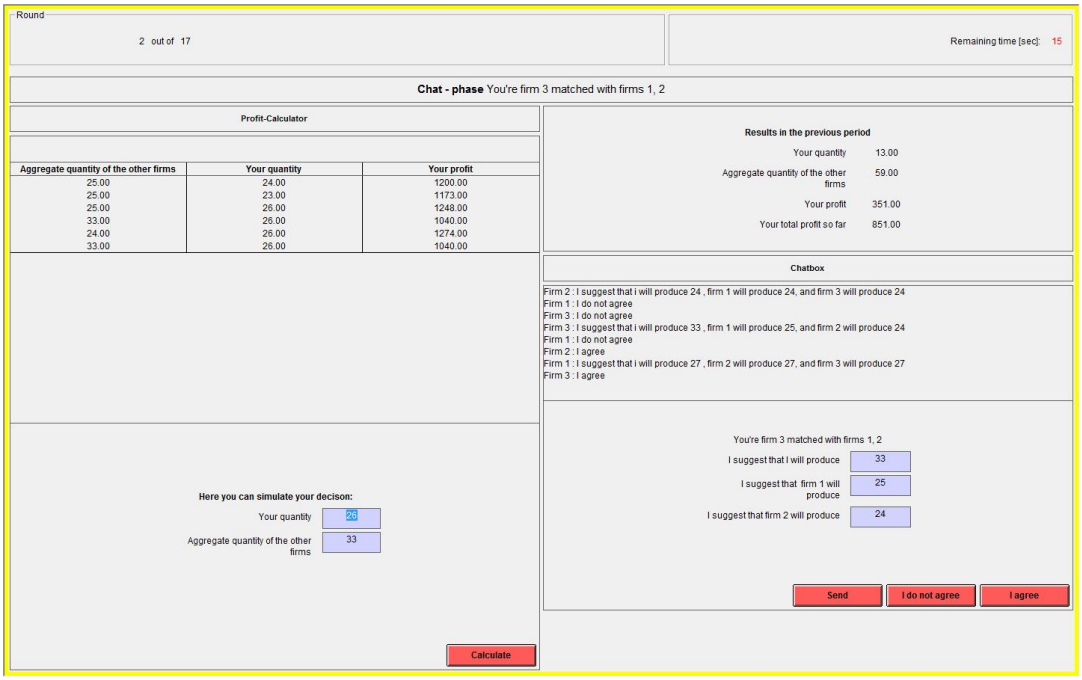


Figure A.2: The communication stage (standardized-communication treatment) in rounds 2-17 of the experiment. The profit calculator is located on the left-hand side of the screen. The results of the previous round are shown on the upper right-hand side of the screen, while the communication is done and displayed on its bottom right-hand side.

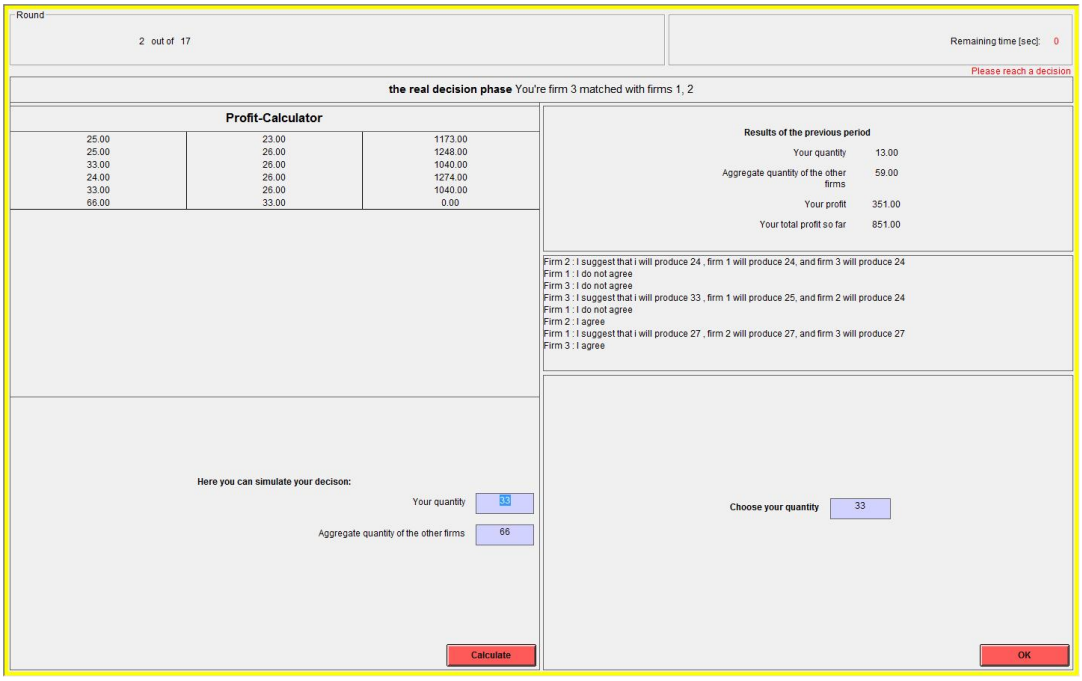


Figure A.3: The decision stage (standardized-communication treatment) in rounds 2-17 of the experiment. The profit calculator is located on the left-hand side of the screen. The results of the previous round are shown on the upper right-hand side of the screen, while the communication is displayed on the middle right-hand side and the output decision is taken on its bottom right-hand side.

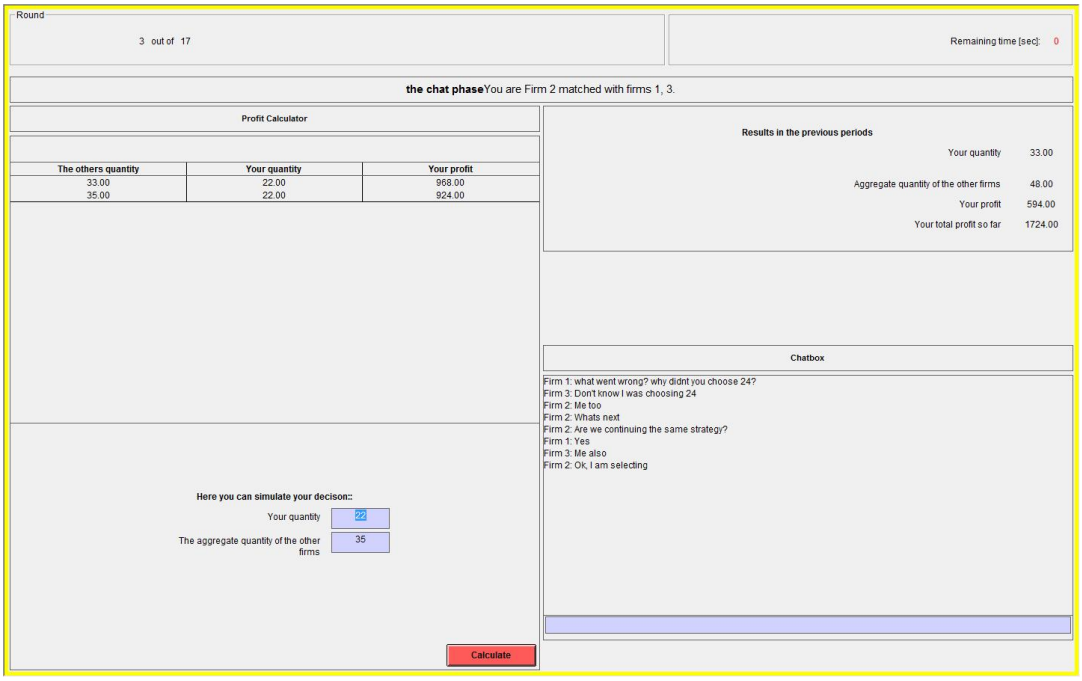


Figure A.4: The communication stage (free-communication treatment) in rounds 2-17 of the experiment. The profit calculator is located on the left-hand side of the screen. The results of the previous round are shown on the upper right-hand side of the screen, while the communication is done and displayed on its bottom right-hand side.

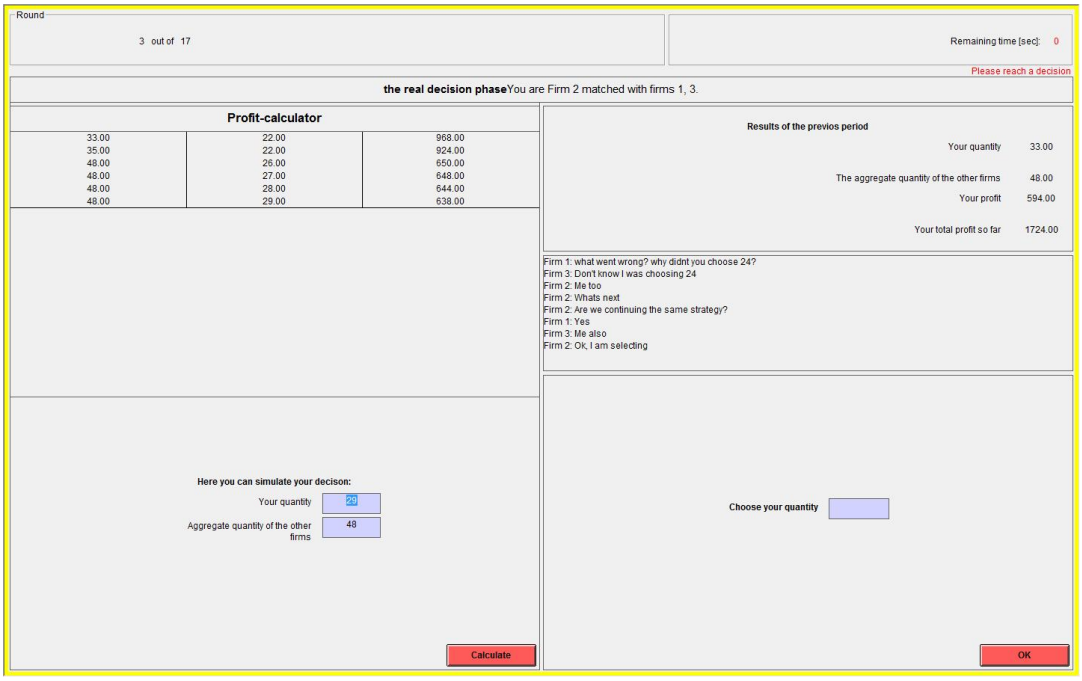


Figure A.5: The decision stage (free-communication treatment) in rounds 2-17 of the experiment. The profit calculator is located on the left-hand side of the screen. The results of the previous round are shown on the upper right-hand side of the screen, while the communication is displayed on the middle right-hand side and the output decision is taken on its bottom right-hand side.

B Individual Characteristics of the manager sample (not for publication)

Table B.1: Characteristics of the Duopoly MNC manager sample. In the "Ethnicity" column, "C" means Malaysian of Chinese descent and "I" means Malaysian of Indian descent. In the gender column, "M" means male and "F" means female.

Nr.	Gender	Ethnicity	Age	Degree	Job Description	Industry
1	M	M	26	Bachelor	Safety manager	Plastic molding and coloring
2	M	C	38	Bachelor	Production planner	Computer assembler
3	M	C	27	Bachelor	Production manager	Automation
4	F	C	29	Bachelor	Senior accountant	Hardware
5	M	C	36	Bachelor	Unit sales manager	Insurance
6	M	C	39	Bachelor	Production manager	Frozen food company
7	M	C	35	Bachelor	Investment manager	Frozen food company
8	M	C	29	Bachelor	Deputy Director	Ministry of Finance
9	F	C	30	Bachelor	Promotion (marketing and sales) manager	Electric and electronic related good manufacturer
10	F	C	36	Bachelor	Sales (team) manager	Computer chip and parts manufacturer
11	F	C	37	Bachelor	Production manager	Electric and electronic related good manufacturer
12	F	C	40	Bachelor	Director	Electric and electronic related good manufacturer
13	F	C	38	Bachelor	Strategic consultant	Automation
14	F	C	33	Bachelor	Manager of human resources	Plastic molding and coloring
15	M	I	36	Bachelor	Production manager	Electric and electronic related good manufacturer
16	F	C	36	Bachelor	Head of human resources	Finance and banking
17	F	C	35	Bachelor	Promotion (marketing and sales) manager	Jewelry
18	F	C	38	Bachelor	Financial consultant	Finance and banking
19	F	C	26	Bachelor	Senior accountant	Electric and electronic related good manufacturer
20	M	C	39	Bachelor	Chief technician	Electric and electronic related good manufacturer

Table B.2: Characteristics of the Duopoly MSC manager sample. In the "Ethnicity" column, "C" means Malaysian of Chinese descent and "I" means Malaysian of Indian descent. In the gender column, "M" means male and "F" means female.

Nr.	Gender	Ethnicity	Age	Degree	Job Description	Industry
1	M	C	37	Bachelor	Branch manager	Jewelry
2	M	C	35	Bachelor	Senior accountant	Finance and banking
3	F	C	28	Bachelor	Production manager	Electric and electronic related good manufacturer
4	F	C	35	Bachelor	Head of IT department	Telecommunication
5	F	C	31	Bachelor	Administration manager	Plastic molding and coloring
6	M	C	37	Bachelor	Production manager	Hardware
7	F	C	31	Bachelor	Production planner	Cable manufacturer
8	M	C	31	Bachelor	Marketing (strategy) manager	Automation
9	F	C	30	Bachelor	Head of IT department	Telecommunication
10	M	C	27	Bachelor	Chief officer for labor relations	Chief ministry of Penang
11	F	C	26	Bachelor	Strategic consultant	NGO
12	F	C	28	Bachelor	Production manager	Electric and electronic related good manufacturer
13	F	C	34	Bachelor	Production manager	Electric and electronic related good manufacturer
14	F	C	27	Bachelor	Researcher (chemist)	Chemical industry
15	M	C	28	Bachelor	Head of IT department	Computer chip and parts manufacturer
16	F	C	27	Bachelor	Production manager	Plastic molding and coloring
17	M	C	26	Bachelor	Accountant	Computer chip and parts manufacturer
18	M	C	31	Bachelor	Production manager	Electric and electronic related good manufacturer
19	F	C	28	Bachelor	Production manager	Computer assembler
20	M	C	25	Bachelor	Researcher (chemist)	Chemical industry
21	M	C	29	Bachelor	Financial consultant	Finance and banking
22	F	C	28	Bachelor	Sales (team) manager	Insurance
23	M	C	32	Bachelor	Production planner	Plastic molding and coloring
24	F	C	26	Bachelor	Accountant	Finance and banking

Table B.3: Characteristics of the Duopoly MFC manager sample. In the "Ethnicity" column, "C" means Malaysian of Chinese descent and "I" means Malaysian of Indian descent. In the gender column, "M" means male and "F" means female.

Nr.	Gender	Ethnicity	Age	Degree	Job Description	Industry
1	F	C	36	Bachelor	Head of IT department	Telecommunication
2	M	C	32	Bachelor	Sales (team) manager	Plastic molding and coloring
3	F	C	30	Bachelor	Administration manager	Computer assembler
4	F	C	36	Bachelor	Operation director	Electric and electronic related good manufacturer
5	F	C	29	Bachelor	Administration manager	Finance and banking
6	F	C	31	Bachelor	Administration manager	Plastic molding and coloring
7	F	C	39	Bachelor	Factory Manager	Electric and electronic related good manufacturer
8	M	C	35	Bachelor	Safety manager	Telecommunication
9	F	C	33	Bachelor	Head of IT department	Electric and electronic related good manufacturer
10	M	C	36	Bachelor	Head of human resources	Computer assembler
11	F	C	36	Bachelor	Production planner	Plastic
12	M	C	37	Bachelor	Production manager	Hardware
13	F	C	31	Bachelor	Production planner	Cable manufacturer
14	F	C	38	Bachelor	Consultant	Human resource consultancy
15	M	C	45	PhD	Director	Plastic molding and coloring
16	M	C	35	Bachelor	Strategic consultant	Finance and banking
17	F	C	39	Bachelor	Sales (team) manager	Electric and electronic related good manufacturer
18	M	C	35	Bachelor	Promotion (marketing and sales) manager	Chemical Industry
19	M	C	38	Bachelor	Promotion (marketing and sales) manager	Insurance
20	M	C	26	Bachelor	Production manager	Electric and electronic related good manufacturer
21	M	C	26	Bachelor	Accountant	Computer chip and parts manufacturer
22	M	C	27	Bachelor	Senior accountant	Computer chip and parts manufacturer
23	M	C	41	Bachelor	Head of human resources	Cable manufacturer
24	F	C	26	Bachelor	Strategic consultant	Electric and electronic related good manufacturer

Table B.4: Characteristics of the Triopoly MNC manager sample. In the "Ethnicity" column, "C" means Malaysian of Chinese descent and "I" means Malaysian of Indian descent. In the gender column, "M" means male and "F" means female.

Nr.	Gender	Ethnicity	Age	Degree	Job Description	Industry
1	M	I	42	Bachelor	Sales (team) manager	Finance and banking
2	F	C	38	Bachelor	Promotion (marketing and sales) manager	Plastic molding and coloring
3	F	C	50	Bachelor	Administration Manager	Finance and banking
4	F	I	36	Bachelor	Head of human resources	Computer chip and parts manufacturer
5	M	I	39	Bachelor	Safety Manager	Cable assembler
6	M	C	40	Bachelor	Factory Manager	Plastic molding and coloring
7	F	C	39	Bachelor	Head of human resources	Electric and electronic related good manufacturer
8	M	C	36	Bachelor	Senior Accountant	Computer chip and parts manufacturer
9	F	C	36	Bachelor	Senior Accountant	Computer assembler
10	M	C	36	Bachelor	Administration manager	Prime minister office
11	F	C	35	Bachelor	Production manager	Cable assembler
12	M	C	37	PhD	Investment manager	Computer chip and parts manufacturer
13	M	C	39	Bachelor	Production manager	Computer assembler
14	M	C	54	PhD	Operation director	Plastic Molding and coloring
15	F	C	36	Bachelor	Safety manager	Computer chip and parts manufacturer
16	F	C	38	Bachelor	Senior accountant	Finance and banking
17	F	C	36	Bachelor	Purchasing Manager	Plastic molding and coloring
18	M	C	38	Bachelor	Promotion (marketing and sales) manager	Plastic molding and coloring
19	M	C	35	Bachelor	Senior accountant	Electric and electronic related good manufacturer
20	M	C	29	Bachelor	Head of human resources	Computer assembler
21	M	C	38	Bachelor	Head of IT department	Electric and electronic related good manufacturer
23	F	C	38	Bachelor	Production manager	Computer assembler
24	F	C	37	Bachelor	Administration Manager	Electric and electronic related good manufacturer
25	M	C	42	Bachelor	Branch Manager of a Bank	Finance and banking
26	F	C	39	Bachelor	Senior accountant	Finance and banking
27	M	C	36	Bachelor	Safety Manager	Computer assembler
28	M	C	38	Bachelor	Branch (regional) Manager	Electric and electronic related good manufacturer
29	M	C	39	Bachelor	Production Manager	Computer assembler
30	F	C	37	Bachelor	Production Planner	Plastic molding and coloring
31	M	C	35	Bachelor	Promotion (marketing and sales) manager	Plastic molding and coloring
32	F	C	37	Bachelor	Promotion (marketing and sales) manager	Computer assembler
33	M	C	36	Bachelor	Production manager	Computer chip and parts manufacturer
34	M	C	41	Bachelor	Promotion (marketing and sales) manager	Education company focuses in trainee education

Table B.5: Characteristics of the Triopoly MSC manager sample. In the "Ethnicity" column, "C" means Malaysian of Chinese descent and "I" means Malaysian of Indian descent. In the gender column, "M" means male and "F" means female.

Nr.	Gender	Ethnicity	Age	Degree	Job Description	Industry
1	M	C	35	Bachelor	Sales (team manager)	Computer chip and parts manufacturer
2	M	C	42	Bachelor	Administration manager	Electric and electronic related good manufacturer
3	M	C	54	PhD	Operation director	Plastic molding and coloring
4	M	C	36	Bachelor	Factory Manager	Cable assembler
5	F	C	38	Bachelor	Production manager	Computer assembler
6	F	C	33	Bachelor	Administration manager	Plastic molding and coloring
7	M	C	36	Bachelor	Safety manager	Computer assembler
8	M	C	36	Bachelor	Head of IT department	Electric and electronic related good manufacturer
9	F	C	38	Bachelor	Head of human resources	Cable assembler
10	F	C	35	Bachelor	Production manager	Cable assembler
11	F	C	35	Bachelor	Production Planner	Plastic molding and coloring
12	F	C	38	Master	Senior accountant	Computer assembler
13	M	C	36	Bachelor	Purchasing manager	Computer assembler
14	M	C	39	Bachelor	Sales (team) manager	Electric and electronic related good manufacturer
15	M	M	36	Bachelor	Strategic consultant	Electric and electronic related good manufacturer
16	F	C	35	Bachelor	Promotion (marketing and sales) manager	Computer chip and parts manufacturer
17	M	C	38	Bachelor	Sales (team) manager	Computer chip and parts manufacturer
18	F	C	35	Bachelor	Promotion (marketing and sales) manager	Cable assembler
19	M	M	45	Bachelor	Branch manager	Electric and electronic related good manufacturer
20	F	C	36	Bachelor	Head of IT department	Electric and electronic related good manufacturer
21	F	C	38	Bachelor	Business strategy manager	Plastic molding and coloring
22	M	M	36	Bachelor	Production manager	Computer assembler
23	F	I	35	Bachelor	Senior accountant	Electric and electronic related good manufacturer
24	M	C	36	Bachelor	Sales (team) manager	Computer chip and parts manufacturer
25	F	C	36	Bachelor	Safety manager	Computer chip and parts manufacturer
26	M	C	35	Bachelor	Production manager	Computer assembler
27	M	C	29	Bachelor	Manager of human resources	Computer assembler
28	M	C	35	Bachelor	Senior accountant	Electric and electronic related good manufacturer
29	M	C	36	Bachelor	Senior accountant	Computer chip and parts manufacturer
30	M	C	37	Master	Investment manager	Computer chip and parts manufacturer
31	M	C	38	Bachelor	Branch manager	Electric and electronic related good manufacturer
32	F	C	36	Bachelor	Senior accountant	Computer assembler
33	F	M	37	PhD	Head of human resources	Electric and electronic related good manufacturer

Table B.6: Characteristics of the Triopoly MFC manager sample. In the "Ethnicity" column, "C" means Malaysian of Chinese descent and "I" means Malaysian of Indian descent. In the gender column, "M" means male and "F" means female.

Nr.	Gender	Ethnicity	Age	Degree	Job Description	Industry
1	F	C	36	Bachelor	Head of IT department	Telecommunication
2	M	C	32	Bachelor	Sales (team) manager	Plastic molding and coloring
3	F	C	31	Bachelor	Administration manager	Plastic molding and coloring
4	F	C	28	Bachelor	Sales (team) manager	Insurance
5	F	C	26	Bachelor	Production manager	Electric and electronic related good manufacturer
6	M	C	31	Bachelor	Marketing manager	Automation
7	F	C	30	Bachelor	Head of IT department	Telecommunication
8	M	C	37	Bachelor	Production manager	Hardware
9	F	C	31	Bachelor	Production planner	Cable manufacturer
10	F	C	45	Bachelor	Branch manager	Finance
11	M	C	36	Bachelor	Marketing manager	Private collage
12	F	C	35	Bachelor	Communication Manager	Transportation
13	M	C	31	Bachelor	Production manager	Electric and electronic related good manufacturer
14	F	C	28	Bachelor	Production manager	Computer assembler
15	M	C	38	Bachelor	Head of IT department	Computer assembler
16	M	C	26	Bachelor	Safety manager	Automation
17	F	C	33	Bachelor	Head of human resources	Plastic molding and coloring
18	M	I	36	Bachelor	Production manager	Electric and electronic related good manufacturer
19	M	C	36	Bachelor	Owner	Hardware
20	F	C	34	Bachelor	Production manager	Electric and electronic related good manufacturer
21	M	I	36	Bachelor	Administration manager	Computer assembler
22	M	C	39	Master	Engineer	Telecommunication
23	F	C	41	Bachelor	Financial consultant	Bank
24	F	C	38	Bachelor	Consultant	Human resources consultancy
25	F	C	37	Bachelor	Production manager	Plastic molding and coloring
26	M	C	38	Bachelor	Administration manager	Computer assembler
27	F	C	42	Master	Marketing manager	Private collage
28	F	C	40	Bachelor	Owner	Financial planning company
29	M	C	39	Master	Investment manager	Financial consultancy company
30	M	I	52	Bachelor	Owner	Company for library supplies
31	M	C	48	Master	Owner/Partner	Financial consultancy company
32	M	C	36	Bachelor	Marketing manager	Finance
33	M	C	38	Bachelor	Sales (team) manager	Hardware

C Free-communication conversations

C.1 Managers duopoly

Round1

1: “Hi”
2: “Hi”
1: “Any idea?”
2: “I also dunno”
2: “You sell[?], how much[?]”
1: “Can we try 30... [to] test [the] market”
1: “Hi, I produce 25, you produce 25”
2: “Hi”
1: “Ok?”
2: “Well”
1: “Ok”

Round2

1: “Are we competitors, or in the same group?”
2: “We [are] in the same group.”
1: “I see”
2: “ [We are] no[t] competitors, what are you gonna put this round?”
1: “About 30”
2: “[Do] you want to increase to 32”
1:“”
1: “Is that ok”
2:“ok, you put 30”
1: “Sure”
2: “We earn Kau kau”
1: “Great, haha, it is great to have such partner”
2: “Muhaha, same to you”
1: “ ;) ”

(2 selected 35, 1 selected 25...)

Some others

1: “You 5, I 50”
2: “[It is] too early to dream”
1: “You obviously do not want to cooperate”
2: “So, this time, how many do you want?”

Round 9

1: “How nice and peaceful the world if everyone is like you”

2: “like us, not only me”
1: “same, same”
2: “haha”

round 12

“Greediness is one of the worst things, but you make me feel the world has still hope...”

Round 13

1: “I just want to earn money”
2: “Yes, same goal.”
1: “Business is earning[!]”

Round 17

“Money is coming to you and me”

C.2 Managers triopoly

Round 3

1: “[It is] better [to] put lower output”
2: “How come [that] my profit become - ?”
1: “My profit become negative, we are the same”
3: “Mine too”
2: “So what’s next[?]”
1: “No idea”
2: “Is there a wrong number to put[?]”
3. “Of course... [aggregate] output is 83 total”
2: “Oh, I see”

Round 6

1: “Someone produced extra”
2: “ya”
1: “If [we] continue like that, then the balance will go off, [and we] end up nobody earns come to any conclusion”
2: “I agree to plan”
1: “OK, we will stick to it, then we will see next round how”

Round 17

1: “If we have a chance to do business I know I can trust you firm 2, but not

[firm] 3”

(Subject 3 did not answer...)