Do Antitrust Laws Facilitate Collusion?
Experimental Evidence from Bertrand Supergames

Master’s Thesis
July 3, 2003
Department of Economics
Lund University

Authors:
Ola Andersson
Erik Wengström

Supervisors:
Hans Carlsson
Jerker Holm
# Contents

1 Introduction 3  
1.1 Purpose ............................................. 4  
1.2 Demarcations ....................................... 4  
1.3 Disposition ......................................... 4  

2 Theoretical framework 6  
2.1 Bertrand price competition ......................... 6  
  2.1.1 Bertrand setup .................................... 6  
  2.1.2 Bertrand supergame ................................ 9  
2.2 Bertrand game, Communication and Collusion ........ 10  
  2.2.1 Infinitely costly renegotiation .................... 11  
  2.2.2 Costless renegotiation ............................ 11  
  2.2.3 Costly renegotiation .............................. 17  
2.3 The antitrust law and renegotiation .................. 18  

3 Methodology 20  
3.1 Why use experiment? ................................. 20  
3.2 Experimental Design ................................ 21  
  3.2.1 Number of Repetitions ............................ 22  
  3.2.2 Subjects ......................................... 22  
  3.2.3 Instructions .................................... 23  
  3.2.4 Incentives .................................... 23  
3.3 Communication ...................................... 24  
3.4 Exit-poll ........................................... 25  
3.5 Hypothesis ......................................... 25  

4 Results 26  
4.1 Bids and Prices .................................... 26
4.2 Messages and Contracts ........................................ 30
4.3 Statistical analysis .............................................. 32
4.4 Summary ............................................................. 34

5 Conclusions .......................................................... 35

A Instructions .......................................................... 39

B Message and Price forms .......................................... 41
   B.1 Message form .................................................. 41
   B.2 Price form (Yellow form) .................................... 41

C Exit Poll .............................................................. 42
Chapter 1

Introduction

Recent years have seen an increased attention on price-fixing agreements among firms. The Swedish Competition Authority has reclaimed power by actively controlling prices and possible collusions. Since firms have private information concerning price-fixing arrangements, the authorities must rely on indirect evidence to imply the existence of collusion. In search for evidence the Swedish Competition Authority have conducted several “dawn raids” on firms, confiscating any suspicious material including entire computers. Not surprisingly they have often been right in their suspicions.

These actions put strains on firms’ ability to meet and discuss cooperation, thus making communication between firms costly. Using commonsense this ought to make firms act more competitive. This kind of reasoning has lead policymakers to construct the Swedish Antitrust Law, as well as the American counterpart, the Sherman Act. Since these policymakers in most cases have consisted of lawyers, the analysis of the economic dynamics of the antitrust laws is incomplete. Theoretical work by McCutcheon [1997] suggest that these laws might not prevent firms from colluding. So even if the policymakers that constructed these laws had the public interest in mind, the laws might work in the interest of firms.

These economic conclusions stand off as a serious implication to the existence of antitrust laws that deter communication between firms. The predictions build, however, solely on theoretical reasoning. We have not found any experimental research concerning costly communication in games, and thus, the predictions of McCutcheon [1997] have not yet been tested.
1.1 Purpose

Policymakers and economists seem to disagree concerning the effects of antitrust laws. Therefore we are interested in the validity of the theory put forth by McCutcheon [1997]. Using the words of Roth [1995] the main purpose of this thesis might be expressed as *speaking to a theorist*. Our intention is to experimentally test the theoretical predictions of McCutcheon [1997] and hopefully convey some feedback concerning the validity of the predictions. Moreover we theoretically investigate the sensitivity of the predictions to changes in the underlying assumptions.

Since the theory rejects the need for antitrust laws there is also a case for the metaphor *whispering in ears of princes* - stated by Roth [1995]. By this we mean that, results from the test may be of interest to policymakers since it delivers indications of how firms operate in actual markets. However since this test is a first, we are not eager to draw any general conclusions but merely hope that our study will be replicated in order to test the robustness of the results. It is also our intention to give the reader an insight to the tradeoffs experimenters have to make in order to construct feasible tests.

1.2 Demarcations

The main focus of this thesis is to test the specific theoretical predictions of McCutcheon [1997] and not collusive behavior in general. We are mainly interested in the internal workings of the theory, thereby paying less attention to the structural assumptions. That is, we do not question if the theory is a good description of structures in actual market. Instead we examine the outcomes, taking the structure as given.

1.3 Disposition

In chapter 2 we start by presenting the standard Bertrand supergame, thereafter extending the setup to allow for communication between firms. We use the concept of Weakly Renegotiation Proof-equilibria developed by Farrell and Maskin [1989] to study behavior among firms. Furthermore we examine what happens if we impose a cost on communication. The last section of the chapter is devoted to a discussion of the theory’s implication to antitrust legislation.
Chapter 3 contains a brief discussion of the experimental approach in economics. Furthermore we present the specific design of our study and state the hypotheses.

In chapter 4 we start by giving the descriptives of the experiment, this is mainly presented in figures and tables. We then turn to testing our hypothesis using statistical methods. Finally we summarize our findings.

Chapter 5 contains a concluding discussion of our study.
Chapter 2

Theoretical framework

Modern Industrial Organization uses game theory to explain strategic behavior in a wide variety of competitive contexts. Cooperation among firms is one area of research that frequently uses game theoretic tools. This is also the case of McCutcheon [1997], who builds her argumentation on a simple Bertrand supergame. We therefore start the chapter by giving a formal description of this game. Thereafter we investigate what happens if we allow firms to communicate during the game. The last section concludes the chapter by discussing theory and actual market outcomes.

2.1 Bertrand price competition

For expositional purposes we present the duopoly version of the Bertrand game. Furthermore following McCutcheon [1997] we only consider pure strategies. We assume that the firms produce homogenous goods, i.e. the goods are perfect substitutes in the consumers’ utility functions, implying that consumers will buy from the firm that charges the lowest price.

2.1.1 Bertrand setup

Firm $i$, $i = (1, 2)$, chooses price $p_i \in P = \{p_i | p_i = [0, p_{max}]\}$ that maximize profits. Assuming that firms have identical technologies, i.e both have the same marginal cost, $c$, the profits for firm $i$ are given by:

$$ \Pi_i(p_i, p_j) = (p_i - c)D_i(p_i, p_j) $$

(2.1)
where demand, $D_i$ is given by:

$$D_i(p_i, p_j) = \begin{cases} D(p_i) & \text{if } p_i < p_j \\ 1/2D(p_i) & \text{if } p_i = p_j \\ 0 & \text{if } p_i > p_j \end{cases} \quad (2.2)$$

The aggregated profits

$$\Pi_1 + \Pi_2 = \min_{p_i}(p_i - c)D(p_i) \quad i = 1, 2 \quad (2.3)$$

cannot exceed the monopoly profit given by

$$\Pi_m = \max_{p}(p - c)D(p) \quad (2.4)$$

hence the following inequality must hold

$$\Pi_1 + \Pi_2 \leq \Pi_m \quad (2.5)$$

The Bertrand game is static, meaning that the firms choose their prices simultaneously not knowing the other firm’s choice of price. To find a solution for this game, we ask how firms should act to maximize profits. The most common way of solving this problem is to use the following definition stated by Nash.$^1$

**Definition 1** A Nash-equilibrium in prices is a pair of prices $(p^*_1, p^*_2)$ such that for firm $i$, $p^*_i$ maximizes profits given that firm $j$ chooses $p^*_j$. Formally

$$\max_{p_i} \Pi_i(p_i, p^*_j) \quad i = 1, 2, \ i \neq j \quad (2.6)$$

$^1$We are using standard game-theoretic notations with the exceptions that we denote actions $(a)$ as prices $(p)$ and payoffs $(g)$ as profits $(\Pi)$.  

7
The definition states that, in equilibrium, each firm will have no incentive to deviate from their current choice of price.

What is the Nash-Equilibrium in the Bertrand duopoly? It may be somewhat surprising, but in the unique Nash-equilibrium, both firms charge a price equal to marginal cost \( (p_1^*, p_2^*) = (c, c) \). This is often referred to as the Bertrand Paradox, see e.g. Tirole [1988]. Because profit functions here are discontinuous, we cannot argue the case by differentiating and solving the first-order conditions. Instead, we will just use some common sense.

First note that \( p_i = c, i = (1, 2) \) is a Nash-equilibrium in the Bertrand game. Each firm serves half the market and earns zero profit, but if one firm increases its price it ceases to obtain any demand at all. Therefore \( p_i = c \) is firm \( i \)'s profit-maximizing choice of price given \( p_j = c \).

Next we need to show that there is no other Nash-equilibrium. Assume that there exists a Nash-equilibrium in prices \( (p_i, p_j) \) such that \( p_i > p_j > c \). In this case firm \( i \) will sell no goods and therefore make a zero-profit Firm \( j \) on the other hand is making a strictly positive profit. But this cannot be a Nash-equilibrium since \( p_i \) is not firm \( i \)'s profit maximizing price given \( p_j > c \). Setting \( p_i = p_j - \varepsilon \), where \( \varepsilon \) is some arbitrary small decrease in firm \( j \)'s price, will lead to positive profits for firm \( i \) since \( p_i - \varepsilon > c \). Firm \( j \) will respond in the same way by undercutting firm \( i \)'s price by \( \varepsilon \). Therefore there cannot exist a Nash-equilibrium such that \( p_i > p_j > c, i \neq j \).

Moreover, splitting the market by setting \( p_i = p_j > c \) cannot be a Nash-equilibrium either, since firm \( i \) will earn higher profits by setting price \( p_i = p_j - \varepsilon \) slightly lower than firm \( j \) and thereby supply the entire market.

We finally must consider the possibility of an equilibrium such that \( p_i > p_j = c \). But this is obviously not a Nash-equilibrium of the Bertrand game. Firm \( j \) increases profit by raising its price to \( p_j = p_i - \varepsilon \), transferring us to the already considered case where \( p_i > p_j > c \). So the only possible Nash-equilibrium is is \( p_i = c, i = (1, 2) \).

The main conclusion from the Bertrand game is that firms who act optimally will set their price equal to marginal cost and hence make zero profit. This corresponds to a social-optimal allocation. In this efficient market there will be no need for an institution like the Swedish Competition Authority. It is remarkable that even though there are only two firms, competition will drive price down to an efficient level. It is, however, hard to imagine this happening in actual markets, firms on oligopolistic markets.
are often able to use their market power in order to raise price over the competitive level. The next section will show that letting firms compete over time can have a such an effect on the equilibrium prices.

2.1.2 Bertrand supergame

The results from the previous section might not seem probable in actual markets. Switching focus to a supergame context will, however, extend firms ability to make non-zero profits.

We form a finite Bertrand supergame by replicating the one-shot Bertrand game $T + 1$ times. Letting $T$ be infinite, we get an infinite game. $\Pi_i(p_{it}, p_{jt})$ denotes firm $i$’s profit at date $t$, $t = (0, 1, ..., \infty)$ given the firms choice of prices at that date. Assuming that firms share the same discount factor $\delta$, each firm tries to maximize the present value of its profits:

$$\sum_{t=0}^{\infty} \delta^t \Pi_i(p_{it}, p_{jt}) \quad \text{for} \quad i = 1, 2. \quad (2.7)$$

The choice of price, $p_{it}$, at date $t$ depends on the prices chosen in earlier periods which is referred to as the history

$$H_t \equiv (p_{10}, p_{20}; ...; p_{1t−1}, p_{2t−1}). \quad (2.8)$$

A price strategy $\sigma_i$ for firm $i$ is a function that for every date $t$ and every possible history $H_t$ specifies a price $p_i$ at date $t$.

**Definition 2** A strategy pair $\sigma = (\sigma_1, \sigma_2)$ constitutes a subgame perfect Nash-equilibrium if it for each firm maximizes the present value of profits at every date $t$ and for every possible history $H_t$, given the other firm’s price strategy.

In contrast to the one-shot Betrand game described in the previous section, the supergame offers multiple equilibrium solutions. One obvious subgame perfect Nash-equilibrium is of course the one shot Nash-equilibrium, $(p_{1t}(H_t)), (p_{2t}(H_t)) = (c, c)$, charging price equal to marginal cost, $c$, in every period $t$, $t = (1, ..., \infty)$ regardless of history $H_t$. Using more complex
strategies will, however, generate subgame perfect Nash-equilibria, where firms make non-zero profits. Consider for example the following symmetric strategy commonly referred to as \textit{trigger}-strategy: Set price in period $t$ equal to monopoly price if both firms in every period preceding $t$ charged the monopoly price, otherwise set price equal to $c$ forever. These strategies will constitute a subgame perfect Nash-equilibrium of the Bertrand supergame if $\delta$ is sufficiently close to one. Using the Folk-theorem, it can be shown that any price pair $(p_1, p_2)$ with $p_1 = p_2 \geq c$ can make up a subgame perfect Nash-equilibrium using trigger strategies for $\delta$ sufficiently close to one.\footnote{See Gibbons [1992] for a complete description of the Folk-theorem.} By equation (2.5) it is easily seen that the firms can do no better than splitting the monopoly profit.

When firms interact repeatedly they will be able to tacitly collude and raise prices above the competitive level thereby creating an socially inefficient outcome. Contrarily to the one-shot game there will be a case for a competitive authority trying to increase competition among firms.

This analysis of the Bertrand game is standard and can be found in numerous textbooks, the framework is however needed for presenting the results found in McCutcheon’s article. In the next section we will extend the standard Bertrand game to include communication between firms. As we will discover, the cost of communication can have a dramatic effect on the set of equilibrium outcomes.

\section*{2.2 Bertrand game, Communication and Collusion}

The previous section implicitly assumes that firms cannot communicate with each other, which however is not a realistic assumption. The Swedish Competition Authorities has on numerous occasions proved that illegal communication has occurred between firms. McCutcheon [1997] uses the metaphor "meetings in smoke-filled rooms" in her headline to point out that meetings have to occur secretly and in the shadow of the law. In the following three subsections we describe, using different setups, how alternating the costs of communication affect firms strategic behavior.
2.2.1 Infinitely costly renegotiation

First McCutcheon [1997] asks what would happen if there were costless communications between the firms before the first period, but no communication during the actual game. The straightforward result follows from the discussion in section (2.1.2) - firms would agree to collude and set price equal to the monopoly price - thereby sharing the monopoly price at every date \( t \).

2.2.2 Costless renegotiation

The analysis of the previous section suggests that in absence of communication firms will collude and share the monopoly profit. In real life it is, however, hard to imagine a situation were firms would not have any possibility to meet once the initial agreement is done. Therefore it is relevant to examine what happens if firms have the possibility to communicate freely during the game.

If firms can renegotiate after one firm cheats on the agreement, the threat of competitive pricing might not be carried out. For example if firms play trigger strategies, cheating on the agreement leads to a competitive outcome in every succeeding period. But if firms believe that they are better off in collusive coalition they will try to renegotiate back to it, instead of playing the Pareto-inefficient competitive outcome.

There is a wide range of literature concerning renegotiation in supergames, see for example Bernheim and Ray [1989], Evans and Maskin [1989] and van Damme [1989]. Following McCutcheon [1997] we use the concept of weakly renegotiation-proof equilibrium (WRP) developed by Farell and Maskin [1989].

Before defining the WRP equilibrium we note that, for a price strategy \( \sigma \) with period-\( t \) prices \( (p_1, p_2) \), the price strategies for periods \( (t + 1, t + 2, \ldots, \infty) \) are referred to as continuation strategies, \( \sigma^c \). Given that \( \sigma \) is a subgame-perfect Nash-equilibrium, the continuation strategies, \( \sigma^c \) constitutes a continuation equilibrium. We define the set of one-period profits as

\[
V = \{ (v_1, v_2) \mid \exists (p_1, p_2) \text{ with } \Pi(p_1, p_2) = (v_1, v_2) \}. \tag{2.9}
\]

The minimax profits for firm \( i \),
\[ \min_{p_i} \max_{p_j} \Pi(p_i, p_j) \]

is the lowest profit that firm \( j \) can hold him to by any choice of \( p_j \), for \( i = (1, 2) \). We call any profit pair that Pareto dominate the minimax profits \textit{individually rational}. In the Bertrand game, the minimax profits are \((0, 0)\), so the set of feasible strictly individually rational profits is

\[ V^* = \{(v_1, v_2) \in V \mid v_1 > 0, \ v_2 > 0\} \quad (2.10) \]

Note also that we write the discounted future profits when firms use strategies \( \sigma \) as \( \Pi(\sigma) \).

\[ ^3 \]

\textbf{Definition 3} A subgame perfect equilibrium \( \sigma \) is \textit{weakly renegotiation-proof} if there do not exist continuation equilibria \( \sigma^1, \sigma^2 \) of \( \sigma \), such that neither strictly Pareto-dominates the other. If an equilibrium \( \sigma \) is WRP then we also say that the profits \( \Pi(\sigma) \) are WRP.

The main idea behind WRP equilibrium is as follows. Suppose that the two firms make an agreement, or contract, to play the game in a certain way, giving profits \((v_1, v_2)\) in every period. We assume that this agreement must be self-enforcing, i.e. it must at least be subgame-perfect. However, it should also be self-enforcing in a collective sense. The contract will need to specify what happens if one party violates the agreement. Defining the one period profits from this continuation equilibrium as \((\tilde{v}_1, \tilde{v}_2)\), it may be, for example, that the continuation equilibrium pair \((\tilde{v}_1, \tilde{v}_2)\) is Pareto-dominated by \((v_1, v_2)\). The two parties would then want to let bygones be bygones and renegotiate to the Pareto-superior continuation \((v_1, v_2)\). This argument would then establish that the original agreement is in fact not credible.

In the Bertrand supergame, the trigger strategy mentioned earlier cannot be supported as a WRP equilibrium, because the competitive continuation

\[ ^4 \text{Formally future profits also depend on the discount factor } \delta \text{ we will, however, ignore this in the notation.} \]
equilibrium will be Pareto-dominated by the collusive continuation equilibrium. If one firm cheats, both firms will earn zero profit in the following periods but by renegotiation they can set up the initial agreement and hence split the monopoly profit, which leaves both players better off.

In order to establish a formal discussion of WRP equilibria in the Bertrand supergame, we use the theoretical framework of Farrell and Maskin [1989]. Proposition 1 holds for a general class of games \( g : P_1 \times P_2 \rightarrow \mathbb{R}^2 \), with strictly individual rational profits, \( V^* \), as in (2.10).\(^4\) Before stating the proposition we let \( p^i = (p^i_1, p^i_2) \) be a pair of prices and define \( \gamma_i(p) \), as \( i \)'s cheating profit from the price pair \( p \).

Formally we let \[
\gamma_i(p) = \max_{p'_i} \Pi_i(p'_i, p_j)
\]
define \( i \)'s profit from his best response to \( j \)'s move \( p_j \).

**Proposition 1**\(^5\)

Let \( v = (v_1, v_2) \) be in \( V^* \). If there exists price pairs \( p^i = (p^i_1, p^i_2) \) \( (i = 1, 2) \) in \( g \) such that \( \gamma_i(p^i) < v_i \) while \( \Pi_j(p^i) \geq v_j \) for \( j \neq i \), then the profits \( (v_1, v_2) \) are WRP for all sufficiently large \( \delta < 1 \).

We sketch a proof for the pure strategy version of proposition 1. We first denote the prices, \( p^v = (p^v_1, p^v_2) \) with \( \Pi(p^v) = v \), as the normal phase. Next we need to construct renegotiation proof punishments to deter deviations from this normal phase.

If firm \( i \) deviates, the price pair \( p^i \) is played a suitable number of times before returning to the normal phase. In order to deter firm \( i \) from deviating, \( p^i \) must be played \( t \) periods, where \( t \) is the smallest positive integer satisfying:

\[
\gamma_i(p^v) + \delta \Pi_i(p^i) + \ldots + \delta^t \Pi_i(p^i) + \frac{\delta^{t+1}}{\delta^t(1-\delta)} \leq \frac{v}{(1-\delta)}, \tag{2.11}
\]

That is, firm \( i \)'s profits from deviating and thereafter taking the punishment must be less (or equal) to staying in the normal phase. Moreover firm \( i \) must be willing to stay in the punishment phase, which is the case if the following

\(^4\)E.g. the firms minimax profits are normalized to zero.

\(^5\)This corresponds to the first part of Theorem 1 in Farrell and Maskin [1989].
holds:

\[ \Pi_i(p^i) + \ldots + \delta^{t-1}\Pi_i(p^i) + \frac{\delta^t v}{(1 - \delta)} \geq \gamma_i(p^i) + \delta\Pi_i(p^i) + \ldots + \delta^t \Pi_i(p^i) + \frac{\delta^{t+1} v}{(1 - \delta)}. \]  

(2.12)

This equation simplifies to

\[ \Pi_i(p^i) + \delta^t v_i \geq \gamma_i(p^i) + \delta^t \Pi_i(p^i), \]  

(2.13)

which - since we have that \( v_i > \gamma_i(p^i) \) - holds for \( \delta \) sufficiently close to 1.

We can now define the equilibrium \( \sigma(v) \):

Play begins in the normal phase, in which firms sets prices equal to \( p^v = (p^v_1, p^v_2) \), with \( \Pi(p^v) = v \). If firm \( i \) deviates from the normal phase, the continuation equilibrium is "set price \( p^i \) for \( t \) periods, then return to the normal phase." If firm \( i \) cheats during the punishment, punishment begins again. If player \( j \) cheats during the punishment, then firm \( j \)'s punishment begins immediately. If both firms cheat simultaneously, firm 2 is punished.

The continuation equilibrium that follows if firm \( i \) deviates is not preferred to the normal phase by firm \( i \), but it is preferred by firm \( j \) since \( \Pi_j(p^i) \geq v_j \). Thus none of the continuation equilibrium of \( \sigma(v) \) strictly Pareto-dominates the other. The equilibrium \( \sigma(v) \) is therefore WRP for \( \delta \) sufficiently close to 1.

Farrell and Maskin [1989] argue that the unique WRP equilibrium in the Bertrand game is both firms setting price equal to marginal cost, \((p^*_1, p^*_2) = (c, c)\) at every date \( t \). Arriving at this conclusion requires a well defined cheating function \( \gamma_i(p) \), but in the case of the Bertrand game the cheating function \( \gamma_i(p) \) is discontinuous. Consider for example a situation where \( p = (p_i, p_j) = (\alpha, \alpha) \gg (c, c) \). Naturally firm \( i \) wants to undercut his opponent by setting the price slightly lower, e.g. \( p_i = \alpha - \varepsilon \) where \( \varepsilon \) is

---

\( ^6 \) If this equation holds it guarantees that it will not be optimal for firm \( i \) to deviate before the first period of the punishment phase. Cheating later on in the punishment phase will, however, be even less beneficial.
a small number. However, for every price $\alpha - \varepsilon$ that firm $i$ chooses, it is easily seen that $i$ can always do better by reducing $\varepsilon$ even more. Farrell and Maskin [1989] do not discuss this issue, but they implicitly define $\gamma(p)$ as

$$
\gamma_i(p) = \begin{cases} 
D(p_j)(p_j - c) & \text{if } p_j > c \\
0 & \text{if } p_j \leq c.
\end{cases}
\tag{2.14}
$$

Hence, firm $i$’s best response, $p_i^*(p_j)$ to his opponent’s price, $p_j$ is approximated as

$$
p_i^*(p_j) = \lim_{\varepsilon \to 0} p_j - \varepsilon = p_j
$$

In other words since firm $i$ can undercut his opponent by an arbitrary small number $\varepsilon$, it can set price infinitely close to $p_j$ and thereby firm $i$’s profits from deviating can be approximated as $D(p_j)(p_j - c)$.

First we note that, both firms setting price equal to marginal cost, $(p_1^*, p_2^*) = (c, c)$, in every period $t = (1, 2, ..., \infty)$ is a WRP since it has no continuation equilibria other than itself. Moreover the definition of $\gamma(p)$ in (2.11) enables us to conclude that this WRP equilibrium is unique.

To see this, assume that there exists a WRP equilibrium where $(v_1, v_2) \gg (0, 0)$, in order to sustain a WRP equilibrium of the type described above, we must find price-pairs $p^i = (p^i_1, p^i_2) \ (i = 1, 2)$ such that the following must hold

i) $\gamma_i(p^i) < v_i$ and $\Pi_j(p^i) \geq v_j, \quad i \neq j$

In other words $p^i$ must punish firm $i$ and still give firm $j$ profits greater or equal to $v_j$. In the Bertrand game, using the definition of $\gamma(p)$ in (2.14), firm $i$ can always undercut $j$’s price and thereby supply the whole market alone. Formally

ii) $\gamma_i(p) \geq \Pi_j(p)$.

Combining i) and ii) yields $v_i > \gamma_i(p^i) \geq \Pi_j(p^i) > v_j$ implying $v_i > v_j$, but by symmetry we also get $v_j > v_i$, hence a contradiction.

Thus the only equilibrium of this game is firms setting the competitive price in every period. Therefore McCutcheon [1997] argues that, in absence of antitrust laws, firms will not be able to collude, resulting in an efficient outcome.
Revision of assumptions

The concept of WRP equilibrium imposes, however, implicit assumptions that are open to questions. It assumes for instance that renegotiation is possible after every history. In particular this means that each firm believes that the other firm would renegotiate back to a cooperative outcome from which a deviation just occurred. The study of WRP might thus underestimate the importance of history in determining firms’ behavior in repeated games.

It is also important to examine the sensitivity of the result presented in the last section. Will small changes in the underlying assumptions affect the set of possible WRP equilibria? We argue that the result in the Bertrand context is in fact sensitive to changes in the set of prices, $P$. To illustrate this, consider the following version of the Bertrand game. Let $D(p) = 1$, $c = 0$ and $P = \{0, 1, \ldots, 9\}$, i.e. firms face constant demand, zero marginal cost and choose prices as any integer between 0 and 9. Using this setup it can be shown that any price pair $(p_1, p_2)$ with $p_1 = p_2 \geq 3$ constitutes a WRP equilibrium. Sharing the monopoly profit, $v = (4.5, 4.5)$, can now for example be sustained as an equilibrium using the following penance strategies: 

"Both firms set price $p = (9, 9)$, if firm 1 deviates they switch to a punishment phase where $p_1 = (9, 5)$, if instead firm 2 deviates they switch to $p_2^2 = (5, 9)$. In other words the deviating firm is required to punish itself one period by setting a price higher than his opponent. After the punishment phase they return to the cooperative phase, $p = (9, 9)$.” Using Proposition 1 it is easily verified that these strategies are WRP.

It is striking that this slight modification of $P$, will generate a different set of WRP equilibria. In fact, as soon as firm $i$ cannot undercut his opponent by an arbitrary small number, there is no longer a unique WRP equilibrium. In other words if $\varepsilon$ cannot be infinitely small, it might not be reasonable to approximate $\gamma(p)$ as in (2.14), and therefore the argumentation for uniqueness will thus no longer hold. Since all currencies display the above characteristics, i.e. there is a smallest unit, the critique is not far fetched. Considering actual markets, there may not be a unique WRP equilibrium, hence the predictions of McCutcheon [1997] concerning antitrust laws are questionable. In fact, using penance strategies firms can indeed maintain collusive agreements.
2.2.3 Costly renegotiation

With the occurrence of antitrust laws it is however not likely that communication can go on freely as assumed in the previous section. Antitrust laws put constraints on firms ability to meet, making communication costly. Building on the work of Blume [1994], McCutcheon [1997] shows that costly communication gives firms a possibility to collude. This somewhat counter-intuitive result builds on the assumption that firms meet once and set up an agreement.

Considering the Bertrand supergame, assume that firms agree to set the monopoly price and that cheating will be followed by setting price equal to marginal cost in enough periods to make the cost of cheating greater than the benefits from deviating. The number of periods $t$ of punishment is then given by the smallest positive integer such that

$$
\frac{\Pi_m/2}{1 - \delta} \geq \Pi_m + \frac{\delta^{t+1}\Pi_m/2}{1 - \delta}.
$$

(2.15)

After punishment the firms can go back to the collusive agreement, which is a subgame-perfect Nash-equilibrium, since the costs of cheating is greater than the benefits. With costless renegotiation this is however not a WRP equilibrium since the continuation equilibrium following cheating is Pareto-dominated by the collusive continuation equilibrium. Therefore, if any of the firms cheat, both firms will prefer to renegotiate back to the collusive phase instead of carrying out the punishment. But if renegotiation is costly this might not be the case. If the cost of renegotiation exceeds the cost of staying in the punishment phase, renegotiation is ruled out and the punishment is carried out. Formally, defining $k$ as the cost of renegotiation the following must hold:

$$
k \geq \Pi_m \frac{1}{2} \left( \frac{1 - \delta^t}{1 - \delta} \right).
$$

(2.16)

This raises the question how large $k$ must be in order to facilitate collusion. For example using $\delta = 0.9$ then the renegotiation cost $k$ must be at least $0.95\Pi_m$ to sustain collusion.
Thus, costly renegotiation can make the collusive equilibrium possible. Underlying the above analysis is that there is no other legal or non-legal mechanism for the firms to punish a firm that deviates from the collusive agreement.

2.3 The antitrust law and renegotiation

As Dufwenberg [2002] points out, it is not probable that the law is infallible, innocent people sometimes get convicted and vice versa. But the legal prerequisite to punish firms that try to agree on future prices might have a built-in opposite effect of what it was created to achieve, and it is set to do so every time. To see why consider the arguments in the previous sections on renegotiation. The costless setup corresponds to a market where the antitrust authority does not intervene. Here firms are able to communicate freely and will do so, trying to agree on acting as a monopoly. However the dynamics of the market will lead firms to renege on their agreements over and over, which leaves the zero-profit strategy of setting price equal to marginal cost as the only sustainable equilibrium. Remarkably the market is guided towards an efficient allocation without any restrictions from an antitrust authority.

If the antitrust authority infers a restriction on communication by making communication illegal the equilibrium outcome changes. When firms are contemplating to renege on any agreement it weighs in the cost of renegotiation, and since communication is illegal and there is a probability of getting caught, this cost might be substantial enough to outweigh the benefit of the alternative deviation. The firms will then choose to hold their agreement, charging a price above marginal cost and thereby making collusion work. Strikingly, the antitrust law that is set out to ensure competition among firms actually helps them to commit to price-fixing agreements.

An immediate consequence is that any legal prerequisite that hinder communication among firms should be removed from antitrust laws. However this conclusion builds solely on theoretical reasoning, and as noticed earlier, the behavioral assumptions sometimes seem to be counterintuitive. Moreover as we have shown, the result is sensitive to changes in the underlying assumptions. So before any antitrust authority make any drastic changes in their antitrust laws, and as Dufwenberg [2002] and Charness
and Dufwenberg [2003] point out, it is both necessary and interesting to test McCutcheon’s [1997] prediction against outcomes on actual markets. In chapter 3 we ask what method is the appropriate for the task of testing the predictions the theory.
Chapter 3

Methodology

This chapter is devoted to a discussion of the appropriate method for testing the theory presented in chapter 2. We start by giving a brief introduction to the use of experiments in economics. Thereafter we present the experimental setup and discuss some methodological issues concerning subject pools, incentives and communication. Finally we state the hypotheses.

3.1 Why use experiment?

Experiments play an increasingly important role in economic research. Economic theories, just like physics or any other branch of science are abstractions of the real world. Holt [1995] points out that the link between the abstraction and reality relies on both structural and behavioral assumptions. In game theoretic terminology the structural assumption determines the extensive form of the game whereas behavioral assumption determines the equilibrium concept. So in order for a theory to be useful, the structure of the game must correspond to reality and the equilibrium concept should be plausible.

In contrast to econometric studies, experiments do permit us to isolate the behavioral assumptions from the structural assumptions. By replicating the structure of the game, experiments can evaluate the internal workings of the theory. As Holt [1995] mentions, experiments may also be useful in testing the sensitivity of violations of the structural assumptions. Unfortunately experiments are less useful in testing whether the simplifying structural assumptions can be justified.

A main critique of the experimental method in economics is that the lab-
oratory environment hardly corresponds to the reality it tries to describe. The theoretic concepts are however general and should apply to the laboratory market just as well as any other market. If the theory does not make correct predictions about the outcome in a laboratory setting especially designed to fulfill the structural assumptions, how could we expect the predictions concerning the far more complex reality to be valid. Since our main focus is to investigate behavioral assumptions of the theory put forth in chapter 2 an experimental approach seems appropriate.

3.2 Experimental Design

In order to test the predictions laid out in chapter 2, we used the following variation of the Bertrand supergame: Demand $D(p) = 1$, marginal cost $c = 0$ and the set of possible price choices $P = \{p|p = [1,9]\}$. We conducted separate sessions for the following three treatments.

**Treatment 1 (T1) Zero-cost communication.**
Subjects were allowed to send messages free of cost. The theoretical prediction for this setup, as seen in chapter 2, is that subjects will not be able to sustain any agreement other than setting price equal to 1.

**Treatment 2 (T2) High-cost communication**
Subjects were allowed to send messages at the cost of 9. The cost was chosen using equation (2.16) guaranteeing it to be high enough to support collusive pricing.

**Treatment 3 (T3) Low-cost communication**
Subjects were allowed to send messages at the cost of 2. We used equation (2.16) to guarantee that this cost is too low to support collusive pricing.

In each treatment subjects were divided into two groups and placed in two separate rooms. Written instructions were handed out to all participants. Communication was allowed prior to each period, subjects were thereafter asked to choose a price between 1 and 9. Before the next period each par-

---

1 The interval was chosen in order to avoid natural focal points.
2 See appendix A for a translation of the written instructions.
3 Subjects wrote their choice on the price form, see appendix B.
participant was informed about the prices of the prior periods. In the following sections we discuss some important issues concerning the specifics of the experimental design.

3.2.1 Number of Repetitions

Cooperation in experimental games might change over time; it is therefore essential to not truncate treatment sequences before the behavior stabilizes. Too many repetitions might however lead the subjects into boredom, resulting in unreliable observations. Choosing the number of periods is therefore a trade-off. On one hand it is essential to let the participants learn the game but on the other hand is costly in terms of time and monetary incentives. Following Holt [1995] we concluded that the game should contain between 10-15 repetitions.

Since the game has an infinite horizon we also have to decide on which stopping rule to use. Using a computer we simulated the number of repetitions before conducting the experiment. In order to get useful data we randomly selected series, where the number of repetitions were close to the expected value $14\frac{1}{3}$, corresponding to $\delta = 0.925$. However, when conducting the actual experiment we miscalculated the time which forced us to end the experiment prematurely. But since all treatments were ended in this manner it should not affect outcomes.

3.2.2 Subjects

As noted in section 3.1, one line of arguments against the use of experiments in economics are that decision makers (typically students) are less sophisticated than the decision makers in the relevant natural environment. But apart from the already given theoretical argument that the equilibrium concepts are general, experimental evidence suggest that the behavior of experienced business people is not significantly different from that of college students. Our choice of subject pool - first year economics students - can therefore be motivated on theoretical ground as well as experimental evidence. The student were recruited by an oral invitation at the end of

\footnote{The number of periods follows a geometric distribution, the expected number of repetitions are calculated using $\frac{1}{1-\delta}$.}

\footnote{See for example Holt [1995].}
an introductory economics lecture. A total of 42 students played the three different treatments, with 7 pairs in each treatment.

3.2.3 Instructions

To perform a valid test of the theory is essential to have good instructions. We therefore spent hours on developing these instructions, making sure that they were brief and yet not lacking any important information. Using written instructions allowed us to keep information between treatments similar, which is essential when testing for differences in behavior. To avoid inducing behavior in accordance to social convention, we tried to steer clear of any words describing the actual variables being measured, e.g. we used "pick a number" instead of "pick a price". Holt [1995] points out that, for example, the word oligopoly can "give away" the purpose of the experiment and thereby rendering the data somewhat useless.

To convey if instructions were faulty or if any essential information was left out, we let other students read the instructions and then asked them to describe the game to us. Thereafter a pilot session with four subjects playing one of the treatments was conducted. This gave us an opportunity to see what questions arouse and how the actual experiment should be organized.

3.2.4 Incentives

As in most economic models, the equilibrium concepts used in chapter 2 assume that firms act in order to maximize profits. Constructing an experiment must therefore try to induce some financially based incentives onto the participants of the experiments. The conventional way of doing this is to pay the subjects according to their performance in the game. As Camerer and Hogarth [1999] point out, this convention among economist stands in contrast to the principle of not using financial awards used by psychologists. Luckily there is a great deal of research concerning the use of monetary incentives. This research suggests that the level effect of monetary incentives depends largely on what kind of task being studied. Camerer and Hogarth [1999] point out:

In the kinds of tasks economists are most interested in, like trading in markets, bargaining in games and choosing among gamb-

---

6See Camerer and Hogarth [1999] for an extensive survey of this literature.
bles, the overwhelming finding is that increased incentives do not change average behavior substantively (although the variance of responses often decreases).

Regarding the Bertrand game considered in our study, it seems therefore that the level of financial incentives should not substantively change behavior of the players.

It is also, as Holt [1995] argues, worth noting that the subjects expect to make money, and thus the behavior might become unreliable if subjects make zero- or very low profits. We therefore gave each participant a starting amount of 25 SEK, and then rewarded the payers according to the performance in the game. The rewards were calculated and distributed in anonymous envelopes at a lecture the following week.

### 3.3 Communication

It is important to pay special notice to the communication setup of the experiment since the theoretical predictions fundamentally depend on how firms are able to communicate. The laboratory setup allows us to isolate the effects of different costs of communication. Theory does, however, not give any guidance in what form the communication should take. Therefore we are faced with several options.

Communication can occur either face-to-face or via mail contact. We envision two types of effects from changing the mode of communication. First, we conjecture that face-to-face communication may be more realistic in trying to mitigate real-life situations of collusive behavior among subjects. Second, we posit that face-to-face communication can lead to a greater sense of community and hence leave stronger residual trails of cooperative behavior. Roth [1995] argues that letting subjects meet face-to-face induces a social preference since the subjects, after meeting each other have a group identity. This social preference may work in opposite direction of the explicit preference induced by the incentive payments of the experiment, rendering the gathered data somewhat useless to the experimenters. By letting communication take place through mail only, we believed that we would overcome the social preference issues.

---

7 At the time of the experiment 1 USD ≈ 8 SEK.
After choosing the mail communication we also had to decide what type of messages that were allowed to be sent. Two different modes were considered. First, we considered using restricted communication, only allowing participants to send labels with their price decision in the underlying game. This setup would allow us to focus on the actual agreement and not worrying about subjects being able to begin a social interaction. The second alternative was to let participants form their own messages and thereby allowing some social interaction. In using the first mode we would have had more strict control over preferences, but it would however taken us far from the market setup where communication between colluding firms is more complex.

Since the main purpose of the thesis is to test McCutcheon [1997] where firms are profit maximizing, we choose the restricted communication structure, thereby minimizing the risk of inducing social preferences. The participants were allowed to send pre-printed messages where they could signal their price strategy. Participants responded by indicating if they accepted or rejected the offer, see appendix B. It would have been optimal to let both participants send messages simultaneously, but since we were restricted by time, we randomly let one of the two begin communication in each period.

3.4 Exit-poll

In order to further investigate participants actual strategies and beliefs we constructed a questionnaire, which was handed out at the end of the session. The questions were meant to capture how beliefs are affected by strategy choices and vice versa.

3.5 Hypothesis

In order with the conclusions in chapter 2 our first hypothesis is that prices are equal in T1 and T3, but lower in T2. Moreover in our second hypothesis we conjecture that breach of contracts will be more frequent in T1 and T3 than in T2.

\footnote{See Dufwenberg and Charness [2003] for an examples of a study where players communicate using a free message setup.}

\footnote{See appendix C for a copy of the exit poll.}
Chapter 4

Results

In this chapter we present the experimental results, followed by an analysis of the findings.

4.1 Bids and Prices

Every pair of participants is considered as a separate market, where the price is determined by the lowest bid in each pair. In Figure 4.1 below, the prices for T1, zero-cost communication, are presented.

Figure 4.1: Prices, Treatment 1, Zero-cost Communication.
There seems to be no trend or convergence, and the varying prices indicate difficulties among pairs to sustain stable collusions. In fact, only one pair managed to sustain collusive pricing in the last period. Theory predicts that prices should be 1. The out-of-equilibrium results observed in Figure 4.1 is, however, not surprising, since these are accordance with earlier studies.\(^1\) Studying the actual price levels is therefore of little use. Instead we concentrate our analyze to differences between treatments.

The pattern changes dramatically when considering treatment 2, high-cost communication, Figure 4.2. Prices were higher than in treatment 1 in the first period and over time there seemed to be a convergence towards collusive pricing. In fact, in the last period all pairs charged the collusive price, 9.

\(^1\)See for example Dufwenberg and Gneezy [2000].
The results from treatment 3, low-cost communication, Figure 4.3, shows no clear pattern. Just by eye-balling the figure, it looks like something in between Figure 4.1 and Figure 4.2. In the last period we observe that prices were close to 9 in all markets except one. Yet prices seem somewhat less stable than in T2 indicating that an increase in the cost of communication tends to cause higher market prices.

Comparing the average bids and prices presented in Table 4.1 also indicates that the cost of communication seems to have an impact on prices. In fact, in exception of one period, average prices were lower in T1 than in T2. Moreover the gap increased during the session.

Table 4.1. Bids and prices.

<table>
<thead>
<tr>
<th>Period</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average bid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>7.41</td>
<td>7.96</td>
<td>7.73</td>
<td>7.09</td>
<td>6.78</td>
<td>6.21</td>
<td>7.89</td>
<td>7.06</td>
<td>5.38</td>
</tr>
<tr>
<td>T2</td>
<td>8.32</td>
<td>7.54</td>
<td>8.36</td>
<td>8.88</td>
<td>8.82</td>
<td>9.00</td>
<td>9.00</td>
<td>9.00</td>
<td>–</td>
</tr>
<tr>
<td>T3</td>
<td>7.51</td>
<td>7.35</td>
<td>7.75</td>
<td>7.81</td>
<td>8.93</td>
<td>8.36</td>
<td>8.21</td>
<td>7.74</td>
<td>8.05</td>
</tr>
<tr>
<td><strong>Average price</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>7.14</td>
<td>7.71</td>
<td>7.31</td>
<td>6.71</td>
<td>6.06</td>
<td>5.27</td>
<td>7.44</td>
<td>6.40</td>
<td>4.69</td>
</tr>
<tr>
<td>T2</td>
<td>7.64</td>
<td>6.28</td>
<td>7.71</td>
<td>8.75</td>
<td>8.64</td>
<td>9.00</td>
<td>9.00</td>
<td>9.00</td>
<td>–</td>
</tr>
<tr>
<td>T3</td>
<td>6.64</td>
<td>7.07</td>
<td>7.50</td>
<td>7.13</td>
<td>8.86</td>
<td>8.14</td>
<td>8.00</td>
<td>7.41</td>
<td>7.83</td>
</tr>
</tbody>
</table>
The results presented in Table 4.1 indicate differences in prices between treatments, thus giving some support for our first hypothesis. In section (4.3), we will use statistical methods to test if these differences are significant.

4.2 Messages and Contracts

As noted in the previous section prices in the different treatments are apparently affected by the communication cost. We therefore turn to describing communication and contractual agreements among participants. In Table 4.2 we present some key results from the communication during the game. Not surprisingly the number of messages decreases as the cost of communication rises. But we conjecture that the important issue here is not the number of messages, but rather the stability of contracts.

A pair of subjects is considered to have a contract in the present period if one of the subjects have proposed a price by sending a message. Moreover, they are also considered to have a contract if they have an agreement from a previous period, from which no deviation has occurred. From Table 4.2 it is evident that there is no clear difference in the number of contracts between treatments. Remarkably, this implies that putting a strain on communication does not affect the number of contracts in each period.

Subjects are considered to cheat on a contract whenever they deviate from the type of contractual agreement described above. Table 4.2 indicates that subjects are more likely to cheat on contracts in the zero-cost treatment. This in turn explains why the number of contracts is equal between treatments, while the number of messages is much higher in T1. The pattern is more evident in the cheating ratios i.e. the percentage of contracts that was cheated on in each period. For T2 the cheating ratio is 0 percent in most cases while for T1 it is almost always above 30 percent. This gives some support for our second hypothesis that breaches on contract ought to be more frequent in T1 than T2. However, T3 seems to correspond better to behavior in T2 than in T1.
Table 4.2. Messages and contracts.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of messages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>11</td>
<td>8</td>
<td>7</td>
<td>14</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>T2</td>
<td>11</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>T3</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Number of contracts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>–</td>
</tr>
<tr>
<td>T3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Cheating on contract</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>T2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>T3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Cheating ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>40%</td>
<td>17%</td>
<td>33%</td>
<td>50%</td>
<td>60%</td>
<td>80%</td>
<td>57%</td>
<td>80%</td>
<td>75%</td>
</tr>
<tr>
<td>T2</td>
<td>29%</td>
<td>20%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>17%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>T3</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>0%</td>
<td>29%</td>
<td>0%</td>
<td>17%</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

It is also illustrating to compare the length of contracts, therefore we calculated how long, on average, a contract lasted in the different treatments. This gives us an approximative measure of the stability in contracts.

*Average length of contracts:*

- **T1:** 1.07
- **T2:** 4.18
- **T3:** 3.06

Once again, there is a evident difference between the zero-cost treatment and the costly treatments. There is, however, no clear cut difference between the length of contracts in the two costly treatments. These findings give strong support for the theory, since with costless renegotiation participants did not commit to the contracts. As predicted in section 2.2.2, participants continuously cheated on their agreements and tried to renegotiate back. Similar conclusions can be drawn when studying the results from the exit-poll summarized in *Table 4.3*. 
Table 4.3. Trust and renegotiation

<table>
<thead>
<tr>
<th>Answer:</th>
<th>Yes</th>
<th>No</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you trust your opponent’s messages?*</td>
<td>T1 6 5 3</td>
<td>T2 11 2 1</td>
<td>T3 11 1 2</td>
</tr>
<tr>
<td>Do you believe that your opponent trusted you?*</td>
<td>T1 8 4 2</td>
<td>T2 11 2 1</td>
<td>T3 11 2 1</td>
</tr>
<tr>
<td>If you are cheated on, would you consider to agree on a new contract?*</td>
<td>T1 8 5 1</td>
<td>T2 8 6 0</td>
<td>T3 9 3 2</td>
</tr>
</tbody>
</table>

* See appendix C for the complete exit-poll.

The answers from the first question indicate that the level of trust in the opponent is much lower in T1 than T2 and T3. The same pattern is observed for the second question. These answers are naturally affected by each pairs’ price history, therefore the lower level of trust is partly a reflection of the outcome of the game. In the third question we can not see any clear differences, but this result might be affected by the price of communication. That is, since communication is costless in T1, subjects are more likely to agree even if their attention is to deviate.

In conclusion, inferring a cost of communication does lower the number of messages, but more importantly it seems to increase the stability of contracts.

4.3 Statistical analysis

In order to test our first hypothesis we calculated the average price for each pair.\(^2\) We used the Kruskal-Wallis test to examine if prices in the different treatments were drawn from the same population.\(^3\)

\(^2\)Using average prices is not unproblematic, since the observations should be independent of the history. Average prices do depend on the history. We will, however, assume independency in order to be able to compare prices between treatments.

\(^3\)A description of the statistical methods is found in Mittelhammer [1996].
\( H_0 \): Prices were drawn from the same population.
\( H_1 \): Prices are not drawn from the same population.

Kruskal-Wallis test statistic: 6.73
Critical value at the 5% level: 5.99

By rejecting the null hypothesis at the 5% level, we conclude that there are differences in prices among treatments. In order to investigate these differences closer, we now turn to comparing the treatments pairwise using the Wilcoxon-Mann-Whitney test.

Since we suspect that prices in T1 are lower than T2 and T3 we do one-sided tests for differences. We start by comparing the prices of T1 and T2.

\( H_0 \): There are no differences in prices between T1 and T2.
\( H_1 \): Prices in T1 are lower than prices in T2.

Mann-Whitney test statistic: 33
Critical value at the 1% level: 34

We reject the null hypothesis at the 1% level. As predicted by the theory presented in chapter 2, prices are lower in T1 than in T2. Hence, costly communication seems to enhance cooperation. Theoretically this holds only for high-cost communication, it is therefore interesting to examine if low-cost communication has the same effect. We therefore compare the prices of T1 and T2.

\( H_0 \): There are no differences in prices between T1 and T3.
\( H_1 \): Prices in T1 are lower than prices in T3.

Mann-Whitney test statistic: 39
Critical value at the 5% level: 39

We reject the null hypothesis at the 5% level. Prices are lower in T1 than in T3. This result is not predicted by theory, since the cost is theoretically too low to sustain collusion. Following this result we also compare prices
between T2 and T3.

\[ H_0: \text{There are no differences in prices between T2 and T3.} \]
\[ H_1: \text{Prices in T2 are lower than prices in T3.} \]

Mann-Whitney test statistic: 46
Critical value at the 5% level: 39

We can not reject the null hypothesis that prices are equal in T2 and T3. Whether the communication cost is high or low does not seem to affect prices.

4.4 Summary

The experimental results point out that costly communication results in more stable agreements, leading to higher prices. This provides support for the predictions of McCutcheon [1997].

The results indicate that costly communication helps firms to sustain price fixing agreements, causing higher prices. That is, prohibiting collusive agreements among firms may actually make collusion more probable. Our inability to find significant differences between the price levels in the T2 and T3 leads us, however, to suspect that behavior is not fully captured by the theory. Overall, the results from T3 seem to correspond better to T2 than to T1. Therefore we conjecture that the existence of a communication cost is of greater importance than the actual level. Studying the open answers in the exit-polls gives us some directions to what might be the cause of this phenomena. Costly communication seems to impose a commitment to play in accordance to the agreement. Furthermore, giving up some short-run profits makes the opponent believe the contents of the message. The cost seems thus to change beliefs, and messages is no longer seen only as cheap talk.

Answers from the exit-poll indicate that deviations deteriorate possibilities to establish future agreements, i.e. it takes time to build trust. Thus, the WRP equilibrium seems to underestimate the importance of history. Subjects that are cheated on are not eager on letting bygones be bygones, hence making deviations more costly than predicted by theory.
Chapter 5

Conclusions

Summarizing the experimental findings we conclude that costly communication results in a higher price level. Moreover, making communication costly decreases the number of messages, but more importantly, it enhances the stability of collusive agreements. These results have some important implications for actual market outcomes and antitrust policies. The experimental evidence suggests that antitrust laws may be ineffective, or even counter-productive, in stopping firms from colluding.

The experimental results coincide with the theoretical work by Mccutcheon [1997]. The fact that prices are higher even at low-cost communication is, however, not supported by theory. This indicates that there might be behavior not captured by the theory presented in chapter 2. Therefore, future research should try to incorporate these findings in the theory. Moreover, we showed that the theory is sensitive to changes in the assumptions, which casts a doubt of the theory’s validity.

Since this study is a first we are not eager on drawing any general conclusions for antitrust policy. However, the experimental results point out that Antitrust authorities might be using the wrong prerequisite thereby lowering social efficiency. Our specific setup builds on fairly strict assumptions of homogenous goods, duopoly markets and perfect information of demand. Varying these assumptions might, however, lead to different conclusions. In fact Dufwenberg and Gneezy [2000] shows that increasing the number of competitors have a lowering effect on prices. Moreover results from Feinberg and Snyder [2002] indicate that varying information also affects prices. Future research needs to explore the sensitivity of our results in order to address the question of what prerequisite tomorrow’s antitrust laws should
build on.
References


Appendix A

Instructions

This is a translation of the actual instructions which were written in Swedish to avoid misunderstandings in the experiment. We have tried to make the translation as direct as possible, but in order to get the grammar right some differences are unavoidable. The part that differs between the zero-cost and the costly setup are emphasized.

General instructions

This is an experiment about decisions in markets. It is important that you do not talk to other participants during the actual experiment, and any questions that occur should be addressed to the experimenters. Before the experiment begins there will be given time to ask questions to the experimenters. It is important that you understand the structure of the experiment, therefore it is important that you read the instructions thoroughly so that no uncertainty, regarding the experiment, remains. All participants are divided into two groups which in turn are placed in two different rooms. Every player is assigned an ID-number, yours is located on your bench. You will be paired with a participant from the other room and the two of you will repeatedly play the game described below.

The game

You and your opponent will be asked to choose a number between 1 and 9 (decimal numbers are allowed). You write down your choice, in each period, on the yellow form.
• If you choose a number which is higher than your opponent you will earn 0 SEK this period.

• If you choose a number which is lower than your opponent you will earn as much as the number you chose.

• If you and your opponent choose the same number then you will split the value of the number you chose.

For example: If you choose 3 and your opponent chooses 5 then you earn 3 SEK and your opponent 0 SEK. If both of you choose the number 7 then you will earn 3.5 SEK each.

After you and your opponent have chosen your numbers a new period will begin with 92.5% probability. That is, there is a 7.5% chance that the game will end after each period. The experimenter will inform you if the game will proceed another period and what number your opponent chose. Your final earning will consist of a starting-amount of 25 SEK and the winnings from all periods.

Messages
Before each period you and your opponent will be given the opportunity to send a message. Which of you who will be able to send this message is decided randomly each period. In the message you can agree on selecting the same number and thereby splitting the value of the number you chose. If you want to send a message, write your choice of number on the white form otherwise put a cross in the “no message” square. The experimenter will collect the form and deliver them to your opponent. On the same form your opponent will indicate if she/he agrees or not, the form will then be returned to you. Note that the message is not binding, that is, you are not obliged to chose the same number as you write/agree on in the message. It will cost you 9(2) SEK to send a message. It will also cost 9(2) SEK to reply on a message. The experimenter will register if you send a message and deduct the fee from your final earnings. After the message have been sent and returned you make your choice of number.
Appendix B

Message and Price forms

This is a translation of the message and price forms.

B.1 Message form

<table>
<thead>
<tr>
<th>Period X</th>
<th></th>
</tr>
</thead>
</table>
| ID-number: ........ | No message □ or  
|          | I consider ...... to be an appropriate number. |
| ID-number: ........ | No message □ or  
|          | I agree: □  
|          | I do not agree: □ |

B.2 Price form (Yellow form)

<table>
<thead>
<tr>
<th></th>
<th>Your ID-number: ........</th>
<th>Your opponents ID-number:........</th>
</tr>
</thead>
<tbody>
<tr>
<td>You fill in this column</td>
<td>The experimenter fills in this column</td>
<td></td>
</tr>
<tr>
<td>Period: 1</td>
<td>My choice........</td>
<td>My opponents choice........</td>
</tr>
<tr>
<td>Period: 2</td>
<td>My choice........</td>
<td>My opponents choice........</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Period: 20</td>
<td>My choice........</td>
<td>My opponents choice........</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td>.</td>
</tr>
</tbody>
</table>
Appendix C

Exit Poll

ID-number:.........................
Sex: □ female  □ male

Question 1. Did you have any particular strategy during the game? If yes, describe it.
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................

Question 2. Did you trust that your opponent would choose the number she / he suggested in her / his messages?
...........................................................................................................................................
Why / Why not ?
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
...........................................................................................................................................
Question 3. Do you believe that your opponent did trust that you would choose the numbers that you suggested in your messages?

..........................................................................................................................................................
Why / Why not?
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
If you and your opponent did agree to choose the same number and shared profits, why didn’t you choose a smaller number in order to get all profits alone?
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
If your opponent didn’t keep his word, would you consider agreeing on a new message from your opponent?
..........................................................................................................................................................
Why / Why not?
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................