An Experiment on Partial Cross-Ownership in Oligopolistic Markets

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Abstract

We examine coordinated and unilateral effects of horizontal partial cross-ownership (PCO) in a laboratory experiment. Firms have symmetric, non-controlling shares of each other in a static and a dynamic Bertrand setting. The data of the dynamic game confirm the theoretical prediction and show that firms are more collusive with PCO than without. Average prices are consequently higher. In the static game, firms do not coordinate on the monopoly price but behave less competitively by charging higher average prices with increasing PCO. While standard theoretical predictions are still "no-collusion Nash prices", models assuming bounded rationality show that firms’ incentive to compete are reduced with passive PCO and predict the observed higher average prices very well. We conclude that collusion can add to the unilateral anti-competitive effects of PCO but is not necessary to observe higher prices. Our paper therefore underlines the negative effect of PCO for consumers and its importance for competition policy.

JEL Classification: L13 L41, C90, D90
Keywords: Collusion, Antitrust, Minority Shareholdings, Passive Partial Ownership, Experimental Economics, Bounded Rationality, Quantal Response Equilibrium

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1 Introduction

The European Commission is currently discussing a stricter regulation of non-controlling minority shareholdings (European Commission, 2014, 2016) and expressed concerns about associated anti-competitive effects of this issue already in previous merger cases (e.g. European Commission (2013)). This includes but is not limited to partial cross-ownership in horizontal markets, where direct competitors acquire stakes in each other.\textsuperscript{1}

Previous theoretical research on passive partial cross-ownership in horizontal markets has shown that it may favor both coordinated and unilateral anti-competitive effects. Gilo, Moshe, and Spiegel (2006) show that the critical discount factor for tacit collusion decreases with the degree of passive partial cross-ownership in a repeated Bertrand model. Similarly, Flath (1992) reports that unilateral effects may arise in the context of static Cournot models, i.e. prices may rise even though the acquiring firm does not gain any control over the target. While unilateral effects of passive partial cross-ownership have been shown empirically for a selection of markets (Brito, Ribeiro, and Vasconcelos, 2014; Dietzenbacher, Smid, and Volkerink, 2000; Nain and Wang, 2016), there is no empirical research that considers coordinated effects in such setting.

We contribute to this literature by analyzing the anti-competitive effects of passive partial cross-ownership (PCO) in horizontal industries with homogeneous price competition in a laboratory experiment and separate these effects from each other. We use the model by Gilo et al. (2006) in its simplest mode as basis, i.e. we consider a Bertrand game with two firms, producing a homogeneous good at zero marginal costs. We then vary the degree of symmetric shares firms have of each other per treatment. All degrees of cross-ownership are considered in a static and a repeated-game framework which enables us to make ceteris paribus comparisons and clearly distinguish between unilateral and coordinated effects. Using an laboratory experiment, we can also eliminate any confounding effects of common-ownership, communication or control rights, which appears to be a challenging task in practice. The minority shareholdings in our setup are only hold by rivals and are truly passive in that the acquiring firms exert zero control over the target’s pricing decisions and have only cash flow rights.\textsuperscript{2} Further, the separation of tacit and explicit collusion may be problematic for field data but not in the experiment as there are no means to communicate.\textsuperscript{3} To our best knowledge, we are the first to examine the impact of horizontal passive partial cross-ownership in oligopolistic markets experimentally.

We find strong evidence that partial cross-ownership may induce substantial price increases which go above and beyond the theoretical predictions. This applies to both,\textsuperscript{4}

\footnotesize{\textsuperscript{1}We distinguish here from common-ownership, where, for example, a financial investor acquires stakes in several competing firms. Both cases are highly relevant in real markets and can occur separately or simultaneously. For example, Azar, Raina, and Schmalz (2016) examine the effects of passive investments by competitors and common institutional investors on competition in the U.S. banking sector.\textsuperscript{2}In practice, even minority shareholdings may often provide some control to the acquiring firm since it may gain board seats or the like. Further, common- and cross-ownership are often mixed in a complex network of stakes.\textsuperscript{3}minority shareholdings may open new communication channels, e.g. in joint ventures, see also literature on semi-collusion.}
coordinated effects in the repeated game and unilateral effects in the static game. For
the repeated game, we find that the average selling prices\(^4\) are significantly positively
correlated with the degree of PCO. We also find evidence that this increase in prices
is driven by collusive behavior. The higher the degree of PCO, the higher the share of
duopolies which coordinate on the maximum price. The results for the repeated game
are at the same time consistent with economic theory and exceeding the theoretical
predictions. Theory predicts that tacit collusion is more often sustainable if the degree of
PCO increases since the critical discount factor decreases with the degree of PCO.\(^5\) This
is due to the fact that the incentives to deviate decrease. A benevolent interpretation is
that collusion gets easier for higher mutual shareholdings and that the observed patterns
are consistent with this. However, in the experiments, subjects’ discount factor is fixed
and allows for fully collusive behavior in all treatments including the one with zero partial
cross-ownership. Consequently, the set of subgame-perfect equilibria is identical across
all treatments in the repeated game and the decrease of the critical discount factor does
not necessarily lower the bar for collusion. The data show that the reduced incentive to
deviate stabilizes collusive agreements or enables them in the first place.

In the static game we observe a similar yet more attenuated pattern. There is a
significantly positive correlation between average selling prices and the degree of PCO. As
expected, this price increase is not driven by collusive behavior as subjects virtually never
coordinate on the maximum price. Instead, they choose prices less aggressively such
that the distribution of prices shifts to the right as the mutual shareholdings increase.
This price increase in the static game is inconsistent with standard economic theory.
The Nash prediction is that behavior in the static game should be unaffected by the
degree of PCO since firms have an incentive to undercut their rivals for any degree
of PCO. Hence, the Nash equilibrium is unchanged and prices should equal marginal
costs in all treatments. However, Nash equilibrium does not account for the fact that
a players’ incentives to undercut their rival is smaller the higher the degree of PCO.
In other words, partial cross-ownership reduces the losses players make when they fail
to undercut their competitors. In contrast to standard game theory, behavioral game
theory can account for such aspects. The patterns observed in the experiment are
predicted well by behavioral models such as Quantal Response Equilibrium (McKelvey
and Palfrey, 1995).

We conclude that PCO reduces the incentives to compete and favors unilateral effects
that result in higher average prices. Collusion, facilitated by PCO, can increase these
unilateral effects but it not necessary for higher prices in this setup. Hence, the experi-
mental data show negative repercussions of passive minority shareholdings for consumers
and its importance for competition policy.

The remainder of this paper is structured as follows. Section 2 summarizes the
related literature, the model we base our experiment on in presented in Section 3. The
predictions from QRE are derived in Section 4. Section 5 gives an overview of our

\(^4\)The term “selling price” refers to the minimum price of either firm in a period.

\(^5\)Gilo et al. (2006), p.84: “[I]t widen[s] the set of discount factors for which the fully collusive scheme
can be sustained”
experimental design and procedures. In Section 6 we derive our hypotheses from theory and its implementation in our experiment. The results are shown in Section 7. Section 8 concludes.

2 Related literature

The present paper connects to several streams of the literature concerned with horizontal minority shareholdings which is summarized in the following section. One important distinction in literature is made between controlling and non-controlling minority shareholdings and its implications are of importance from an economic but also from an antitrust point of view. In general, the anti-competitive effects of a partial acquisition where the acquiring firm obtains at least some control over the pricing decision of the target firm could be larger than without control (O’Brien and Salop, 1999). Assuming firms are able to obtain effective corporate control over all pricing decisions through voting stocks, Foros, Kind, and Shaffer (2011) show that partial ownership could result in even less competitive outcomes than a full merger since firms may increase their price above the price which would maximize joint profits and reduce competition even more (than under a full merger). Brito, Cabral, and Vasconcelos (2010) shed further light on the differences between voting shares and non-voting shares and conclude, that it does not matter if firms acquire a minority or majority share, as only the voting rights are crucial for the outcome. Stühmeier (2016) argues that the total effect on competition depends on both the financial stake and the level of corporate control of the acquiring firm in the target.

Most national competition authorities in Europe as well as the European Commission (EC) itself have a handle on partial acquisitions among horizontally or vertically related firms if a change in control occurs. However, under current legislation competition authorities in most jurisdictions cannot intervene when passive or non-controlling stakes of a company are acquired. In some countries like Austria, Canada, Germany, Japan, USA and UK acquisition of non-controlling minority shareholdings is subject to merger control at a certain (high) threshold (compare European Commission, 2014). In the U.S., passive minority investments have gone unchallenged or granted an exemption many times (Gilo, 2000).

We focus on passive ownership, as with passive stakes the investing firm has only financial interest and cannot influence important parameters of competition (e.g. the pricing decision). This is, in our opinion, the simplest case and should have the weakest effects on competition. Considering the literature, we expect our results to be more pronounced if mutual shareholdings would come with a certain degree of control.

Another distinction is made between the actual effects on competition from partial ownership. They are roughly divided into unilateral effects such that firms increase prices and coordinated effects such that tacit collusion is more often sustainable.

Unilateral anti-competitive effects of passive cross-ownership have been analyzed in a static model of quantity (oligopoly) competition by Reynolds and Snapp (1986), Farrell and Shapiro (1990) and Flath (1992). They find that as the degree of cross-
ownership among competitors increases, competition is softer than in a perfectly competitive market and production levels fall toward the monopoly outcome because of firms’ financial interests in their competitors. In Bertrand markets, it has been shown that cross-ownership induces firms with interests in their competitors to set higher prices (Flath, 1991; Dietzenbacher et al., 2000). Shelegia and Spiegel (2012) find that price levels can be up to the monopoly outcome since firms internalize some of the competitive externality they exert on the other firms in the market.

Coordinated anti-competitive effects of passive cross-ownership have been analyzed as well. Malueg (1992) analyses collusion between firms with passive partial ownership in a dynamic symmetric Cournot model and stretches the importance of the demand function that enables sustainable collusion. Gilo et al. (2006) consider coordinated anti-competitive effects of partial cross-ownership in a repeated Bertrand game. In this setup, higher partial ownership never hinders tacit collusion. However they cannot observe unilateral effects since the best response of all firms is always independent of the degree of partial cross-ownership - a prediction we will look at in more detail.

The empirical research on partial cross-ownership in horizontal markets confirmed previous predictions from theory and showed anti-competitive effects in different industries but do not distinguish the effects or consider controlling minority shareholdings. Brito et al. (2014) estimate specifically unilateral effects of passive partial cross-ownership in the wet shaving industry and find higher prices. Other authors find an increased price-cost margin in the respective investigated industry, e.g. Dietzenbacher et al. (2000) for the Dutch financial sector or Nain and Wang (2016) in U.S. manufacturing industries due to partial cross-ownership.

Coordinated effects have been examined only in studies that do not distinguish controlling and non-controlling shares. Alley (1997) find anti-competitive effects of partial cross-ownership in the Japanese and US automobile industries but include active shares. They also cannot exclude possible information flows. Parker and Röller (1997) consider the U.S. cell phone industry and find higher prices for companies that are related through joint-ventures. Trivieri (2007) confirm former results with data of the Italian banking industry and show that firms with cross-ownership are less competitive than firms without these ties. They also do not separate active from passive shares. Heim, Hüscherlath, Laitenberger, and Spiegel (2017) conduct an analysis of partial acquisition over all industries in 63 countries. They find that partial cross-ownership may function as a tool to stabilize collusive agreements but do not differentiate between active and passive minority shareholdings either.

We look specifically at truly passive partial cross-ownership and its unilateral and coordinated effects.

3 The Model

In this section, we briefly present the simple version of the model by Gilo et al. (2006) which we use in the experiments. See Gilo et al. (2006) for more details and for the general model. The starting point is standard Bertrand game with $n = 2$ symmetric
firms. All firms produce the same homogeneous product at zero marginal costs. Each firm can supply the entire market. Firms set their prices simultaneously at the beginning of every period. Demand $Q(p)$ consists of 100 consumers who buy at the lowest price only. If more than one firm set the lowest price, the demand is split equally between these firms. The profits from the standard Bertrand game without any cross-ownership is referred to as “product-market profits” and denoted by $\hat{\pi}_i$.

$$\hat{\pi}_i(p_i, p_j) = \begin{cases} 100 \cdot p_i & \text{if } p_i < p_j \\ 50 \cdot p_i & \text{if } p_i = p_j \\ 0 & \text{if } p_i > p_j \end{cases}$$

Gilo et al. (2006) introduce the concept of “accounting profits” to adequately model partial cross-ownership. The accounting profits consists of the product market profits plus dividends from the firms they have shares of. In the general model, cross-ownership is specified using an ownership matrix. However, in our simplified version, we only consider symmetric duopolies such that a single parameter $\alpha$ is sufficient. In our version, $\alpha$ defines the share of firm $i$ that belongs to firm $j$ and vice versa. The resulting accounting profits are defined by a system of equations of the form $\tilde{\pi}_i = \hat{\pi}_i + \alpha \cdot \tilde{\pi}_j$ with the solution $\tilde{\pi}_i = (\hat{\pi}_i + \alpha \cdot \hat{\pi}_j)/(1 - \alpha^2)$.

There are several aspects which are worth noting about the accounting profits. In what follows, we will briefly comment on two aspects: the intuition for introducing accounting profits, and a small modification we introduce to avoid confusion among subjects in the experiment.

The reason for introducing accounting profits is that relying solely on the product market profits would not adequately capture partial cross-ownership. Consider, for example, a standard Bertrand outcome with $\hat{\pi}_i = 1000$ and $\hat{\pi}_j = 0$ and assume that either firm owns 20% of its rival. If the dividend payments are calculated using only the product-market profits, firm $i$ would get final profits of 800 and firm $j$ would get final profits of 200. Given the final profits, the dividend paid by firm $i$ is too high ($0.2 \cdot 800 < 200$) and firm $j$ pays zero dividends even though it realizes positive profits. The concept of the accounting profits ensures that the dividend payments are in line with the final profits.

We use a small modification of the model to avoid confusion among the participants. The sum of the accounting profits as defined above will typically exceed the sum of the product-market profits. While this is unproblematic in the context of theoretical analyses, it may appear unintuitive and confusing to the participants of a laboratory experiment. Thus, we use a linear transformation of the accounting profits to align the aggregate final profits to the aggregate product-market profits. The transformation does not change the theoretical predictions in any way. It may be interpreted to result in the “profits of the real owners” of the firm. That means that the final profits only comprise the share of the accounting profits which is not paid out as a dividend. Technically, we have $\pi_i = (1 - \alpha)\tilde{\pi}_i$. The profits functions used in the experiment are therefore given by

$$\pi_i = \frac{\tilde{\pi}_i + \alpha \cdot \tilde{\pi}_j}{1 + \alpha}$$
Static Game Equilibrium

We can see from the formula above that the static Bertrand equilibrium is unaffected by minority shareholdings. Since $0 \leq \alpha < 1$, the accounting profit is more sensitive to changes in the own product-market payoffs compared to the product-market payoffs of the other firm. Hence, chosen prices do not depend on $\alpha$. Put differently, equilibrium prices are identical to the model without partial cross-ownership. Prices will equal marginal costs ($p = 0$) for any $\alpha < 1$ even if the shares approach 100%. The firms are consequently making zero profits in equilibrium.

Note that this result is also true for a model where firms maximize the accounting profits and not just the profits of the real shareholders. The derivative w.r.t. the own product-market payoff is still steeper than the one w.r.t. to the other product-market payoff.

Infinitely-repeated Game Equilibrium

Let $\pi_i^C$ and $\pi_i^D$ denote the final profits from collusion and from deviation, respectively. In general, collusion in a sense that all firms charge some price $p^C$ exceeding marginal costs may be implemented as a subgame-perfect equilibrium of the infinitely repeated Bertrand game if the intertemporal discount factor $\delta$ is sufficiently high (compare Tirole, 1988, Ch. 6.3.2.1). Since firms make zero profits in the Nash equilibrium of the stage game, the condition for collusion to be sustainable is

$$\frac{\pi_i^C}{1 - \delta_i} \geq \pi_i^D \quad \text{or} \quad \delta_i \geq \hat{\delta} = 1 - \frac{\pi_i^C}{\pi_i^D} \quad \forall \ i \in \{i, j\}$$

If $\hat{\pi}^C$ denotes the collusive payoff on the product-market, we get the final profits $\pi_i^C = \hat{\pi}^C / 2$ and $\pi_i^D = \hat{\pi}^C / (1 + \alpha)$ for collusion and defection, respectively. Substituting these into the expression for the critical discount factor yields the following condition for Nash reversion:

$$\hat{\delta} = \frac{1 - \alpha}{2}$$

As we can see from the formula, the intertemporal discount factor $\delta$ gets lower the higher the degree of partial cross-ownership $\alpha$ is, i.e. collusion gets "easier" with a higher stake. Again, this result is independent of the question whether firms maximize their accounting profits or the net payoffs of the real shareholders.

4 Quantal Response Equilibrium

Nash equilibrium predictions are strict and usually not accurate for experimental Bertrand markets. We make predictions of the impact of PCO on chosen prices using quantal response equilibrium (QRE) to incorporate realistic limitations of participants (bounded rationality) in our equilibrium analysis which bases on rational choice modeling. QRE is a generalization of Nash equilibrium where players are assumed to make errors in
their decisions. It is defined by the following system of equations (one equation per pure strategy/price).

\[ \sigma^i_j = \frac{e^{\lambda \pi^i_j(\sigma)}}{\sum_{s_i \in S_i} e^{\lambda \pi^i_k(\sigma)}} \]

In the equation, \( \sigma^i_j \) denotes the probability that player \( i \) chooses the \( j \)th pure strategy. Player \( i \)'s expected profits from choosing the \( j \)th strategy are denoted by \( \pi^i_j \). The model also has one free parameter \( \lambda \) which captures the amount of noise in players’ behavior. For \( \lambda = 0 \), the chosen prices are purely random regardless of their expected payoff. In contrast, QRE will approach a Nash equilibrium as \( \lambda \to \infty \).

Partial cross-ownership changes the payoff structure in a way that does not affect the standard Nash prediction but has an impact on the QRE predictions. To derive behavioral predictions for the static game, we solve the system using the parameters from the experiment. This implies 101 pure strategies representing integer prices between zero and 100 and four different degrees of partial cross-ownership. To solve the system, we follow the homotopy approach described in Turocy (2005) using a transformation from Turocy (2010).

Figure 1 illustrates the predictions of the behavioral model. The right panel displays different predicted mixed strategy profiles for a selection of \( \lambda \) and \( \alpha \). It can be seen that higher degrees of PCO imply more probability mass on higher prices when keeping \( \lambda \) constant. This can be interpreted such that participants are expected to choose higher prices the higher the degree of partial cross-ownership. The intuition is that the higher the degree PCO, the lower the losses of participants who are undercut by the other firm.
Since QRE assumes that players best-respond in a noisy fashion, the probabilities for higher prices increase with the degree of PCO. The relation between prices and PCO is visualized in the left panel of the figure. Here, we plot the expected prices given the predicted strategy profiles as a function of the QRE parameter $\lambda$. It can be seen that higher degrees of PCO practically always imply higher expected prices—indeed of the precise value of $\lambda$. Hence, the behavioral model contradicts standard game theory in that it predicts a positive correlation between prices and the degree of PCO in the static game.

5 Experimental Design & Procedures

In the experiment, subjects play the game as described in Section 3 with choices limited to integer prices. Hence, subjects are paid according to the payoff function $\pi_i = (\hat{\pi}_i + \alpha \cdot \hat{\pi}_j)/(1 + \alpha)$ where $\alpha$ denotes the degree of cross-ownership and $\hat{\pi}$ denotes the profits from a standard Bertrand duopoly with zero marginal costs and an inelastic demand function. We use the following wording to explain the payoff function to the participants. Subjects are told that their “profits” equal “their income” times an “income factor” plus the “income of the other firm” times an “ownership factor”. The income and ownership factors are defined as $1/(1 + \alpha)$ and $\alpha/(1 + \alpha)$, respectively. The numerical values are listed in the instructions and displayed on the screen.

In total, the experiment consists of eight treatments which are conducted between-subjects. We have a $4 \times 2$ design. The first dimension is the degree of partial cross-ownership. The second one is the matching routine. We consider these aspects in turn.

We consider four different degrees of PCO including a baseline case where the firms have no shares of their rival ($\alpha = 0$). The remaining values ($\alpha = 1/9$, $\alpha = 1/3$, and $\alpha = 2/3$) are chosen to cover a broad spectrum. At first, the case where $\alpha = 2/3$ may appear to be of purely theoretical interest as in real industries shareholdings exceeding 50% will typically imply a change in control. Yet, even in the real world, exchanging non-voting stocks might result in dividend payments of similar magnitude. Further, the “ownership factor” of $\alpha = 2/3$ is exactly 40%, why this value might still be perceived as minority shareholding.

We use two different matching routines in the experiment. Stranger matching is used to analyze unilateral effects in the static game and partner matching tackles the scope of collusive behavior in the repeated game (coordinated effects). Note that our design features a number of peculiarities (sessions are split into parts, random-ending rule) which are motivated by the repeated game and which make less sense in the static game. Yet, to ensure the comparability, we apply the same procedures to both matching routines.

All sessions are divided into two parts. The reason is that we wanted to rematch subjects once in the repeated game. Hence, in the repeated game, subjects play with the same rival in all periods of the first part. At the beginning of the second part, they are

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$^6$The exceptions are $\lambda = 0$ and $\lambda \leftarrow \infty$ where the expected prices may be identical.
matched with a new opponent (perfect stranger), and the new matching remains constant for all periods of the second part. Because of the perfect-stranger rematching, one session of 36 subjects results in six independent observations.\(^7\) In the static game, everything is identical to the repeated game, except for the matching. Here, each participant is matched with a random rival at the beginning of each period. In the static game, we use matching groups of twelve subjects to avoid spillovers across too many subjects. As a consequence, one session with 24 participants translates into two independent observations for the static game.

Since partner matching is supposed to model an infinitely repeated game, a random walk with continuation probability of \(9/10\) determined the number of periods in the first and second part of each session. In the repeated game, this continuation probability may be interpreted as an induced discount factor of \(\delta = 0.9\). This interpretation does not hold in the static game, but to minimize the differences between the treatments, we apply the same design to both matching routines.

The structure of a single period is as follows. Subjects are first informed about the degree of cross-ownership (including the numerical values of \(\alpha\) as well as the income and ownership factors as defined above) and whether or not they are matched with a new rival. On the next screen, they have the possibility to simulate multiple outcomes using a payoff calculator. Afterwards, they have to decide on their final price for the current period. At the end of each period, participants are informed about the outcome of the respective period. The feedback includes information on their own price, the price of the other firm, their own profit, the profit of the other firm, the degree of PCO, and their cumulative profit.

Payoffs consist of a show-up fee of 5 Euro plus the sum of profits participants earned during the experiment. We use an Experimental Currency Unit (ECU) for payments, with 10,000 ECU being worth 1 Euro. Sessions were run in the DICE Laboratory for Experimental Economics. Subjects were students and non-students from a variety of backgrounds. A translation of instructions can be found in the appendix (remains to be done). Final payments were between 9 Euro and 27 Euro with an average of 16.47 Euro. A session lasts for approximately 75 minutes.

\(^7\)Participants actually played four parts with two different degrees of PCO. The analysis of the parts three and four is the subject of another paper.
6 Hypotheses

In this section we briefly present our hypotheses concerning behavior in the repeated game and in the static game. In short, we expect prices to be positively correlated in both cases. However, in the repeated game, we expect this correlation to be driven by coordinated effects whereas behavior in the static game will be caused by unilateral effects.

**Hypothesis 1. In the repeated game, we expect more collusive behavior the higher the degree of partial cross-ownership.** Consequently, we also expect a positive correlation between average prices and the degree of PCO.

These expectations are largely consistent with the equilibrium analysis in Section 3 where we show that the critical discount factor for tacit collusion decreases with $\alpha$. While the theory does not necessarily predict more collusion, the decrease in the critical discount factor is driven by lower defection profits. Hence, deviation is less attractive for subjects which may stabilize collusive agreements even though the discount factor we induce using the random ending rule is high enough for collusion to be sustainable for all degrees of partial cross-ownership we consider in the experiment.

In the static game, collusion cannot be an equilibrium and we do not expect firms to coordinate on collusive outcomes. Yet, we still expect to observe a positive correlation between average prices and the degree of PCO. The reason is that the higher the mutual shareholdings, the lower the gains firms realize by undercutting their rival. As a consequence, subjects will choose higher prices more frequently and average prices will rise with the degree of partial cross-ownership. Note that the logic presented above is fully consistent with the predictions of quantal response equilibrium as derived in Section 4.

**Hypothesis 2. In the static game, firms will not collude on higher prices independent of the level of PCO. We do expect a positive correlation between prices and the degree of cross-ownership, but this correlation will be driven by a general shift in the distribution of prices without coordination among firms.**

7 Results

We first consider the selling prices chosen by the participants. The selling price is defined as the lowest price in a market and is henceforth referred to as $p_{\text{min}}$. Figure 2 summarizes the average selling prices for all PCO levels and the different treatments. Note that the graph also distinguishes between the two supergames. The figure suggests there are three noteworthy effects. First, prices tend to be higher the higher the degree of PCO, second, prices are higher in the second supergame compared to the first one, and third, prices are higher in the second supergame compared to the first one, and third,
prices are higher in the repeated game compared to the static game. We now consider these aspects in turn.

The degree of partial cross-ownership as measured by $\alpha$ affects prices positively in both treatments. Average selling prices are in between 30.3 and 90.8 in the repeated game and in between 18.9 and 58.2 in the static game. In both cases, they are lowest for $\alpha = 0$ and highest for $\alpha = 2/3$. The relation is almost monotonic, but the graph reveals one anomaly. The session with $\alpha = 1/3$ in the repeated game shows lower prices than the one for $\alpha = 1/9$. Apart from that, the picture drawn by the figure is clear. The higher the degree of partial cross-ownership, the higher the average selling prices. This notion is confirmed by the regression analysis presented in Table 2. The coefficients of $\text{Alpha}$ are highly significantly positive in all regressions where $p_{min}$ is the dependent variable.

In the repeated game, there is some learning across supergames. The prices subjects charge in the second supergame exceed the prices from the first supergame by about 15 units. This difference is significant as regression (1) confirms. Such learning is not present in the static game. Here, subjects’ average selling prices increase only by about 1 unit, and the difference is not significant (see regression (2)). Interestingly, the regressions (1) to (3) also show that there is no learning within a supergame.

Comparing the results from the repeated and from the static game, we find that prices are higher in the repeated game. To analyze this, we conduct regression (3) where we pool the data from both treatments and introduce a dummy variable for the data from the repeated game. We find that average selling prices in the repeated are about 15 units higher compared to the static game. The regression confirms that this difference is highly significant.
### Table 2: OLS regressions of the average selling prices and probit regressions of subjects choosing a price of 100. Note that *Period* refers to the period within a supergame and not to the period within the experimental session.

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<th>(4)</th>
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<td>stat.</td>
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<td>53.941***</td>
<td>58.392***</td>
<td>1.998***</td>
<td>-0.881***</td>
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<td>7.813***</td>
<td>0.524***</td>
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<td>0.451***</td>
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<td>(1.743)</td>
<td>(0.103)</td>
<td>(0.164)</td>
<td>(0.128)</td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>0.001</td>
<td>-0.548*</td>
<td>-0.219</td>
<td>-0.003</td>
<td>-0.038</td>
<td>0.050***</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>(0.312)</td>
<td>(0.264)</td>
<td>(0.217)</td>
<td>(0.015)</td>
<td>(0.032)</td>
<td>(0.016)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Repeated</td>
<td>15.169***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.703)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>18.507***</td>
<td>26.192***</td>
<td>12.480***</td>
<td>-1.632***</td>
<td>-0.633*</td>
<td>-2.453***</td>
<td>-2.110***</td>
</tr>
<tr>
<td></td>
<td>(4.704)</td>
<td>(4.956)</td>
<td>(4.366)</td>
<td>(0.270)</td>
<td>(0.336)</td>
<td>(0.428)</td>
<td>(0.390)</td>
</tr>
<tr>
<td>Observations</td>
<td>1,440</td>
<td>960</td>
<td>2,400</td>
<td>1,440</td>
<td>960</td>
<td>1,440</td>
<td>480</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.231</td>
<td>0.429</td>
<td>0.302</td>
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</tr>
</tbody>
</table>

Standard errors clustered at the matching group level

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

7.1 Collusive behavior

Standard economic theory suggests that tacit collusion may affect subjects’ behavior in the repeated game. The analysis in Section 3 shows that theory also suggests that collusive outcomes are more sustainable the higher the degree of cross-ownership. As a consequence, the aim of this subsection is to find out to what degree the experimental results are driven by collusive behavior.

We consider two different measures to analyze collusive behavior. The first measure is a dummy variable indicating whether or not at least one firm in a market chooses the maximum price of 100 ECU. The intuition is that players who choose the maximum price try to establish a collusive outcome by not undercutting their rival and signal their willingness to collude. The second measure captures whether or not the collusive outcome is actually achieved. It is defined as a dummy which equals one if both firms in a market charge the maximum price.\(^9\) The first measure is denoted by $p^{max}$. The symbol $c^{max}$ refers to the second measure.

Figure 3 summarizes both measures for all levels of $\alpha$ in both treatments. It presents the share of markets where at least one ($p^{max}$) and both firms ($c^{max}$) charge the max-

\(^9\)We think these measures are suitable to capture collusive behavior even though theory does not directly predict higher prices and 100 is just one possible collusive price among many. The reason is that a price of 100 will not only result in the highest profits for subjects, but it is also the most salient number in the action set (compare also focal points (Schelling, 1980)). In fact, no other price was chosen by both firms at the same time.
minimum price. The figure suggests that there is a positive relation between $\alpha$ and either measure in the repeated game. For $\alpha = 2/3$ more than 60% of the markets achieve fully collusive outcomes compared to only about 6% for $\alpha = 0$.\textsuperscript{10} Not surprisingly, collusive behavior does not play a role in the static game. While some subjects do try to achieve collusive outcomes in all variants, the collusion is hardly ever successful. The relation between $p_{\text{max}}$ appears to be opposed to the one we observe in the repeated game. In the static game, higher degrees of PCO appear to lower subjects’ efforts to collude.

To shed further light on the effect of collusive behavior, we conduct the regressions (4) to (7). These are probit regressions where the dependent variables are the aforementioned dummies $p_{\text{max}}$ and $c_{\text{max}}$. Regressions (4) and (5) tackle the probability that at least one firm chooses the maximum price in the repeated and in the static game, respectively. They confirm the aforementioned aspect that the relation between $p_{\text{max}}$ and $\alpha$ is positive in the repeated game and negative in the static game. An additional insight is that firms in the repeated game learn to go for collusion across supergames. The regressions (6) and (7) check for drivers of successful collusion. In the static games, this hardly happens such that regression (7) does not generate new insights. This is in contrast to regression (6) considering the repeated game. The regression not only confirms the effects of PCO and learning across supergames, but it also documents successful cooperation is more likely to occur in later periods of the same supergame. This is somewhat surprising since it contradicts the idea of Nash reversion which support the collusive equilibria.

\textsuperscript{10} Again, we observe an anomaly for $\alpha = 1/3$. 

Figure 3: Share of collusive outcomes
We also consider selling prices in situations where firms did not collude on the maximum price. Our results show that firms charge higher average prices, even if they do not coordinate, the higher the degree of PCO. An ambitious interpretation could be that this shows unilateral effects of PCO even in the repeated game. Figure 4 shows the average prices when we drop all periods with collusion. Theory does not provide a good prediction for price levels in the repeated game when firms do not collude. Possibly, QRE for repeated games could make better predictions here (remains do be done). The figure shows that firms charge higher average prices also in the static game if they do not coordinate on a price. This, however, is already visible in our previous results. A regression analysis without all observations where the selling price is 100 gives highly significant coefficients for the degree of PCO, $\alpha$ (see appendix (remains to be done)). This supports the notion that collusion only enhances the unilateral effects of PCO.

8 Conclusion

To date, competition authorities have only limited means concerning the regulation of minority shareholdings and, more specifically, passive partial cross-ownership. There is, however, a lively debate on the advantages and disadvantages of introducing such legislation (European Commission, 2014). Academic research has also addressed the topic from different perspectives. Theoretical studies have shown that non-controlling, horizontal partial cross-ownership among product market rivals may cause softer com-

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11The Nash equilibrium here is the same as in the static game, i.e. prices at marginal costs of zero.
petition. Empirical literature could only add evidence to some degree of certain aspects of this topic.

The present paper contributes to this discussion in a number of ways. To the best of our knowledge, this is the first experimental study examining non-controlling partial cross-ownership in horizontal markets. The laboratory environment enables us to control for possible confounding factors such as interests of other shareholders, communication or control rights. We are also able to differentiate between unilateral and coordinated effects. This separation arises from theoretical considerations and refers to unilateral price increases and price increases which are due to higher collusion rates. Disentangling these effects appears rather challenging using field data but not in the experiment.

The experiment provides strong evidence for coordinated anti-competitive effects to occur. The price increases we observe in the repeated game are not only of substantial magnitude, it can also be shown that they are a direct result of collusive behavior. Participants in the experiment managed to coordinate on the monopoly price in up to 61% of all cases. We also find that such coordination is positively affected by the degree of partial cross-ownership.

While coordinated effects are consistent by established theoretical models, theory does not exactly predict prices to increase with the degree of partial cross-ownership. Further, the decreasing discount factor that comes with higher PCO does not necessarily predict higher collusion rates as the experimental setup allows for collusion in all treatments. However, with PCO, the rival firm is less exposed as it still earns profits through its shares. The deviating firms gains less extra profit, as it has to pay dividends to the rival. Therefore, the incentives to deviate from a collusive agreement decrease. The high collusion rates seem to support this line of reasoning as explanation.

The experiment also reveals that firms soften their competitive behavior in the static game. This is due to unilateral effects. There is a linear increase of average prices with the degree of PCO which can not be attributed to more collusive behavior.

In the static game, standard theory offers only limited guidance. Here, firms’ behavior is predicted to be unaffected by cross-ownership in that firms are expected to play prices equaling marginal costs. Hence, according to Nash equilibrium unilateral effects should not occur and PCO should have no effect on pricing behavior. From a behavioral point of view, this prediction is not very likely to hold. While the existence of firms’ incentive to undercut their rivals is unaffected by partial cross-ownership, their magnitude is not. In other words, the higher the degree of partial cross-ownership, the lower firms’ incentive to lower their price. As a consequence firms should be more likely to charge higher prices the higher the degree of partial cross-ownership. This line of reasoning is consistent with quantal response equilibrium which predicts unilateral effects i.e. firms set higher prices on average with increasing PCO. The price patterns we observe are roughly consistent with the ones predicted by QRE. Hence, our experiment shows that bounded rational behavior may explain the negative repercussions of partial cross-ownership.

We conclude that partial cross-ownership indeed allows for unilateral and coordinated effects to arise and thereby decreases competition. Moreover, it appears that collusion
can add to unilateral anti-competitive effects but is not necessary for market outcomes to be less competitive when partial cross-ownership exists. Even without collusion market prices are significantly higher in this setting. These findings add evidence to the potential harm for consumers by passive partial cross-ownership in single industries.
References


