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Shrouding add-on information: an experimental study*

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Abstract

We explore how increased competition affects firms' obfuscation strategies in a laboratory experiment. Firms sell a base good and an add-on product. Besides choosing the base-good price sellers take an action that mimicks the effects of shrouding the add-on product. Shrouding is an equilibrium but an unshrouding equilibrium coexists. In our experiment, more competition matters in that only duopolistic markets are frequently shrouded whereas four-firm markets are not. With repeated interaction, shrouding rates do not increase. However, the opportunities to shroud facilitate tacit collusion on the base-good price for the duopolies: the unshrouding equilibrium serves as a credible punishment if deviations occur.

JEL Classification: C7, C9, L4, L41

Keywords: add-on price, non-attentive consumers, shrouding

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I Introduction

For behavioral industrial organization, a key question is to what extent firms can exploit consumer irrationalities. It is by now well accepted that consumer decision making is far from perfect. Consumers make mistakes, may use simple (non-optimal) rules of thumb (Ellison, 2006), and are subject to behavioral biases (DellaVigna, 2009). How rational firms respond to those consumer behaviors is at the heart of recent behaviorally founded theories in industrial economics (see Ellison, 2006; Spiegler, 2011).

A prime example of this kind of behavioral IO are obfuscation strategies which firms may use to target myopic, inattentive consumers. Consumer myopia has been observed, for example, in financial markets (e.g., Campbell, 2006; Choi *et al.*, 2010), electricity markets (Wilson and Waddams Price, 2010) and online auctions (Hossain and Morgan, 2006). In these examples, consumers do not choose optimally but myopically pick a sub-optimal tariff or inefficient bid. The examples also show that firms may respond with some obfuscation strategy. They may highlight irrelevant information (Choi *et al.*, 2010), develop redundant financial innovations (Henderson and Pearson, 2011), or shroud certain price elements (Campbell, 2006).

Whether firms' attempts to exploit myopic consumers are successful is more difficult to answer, not least since competition is a forceful argument suggesting this may *not* be the case. In a pioneering and frequently cited paper, Gabaix and Laibson (2006) show, however, that intensified competition might not have any bite. In a model with rational (attentive) and myopic (inattentive) consumers, they show that the shrouding of add-on information can be an equilibrium despite perfect price competition.

In this paper, we conduct a laboratory experiment to explore the effects of increased competition on shrouding behavior. We consider a stylized version of Gabaix and Laibson (2006) where firms sell a base good and an add-on product. Firms decide on the base-good price as well as on an action that mimicks the effects of shrouding the add-on. This decision is a coordination decision where the add-on is shrouded to consumers only if all firms decide to shroud. Otherwise, if at least one firm unshrouds, all consumers are perfectly informed about the add-on. We consider both a static game where firms only interact once as well a dynamic game where firms repeatedly compete over a finite number of periods. Both shrouding and unshrouding equilibria coexist in the static game.

An experimental approach seems well suited for exploring this issue because theory is often bland regarding the equilibrium multiplicity (the shrouding equilibrium exists for any number of firms). We implement a stylized design with a focus on the firm side and where the buyer side is computerized (see our literature survey below for experiments analyzing the buyer side). We consider the following treatments. The degree of competition is varied by changing the number of firms: we conduct experiments with two and four sellers. A second treatment variable is the matching scheme: we have markets with random and fixed matching to test the implications of the static as well as of the repeated game. Repeated interaction itself may lead to improved coordination in a shrouding equilibrium. Moreover, one of our main goals is to study how the shrouding and the pricing decision affect one another. Therefore, we additionally examine two treatments which study either the shrouding or the pricing decision in isolation. These can be compared *ceteris paribus* to the treatments involving both decisions.

Despite the Gabaix and Laibson (2006) argument, we find that more competition is detrimental toward the shrouding of add-on prices. A first channel for this to happen is simply that coordination on a shrouding equilibrium is more difficult for four firms: shrouding is the more risky choice and, all else equal, coordination on the shrouding equilibrium is easier with fewer competitors. A second channel as to how increased competition can be a force against shrouding strategies stems from an analysis of the repeated game. In our setup, there exist tacitly collusive equilibria where firms raise the base good price above the competitive level even with finitely many repetitions (Benoit and Krishna, 1985; Friedman, 1985). Shrouding possibilities are worrisome in the repeated game because it helps to sustain tacit collusion: unshrouding serves as a simple but credible threat to sustaining cooperation regarding prices. Whether such tacit collusion is feasible will again depend on the number of competitors. Indeed, we find that shrouding leads to higher base good prices where again, the effect is limited to duopolies.

II Literature

Our paper is related to two streams of the literature. First, we complement the literature on behavioral industrial organization. Second, we contribute to a literature that experimentally investigates spillovers between decisions.

Our paper adds to the growing literature on behavioral industrial organization theory that studies firm behavior in the presence of behaviorally biased consumers, most closely to papers that analyze firms' incentives to shroud a price element or an add-on from myopic, inattentive consumers.[1] The seminal paper in the theoretical literature is, as discussed above, the paper by Gabaix and Laibson (2006). In contrast to Gabaix and Laibson (2006) we also consider a repeated game analysis which permits us to analyze whether shrouded markets facilitate price collusion.

Buyer confusion and to what extent firms can exploit such confusion are topics that are relatively new to the experimental literature. Kalayci and Potters (2011) study the impact of confusion caused by firms (represented by participants in the laboratory) on buyers (also represented by subjects). Sellers can confuse buyers by choosing a large number of product attributes, but these attributes do not affect buyers' valuations of the good. They find that, all else equal, seller profits increase in the number of attributes, and prices and profits are also higher than those in a benchmark treatment with perfectly rational robot buyers. Kalayci (2015) presents experimental evidence that a seller's complexity and price choices are positively correlated. In a related experiment Kalayci (2016) uses this setup to study the effect of more competition by varying the number of sellers. He finds that the number of attributes chosen by sellers does

[1] There is also a growing body of empirical evidence of inattentive consumer behavior. Such evidence is documented, for instance, in the context of shipping fees in online auctions (Hossain and Morgan, 2006; Brown *et al.*, 2010), non-posted taxes applied at the register (Chetty *et al.*, 2009) or management fees of index funds (Choi *et al.*, 2010).

not vary with the number of sellers and concludes that the intensity of competition has no effect on obfuscation. In contrast to these papers, we focus on the firm side. Moreover, we also analyze dynamic competition where the same set of participants interact repeatedly over time.

We share our focus on collusive effects with the study by Crosetto and Gaudeul (2017) who report an experiment where sellers can choose a price and a price format. They find that, if rivals' behavior is observable, firms are able to coordinate on different price formats which is consistent with tacit collusion on price formats. In our case, we show that the possibility to shroud leads to higher prices in a setting where sellers repeatedly interact over time.

In a stylized experiment, where - as in our experiment - the consumer side is computerized Gu and Wenzel (2015) study the effects of different policies (a consumer protection policy and policies that level the playing field among firms) on firms' incentives to strategically obfuscate the market.

Our research is also related to a small number of experimental studies that analyze spillovers in two-stage games. In most cases, both decisions to be made are cooperation decisions by nature whereas we analyze the spillovers between a cooperation decision and a coordination decision. For instance, Suetens (2008) analyzes whether R&D cooperation facilitates tacit price collusion. She has treatments with and without binding R&D contracts, and two different levels of spillovers. She finds that the level of tacit collusion in the contract treatments is significantly higher in periods where R&D contracts are made than in periods without contracts. Prices are also higher than in the baseline treatments. The differences to our paper are Suetens' focus on explicit commitment to R&D and that both decisions are cooperation decisions by nature. Also, a comparison to a treatment without R&D is not feasible. Cason and Gangadharan (2013) also consider potential spillovers between R&D cooperation and collusive price setting, but in their experiment they consider a more competitive trading institution (double auction). Similarly to our paper, they also consider treatments with both decisions in isolation. They find that the presence of competition reduces the incentive to cooperate. Unlike

Suetens (2008), they find no evidence that R&D cooperation facilitates collusive price setting. More recently, Cason *et al.* (2012) consider spillovers between two coordination decisions. They study minimum- and median-effort coordination games where participants make the two decisions either simultaneously or sequentially. They show that successful coordination on the Pareto optimal equilibrium in the median effort stage influences decision making in the minimum effort stage when the two stages are played sequentially. Their research differs to ours in that we study spillovers between a coordination and a cooperation decision. Our results are also slightly different: we observe a positive spillover in the cooperation decision (higher prices) and a negative spillover in the coordination decision (lower shrouding rates).

III A simple model of add-on pricing

Model setup

The model we consider is a stylized version of Gabaix and Laibson (2006).[2] Consider an oligopoly market with $n \geq 2$ firms offering a homogeneous product (the base good) which, for simplicity and without loss of generality, can be produced at zero costs. There is a unit mass of consumers each demanding one unit of this base good. Firms set a price of $p_i \in [0, \bar{p}]$ for the base good.

There is an additional service or add-on product consumers may purchase and firms can choose to shroud the price of this add-on or its very existence to consumers. Consumers—who may not be aware of the add-on's existence—can be exploited by such a shrouding strategy. In contrast, if firms actively advertise (or unshroud) add-on information, consumers become informed about the presence of the add-on and can take it into account when making their purchase decision. Initially, all consumers are unaware of the add-

[2] In our simplified setup, the shrouding and the add-on pricing decision are combined into one single decision and, depending on firms' shrouding decision, either all consumers are myopic or sophisticated. Moreover, as in Heidhues *et al.* (2017), there is a lower bound on the base good price allowing for positive profits in equilibrium.

on, but become educated if at least one firm decides to unshroud.[3]

Following Gabaix and Laibson (2006), the add-on shrouding decision of the firms is a coordination decision. If all firms decide to shroud add-on information, (myopic) consumers can be exploited and be charged high add-on fees. In the following, we refer to markets where all sellers decide to shrouded as a shrouded market. We assume that, in this case, firms earn an extra profit of $\overline{f}$ for each consumer who buys the base good from this supplier.[4] If a firm unshrouds add-on information, this firm earns a lower extra profit of $\underline{f} < \overline{f}$ for each unit of the base good sold. The main insight of Gabaix and Laibson (2006) is that firms cannot gain additional customers by unshrouding: the act of unshrouding makes consumers become aware of this practice, but they still will not buy the add-on from the unshrouding supplier and will rather turn to an outside option. The unshrouding decision imposes a negative externality on firms still shrouding add-on information—they do not sell the add-on any more.

We summarize the model as follows. The n firms simultaneously and independently decide on both the pricing and the shrouding decision. The indicator function $\mathbb{1}_i$ indicates whether firm i shrouds. Further, let $\underline{p} = \min\{p_1, p_2, ..., p_n\}$ denote the smallest price charged for the base good, and let m be the number of firms who set $\underline{p}$. Then profits, π_i, are

$$\pi_i = \begin{cases} \dfrac{p_i + \overline{f} \prod_j \mathbb{1}_j + \underline{f}(1 - \mathbb{1}_i)}{m} & \text{if} \quad p_i = \underline{p} \\ 0 & \text{if} \quad p_i > \underline{p} \end{cases} \tag{1}$$

where $\prod_j \mathbb{1}_j$ is the product across all n shrouding decisions. In words, provided firm i charges the lowest price, its profits are the price for the base good, plus possibly $\overline{f}$ (provided *all* firms shroud) or $\underline{f}$ (provided i unshrouds). If firm i does not charge the

[3]In our model all consumers are, in the terminology of Gabaix and Laibson (2006), either myopic or sophisticated. In their paper, also situations are considered where both types of consumers coexist. This simplifying assumption has also been imposed in Heidhues *et al.* (2017), and is useful to reduce the complexity of the experiment.

[4]Note that in Gabaix and Laibson (2006) can freely choose the add-on price, but it is shown that a shrouding firms always sets the maximal possible price. To simplify the experiment, we directly impose this price which corresponds to $\overline{f}$.

lowest price, its profits are zero.

Static game

We start by analyzing the one-shot game where firms compete only once. There exist two equilibria in pure strategies, one in which all firms decide to shroud and one in which all firms unshroud add-on information:

Proposition 1. *i) There exists an equilibrium where all firms shroud add-on information. Each firm sets a base good price of* $p^* = 0$ *and earns profits of* $\pi^* = \frac{\overline{f}}{n}$. *ii) There exists an equilibrium where all firms unshroud add-on information. Each firm sets a base good price of* $p^* = 0$ *and earns profits of* $\pi^* = \frac{f}{n}$.

The proof is simple. From (1), firm i's best reply is to shroud provided $\prod_{j \neq i} \mathbb{1}_j = 1$ and regardless of p. Any static equilibrium must involve $p^* = 0$. Hence, i) is a Nash equilibrium. If $\prod_{j \neq i} \mathbb{1}_j = 0$, firm i's best reply is to unshroud. Hence, ii) is a Nash equilibrium. In addition, there exists a symmetric equilibrium in mixed strategies.

Coordination games typically exhibit multiple equilibria, and in our model one part of the game (the shrouding decision) has the properties of the stag-hunt game. There exist two equilibria in pure strategies—one in which all firms coordinate on shrouding and one in which all firms coordinate on unshrouding. Both types of equilibrium exist independent of the number of competing firms.[5]

In either equilibrium the base good price is driven to zero, the lowest possible price as we assume they are bounded below by zero. This implies that even though base goods offered by different firms are homogeneous, firms can earn positive profits in equilibrium.[6] In addition, profits in the shrouding equilibrium are higher than in the

[5]In this paper we focus on situations where multiple equilibria exist. Indeed, also in the model by Gabaix and Laibson (2006), multiple equilibria exist when the effects of shrouding are sufficiently large.

[6]If we allowed for negative prices, all profits from add-on sales would be competed away by subsidized base good prices (Gabaix and Laibson, 2006). In our model, with a lower bound on the base-good price equal to zero, this is not possible and hence, firms are able to earn positive profits. A lower bound is also imposed in Heidhues *et al.* (2017).

unshrouding equilibrium. That is, from the firms' perspective it would be beneficial to coordinate on the shrouding equilibrium.[7]

Finitely repeated game

We now turn to the analysis of the finitely repeated game. Suppose that the stage game from above is repeated for T periods. In each period, $t = 1, .., T$, firms decide on the price and on whether to shroud add-on information.

Many subgame-perfect equilibria exist in this repeated game. In particular, the shrouding and unshrouding equilibria of the one-shot game are also equilibria in the repeated game where, in each period, firms play the equilibrium strategies of the one-shot game. In addition, there are also equilibria where firms play the shrouding equilibrium in some periods and the unshrouding equilibrium in other periods. In all of these equilibria, the price for the base good is zero.

More interestingly, the finitely repeated game also possesses (tacitly) collusive equilibria which are not equilibria of the one-shot game (Benoit and Krishna, 1985; Friedman, 1985).[8] The reason is that the one-shot game has multiple equilibria. We will show that, in our case, there exist equilibria where firms raise the base good price above the competitive level of $p = 0$ (at least for some periods) if the time horizon of the game is sufficiently long. There exist equilibria in which firms charge the monopoly price for the base good, $\overline{p}$, over many periods because the unshrouding equilibrium (with lower profits than in the shrouding equilibrium) can be used as a credible punishment strategy if a firm deviates from collusion.

We construct collusive equilibria where firms collude on a base good price $p^c > 0$ in the first periods of the game and then return to the competitive price of $p = 0$ toward the end of the game. As in Friedman (1985), we consider trigger strategies: if firms behave

[7]Note that in Gabaix and Laibson (2006) profits in both shrouding and unshrouding equilibria are identical. In the case of a perfectly competitive industry, firm profits are equal zero in both types of equilibrium. That is, the conditions for shrouding to occur are more favorable in our setup than in theirs.

[8]Harrington (1987) shows for multiproduct oligopoly that defection from the cooperative outcome can be prevented by threatening the defector with being forced to exit the industry.

according to the collusive equilibrium, they will coordinate on shrouding. As soon as a deviation by any firm is observed, they switch to unshrouding for the remaining periods. Specifically, suppose that in period t, $H+1$ periods remain to be played (period t plus H further periods). We want firms to cooperate on a price $p^c > 0$ and to shroud in period t, and to charge $p^c = 0$ and to shroud in the final H periods. If some firm j deviates by setting $p_j < p^c$ in period t, the trigger strategy calls for unshrouding in the final H periods.

When does this trigger strategy constitute an subgame perfect Nash equilibrium? Sticking to the tacitly collusive agreement, firm i earns a profit of $\frac{(p^c+\overline{f})}{n}$ in period t and a profit of $\frac{\overline{f}}{n}$ in each of the following periods. Total profits from cooperating in period t are then $\frac{(p^c+\overline{f})}{n} + H\frac{\overline{f}}{n}$. Suppose now firm i deviates from collusion in period t. The optimal deviation is to marginally undercut the collusive price p^c in order to obtain the whole market and to keep shrouding in t. Profits in this period are $(p^c + \overline{f})$. After the deviation has occurred, the unshrouding will be triggered for the remaining periods, leading to profits of $\frac{\underline{f}}{n}$ in each of these periods. Total profits from deviating are then $(p^c + \overline{f}) + H\frac{\underline{f}}{n}$.

Adhering to the trigger strategy is better than deviating if and only if

$$H \geq H^*(p^c) = \lceil \frac{(p^c + \overline{f})(N-1)}{\overline{f} - \underline{f}} \rceil \tag{2}$$

where $\lceil x \rceil$ denotes as the smallest integer not less than x. The threshold $H^*(p^c)$ is the critical number of remaining periods (after t) such that firms stick to the collusive agreement in period t.

How does this logic extend to the periods before t? Obviously, firms will not only stick to the collusive agreement in the period immediately preceding $H^*(p^c)$ but will also adhere to this agreement in all prior periods. In fact, the incentive to stick to collusion is stronger with a larger number of periods (and therefore equilibria with prices that decline over time toward period T are possible). It follows that a collusive equilibrium exists if the number of periods of the game, T, is at least $H^*(p^c) + 1$. The following

Proposition summarizes our analysis:

Proposition 2. *Provided $T \geq H^*(p^c) + 1$, there exists an subgame perfect Nash equilibrium where firms tacitly collude on a price $p^c > 0$ from periods $t = 1, ..., T - H^*(p^c)$.*

The Proposition is specified for arbitrary collusive prices $p^c > 0$, including $\bar{p}$. In equilibrium, firms shroud the add-on in all periods; they charge a collusive price in $t = 1, ..., T - H^*(p^c)$ and the competitive price in $t = T - H^*(p^c) + 1, ..., T$.

Note that the higher the collusive price, the longer the time horizon needed to sustain collusion. This follows immediately as $H^*(p^c)$ is strictly increasing in p^c. Indeed, this might give rise to more elaborate (tacitly) collusive agreements where firms successively reduce the collusive price toward the end of the game, allowing them to collude for a longer period of time.

IV Experimental design

Our main goal is to analyze the impact of increased competition on the shrouding of markets. We therefore ran sessions with two and four sellers playing a game resembling the one in our theory section. We ran sessions with both random and fixed matching schemes. The random-matching procedure corresponds to the one-shot game, which is the assumption underlying Gabaix and Laibson (2006). The fixed matching procedure mimics the nature of the finitely repeated game, as outlined above. In all treatments, participants take the role of sellers while buyer behavior is simulated by the computer.

In each round of the experiment, sellers simultaneously had to make two decisions. Sellers had to decide on the base good price, which had to be an integer in [0,10], and whether or not to shroud the add-on. Buyers are computer simulated and would buy from the seller offering the lowest price. In the case of a tie, each seller receives the same share of buyers.[9]

Parameters regarding shrouding were $\underline{f} = 5$ and $\overline{f} = 10$. In the case a seller decides to unshroud the seller earns an extra amount of $\underline{f} = 5$ for each unit of the base good sold. In the case of shrouding a seller receives an extra amount of $\overline{f} = 10$ for each unit sold if the market is shrouded, that is, if also all other sellers decide to shroud. Otherwise, if at least one seller decides to unshroud, a shrouding seller would receive no extra revenues. The total payoff to a seller is then calculated by multiplying the number of sold units with the chosen price plus the extra revenues from add-on sales (as described above). A seller not charging the lowest price receives zero payoff.

It should be noted that while the pricing decision was framed, the shrouding decision was not and we used a neutral description. Participants of the experiment were told that they could earn extra profits by deciding between two actions, A and B where action A corresponded to unshrouding and action B to shrouding. We decided to use a neutral frame because any description along the lines "you may hide this information from buyers" may have biased seller participants against shrouding.

At the end of each round, sellers were informed of the price choices and shrouding decisions by all sellers. In addition, they received information on the profits earned in this round. The experiment was repeated for 15 rounds.

To analyze behavioral spillovers between the decisions, we ran two extra treatments where the shrouding and the pricing decisions were played in isolation. The first control treatment involved the shrouding decision only, the second additional treatment involved the pricing decision only. In treatment "shrouding only", there was no price competition, so we implicitly set both prices equal to zero when determining the payoffs for this game. Essentially, subjects were playing a simple 2×2 stag-hunt game with (60, 60), (30, 30), (30, 0) and (0, 30) as payoffs. These payoffs roughly correspond to the average payoffs made in the "price and shroud" treatment. The second decision (price) was

[9] We decided not to add further complexity to the experiment by adding subjects acting as buyers. Indeed, Jin *et al.* (2015) find evidence that receivers are often naive about non-disclosed information while reacting nearly optimally when information is disclosed which can be viewed as support for our assumptions on computerized buyer behavior.

Treatment	# sellers	matching	decisions	# participants	# groups
1	two	random	shroud and price	48	6
2	four	random	shroud and price	48	4
3	two	fixed	shroud and price	22	11
4	four	fixed	shroud and price	20	5
5	two	fixed	shroud only	22	11
6	two	fixed	price only	22	11

Table 1: Treatments

not mentioned. In the "price only" treatment, firms' profit per unit included a base payment of 10 which corresponds to the payoff from shrouding in the "price and shroud" treatments, although no mention of the second (shrouding) decision was made. Both extra treatments were done with fixed-matching duopolies.

We can use the additional treatments to detect possible interactions between decisions, that is, whether the presence of one decision (say, shrouding) has an impact on the behavior of the second decision (price competition). Those treatments were done with $n = 2$ and with a fixed matching scheme. Table 1 summarizes the treatments.

All sessions were conducted at the experimental economics laboratory University of Duesseldorf. The experiment was implemented using the software z-Tree (Fischbacher, 2007). Sessions lasted for about 45 minutes. The appendix contains an English translation of the instructions.

Subjects received a show-up of 4 EUR and could earn additional amounts during the experiment. On average, participants received an amount of 8.38 EUR. In total, 182 subjects participated in our experiment. Subjects came from all departments (with 25% from Economics and Business studies), and 50% were female. The average age of a participant was 24.6 years. No subject participated in more than one session and none of the subjects had ever participated in any similar experiment before.

V Hypotheses

The theory section has established a multiplicity of equilibria and how these may effect tacit collusion in the repeated game. Our theory section does, however, not directly suggest any hypotheses as to how our treatment variants will affect the decision to shroud. We therefore refer to equilibrium-selection criteria and existing experimental evidence in most of this section.

Our first hypothesis is about the shrouding frequency of $n = 2$ vs. $n = 4$ firms in the treatments with random matching. Intuitively, the larger the number of players, the less likely players will coordinate on the payoff dominant shrouding equilibrium. After all, one unshrouding decision in the market already implies a payoff of zero for the firms that shroud, so shrouding gets more risky with a larger n. Carlsson and van Damme (1993) show that, for $n > 2$ players, the predictions of various equilibrium-selection criteria differ, but many criteria including the Selten-Harsanyi tracing procedure and global games predict that the unshrouding outcome is the risk dominant equilibrium for a larger n and indeed in our case for $n = 4$. See also Kim (1996). Thus we have:

Hypothesis 1. *With random matching, players decide to shroud more often in duopolies than in quadropolies.*

Regarding the same question with fixed matching, existing experiments where the same participants interact repeatedly over time suggest a negative correlation of coordination on the payoff dominant equilibrium and number of players. We refer here to the minimum-effort game which is essentially a generalization of the stag-hunt game to more than two actions (typically seven). See van Huyck *et al.* (1990) for details and Engelmann and Normann (2010) for a meta study.[10] We propose:

Hypothesis 2. *With fixed matching, players decide to shroud more often in duopolies than in quadropolies.*

[10]For stag hunt experiments, see for example, Battalio *et al.* (2001), Clark and Sefton (2001) or Schmidt *et al.* (2003). In those experiments, the coordination action was the only decision while in our main setup participants simultaneously decide whether to shroud and on a price.

A third hypothesis regards the frequency of shrouding decisions in fixed vs. random matching. For instance, Clark and Sefton (2001) observe that in stag-hunt coordination experiments participants tend to choose the more risky strategy (corresponding to shrouding in our case) significantly more often with a repeated matching protocol than with a random matching protocol. In addition, coordination failure is less often observed. We thus hypothesize:

Hypothesis 3. *Markets are shrouded more often with fixed matching than with random matching.*

Our analysis of the finitely repeated game suggests that unshrouding may occur as a punishment for (off equilibrium) deviations in the price dimensions. We will compare data from fixed-matching duopolies to those where subjects play the stag-hunt game only. The aforementioned results in minimum-effort games suggest that virtually all two-player groups (87.5 %) coordinate on the payoff dominant equilibrium (see Engelmann and Normann, 2010). This coordination success in the stag-hunt only treatment should thus be higher than in the price-plus-stag-hunt treatment:

Hypothesis 4. *With fixed matching, there is more shrouding in the treatment which involves only the shrouding decision than in the treatment which involves both the pricing and the shrouding decisions.*

The repeated game gives rise to the existence of tacitly collusive equilibria with above marginal cost pricing. For our experimental design, Proposition 2 predicts, for example, that duopolies and quadropolies can (tacitly) collude on the maximum price of 10 for the first 11 or 3 periods, respectively. Supra competitive pricing is theoretically not feasible in the treatment where the shrouding decision is absent. We thus obtain our final hypothesis:

Hypothesis 5. *With fixed matching, markets that involve the pricing decision only will exhibit lower prices than our shrouding-plus-price-setting markets.*

Treatment	number of sellers	matching	decisions	shrouding rate	shrouded markets	selling price
1	two	random	shroud and price	0.73	0.56	2.48
2	four	random	shroud and price	0.15	0.0	0.14
3	two	fixed	shroud and price	0.73	0.62	4.36
4	four	fixed	shroud and price	0.29	0.07	0.79
5	two	fixed	shroud only	1.00	1.00	–
6	two	fixed	price only	–	–	1.46

Table 2: Main results

VI Results

We start by describing the results with random matching before proceeding with the results from the treatments with fixed matching. Finally, we evaluate the spillover effects between the pricing and the shrouding decisions.

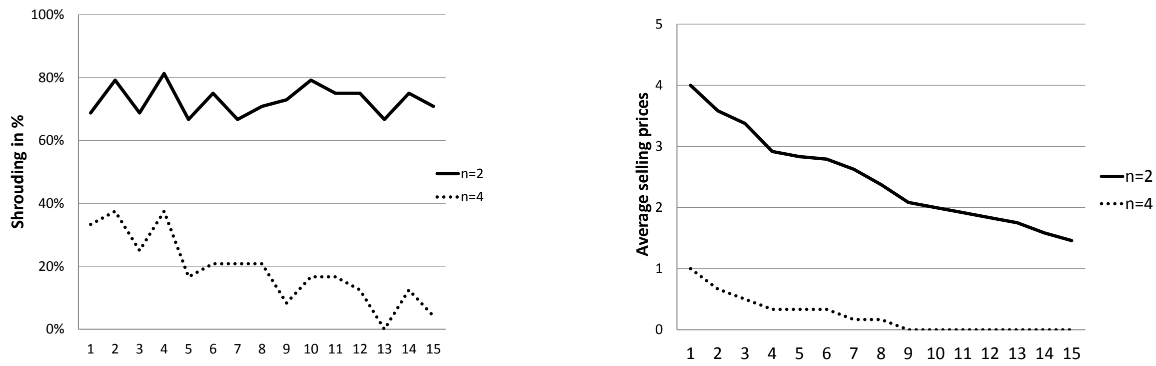
All tests are based on data from all periods. We employ non-parametric tests, where the number of independent observations corresponds to the number of matching groups. We report two-sided p-values throughout.

For an overview, Table 2 contains our main findings, comprising the average shrouding rate, the share of shrouded markets as well as the average selling price in each treatment. Further evidence is contained in Figures 5 and 6 in the appendix which shows how the main variables evolve over time.

Random matching

Under the random matching protocol (mimicking one-shot interactions), shrouding rates and shrouded markets are significantly lower with four than with two firms (Mann-Whitney rank-sum test, $p = 0.011$ and $p = 0.010$, respectively). The rejection of the null hypothesis is statistical support for our Hypothesis 1.

Table 2 provides the shrouding rates and the share of shrouded markets in the treatments with two and four firms. The left panel Figure 1 shows how shrouding rates



(a) The evolution of shrouding rates

(b) The evolution of selling prices

Figure 1: The evolution of shrouding rates and selling prices with random matching

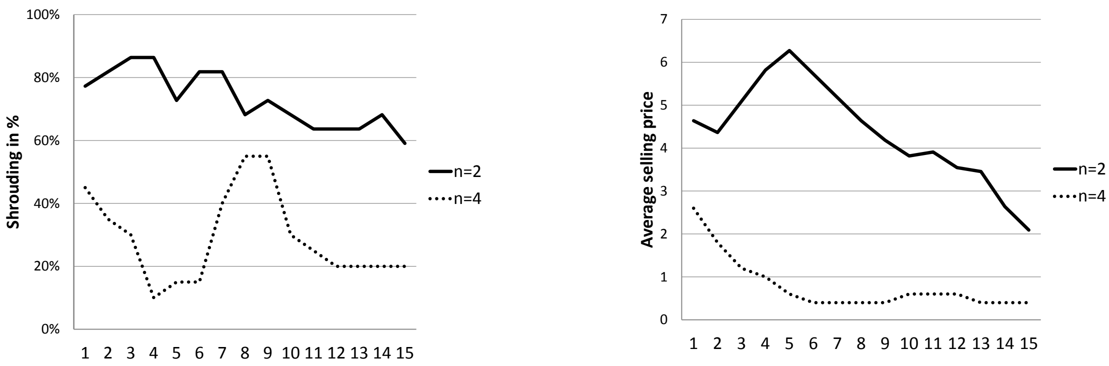
evolve over time. We can see that high shrouding rates and shrouded markets are prevalent in duopoly markets (73% shrouding rate and 56% shrouded markets).[11] We can also see that shrouding rates are stable over time. In contrast, shrouding with four sellers is relatively rare. We observe shrouding in only 15% of all observations. In addition, shrouding rates decrease over time and are close to zero in the final periods. Shrouded markets, that is, coordination success with all four sellers choosing to shroud is almost never observed.

Regarding selling prices (that is, winning bids) we observe the expected result that prices tend to be higher with fewer firms (Mann-Whitney rank-sum test, $p = 0.011$). In all periods, prices are higher with two sellers, however, as the right panel of Figure 1 shows, selling prices decline over time. The selling price with four sellers rapidly converges toward zero while the selling price with two sellers remains positive even in the final periods. This is consistent with the findings in the previous literature (Dufwenberg and Gneezy, 2000).

We summarize our results with random matching as follows:

Result 1. Shrouding with random matching. *Consistent with Hypothesis 1, there is a substantial amount of shrouding in the duopoly markets which does not decline over time, and*

[11]Note that the observed shrouding rate is less than 100% but above the symmetric mixed-strategy equilibrium level of shrouding (50%). Risk aversion might prevent convergence to complete shrouding.



(a) The evolution of shrouding rates (b) The evolution of selling prices

Figure 2: The evolution of shrouding rates and selling prices with fixed matching

there is little shrouding in the $n = 4$ *markets which, moreover, converges to zero.*

Fixed matching

We now turn to the results in the treatment with fixed matching where the same sellers (two or four) repeatedly interact over the entire length of the experiment. Table 2 provides overall shrouding rates and the left panel of Figure 2 shows the evolution over time.

As in the treatments with random matching and consistent with Hypothesis 2, we observe that shrouding is more prevalent in markets with fewer sellers (Mann-Whitney rank-sum test, $p = 0.015$). There is substantial shrouding with two sellers, which, however, decreases over time, but is still significant at the end of the experiment. Coordination success on shrouding is also high. As in the treatment with random matching, with four sellers, shrouding rates and coordination success is much lower.[12]

The right panel of Figure 2 displays selling prices over time. We observe that prices are higher with two than with four sellers (Mann-Whitney rank-sum test, $p = 0.002$). With two sellers, prices are above the static Nash equilibrium prediction of zero, but de-

[12]Note that in periods 6 - 10 we observe a transitory increase in the shrouding rates which is driven by two groups. However, shrouding was never successful and by period 11 all firms in these two groups have returned to unshrouding. We interpret this as an (unsuccessful) attempt to initiate cooperation.

crease over time, in particular, in the final periods of the experiment. That is, prices are somewhat collusive with two sellers. With four sellers, selling prices are close to zero from period 5 on and, hence, sellers are not able to sustain (tacitly) collusive prices. This numbers effect is consistent with previous findings which find that tacit collusion is unlikely in markets with more than two sellers (Huck *et al.*, 2004; Fonseca and Normann, 2012).

Summarizing our findings:

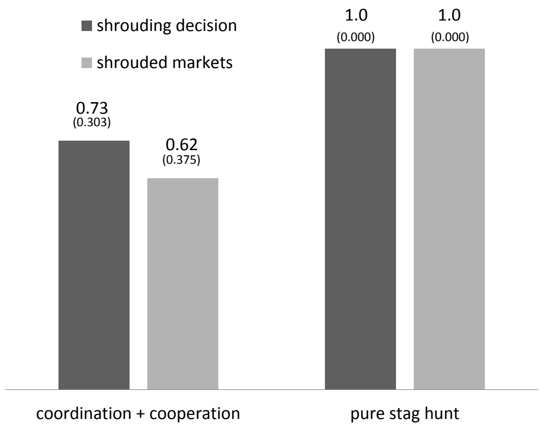
Result 2. Shrouding with fixed matching. *Consistent with Hypothesis 2, there is a substantial amount of shrouding in the duopoly markets which does, however, decline over time. With $n = 4$ firms, only one market is shrouded toward the end.*

The impact of the matching procedure

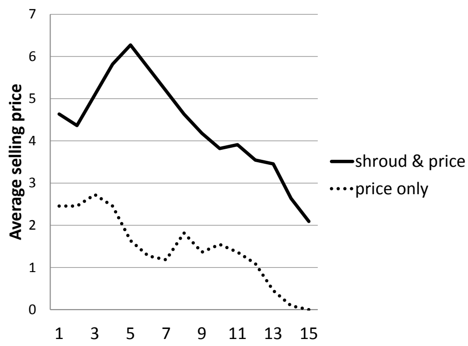
An interesting result is that coordination on the shrouding equilibrium does not improve much with fixed matching. For $n = 2$, we note that there is not more shrouding with fixed matching than with random matching - which seems surprising. From Hypothesis 3, we expect more shrouding (that is, better coordination) with fixed matching. However, the shrouding rates with fixed and random matching are not statistically different for $n = 2$ (Mann-Whitney rank-sum test, $p = 0.513$).[13] For $n = 4$, we do observe better coordination success on shrouding with fixed matching, however, the effect is weak overall. Since we cannot reject the null hypothesis (Mann-Whitney rank-sum test, $p = 0.459$), we find no support for Hypothesis 3. This result suggests that the shrouding mechanism is possibly used by players in a different manner with fixed matching, at least for the duopolies. We explore this issue in the next subsection in more detail.

Result 3. Impact of matching scheme on shrouding behavior. *We find virtually no support for Hypothesis 3. With fixed matching we do not observe more shrouding than with*

[13]We note that with two sellers prices are higher with fixed matching than with random matching (Mann-Whitney rank-sum test, $p = 0.035$). However, due to endgame effects this difference becomes smaller towards the final periods, see Figure 5 in the appendix.



(a) Comparison to shrouding in isolation



(b) Comparison to pricing decision in isolation

Figure 3: Spillovers between coordination and cooperation decision

random matching.

Spillovers between decisions

Our previous results suggest that spillovers exist between the pricing and the shrouding decision, for instance, because participants might use shrouding (unshrouding) as a reward (threat) for sticking to (deviating from) collusive prices. To shed light on the spillovers, we now compare the $n = 2$ treatment with fixed matching to treatments where

i) players play the shrouding decision only,

ii) players play the pricing decision only.

Figure 3 provides the results from those two treatments. The left panel of the figure shows that shrouding is significantly more frequent in the treatment where the shrouding decision is played in isolation (Mann-Whitney rank-sum test, $p < 0.001$). Indeed, we observe that participants always choose to shroud. This is consistent with our finding that, with fixed matching, when both decisions are played simultaneously players punish deviation by unshrouding.

Result 4. Less shrouding due to spillovers between decisions. *Consistent with Hypothesis 4, shrouding is significantly more frequent in the treatment where subjects play the shrouding decision only.*

The right panel of Figure 3 reports the results of the pricing decision played in isolation. It shows that the average selling price is significantly higher in the treatment with both pricing and shrouding decision compared to the pricing decision only, suggesting tacit collusion on prices is supported by shrouding (Mann-Whitney rank-sum test, $p = 0.005$), as conjectured in Hypothesis 5.

Thus, we conclude:

Result 5. Shrouding opportunities facilitate tacit collusion. *Consistent with Hypothesis 5, the opportunity to shroud/unshroud leads to higher prices than the comparable game without such opportunities.*

This is in line with the observation that shrouding rates and selling prices are correlated within groups for the duopolies with fixed matching. Out of eleven groups in the duopolies with fixed matching, eight have a positive Spearman correlation of (selling) prices and shrouding rates, two groups show no correlation at all, and only one group exhibits a negative correlation. We conclude that prices and shrouding decisions are significantly positively correlated (sign test, $p = 0.039$). Beyond that, we also find that average prices and shrouding rates are correlated across groups. Figure 4 plots the correlation between the share of shrouded markets and selling prices at the group level. The figure shows that groups that are more likely to shroud are also more successful at obtaining high prices.

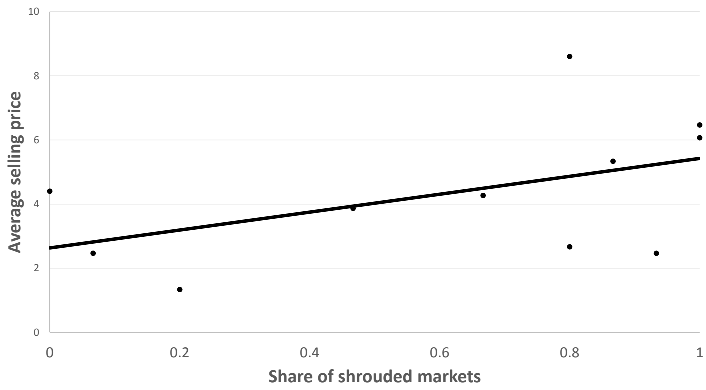


Figure 4: Correlation between shrouded markets and selling prices

VII Conclusion

In a seminal paper, Gabaix and Laibson (2006) show that obfuscation strategies theoretically survive even under perfect competition. Due to a "curse of debiasing", competitive firms will find that informing consumers about their competitors' shrouding and overcharging policy will not be profitable. Similar findings have also been obtained in Armstrong and Vickers (2012) and Heidhues *et al.* (2017).

Our experiment supports the hypothesis of Gabaix and Laibson (2006) in that markets are indeed often and substantially shrouded even with competitive (one-shot) interactions, but they also suggest two channels through which tougher competition has an effect. First, shrouding and unshrouding equilibria coexist. The shrouding decision resembles a coordination decision with shrouding being the more profitable but also the riskier strategy. With a larger number of players (four as opposed to two, in our case), unshrouding becomes prevalent, so more competition is detrimental to shrouding. The second effect of intensified competition on shrouding occurs with repeated interactions. For concentrated markets (duopolies in our case), our model argues that shrouding opportunities facilitate tacit collusion: prices are higher than in a comparable game without the shrouding/unshrouding decision. The reason is that unshrouding can serve as a credible threat to sustain cooperation. Even though unshrouding—possibly as a punishment—is sometimes carried out, an anti-competitive effect occurs in terms of higher base good prices. In less concentrated markets, prices above marginal cost do not occur anyhow (Huck *et al.*, 2004) so more competition curbs the effect of shrouding in this case, too.

There are examples where shrouding exists in markets with many competitors, and they appear to establish counter examples to our hypothesis that increased competition is detrimental to shrouding. In the market for pre-dial call-by-call landline telephony, there are often a lot of companies offering even more tariffs. Buyers are easily confused as there many price dimensions, some of which are indeed shrouded (call destination, time, duration, method of payment, registration, local availability, etc.). In our view, the problem in such markets is not that competition has no effect but that tougher competition forces firms to invent more price or product attributes they can shroud (see Spiegler (2006) who models this situation). Given an industry is stuck with one or a few possible shrouding opportunities, we expect competition to have an effect.

The implications for competition policy are as follows. At least in markets with multiple equilibria, a larger number of competitors has the desirable potential of eradicating non-desirable obfuscation strategies. In markets with imperfect competition, however, not only do obfuscation strategies survive, but in addition, our experiments suggest that shrouding opportunities facilitate tacit collusion, that is, they cause higher base good prices. Hence, whereas the scope for shrouding may be limited by competitive forces, shrouding is particularly worrisome in concentrated markets.

Appendix

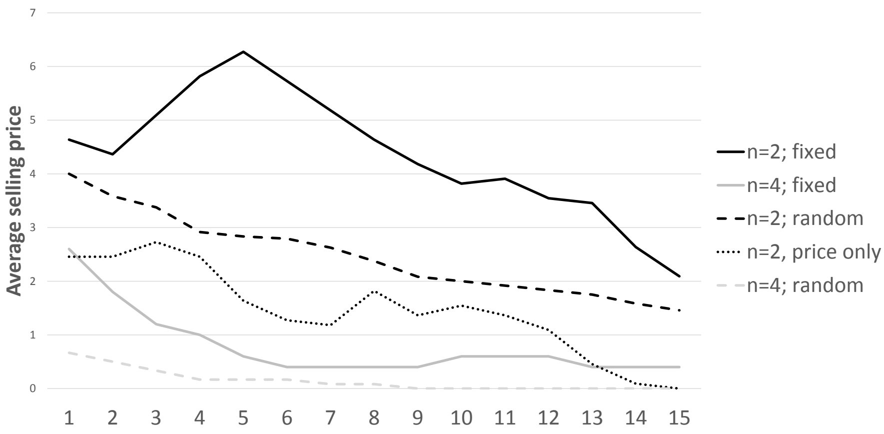


Figure 5: The evolution of selling prices in all treatments

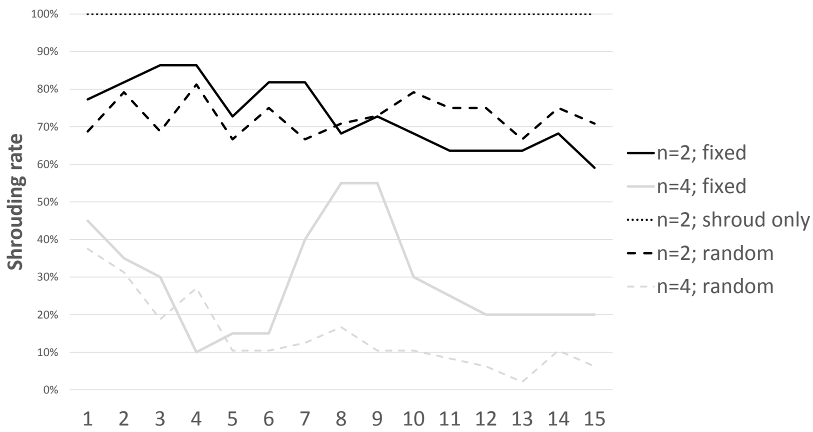


Figure 6: The evolution of shrouding rates in all treatments

Instructions

Here we provide a translation of the instructions. The original instructions are in German. We provide the instructions for the treatment with two sellers and fixed matching:

Welcome to this experiment in decision making. Please read the instructions carefully.

During the experiment you can earn points depending on your own decisions and those of the other participants. At the end of the experiment these points are converted at a rate of 200 points = 1 EUR into Euro and paid to you.

You are starting with an amount of 800 points. This amount is increased by the earnings in each period.

The setup

In this experiment you are assigned the role of a seller. There are two sellers in a market. At the start of the experiment participants are assigned into groups of two sellers. This assignment is the same in all rounds of the experiment, that is, in each round you are interacting with the same participant.

You and the other seller are selling a good on this market. Buyers decide from which seller to purchase the good. There are 12 buyers and each buyer purchases exactly one unit of the good. The buyers are simulated by the computer.

In each round both sellers simultaneously choose a price. The chosen price must be an integer between 0 and 10. The computerized buyers are programmed to buy from the seller who has chosen the lower price. The seller who has chosen the higher price does not sell at all. In the case of a tie, each seller receives half of the buyers.

In addition, in each round, the sellers decide between two actions, A and B:

- If you choose action A, you receive an additional income of 5 points for each unit sold.
- If you choose action B, the additional points you can earn depend on the decision by the other seller. If the other seller also chooses action B, you receive 10 extra points for each unit sold. If the other seller chooses action A, you receive no extra points.

End of each period

At the end of each period, the computer calculates how many units you and the other seller have sold. Finally, you receive information about the points that you have earned this period:

Your points = (price x quantity sold) + (extra earning x quantity sold)

End of the experiment

The experiment is repeated for 15 rounds. As already stated above, in each round you will interact with the same participant. At the end of the experiment your earnings will be paid out to you. Your earnings comprise the show-up fee and the points you have earned during the experiment.

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