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Shrouding add-on information: an experimental study*

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Abstract

We explore how competition affects firms' obfuscation strategies in laboratory experiments. Firms sell a base good and an add-on product. The price of the add-on may be shrouded and, if so, myopic consumers pay too much. Shrouding is an equilibrium but an unshrouding equilibrium coexists. In our experiments, 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

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1 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 myopias have 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 simply do not choose optimally and myopically pick a suboptimal 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 competitive environments, obfuscation or shrouding strategies might not survive because a competitor could introduce a transparent strategy to gain a competitive advantage (Shapiro, 1995). Specifically, if obfuscation leads to supra-competitive prices, it is not straightforward to see how such strategies can survive competition.

In a pioneering and frequently cited paper, Gabaix and Laibson (2006) show, however, that 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. A firm may find that informing consumers about their competitors' shrouding and overcharging policy will not be profitable: when consumers become aware of the price for the add-on, they do not switch to the transparent competitor but purchase the add-on elsewhere. Hence, given all firms shroud, deviating does not pay and shrouding may be a persistent

phenomenon even in competitive markets.

Despite the Gabaix and Laibson (2006) argument, we believe that competition might be detrimental toward the shrouding of add-on prices. We identify two channels which show how competition can have an effect, and both are based on the fact that there are multiple equilibria in the model of Gabaix and Laibson (2006). Before turning to our two arguments, we first explain the multiplicity issue in detail.

In Gabaix and Laibson (2006), both shrouding and unshrouding equilibria typically coexist.[1] In the shrouding equilibrium, firms charge myopic customers the reservation price for the add-on. If (at least) one firm unshrouds, a share of the myopic consumers become attentive and buy the add-on elsewhere. If this share is sufficiently large, it is a best reply for all others to unshroud, too, and hence unshrouding is an equilibrium. The shrouding/unshrouding decision is a coordination game where, under plausible assumptions, the shrouding equilibrium is the Pareto dominant equilibrium whereas unshrouding yields a lower but risk-free payoff.[2] In Gabaix and Laibson (2006), both shrouding and unshrouding equilibria exist when the share of myopic consumers that can be turned into sophisticated consumers via education is positive. If this assumption is not met, the Gabaix and Laibson (2006) boils down to a model of price discrimination of myopic consumers.

Our first argument in favor of the positive effect of competition refers to the one-shot game. As just seen, the shrouding/unshrouding decision is a coordination game. For the myopic consumers to become rational, it is sufficient that one single firm unshrouds the add-on price. Therefore, unshrouding is the less risky choice. Whether a shrouding equilibrium emerges will thus

[1] See page 518 of their paper. Multiple equilibria also exist in their introductory example: hotels sell rooms and an add-on (say, internet access) which costs them zero to provide. All consumers are initially myopic and pay up to \$20 for the add-on. Attentive consumers would purchase it upfront and elsewhere for \$10. There exists a shrouded prices equilibrium in which all firms shroud the add-on price and charge \$20 for it. There is, however, also an unshrouded prices equilibrium: given all other firms unshroud, it is a best reply to unshroud; all consumers become attentive and buy the add-on for \$10 at the hotel.

[2] The shrouding equilibrium will be Pareto superior if prices are restricted to be above marginal cost. An assumption imposed in a similar context, for example, in Armstrong and Vickers (2012). This is plausible if competition authorities suspect below-cost pricing as anti-competitive. If firms are allowed to charge prices below cost, both equilibria have identical payoffs.

depend on the degree of competition; market fragmentation or simply the number of players will matter. All else equal, coordination on the shrouding equilibrium will be easier with fewer competitors.

The second argument as to how competition can be a force against shrouding strategies stems from an analysis of a repeated game (Gabaix and Laibson (2006) only consider one-shot games). Since the one-shot game has multiple equilibria, 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 not only because shrouding per se may not be desirable but also because shrouding helps to sustain tacit collusion. Unshrouding serves as a simple but credible threat to sustaining cooperation regarding prices. Whether such tacit collusion—the absence of competition—is feasible will again depend on the number of competitors.

The notion of rational cooperation in the repeated game highlights a very interesting general aspect of the Gabaix and Laibson (2006) setup: there are aspects of both coordination and cooperation in this game. The pricing decision in their framework corresponds to a cooperation game where firms have a collective interest to charge a high price, but individually each firm has incentive to undercut its competitors. The shrouding decision corresponds to a coordination game where shrouding is a risky strategy that offers the possibility of a high payoff from add-on sales if all firms coordinate on this strategy and the safe strategy (unshrouding) offers a low, but secure payoff.

This raises the question of how the coordination decision (shrouding) affects the cooperation decision (prices) and vice versa. Such interplay of strategic decisions can be found in oligopoly (coordination on a minimum advertising or R&D level plus cooperation in the market game) and every day life (coordination and cooperation with colleagues or partners). In our literature survey below, we found, however, that almost all experiments analyze the case of two (possibly explicit) cooperation decisions. Behaviorally, there might be spillovers "between games": the presence of the price (cooperation) game influences decisions in the shrouding (coordination) game, or vice versa. Experiments seem particularly suitable for investigating the interaction of the actions of two games, but the number of existing studies is

surprisingly small (see our literature review below).

In this paper, we explore the effect of competition on shrouding behavior in laboratory experiments. Experiments seem well suited for exploring this issue because theory is often bland regarding this topic (the shrouding equilibrium exists for any number of firms). The degree of competition is varied by changing the number of firms: we conduct experiments with two and four sellers who play a stylized version of the Gabaix and Laibson (2006) model. A second treatment variable is the matching scheme: we have markets with random and fixed matching. Finally, one of our main goals is how the coordination and cooperation decision of the shrouding game affect one another. Therefore, we additionally examine two treatments which study either the coordination or cooperation decision in isolation. These can be compared *ceteris paribus* to the treatments involving both decisions.

Our results are as follows. Competition matters in our experiments in that only duopolistic markets are frequently shrouded whereas four-firm markets are not. The main reason for this is that coordination failures (in the sense of the market not being shrouded) occur in the four-firm markets almost throughout. The second reason is that shrouding opportunities facilitate tacit collusion for the base good where, again, the effect is limited to duopolies.

2 Literature

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

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. The seminal paper in the literature is, as discussed above, the paper by Gabaix and Laibson (2006). We extend the Gabaix and Laibson (2006) paper by adding a repeated-game analysis in the presence of multiple equilibria.

Shulman and Geng (2013) consider asymmetric firms (firms may differ in the quality of the base good and in the quality of the add-on) in the Gabaix and Laibson (2006) framework and introduce a group of consumers who only consume the base good. They show that a larger number of inattentive consumers may lead to less surplus for attentive consumers (which reverses the prediction of Gabaix and Laibson (2006)). They also show that a firm producing higher quality may benefit from a large number of myopic consumers while a firm offering a low quality loses out. Wenzel (2014) considers a version where the impact of advertising add-on information depends on the number of unshrouding firms. In this setup, unshrouding equilibria can be very stable even in markets with many myopic consumers.

Spiegler (2006) provides an oligopoly model where a product's total price consists of multiple price elements which all need to be evaluated to infer a product's total price. Consumers, however, base their purchase decision on one (random) price element only. Similarly, Heidhues *et al.* (2012) study a setup where firms can confuse consumers by partitioning the total price of a product into two components, one of which may be shrouded. They find that an equilibrium with a hidden price component exists if there is a binding price floor on the base good.

A number of studies analyze strategies by which firms may complicate product comparisons via complex price formats or frames. Carlin (2009) develops a model where firms, by choosing complicated price formats, can increase the share of naive consumers who are not able to actually compare different offers. The main result of this paper is that more intense competition (as measured by the number of firms) can lead to more obfuscation. Gu and Wenzel (2013) study the impact of consumer protection policies in a similar framework.

Piccione and Spiegler (2012) and Chioveanu and Zhou (2013) consider models where firms compete in prices as well as in price frames and where choosing different price frames affects consumers' ability to compare price offers. A larger number of firms may increase firms' incentives to rely on choosing different price frames. Finally, Wilson (2010) and Ellison and Wolitzky (2012) consider models where firms can intentionally raise consumers' search costs to impede on consumer search behavior. Spiegler (2014) develops a general model that encompasses such obfuscation strategies.

Buyer confusion and to what extent firms can exploit such confusion are topics that are relatively new to the experimental literature. A notable exception is Kalayci and Potters (2011). They 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.

In a related experiment Kalayci (2012) uses this setup to study the effect of competition by varying the number of sellers. He finds that the number of attributes chosen by sellers does not vary with the number of sellers and concludes that the intensity of competition has no effect on obfuscation.

Our research is also related to a small number of experimental studies that analyze behavior in two-stage games. In most cases, both stages are cooperation decisions by nature whereas we analyze the spillovers between a cooperation game and a coordination game.

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.

Nicklisch (2012) analyzes how the advertizing may affect tacit price collusion. The baseline model is similar to Suetens (2008), and both prices and advertizing expenditures are strategic substitutes. However, in his experiment, advertizing investments are fixed for several periods whereas prices can be adjusted every period. When advertizing spillovers are lower than the size of the price spillovers, a higher degree of investment collusion facilitates price collusion for experienced players. Otherwise, a higher degree of advertizing negatively influences the degree of price collusion.

There is also an experimental literature on subsequent capacity and price decisions. The aim of this literature is to explore the validity of the Kreps and Scheinkman (1983) result. See Davis (1999), Muren (2000) and Anderhub *et al.* (2003).

More recently, Cason *et al.* (2012) consider spillovers between two coordination games. They study minimum- and median-effort coordination games where participants play the two games simultaneously or sequentially. They show that successful coordination on the Pareto optimal equilibrium in the median game influences decision making in the minimum game when the games are played sequentially. Their research differs to ours in that we study spillovers between a coordination and a cooperation game. Our results are also slightly different: we observe a positive spillover in the cooperation game (higher prices) and a negative spillover in the coordination game (lower shrouding rates).

Cooper and Kuehn (2014) study a two-stage game with and without communication where a cooperation decision is followed by a coordination decision. Their focus is on communication and renegotiation. Communication may serve as a coordinating device, since messages with threats and promises regarding the coordination decision stage facilitate collusion. Contrary to theory, allowing for renegotiation increases collusion. In our game, by contrast, decisions are made at the same time and payoffs of the two games are mutually dependent. We also analyze repeated play. In contrast to Cooper and Kuehn (2014), we provide treatments where the two games are played in isolation (where we add that these treatments would not be particularly useful for the topic Cooper and Kuehn (2014) address).

Bruttel *et al.* (2013) analyze finite-horizon prisoners' dilemma games with an additional "avoid" action which can be a strict or a weak Nash equilibrium. Their results suggest that only a strict additional equilibrium increases cooperation for a given length of the time horizon. They also find that a longer time horizon promotes cooperation. In our setup, both equilibria are strict and we observe more cooperation.

3 A simple model of add-on pricing

3.1 Model setup

The model we consider is a stylized version of Gabaix and Laibson (2006). 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-on.[3]

Following Gabaix and Laibson (2006), the add-on shrouding decision of the firms can be represented as a coordination game. If all firms decide to shroud add-on information, (myopic) consumers can be exploited and be charged high add-on fees. 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. 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 has a negative impact on firms still shrouding add-on information—they do not sell the add-on any more.

[3] In our stylized 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 modification has been made for simplification purposes and does not qualitatively affect the main hypotheses that result from the model.

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 lowest price, its profits are zero.

At this point it is important to note that the firms' two decisions, the pricing decision of the base good and the shrouding decision, can be interpreted in terms of well-known games, a cooperation game and a coordination game. Like any standard Bertrand competition game, the pricing decision is a cooperation game where firms have incentives to collectively agree on higher prices, but individually each firm has an incentive to undercut its competitors. The shrouding decision corresponds to a coordination game; in our case it is a stag-hunt game. The risky strategy (shrouding) offers the possibility of a high payoff if all firms coordinate on this strategy and the safe strategy (unshrouding) offers a lower, but secure payment.

3.2 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 $\pi^* = \frac{\underline{f}}{n}$.

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. Note that, 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 structure 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.

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.[4] In addition, profits in the shrouding equilibrium are higher than in the unshrouding equilibrium. That is, from the firms' perspective it would be beneficial to coordinate on the shrouding equilibrium.[5]

3.3 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 equi-

[4] 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.* (2012).

[5] 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.

libria where firms play the shrouding equilibrium in some periods and the unshrouding equilibrium in other periods.

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).[6] 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 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 SGP 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 $\frac{\overline{f}}{n}$ in each of these periods. Total profits from deviating are then $(p^c + \overline{f}) + H\frac{\overline{f}}{n}$.

[6] 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.

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 SGP Nash equilibrium where firms tacitly collude on a price $p^c > 0$ from periods $t = 1, ..., T - H^*(p^c)$.

Proposition 2 shows that collusive equilibria exist in the finitely repeated game if the time horizon is sufficiently long. The Proposition is specified for an arbitrary collusive price $p^c > 0$, this includes the special case where firms coordinate on the highest possible price for the base good, $\bar{p}$. The collusive equilibria involve choosing the collusive price in the first periods of the game (periods $t = 1, ..., T - H^*(p^c)$) and choosing the competitive price toward the end of the game (periods $t = T - H^*(p^c) + 1, ..., T$). In equilibrium, firms shroud the add-on in all periods.

It should be noted 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.

4 Experimental design

Our main goal is to analyze the impact of 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 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. Parameters regarding shrouding were $\underline{f} = 5$ and $\overline{f} = 10$. The shrouding decision was framed neutrally. Participants of the experiment were told that they could earn extra profits by deciding between two actions, A and B. In the case of action A (corresponding to unshrouding) they would earn an extra amount of $\underline{f} = 5$ for each unit of the base good they sold. In the case of action B (corresponding to shrouding) sellers received an extra amount of $\overline{f} = 10$ for each unit sold if this action B was also chosen by all other sellers. Otherwise, if at least one seller decided to unshroud, a shrouding seller would receive no extra revenues.

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 extra treatments where the cooperation and coordination games 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 not mentioned. In the "price only" treatment,

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

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 interaction 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 session were conducted at the experimental economics laboratory University of Duesseldorf between June and December 2012. 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. No subject participated in more than one session and none of the subjects had ever participated in any similar experiment before.

5 Hypotheses

Our first hypothesis is about the shrouding frequency of $n = 2$ vs. $n = 4$ firms in the static game. 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 "hare" (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, the duopolies are shrouded more frequently than the quadropolies.*

Regarding the same question under repeated interaction, existing experiments with repeated interaction strongly 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.[7] We propose:

Hypothesis 2. *With fixed matching, the duopolies are shrouded more frequently than the quadropolies.*

A third hypothesis regards the frequency of shrouding decisions in one-shot vs. repeated interaction. 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:

[7] For stag hunt experiments, see also, e.g., Battalio *et al.* (2001), Clark and Sefton (2001) or Schmidt *et al.* (2003). Note that in those experiments, the coordination action was the only decision while in our main setup participants simultaneously interacted in a cooperation game.

Hypothesis 3. *Markets with fixed matching are shrouded more frequently than markets 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. *In finitely repeated games, markets that involve the shrouding decision only are shrouded more frequently than our baseline markets.*

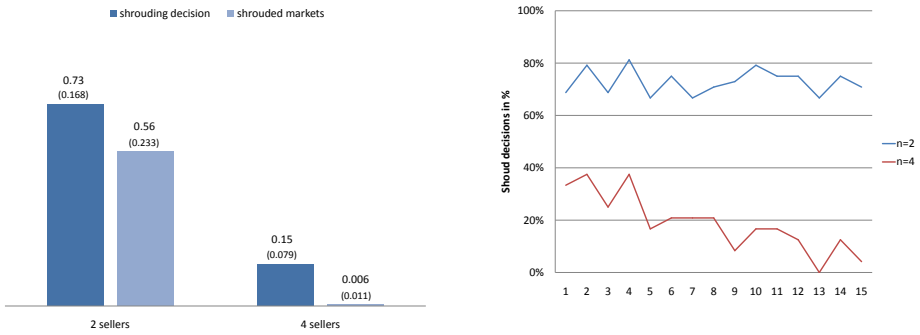
The repeated game gives rise to the existence of tacitly collusive equilibria with above marginal cost pricing. For our experimental design, Proposition 2 predicts, for example, that duopolies and quadropolies can (tacitly) collude on the maximum price of 10 for the first 11 or 3 periods, respectively.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

Hypothesis 5. *In finitely repeated games, markets that involve only the pricing decision will exhibit lower prices than our shrouding-plus-price-setting markets.*

6 Results

This section presents the experimental results. We start by describing the outcomes with one-shot interactions before proceeding with repeated interactions. Finally, we evaluate the spillover effects between the coordination and the cooperation 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.



(a) Shrouding rates and shrouded markets (b) The evolution of shrouding rates

Figure 1: Shrouding decisions and shrouded markets with one-shot interactions

6.1 One-shot interactions

We start by analyzing shrouding decisions in the treatments with a random matching protocol that mimics behavior with 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.

Figure 1 shows the shrouding rates and the share of shrouded markets in the treatments with two and four firms. The left panel provides aggregate rates over all periods while the right panel shows how shrouding rates 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).[8] 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 sell-

[8]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.

ers, however, as figure 2 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).

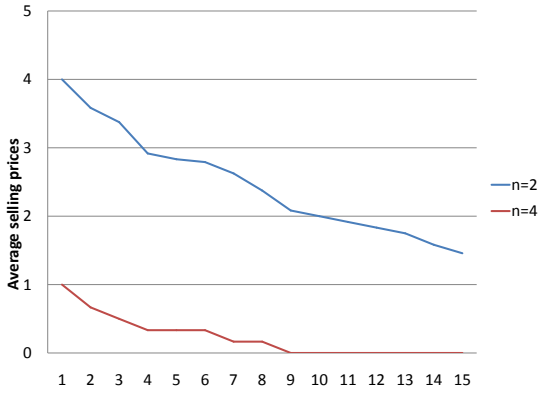


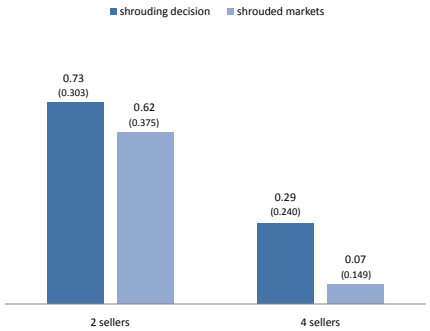
Figure 2: The evolution of selling prices with one-shot interactions

We summarize our results with one-shot interactions as follows:

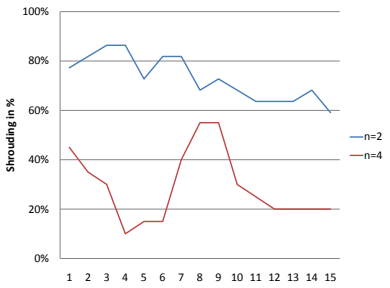
Result 1. Shrouding with one-shot interactions. *Consistent with Hypothesis 1, there is a substantial amount of shrouding in the duopoly markets which does not decline over time, and there is little shrouding in the $n = 4$ markets which converges to zero.*

6.2 Finitely repeated interactions

We now turn to the results in the treatment with repeated interaction where the same sellers (two or four) repeatedly interact over the entire length of the experiment. Figure 3 shows overall shrouding rates as well as the evolution over time. As in the treatments with one-shot interaction and consistent with Hypothesis 2, we observe that shrouding is more prevalent in markets with few sellers (Mann-Whitney rank-sum test, $p = 0.015$). There is substantial shrouding with two sellers, which, however, decreases over time,



(a) Shrouding rates and shrouded markets



(b) The evolution of shrouding rates

Figure 3: Shrouding decisions and shrouded markets with repeated interactions

but is still significant at the end of the experiment. Coordination success is also high. As in the treatment with random matching, with four sellers, shrouding rates and coordination success is much lower.

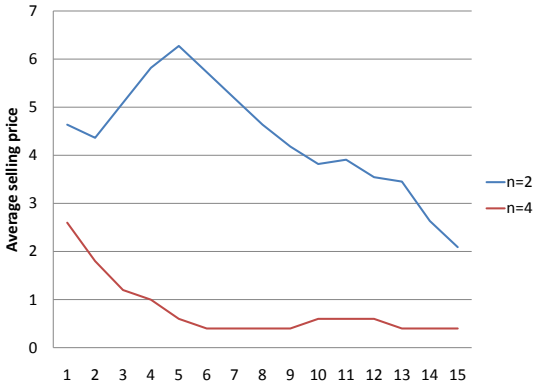


Figure 4: Selling prices over time - repeated

Figure 4 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 decrease 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, sell-

ers 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 finitely repeated interactions. *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.*

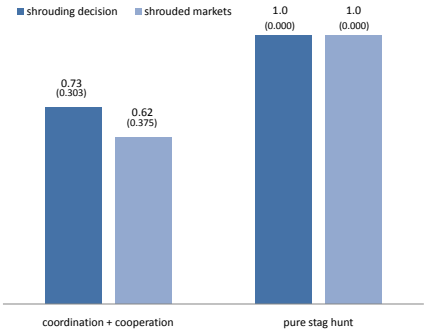
6.3 The impact of the matching procedure

An interesting result is that coordination on the shrouding equilibrium does not improve much with repeated interaction. 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 repeated interaction. However, the shrouding rates with repeated and one-shot interaction are not statistically different for $n = 2$ (Mann-Whitney rank-sum test, $p = 0.513$). For $n = 4$, we do observe better coordination, however, the effect is, overall, weak. Since we cannot reject the null hypothesis, we find no support for Hypothesis 3 (Mann-Whitney rank-sum test, $p = 0.459$). This result suggests that the shrouding mechanism is possibly used by players in a different manner with repeated interaction, at least for the duopolies.

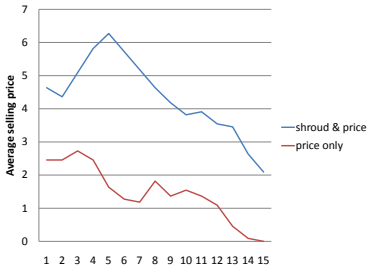
Result 3. Impact of matching scheme on shrouding behavior. *We find virtually no support for Hypothesis 3. Repeated interactions do not lead to more shrouding than one-shot interactions.*

6.4 Spillovers between decisions

Our previous results suggest that spillovers exist between the cooperation and the coordination decision, for instance, because participants might use shrouding (unshrouding) as a reward (threat) for sticking to (deviating from)



(a) Comparison to shrouding in isolation



(b) Comparison to pricing game in isolation

Figure 5: Spillovers between coordination and cooperation

collusive prices. To shed more light on the spillovers, we now compare the $n = 2$ treatment with fixed matching to treatments where

i) players play the coordination game (stag hunt) only,

ii) players play the pricing game only.

Figure 5 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 game is played in isolation (Mann-Whitney rank-sum test, $p < 0.001$). Indeed, we observe that participants always choose to shroud. This corroborates our finding that, with repeated matching, when both games 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 stag-hunt game only.*

The right panel of Figure 5 reports the results of the Bertrand game played in isolation. It shows that the average selling price is significantly higher in the treatment with both coordination and cooperation decision compared to the pricing game 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 facilitates tacit collusion. *Consistent with Hypothesis 5, the opportunity to shroud/unshroud facilitate tacit collusion as it 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 repeated interaction. 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, $p = 0.039$).

7 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.

Our experiments support 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 competition has an effect. First, shrouding and unshrouding equilibria often coexist. The shrouding decision is a coordination game 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 competition is detrimental to shrouding. The second effect of competition on shrouding occurs with repeated interactions. For concentrated markets (duopolies in our case), 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 so 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 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 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, competition has the desirable result of eradicating non-desirable obfuscation strategies. In markets with imperfect competition, however, not only do obfuscation strategies survive, but in addition, 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.

A Appendix

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 25 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 comprises the show-up fee and the points you have earned during the experiment.

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