Semi-collusive advertising and pricing in experimental duopolies

Andreas Nicklisch

Abstract

This article tests experimentally whether a high degree of collusion on advertisement expenditures facilitate tacit price collusion in duopoly markets. Two environments are tested, in which the size of the spillover between advertising expenditures is varied. The results show that the competitiveness of advertising and prices are significantly higher when the advertising spillover is higher than the price spillover than when advertising spillover is lower than the price spillover. In the second environment, a higher degree of advertising collusion leads for experienced players to a higher degree of price collusion. In the first environment, players behave at most semi-collusively, that is, if at all, they collude on advertising, but compete over prices.

Keywords: Advertising, duopoly competition, experimental economics, price collusion, semi-collusive markets

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1 Introduction

This article analyzes the relation between two important issues of industrial organizations, advertising decisions and tacit collusion. Particularly, I will investigate whether a high degree of collusion on advertising expenditures facilitates tacit price collusion. My concern about this issue is that advertising expenditures may be used to signal firms’ intentions with respect to the competitiveness of prices. For this purpose, a simple experimental setup is developed which allows to test this question.

The effect of advertising for price or quantity competition has been subject to well-established literature (e.g., Comanor & Wilson, 1979). The main discussion has been attributed to the question whether advertising increases or decreases the concentration of markets, that is, whether advertisements offer differentiation opportunities for products of new market entrants (e.g., Nelson, 1974, Klein & Leffler, 1981), or whether established brands create market entry barriers (e.g., Cubbin, 1981, Schmalensee, 1981, 1983). Following the seminal articles by Salop and Stiglitz (1977) and Varian (1980), contemporary studies focus on the relation between advertising and price dispersion on markets for homogeneous goods (e.g., Baye & Morgan, 2001, Iyer & Pazgal, 2003). Experimental studies by Morgan, Orzen and Sefton (2006a, 2006b) confirm theoretical predictions.

I consider a setting where firms decide on advertising and prices sequentially; firms run some kind of promotion campaign. Knowing the entire vector of advertising choices, they decide on prices. Hence, firms can impede competition in two dimensions, advertising and prices such that they increase advertising expenditures (prices) jointly maximizing their profit. Here, the advertising decision can be considered as a commitment device indicating an attempt to collude on prices. The issue of tacit collusion has been a major field for experimental industrial organization (see the survey article by Holt, 1995, and Huck, Normann & Oechssler, 2004, Engel, 2007, for a contemporary overview) offering ample evidence (Selten & Stöcker, 1986) of stable cooperation even in the case of a known finite number of interactions. Despite the lack of precise empirical data on price collusion, the experimental method offers the additional advantage of control for a certain aspect. Previous examples analyze the effect of cheap talk communication on cooperation rates (e.g., Holt & Davis, 1990, and Cason & Davis, 1995) or the impact of firm mergers on cooperation rates (e.g., Fonseca & Normann, 2008).\

Closely related to my study are recent laboratory experiments that ex-

\footnote{Overall, Bertrand price competition tends to induce a higher degree of collusion than Cournot quantity competition (Suetens & Potters, 2007).}
plore whether cooperative research and development expenditures leads to price collusion (e.g., Suetens, 2007). Following theoretical considerations by d’Aspremont and Jacquemin (1988) and Kamien et al. (1992), duopolists form binding contracts over research and development expenditures. Results indicate that the degree of price collusion is significantly higher when contracts are formed.

In this paper I will apply a modified version of the two-stage model of d’Aspremont and Jacquemin (1988) to investigate the relation between pricing decisions and advertisement decisions. Firms cannot form binding contracts. Advertising expenditures of one firm increases the demand for its own as well as for competing products. Thus, unlike earlier experimental studies on the effect of capacity commitments on price setting (e.g., Davis, 1999, Muren, 2000, Anderhub et al., 2003), there is a “double” spillover effect in my setting: first in terms of prices (i.e., increasing the own price increases the demand for the opponent’s product), and second in advertising expenditures (i.e., increasing own expenditures increases the demand for the product of the opponent). Treatment conditions will vary the size of the spillover effect for advertising expenditures (henceforth denoted as investments). Between each investment decision, firms will be allowed to adjust prices for several periods. Therefore, I will denote them as price changes within a promotion campaign.

The experimental results are two-fold. In the environment, where the size of the investment spillovers is lower than the size of the price spillovers, a higher degree of investment collusion facilitates price collusion for experienced players (i.e., in later periods of the experiment). Furthermore, collusion is built up subsequently over the promotion campaign, that is, a higher degree of price collusion is induced by a higher degree of investment collusion in the middle and at the end, but not at the the beginning of the promotion campaign. On the contrary, in the environment, where the size of the investment spillovers is higher than the size of the price spillovers, a higher degree of investment collusion negatively influences the degree of price collusion. If at all, players behave semi-collusively, that is, they collude on advertising expenditures, but compete in prices.

The remainder of the article is organized as follows: Section 2 introduces the theoretical model. Section 3 reports the experimental setting and discusses research hypotheses. Section 4 describes the results of the series of laboratory experiments. Finally, Section 5 concludes the article.
2 The model

As the theoretical benchmark for my experiment serves an adaptation of the duopoly market for differentiated products applied by Suetens (2007). Selling differentiated products, two firms compete over prices for a finite number of periods, \( t = 1, \ldots, T \). Firm \( i \) and its competitor \(-i\) choose prices simultaneously facing the following linear demand curve:

\[
q_t^i(p_t^i, p_{-t}^i) = \max\{A_t^i - p_t^i + \alpha p_{-t}^i, 0\}, \tag{1}
\]

where \( p_t^i \) denotes the price of firm \( i \) in period \( t \), \( p_{-t}^i \) the competitor’s price in period \( t \), and \( \alpha \) the degree of price spillovers, \( 0 < \alpha < 1 \). The variable \( A_t^i \) denotes \( i \)’s market size in period \( t \). It is assumed that firms can invest in advertising activities which increase their market size, as well as their competitor’s. Let \( m_t^i \) (\( m_{-t}^i \)) denote firm \( i \)’s investment (the competitor’s investment) in period \( t \) and \( A_0 \) the initial market size, then \( i \)’s market size is defined as

\[
A_t^i = A_0 + m_t^i + \beta m_{-t}^i, \tag{2}
\]

where \( \beta, 0 < \beta < 1 \), characterizes the degree of investment spillovers between the product of \( i \) and \(-i\).\(^2\) Thus, advertisements of firm \( i \) also increase the market size for firm \(-i\)’s product, and vice versa. Importantly, firms’ decisions are restricted such that they are not allowed to change \( m_t^i \) for a fixed number of periods, \( w \). After each decision on investments, firms make \( w \) price decisions where the investment remains unchanged, that is, \( m_t^i = m_t^{i+1} = \ldots = m_t^{i+w} \) for \( t = 1, w+1, 2w+1, \ldots \). Therefore, I will denote investment decisions as promotion campaigns lasting for several periods.

With respect to firms’ payoffs, I assume that firms have a linear production cost function and a quadratic cost function for advertising. Replacing the quantities by the demand function yields for firm \( i \) in period \( t \) the following profit:

\[
\pi_t^i = (A_t^i - p_t^i + \alpha p_{-t}^i)(p_t^i - c) - k(m_t^i)^2, \tag{3}
\]

where \( c \) denotes the marginal cost for production and \( k \) the cost parameter for investments, respectively.\(^3\)

Firms play a two-stage game. In the first stage, they simultaneously choose investments and then, knowing the vector of investment choices, they simultaneously set their prices. Thus for given investments, both

\(^2\)Notice that I model two complementary investments. For an analysis of substitutive investments, see, e.g., Nagel & Vriend (1999).

\(^3\)\(A_0 > c \geq 0\) and \( k \geq \max(1, \frac{(1+\beta)^2}{4(1-\alpha)})\).
firms will choose prices according to their best reply function. This will lead to the subgame perfect Nash equilibrium for prices in each price-setting period. Partial derivation of the profit with respect to prices of firm $i$ and firm $-i$ yields an equilibrium price\(^4\) $p^N$ that equals
\[
p^N = \frac{2}{4-\alpha^2}(A^i_t + c) + \frac{\alpha}{4-\alpha^2}(A^i_{-t} + c).
\] (4)

Likewise, both firms will choose investments according to their best reply function anticipating optimal behavior of their competitors. Substitution the price in the profit function (3) with the equilibrium price according to equation (4), and maximization with respect to investments leads to the symmetric subgame perfect Nash equilibrium for investments $m^N$ that equals in each investment-setting period
\[
m^N = \mu_1 + \mu_2 \frac{A_0(2+\alpha) - c(2-\alpha-\alpha^2)}{\mu_1^2 - \mu_2^2} \left( \frac{4}{4-\alpha^2} \right),
\] (5)
where $\mu_1 = 2k - \frac{2+\alpha\beta}{4-\alpha^2}$, and $\mu_2 = \frac{2\beta+\alpha}{4-\alpha^2}$.

A second benchmark solution is offered by prices and investments that jointly maximize the profit of both firms. Although experiments frequently observe some degree of price collusion, this benchmark is not an equilibrium in the strict game-theoretic sense, since firms interact for a finite number of periods. Assuming that firms collude in price setting, partial derivation of the joined profit function of firm $i$ and firm $-i$ with respect to prices yields
\[
p^C = \frac{A^i_t + (1-\alpha)c}{2-2\alpha}.
\] (6)
If firms expect to collude in the $w$ price-setting periods, they replace the price in the profit function (3) with collusive price according to equation (6). Maximizing the sum of both profit functions with respect to investments leads then to the collusive investments $m^C$ that equals in each investment-setting period
\[
m^C = \frac{(1+\beta)(A_0 + \alpha c - c)}{4k(1-\alpha) - (1+\beta)^2}.
\] (7)

One alternative that has been frequently discussed in the literature, are semi-collusive markets (e.g., Fershtman & Muller, 1986, Kamien et

\(^4\)Notice that the subgame perfect equilibrium allows asymmetric prices if investments are asymmetric. However, if both players simultaneously optimize investments, the subgame perfect Nash equilibrium yields symmetric investments, and, consequently, leads to a symmetric subgame perfect Nash equilibrium price.
al., 1992). Here, firms cooperate in one dimension, for instance research or advertising expenditures, while they compete in another dimension, typically prices. Applying this idea to a semi-collusive market where firms compete in prices but collude on investments requires that I introduce the price $p^N$ in the profit function (3). Maximization of the sum of both profit functions with respect to investments leads to the semi-collusive investment level, $m^S$, that equals

$$m^S = \frac{(2\mu_3 - \frac{2(1-\alpha)\mu_3^2}{1+\beta})(A_0 + c) - \alpha c}{2k + 2(1-\alpha)\mu_3^2 - 2(1+\beta)\mu_3}$$

for $\mu_3 = \frac{1+\beta}{2-\alpha}$.

Summarizing the results, one obtains $p^C > p^N$ and $m^C > m^S > m^N$.

3 Hypotheses and experimental procedure

For the experiment, the parameter values of the model are specified as $c = 1$, $k = 2$, $A_0 = 6$, $T = 60$, and $w = 5$. Therefore, a promotion campaign lasts for five periods, while players decide twelve times on investments. With respect to spillover effects, I introduce two treatment condition denoted as LOW and HIGH. In both settings, the degree of price spillover remains constant at $\alpha = 0.5$. In the LOW condition $\beta = 0.3$, that is, the investment spillover is weaker than the price spillover, whereas, in the HIGH condition, the investment spillover $\beta = 0.7$, that is, the investment spillover is higher than the price spillover.

The theoretical analysis shows that higher investment spillover increases the incentives for collusion considerably, while changing the Nash equilibria only slightly (i.e., $\frac{\partial m^N}{\partial \beta} < \frac{\partial m^C}{\partial \beta}$). All theoretical benchmarks for prices and investments corresponding to the parameter values are reported in Table 1. Notice that empirical studies challenge the theoretical results. Research on investments in product- or process-enhancing technology has found that the degree of cooperation decreases when investment spillovers are high (e.g., Cassiman & Veugelers, 2002, Kaiser, 2002). Interpreting advertising expenditures as product-enhancing technology, one can speculate that decreasing incentives facilitates a higher degree of investment collusion under experimental conditions. To resolve the conjecture I will test the following hypothesis.

$H_1$: The degree of investment collusion is higher in the HIGH than in the LOW condition.

In order to explore the influence between the degree of investment collusion and the degree of price collusion, I will define two measures for collusion. The degree of investment collusion of player $i$ in period $t$ is
Table 1: Theoretical benchmarks for prices and investments

<table>
<thead>
<tr>
<th></th>
<th>(m^N)</th>
<th>(m^S)</th>
<th>(m^C)</th>
<th>(p^N)</th>
<th>(p^C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>1.17</td>
<td>2.49</td>
<td>3.09</td>
<td>5.68</td>
<td>10.52</td>
</tr>
<tr>
<td>HIGH</td>
<td>1.28</td>
<td>5.68</td>
<td>8.42</td>
<td>6.12</td>
<td>20.82</td>
</tr>
</tbody>
</table>

defined as

\[
\kappa_i^t := \frac{\tilde{m}_i^t - m^N}{m^C - m^N}, \quad (9)
\]

where \(\tilde{m}_i^t\) denotes the experimentally observed investment of player \(i\) in period \(t\). Note that \(\kappa_i^t = 0\) indicates \(\tilde{m}_i^t = m^N\) and \(\kappa_i^t = 1\) indicates \(\tilde{m}_i^t = m^C\).

When defining the degree of price collusion, one has to consider that players are informed on investments of both firms before they choose prices; the degree of price collusion are functions of \(\tilde{m}_i^t\) and \(\tilde{m}_{-i}^t\). Thus, I define the degree of price collusion of player \(i\) in period \(t\) as

\[
\lambda_i^t := \frac{\tilde{p}_i^t - p^N(\tilde{m}_i^t, \tilde{m}_{-i}^t)}{p^C(\tilde{m}_i^t, \tilde{m}_{-i}^t) - p^N(\tilde{m}_i^t, \tilde{m}_{-i}^t)}, \quad (10)
\]

where \(\tilde{p}_i^t\) denotes the experimentally observed price, and \(p^N(\tilde{m}_i^t, \tilde{m}_{-i}^t)\) (\(p^C(\tilde{m}_i^t, \tilde{m}_{-i}^t)\)) is calculated using equation (4) (equation (6)) for the investments in period \(t\). Again, one finds \(\lambda_i^t = 0\) for \(\tilde{p}_i^t = p^N\) and \(\lambda_i^t = 1\) for \(\tilde{p}_i^t = p^C\) given the actually observed investments \(\tilde{m}_i^t, \tilde{m}_{-i}^t\). The two measures will allow us to analyze the effect of investment collusion on price collusion. To analyze the effect, I introduce

\(H_2: A\ high\ degree\ of\ investment\ collusion, \ \kappa_i^t,\ corresponds\ with\ high\ degree\ of\ price\ collusion, \ \lambda_i^t.\)

I will test \(H_2\) for three different “points” of the promotion campaign: at the beginning of a promotion campaign (i.e., in the period of the investment decision), in the middle of a promotion campaign (i.e., in the third period of the promotion campaign), and at the end of a promotion campaign (i.e., in the period before new investment decisions are made). Players may learn subsequently to play their best responses, or price collusion is built up subsequently.

Experiments were conducted in the laboratory of the Max Planck Institute Jena of economics, Germany, in spring 2005.\(^5\) In total, 48 subjects, mostly undergraduate students from the University of Jena in their

\(^5\)They were computerized using the software package zTree (Fischbacher, 2007); subjects were recruited using the software package ORSEE (Greiner, 2004).
third or fourth year of studying mathematics, natural sciences, or economics, participated in the experiment. Each subject participated only in one treatment condition; 12 player pairs participated in the LOW condition, 12 player pairs in the HIGH condition. Instructions were handed out to participants and read out aloud thereafter. Participants’ questions concerning the experiments were then answered privately by the instructors. To check their full understanding of the instructions, participants were then asked to answer a multiple-choice questionnaire. During the experiment and for answering the questionnaire, subjects were provided with a simple calculator, pen, and paper.

At the beginning of the experiment, two anonymous players randomly formed a pair that remained matched for the entire 60 periods. In the first and every fifth consecutive period, subjects were simultaneously asked to choose the investment level. Subjects knew that for the following four periods, they could not change this value. Then, players were informed about their own and their competitor’s investment. Players then simultaneously determined their prices. Finally, subjects were informed on their own payoff as well as their competitor’s price and payoff. At the end of the experiment, accumulated profits were converted at an exchange rate of 120 units = 1 Euro. For playing 60 periods, subjects needed approximately 90 minutes (including the time needed for questionnaire) and earned on average 9.93 Euros (standard deviation 2.48 Euros) in the HIGH and 7.63 Euros (standard deviation 1.89 Euros) in the LOW condition.

4 Experimental results

I will first provide an overview of the data by means of average figures, while then comparing the degree of investment collusion across treatment conditions and the relation between investment and price collusion in greater detail. Figure 1 shows in the left column the development of average investments for the HIGH condition, and in the right column the development of average investments for the LOW condition over peri-

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6 Instructions are provided in the Appendix.
7 Before participants answered the questionnaire, it was made clear that there was no competition in answering the questions, but that the purpose was to enhance the understanding of the experimental rules. Wrong answers were privately explained and corrected before the experiment started.
8 Values could range between 0 and 9, with 0.01 as the smallest incremental.
9 Values could range between 0 and 25, with 0.01 as the smallest incremental.
10 Before the experiment started, subjects were asked to agree on covering potential, accumulated losses across the entire 60 periods by clerical work at the institute. All subjects agreed, but none accumulated losses.
Overall, average investments are close to the $m^N$, but the figures suggest that average investment decreases when investment spillovers increase. Indeed, the statistical comparison shows a significant difference between the average investments in LOW, 1.24 and in HIGH, 1.06.\(^{12}\)

Figure 1: *Promotion investments in (a) LOW and (b) HIGH*

When analyzing average prices for the two treatment conditions, results are similar. Considering the range of potential prices, both are also close to the Nash equilibrium given Nash equilibrium investment.\(^{13}\) The development of prices is shown in Figure 2, left column LOW and right column HIGH, where the dotted horizontal lines indicate the Nash price level for the Nash level of investments and the grey lines the average ± one standard deviation. Unlike investments, average prices do not differ significantly across treatment conditions (5.66 for LOW and 5.71 for HIGH).\(^{14}\)

To test $H_1$ for investments, I normalize investments $\hat{m}_t^i$ according to $\kappa_t^i$ as defined in equation (9). Apparently, $\kappa_t^i = 1$ indicates full collusion

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\(^{11}\)The dotted black horizontal line indicates the Nash investment levels, while the grey lines the average ± one standard deviation.

\(^{12}\)p < 0.001, Wilcoxon signed rank test comparing period averages, two-sided.

\(^{13}\)A precise rating for the degree of price collusion respecting the actual investments chosen by both players will be provided below.

\(^{14}\)p = 0.45, Wilcoxon signed rank test comparing period averages, two-sided.
on investments, while \( \kappa_i^t \leq 0 \) shows no collusion on investments. Notice that \( \kappa_i^t(m^S) = 0.69 \) in the LOW and \( \kappa_i^t(m^S) = 0.62 \) in the HIGH condition.

I will classify \( \kappa_i^t \) with respect to categories \( k_x \), where \( x \) denotes the upper bound of disjunctive categories. That is, if \( \kappa_i^t \leq -1/6 \), \( \kappa_i^t \in k_{-1/6} \), if \(-1/6 < \kappa_i^t \leq 1/6 \), \( \kappa_i^t \in k_{1/6} \), and so forth. Hence, \( m^N \) lies in the center of category \( k_{1/6} \), \( m^C \) lies in the center of category \( k_{7/6} \), while \( m^S \) lies approximately in the center of category \( k_{5/6} \) (for both treatment conditions). Table 2 shows the number of investment choices for categories \( k_x \).

Based on the categorization results, I have to reject \( H_1 \). Increasing the investment spillover effect in the HIGH condition does not lead to an increasing degree of collusive investments. Overall, the experimental data tentatively supports the empirical observations;\(^{15}\) there is a weakly significant difference for the second half of periods between treatment conditions,\(^{16}\) but no significant difference for the first half (-0.01 under

\(^{15}\)The average degree of collusion is lower in the HIGH than in the LOW condition; averages for LOW increase from -0.036 in the first half of periods to 0.014 in the second half of periods, whereas averages for the HIGH remain at -0.037 for the first half of periods and -0.04 for the second half.

\(^{16}\)\( p = 0.09 \), Mann-Whitney-U rank sum test comparing period averages, two-sided.
Table 2: Categorization of investments according to $k_x$

<table>
<thead>
<tr>
<th></th>
<th>$k_{-1/6}$</th>
<th>$k_{1/6}$</th>
<th>$k_{3/6}$</th>
<th>$k_{5/6}$</th>
<th>$k_{7/6}$</th>
<th>$k_{9/6}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>period 1-30</td>
<td>LOW</td>
<td>58</td>
<td>40</td>
<td>32</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>HIGH</td>
<td>2</td>
<td>138</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>period 31-60</td>
<td>LOW</td>
<td>42</td>
<td>52</td>
<td>38</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>HIGH</td>
<td>0</td>
<td>142</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>period 1-60</td>
<td>LOW</td>
<td>100</td>
<td>92</td>
<td>70</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>HIGH</td>
<td>2</td>
<td>280</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Notice: Categories $k_x$ classify investments such that $x$ denotes the upper bound of disjunctive categories.

LOW compared to $-0.038$ under HIGH).$^{17}$

Now let us contrast $\kappa_i^t$ with the $\lambda_i^t$. The first panel of Figure 3 shows the experimentally observed $\kappa_i^t/\lambda_i^t$ combinations as gray dots at the first price decision, the second panel the $\kappa_i^t/\lambda_i^t$ combinations at the third decision, and the third panel the $\kappa_i^t/\lambda_i^t$ combinations at the last decision of a promotion campaign.$^{18}$ Small circles indicate the $\kappa_i^t(m^N)/\lambda_i^t(p^N)$ combination, small triangles the $\kappa_i^t(m^C)/\lambda_i^t(p^C)$ combination, and small crosses indicate the $\kappa_i^t(m^S)/\lambda_i^t(p^N)$ combination (characterizing semi-cooperative markets).

With respect to the $\kappa_i^t$ dimension, Figure 3 shows the large concentration of investments at the Nash equilibrium level in the HIGH condition. With respect to the $\lambda_i^t$ dimension, there is not such a clustering for any treatment condition. However, I find for prices some convergence to the Nash equilibrium over the promotion campaigns in the HIGH condition; no significant decrease can be found in the LOW condition.$^{19}$ Thus, in extension of result for investments, I find also for prices a stronger convergence to the best respond in the HIGH than in the LOW condition. Overall, I find the following

Result 1: Increasing the investment spillovers tends to decrease the dis-

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$^{17}$p = 0.70 , Mann-Whitney-U rank sum tests comparing period averages, two-sided.

$^{18}$i. provides the results for the LOW condition and ii. the results for the HIGH condition.

$^{19}$The average distance of prices to the Nash equilibrium decreases weakly significant from $-0.12$ at the beginning of the promotion campaign in the HIGH condition ($-0.096$ in the LOW condition) to $-0.056$ ($-0.072$) at the end of the campaign ($p = 0.077$ for HIGH and $p = 0.79$ for LOW, Wilcoxon signed rank test comparing period averages, two-sided).
Figure 3: Experimentally observed $\kappa_i^l$ and $\lambda_i^l$ combinations.

(a) Beginning of the campaign:  
   i. LOW
   ii. HIGH

(b) Middle of the campaign:  
   i. LOW
   ii. HIGH

(c) End of the campaign:  
   i. LOW
   ii. HIGH
tance to the Nash equilibrium both for investments and prices.

In order to explore the relation between the two variables, I will regress the degree of price collusion on the degree of investment collusion controlling for other factors. Specifically, I will estimate the coefficients of the linear individual random-effect model

\[ \lambda_i^t = \mathbf{x}_i^t \beta + \varsigma_{i,t}, \]  

(11)

where \( \mathbf{x}_i \) denotes the matrix of regressors, \( \beta \) for the vector of (true) coefficients and \( \varsigma_{i,t} \) for the unobserved individual random effect. I estimate the model for the LOW and the HIGH condition separately. As independent variable, \( \kappa_i^t \) is tested. Furthermore, the different points of the promotion campaign are considered by means of the two dummy variables \( \delta_{\text{middle/end}} \) and \( \delta_{\text{end}} \).\(^{20}\) Thus, significant coefficients for the first variable (or interactions with this variable) indicate significant differences in pricing behavior between the beginning of the promotion campaign and the later points of the promotion campaign, whereas significant coefficients for the second variable (or interactions with this variable) indicates significant differences in behavior at the end of the promotion campaign. Finally, the variable \( t = 1, \ldots, 60 \) captures temporal effects like learning between early periods and later periods of the experiment.

According to the hypothesis \( H_2 \), one expects the coefficient of \( \kappa_i^t \) to be significantly positive. If we assume that players learn subsequently to play their best response, the coefficients of \( \kappa_i^t \times \delta_{\text{middle/end}} \) and \( \kappa_i^t \times \delta_{\text{end}} \) should be significantly negative, whereas if price collusion is built up subsequently, the two coefficients are expected to be significantly positive. Table 3 reports the results for the two models, LOW and HIGH, respectively.

The estimated coefficient for the LOW condition shows that the degree of price collusion is initially negative, that is, the constant term is significantly negative, but increases with progress of the experiment, that is, \( t \) is significantly positive. In contrast to \( H_2 \) the coefficient of \( \kappa_i^t \) is insignificantly positive. This result indicates that a higher degree of investment collusion does not significantly induce a higher degree of price collusion. Yet, the (weakly) significantly positive coefficient of \( \kappa_i^t \times \delta_{\text{middle/end}} \times t \) shows for later periods of the experiment that players learn to collude subsequently in the middle and at the end of the promotion campaign. The results suggest the following in the LOW condition: Higher degrees of investment collusion do not facilitate higher degrees

\(^{20}\)The first variable is defined such that \( \delta_{\text{middle/end}} = 1 \) if the pricing decision comes either from the middle or the end of the promotion campaign and 0 otherwise, while \( \delta_{\text{end}} = 1 \) if the pricing decision comes from the end of the promotion campaign and 0 otherwise.
Table 3: Coefficients for regression models of $\lambda_i^t$

<table>
<thead>
<tr>
<th></th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>independent variables</td>
<td>$\kappa_i^t$</td>
<td>-1.44***</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.50)</td>
</tr>
<tr>
<td>$\delta_{middle/end}$</td>
<td>0.01</td>
<td>0.09**</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>$\delta_{end}$</td>
<td>-0.003</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>$t$</td>
<td>0.005***</td>
<td>0.006***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\kappa_i^t \times \delta_{middle/end}$</td>
<td>-0.25</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.70)</td>
</tr>
<tr>
<td>$\kappa_i^t \times \delta_{end}$</td>
<td>0.11</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.73)</td>
</tr>
<tr>
<td>$\kappa_i^t \times t$</td>
<td>0.002</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>$\kappa_i^t \times \delta_{middle/end} \times t$</td>
<td>0.008*</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>$\kappa_i^t \times \delta_{end} \times t$</td>
<td>-0.007</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>constant</td>
<td>-0.23***</td>
<td>-0.32***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.07)</td>
</tr>
</tbody>
</table>

Notice: Stars indicate the significance of coefficients: ***, significant on a 0.01 level, ** significant on a 0.05 level, * significant on a 0.1 level; the number of observations (n) and the fitness of the models are reported by the log-likelihood (logLik) and the Akaike information criterion (AIC); logLik of null model: −660 (LOW) and −712 (HIGH).
of price collusion. However, in later periods of the experiment, players increase the degree of collusion over the promotion campaign.

For the high condition, the significantly positive coefficients of $t$ and $\delta_{\text{middle/end}}$, the degree of collusion increases both over the promotion campaign and in the course of the experiment. However, with respect to the correspondence between the degree of investment collusion and the degree of price collusion, one finds the opposite results to the estimation for the low condition. The significantly negative coefficient of $\kappa_t^i$ indicates that a higher degree of investment collusion leads to a lower degree of price collusion. If players collude on investments, which has rarely been observed in the data, this leads to semi-collusive markets where players compete in pricing.

To summarize the regression analysis, the estimation results partly support $H_2$:

Result 2a: In the low condition, a high degree of investment collusion builds up subsequently higher degrees of price collusion for experienced players, while in the high condition, if at all, one finds a semi-collusive investment level.

Overall, the experimental results suggest that the investment spillovers crucially influence collusion with respect to both dimensions, advertising expenditures and prices. Along several empirical studies (e.g., Kaiser, 2002), I find a lower degree of investment and price collusion when investment spillovers are high. At most, they collude on investments but compete over prices. To the contrary, when investment spillovers are low, a higher degree of investment collusion leads to a higher degree of price collusion at the end of the promotion campaign.

5 Conclusion

In this paper, I analyze the relation between the degree of price collusion and the degree of collusion on advertising expenditures. For this purpose, an experimental duopoly game was tested, where participants were asked to specify simultaneously investments for promotion campaigns. Within each promotion campaign, players had to specify prices repeatedly. I controlled the degree of price collusion at the beginning, in the middle and at the end of the promotion campaign. Experiments were run in two environments, a treatment condition where the size of the investment spillovers is lower, and a treatment condition where the investment spillovers is higher than the price spillovers.

For the relation between investment and price collusion, the econometric analysis indicates that a higher degree of investment collusion facilitates price collusion for experienced players in the low condition. Particularly in later periods of the experiment, collusion is built up sub-
sequently over the promotion campaign. In the HIGH condition, however, I find the opposite effect; a higher degree of investment collusion influences negatively the degree of price collusion.

In general, my findings suggest an important qualification for the propagation of semi-collusive markets. Analyses have to draw profound attention to the size of the investment spillovers as it is an important factor determining the behavior of market participants. There is considerable empirical evidence for semi-collusion (e.g., Steen & Sørgard, 1999, find that Norwegian cement producers compete on capacities, but collude on prices). The current results suggest that these markets are characterized by large investment spillovers. The laboratory evidence provides a warning for public authorities dealing with price collusion: price collusion likely occurs when the joint market structure is less likely to be detected (i.e., when spillovers are low).

References

nomics 17, 214-226.


Appendix: Instructions\textsuperscript{21}

Thank you for participating in our experiment. We kindly ask you to refrain from any public statements and attempts to communicate directly with other participants. If you violate this rule, we have to exclude you from the experiment. If you have any questions, please raise your hand, and one of the persons who runs the experiment will come to your place and answer your questions. Please read these instructions carefully. In this experiment, you will earn money based on repeated decisions. How much you will earn depends on your decisions as well as the decisions of another participant.

You will repeatedly interact with another, anonymous participant for 60 periods. The instructions are identical for all participants. The other participant will be randomly assigned to you and will remain with you for the entire experiment.

In this experiment, you as well as the other participant have to sell a product on a market. Your profit equals the number of sold entities of your product multiplied by the price, minus production costs. You have to decide on the price of the product. The price can range between 0 and 25 ECU, with 0.01 as the smallest incremental step. The higher the price you choose, the smaller the number of sold entities per period. Whenever the price exceeds a certain level, you cannot sell any entity at all. However, the number of sold entities increases if your competitor increases the price for her product. In summary, your number of sold entities (\(q_{\text{own}}\)) equals

\[ q_{\text{own}} = 6 - p_{\text{own}} + 0.5p_{\text{other}}, \]

where \(p_{\text{own}}\) denotes the price you choose and \(p_{\text{other}}\) the price the other participant chooses. Note that for each entity you sell, there are production costs of 1 ECU. Therefore, your profit (\(G_{\text{own}}\)) is

\[ G_{\text{own}} = q_{\text{own}} \times p_{\text{own}} - 1 \times q_{\text{own}}. \]

In every fifth period, you have the opportunity to invest in your product. We denote your investments as \(m_{\text{own}}\). Investments can range between 0 and 9, with 0.01 as the smallest incremental step. Although you can only change your investments in every fifth period, they increase the number of sold entities in every period. Additionally, the investments of the other participant increase the number of sold entities of your product. The number of sold entities of your product (\(q_{\text{own}}\)) equals

\[ q_{\text{own}} = 6 + m_{\text{own}} + 0.3m_{\text{other}} - p_{\text{own}} + 0.5p_{\text{other}}, \]

\textsuperscript{21}Author’s translation of the German instructions for the low condition.
where \( m_{\text{other}} \) denotes the investments of the other participant. However, in every period, investments also cost \( 2(m_{\text{own}})^2 \) (not only in every fifth period when you can change them). You participate in the investments of the other participant without any costs. Thus, your profit equals
\[
G_{\text{own}} = q_{\text{own}} \times p_{\text{own}} - 1 \times q_{\text{own}} - 2(m_{\text{own}})^2.
\]

Please consider that you may accumulate losses due to unfavorable investment choices. If you earn a negative total profit throughout the entire experiment, you will be asked to pay back this amount by doing clerical work at our institute (120 ECU = 1 hour). If you do not accept this rule, please leave the experiment now.

In every first out of five periods (i.e., in periods 1, 6, 11,...), you will be asked to specify your investments. You will not be asked for this in the subsequent 4 periods. Please note that the level of investments cannot be changed for these 4 periods, though you have to carry the costs for them. In each period, you are then informed on the level of investments you chose as well as that chosen by the other participant. Additionally, you are informed on the investments and prices chosen in the previous period. Then you have to choose the price for your product in this period. Finally, we inform you on your profit in this period, the profit of the other participant, and the accumulated profits. At the end of the experiment, we will exchange all ECUs you earned in the 60 periods at a rate of 120 ECU = 1 Euro.

Before the first round starts, we will ask you several questions concerning the rules of this experiment in a questionnaire. Please answer them correctly. One of the persons who runs the experiment will come to your place and clarify incorrect answers.

\[22\text{In the high condition the equation equals } q_{\text{own}} = 6 + m_{\text{own}} + 0.7m_{\text{other}} - p_{\text{own}} + 0.5p_{\text{other}}.\]