

Gaudeul, Alexia; Crosetto, Paolo

Conference Paper

Choosing whether to compete: Price and format competition with consumer confusion

Beiträge zur Jahrestagung des Vereins für Socialpolitik 2016: Demographischer Wandel - Session: Experimental IO, No. E05-V2

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Gaudeul, Alexia; Crosetto, Paolo (2016) : Choosing whether to compete: Price and format competition with consumer confusion, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2016: Demographischer Wandel - Session: Experimental IO, No. E05-V2, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft, Kiel und Hamburg

This Version is available at:

<https://hdl.handle.net/10419/145875>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Choosing whether to compete

Choosing whether to compete:
Price and format competition with consumer
confusion

March 1, 2016

We present results from a market experiment where firms with identical products can choose not only their price but also the format of their product. Products with different formats are difficult to compare but products with the same format are directly comparable. Savvy consumers buy the lowest priced of those products with the same format. We find that firms are unlikely to adopt the same format if there are many savvy consumers and firms can observe each other's decisions. Increases in the number of savvy consumers then lead to higher average prices. We argue that tacit collusion is at the origin of this result. Patterns in the evolution of prices give further support to this hypothesis.

JEL Codes: D03, D18, D43, L13, L15

Keywords: collusion, obfuscation, price comparison, shrouding, spurious differentiation, standardization, transparency.

1. Introduction

[Scitovsky \(1950\)](#) defined an ignorant buyer as “a person who is unable to judge the quality of the products he buys by their intrinsic merit” and proposed that buyer ignorance could be a source of oligopoly power. We consider in this paper why competition does not reduce buyer confusion, and in particular why firms do not adopt common pricing formats and common ways to present their products that would allow consumers to make accurate comparisons across offers and select the best products. Pricing formats can take many forms. Prices can be expressed by the volume, mass or per unit of the good sold. Users may be offered subscriptions or charged on a per-usage basis. After-sale services, insurance and extended guarantees may be included or sold as an add-on. The way the product is presented can also vary, such as the shape of its package, the metrics used in advertising and describing the product, the location of the product on shelves, or the category it is included in when listing online. All this variety in the pricing and presentation of a product – what we call the *format* of the product – affects the process by which the product is evaluated. There are many legitimate reasons why firms may price and present their products in different ways, but one side-effect of choosing a format that differs from that of other firms is that consumers then find it more difficult to compare one’s product with others. It is indeed easier to compare products if their price is expressed in terms of a common metric, if the conditions of use are the same, if comparable information is provided or if they are sold in the same place. Common formats make it easier for consumers to choose based on a product’s essential characteristics without having to go through complicated calculations and extensive search to find out about and translate the value of competing goods in terms of a common unit. However, firms may not want consumers to be able to evaluate their products easily *vs.* the competition. Indeed, while a firm with a superior product may increase sales in the short term by assisting comparison with the competition, this may trigger a price war and lead to lower profits for all firms in the long term. Firms may therefore strategically maintain idiosyncratic pricing schemes, performance metrics, distribution channels and ways to package and present their products.

Context and motivation Standardization is often initiated by policy-makers. An example of forced standardization was the toppling of the seigneurial monopoly of weights and measures during the French revolution. This was replaced by a standard (metric) system of measures, which is now almost universally adopted worldwide. Before then, a major complaint of the “common people” was that the feudal lords could arbitrarily manipulate the definition of the measures to quantify what peasants owed them. Merchants and shopkeepers also frequently exploited confusion about units of measures against their clients ([Kula, 1986](#), Ch. 23).

Unlike in the example above however, the choice of format is most often made by firms themselves rather than imposed from above. To take an example inspired by [Spiegler \(2014\)](#), suppose there are

two yoghurt manufacturers and they can choose to market their product as either a health product or a dessert. Choosing one or the other determines in what shops their product are sold, or, if sold in the same shop, on what shelves the products are presented. Choosing the same category makes of both products direct competitors. Choosing different categories introduces an element of differentiation, at least in the mind of the consumer. Another similar example is branding. Consider two competing soda manufacturers, one who sells its products in a red package and the other in a blue package. The two products differ only in the color of their package and consumers develop habits either to buy the red or the blue product. A third manufacturer entering the market now has to choose the color of its packaging. If it chooses green, then it avoids direct competition with either of the two incumbents, but if it chooses red, then consumers see its product as undistinguishable from the other existing red product and then choose the cheapest of the two. A third example is the decision whether to list one's product at an online intermediary, sell via a supermarket, or locate one's shop in a shopping center (Non, 2010). Using an intermediary or locating close to other firms exposes to direct competition with the other firms that are also using the intermediary, while selling in one's own shop or via one's own website guarantees at least the demand from consumers who do not know of, or do not have access to, the intermediary (Baye and Morgan, 2002; Gaudeul, 2010). That firms do consider such decisions as a strategic matter is illustrated by White (2015), which mentions how airline companies attempt to limit the number of online travel agencies that may list their fares. They do so in order to encourage regular users of their services to purchase their ticket via the airline directly. Comparative advertising involves similar strategic considerations as it can devolve into advertising wars (Beard, 2010), with negative consequences for profits (Barigozzi and Peitz, 2007).

Literature An “old economic intuition” is that the presence of savvy consumers “helps to protect other customers” from exploitation by firms (Armstrong, 2015). Competition for savvy consumers “at the margin” should drive down prices (Salop and Stiglitz, 1977; Varian, 1980). Experience should teach consumers to avoid obfuscating firms by avoiding products that are presented in unusual formats (Gaudeul and Sugden, 2012). New entrants with more transparent offers should enter obfuscated markets (Wenzel, 2014). Recent work challenges the faith in this economic intuition. A developing literature investigates how firms can exploit the cognitive limitations of consumers to establish market power (Scitovsky, 1950). A recent book (Shiller, 2015) and a number of review and policy papers (Beales et al., 1981; Garrod et al., 2009; Armstrong, 2015; Spiegler, 2015) explore how firms manipulate and deceive boundedly rational consumers who “search too little, become confused comparing prices” and fail to switch from their default options (Grubb, 2015). The OFT and Ofcom in the UK, the Consumer Financial Protection Bureau in the US, the Australian Competition and Consumer Commission, the Swedish Competition Authority and the OECD Committee on Consumer Policy, among others, have expressed

concerns about marketing strategies that magnify how difficult it is for consumers to make rational and well informed choices. The practice and ethicality of “confusion marketing” is also a topic in the marketing literature ([Edward Kasabov, 2015](#)). Some marketers call for greater simplicity in offerings ([Cristol and Sealey, 2000](#); [Spenner and Freeman, 2012](#)).

Markets “in which the forces of competition are evaded via intentional obfuscation” have been called “confusopolies” ([Adams, 1997](#)). In such markets, firms make it difficult for consumers to consider all options ([Wilson, 2010](#); [Ellison and Wolitzky, 2012](#)), use complex price schedules ([Carlin, 2009](#)), hide some of the costs of using their product ([Ellison, 2005](#); [Gabaix and Laibson, 2006](#); [Heidhues et al., 2012](#); [Wenzel, 2014](#)) or make it difficult to compare products ([Møllgaard and Overgaard, 2001](#); [Spiegler, 2006](#); [Bar-Isaac et al., 2010](#); [Piccione and Spiegler, 2012](#); [Gaudeul and Sugden, 2012](#); [Chioveanu and Zhou, 2013](#); [Spiegler, 2014](#)). There is some empirical evidence that “intentional obfuscation” does indeed occur in reality ([Hossain and Morgan, 2007](#); [Ellison and Ellison, 2009](#); [Woodward and Hall, 2010](#); [Célérier and Vallée, 2013](#); [McDonald and Wren, 2013](#); [Muir et al., 2013](#); [Wenzel, 2013](#); [Ericson and Starc, 2013](#)), and that mandated standardization can improve consumer welfare ([Ericson and Starc, 2013](#)).

Beyond theoretical arguments and empirical evidences, experiments also play their part in investigating how firms can maintain confusing offers. The advantage of experiments *vs.* empirical studies is that in experiments, one can create purely spurious product differentiation. One can make it so that the format of the product affects only how easy it is to evaluate its value, but not its value itself. Such cases of purely spurious product differentiation are difficult to identify in reality. For example, Coca-Cola’s “contour” design for its bottles may make it more difficult to compare their volume with bottles of another design, but they also make them more attractive to consumers – which was probably the main reason for the design’s adoption.

In this paper, we focus on how the presence of a larger share of savvy consumers – consumers who compare products when they are comparable – can make firms more likely to sustain tacit collusion. Our goal is to determine whether competition for savvy consumers “disciplines or rather exacerbates framing effects” ([Spiegler, 2014](#)), that is, whether savvy consumers drive firms to make their offers comparable, which leads to more competitive markets, lower prices and higher consumer welfare. We focus in particular on how firms “manipulate the scale of similarity judgments” ([Spiegler, 2014](#)) in a strategic way – that is, how firms decide whether to make their offers comparable with those of other firms. We are particularly interested in testing the argument in [Møllgaard and Overgaard \(2001\)](#), whereby improved transparency on the consumer side – more consumers who shop around when products are comparable – is a “mixed blessing” because it makes consumers more sensitive to price changes. Profits are then lower if firms actually compete, so that they are more likely to prefer adhering to a (tacit) collusive agreement.

[Kalaycı and Potters \(2011\)](#); [Kalaycı \(2015a,b\)](#) and [Shchepetova \(2012\)](#) present experiments that are

similar to ours as they let firms manipulate the complexity of their offers. Other related experiments only compare markets with different, exogenously given, levels of product complexity. [Kalaycı and Potters \(2011\)](#) shows that firms “make it overly complex for buyers to assess the quality of their goods”. [Kalaycı \(2015b\)](#) shows that having human consumers rather than robot consumers mitigates the issue. [Shchepetova \(2012\)](#) shows that firms respond to more competition (more firms in the market) by increasing the complexity of their offers, but [Kalaycı \(2015a\)](#) finds the opposite. Our focus on the link between collusion and the share of savvy consumers means that unlike [Kalaycı and Potters \(2011\)](#), we need to control the share of informed consumers, so that we do not employ human consumers, but rather robot consumers. Unlike [Shchepetova \(2012\)](#), we fix the share of savvy consumers in each treatment rather than let the share of informed consumers depend on the level of product complexity that arises in the market. Compared to those two papers, we simplify the decision about the level of complexity of the offers, as firms in our experiment make a binary decision: either make their offer difficult to compare with the competition or not. Finally, we run treatments both with full and with no information about the competition, which allows us to compare an environment that is conducive to collusion (full information) with a “baseline” (no information) where tacit collusion is more difficult to establish.

We find that transparency on the supply side – firms being able to observe each other – is associated with firms preventing transparency on the consumer side – firms present offers in different formats so that consumers cannot compare them. The issue becomes worse in treatments with higher shares of savvy consumers. When firms are not able to observe each other however, firms are more likely to choose common formats, especially so when there are many savvy consumers. Prices and profits are higher under full information, and we present evidence that this is due to tacit collusion.

Outline We first present our model of competition between firms and how this model was implemented experimentally. The choice of treatments is then motivated and predictions of the outcomes of the experiment are made. Empirical results are presented, starting with an evaluation of treatment effects on price levels and frequency of use of common formats. The paper concludes with a discussion of the implications of its findings.

2. A model of competition with spurious differentiation

We first present our model of competition for the case with two firms before extending it to the case with three firms.

2.1. The duopoly

Two firms, A and B , operate in the same market and decide on the *price* of their product and the *format* in which their product or its price is presented. They do this independently and without knowing the choice of the other firms. There are two formats, format A and format B . Firm A must adopt format A while firm B can choose to adopt either format B or format A . In that later case, the two products are said to be *comparable*, in a sense and with consequences that are clarified below.

There are two types of consumers $j \in \{A, B\}$, both in equal number normalized to 1. If firms adopt different formats, then a consumer of type A perceives utility $v + e - p_A$ if he buys from firm A , with p_A the price set by firm A , and utility $v - p_B$ if he buys from firm B . The same holds, *mutatis mutandi*, for a consumer of type B . Parameter e is a measure of product differentiation in the line of [Perloff and Salop \(1985\)](#). However, that differentiation is spurious: if the consumer was able to evaluate products objectively or had equal access to both of them, then he would be indifferent between the two and choose the lower priced. To give an analogy, a consumer may believe that he prefers Coca-Cola to Pepsi, and thus be ready to pay more for the one than for the other. However, he might not be able to discern the two products in a blind tasting experiment. As mentioned in [Kalaycı and Potters \(2011\)](#), there are many interpretations for e other than spurious product differentiation, such as complexity of the price schedule or of the product.

As in [Salop and Stiglitz \(1977\)](#) and [Varian \(1980\)](#), a portion μ of consumers are “savvy”. If firm A and firm B both adopted format A , then a savvy consumer of either type perceives utility $v - p_A$ if he buys from firm A , and utility $v - p_B$ if he buys from firm B . The shroud of confusion is lifted for those consumers because they can compare the products directly. This leads them to simply choose the one with the lowest price. This happens however only if both firms adopt the same format. Not all consumers can be “debiased” in this way. The portion $1 - \mu$ of consumers of either type who are not savvy (“naive”) perceives the utilities of two products with the same format as if the two firms had not adopted the same format. It may be that they do not notice that the two products are comparable, *e.g.* because they do not read the description of the products. It might also be that they are used to buying only from one of the firm or that they developed loyalty to one of the firm.

This specification of consumer preferences leads to the following schedules of demand for the product of firm B , as a function of its choice of format (figure 1). Prices cannot be set higher than v , as was the case in the experiment. We assume $p_A = 2.5$ and we let $\mu = 0.3$.

[Figure 1 about here.]

On the left hand of figure 1 is demand Q_B as a function of p_B when each firm adopts its own format ($ft_A = A$, $ft_B = B$). In that case, firm B keeps its own consumers as long as its price is not higher than that of firm A by more than e . If consumers of a certain type are indifferent between firm A and

firm B , then they divide equally between firms. The demand schedule is then:

$$\left\{ \begin{array}{ll} Q_B = 2 & p_B < p_A - e \\ Q_B = 3/2 & p_B = p_A - e \\ Q_B = 1 & p_B \in]p_A - e, p_A + e[\\ Q_B = 1/2 & p_B = p_A + e \\ Q_B = 0 & p_B > p_A + e \end{array} \right.$$

On the right hand of figure 1 is demand Q_B if firms adopt the same format ($ft_A = A, ft_B = A$). If firm B prices lower than firm A , then it gains firm A 's savvy consumers. It also gains firm A 's naive consumers if its price is lower than that of firm A by more than e . The demand schedule is then:

$$\left\{ \begin{array}{ll} Q_B = 2 & p_B < p_A - e \\ Q_B = (3 + \mu)/2 & p_B = p_A - e \\ Q_B = 1 + \mu & p_B \in]p_A - e, p_A[\\ Q_B = 1 & p_B = p_A \\ Q_B = 1 - \mu & p_B \in]p_A, p_A + e[\\ Q_B = (1 - \mu)/2 & p_B = p_A + e \\ Q_B = 0 & p_B > p_A + e \end{array} \right.$$

This discontinuous schedule of demand can be approximated with a logistic function (shown as a dotted blue line in graph 1). The demand schedule is “steeper” when firms adopt a common format than when they maintain different formats. Choosing the same format lessens differentiation between products, so the demand becomes more sensitive to price changes.

2.2. The triopoly

The case with three firms is very similar to the case with two firms as long as all firms adopt their own format or all firms adopt format A . If all firms adopt their own format, then mass 1 of consumers of each type perceive the product of the firm corresponding to their type as superior to the others by a margin of e . If all firms adopt format A , then savvy consumers choose the lowest priced firm while naive consumer behave as if there was no common format. There is however a case that does not occur in the duopoly, and that is when two firms adopt format A and one firm keeps its own format. The consumers then face a choice between two comparable offers and one that is not comparable. As before, naive consumers ignore the existence of a common format. However, we assume that savvy consumers are subject to the attraction (or decoy) effect, *a.k.a* asymmetric dominance editing (more on this later). This means that savvy consumers favor the lowest priced of the offers with format A over the idiosyncratic

offer. They apply a penalty on idiosyncratic offers, whereby they behave as if the price p of the product with an idiosyncratic format was $(1 + \lambda) \cdot p$. The extent to which savvy consumers dislike offers that are difficult to compare is thus measured by $\lambda > 0$.

Suppose for example that firms A and B share a common format and firm C adopts format C . Then:

- savvy consumers of all types derive utility $v - p_A$ (resp. $v - p_B$) when buying from firm A (resp. firm B). This is because the products of firm A and of firm B are comparable, so that savvy consumers lose any bias for one or the other firm – the offers of firms A and B are unshrouded.
- savvy consumers of type A and of type B derive utility $v - (1 + \lambda) \cdot p_C$ when buying from firm C . This is because the product of firm C is not comparable and therefore suffers a penalty λ .
- savvy consumers of type C derive utility $v + e - (1 + \lambda) \cdot p_C$ when buying from firm C . This is because savvy consumers of type C are not able to compare the product of firm C directly with the competition, so they maintain their bias e in favor of firm C which is induced by confusion. However, they still prefer comparable offers, which means they also apply a penalty λ to the price of firm C .

2.3. Discussion of the model and of the method

We justify some of the modelling, assumptions and methodological choices in this section, in particular why we focus on comparability rather than complexity and why we explore the issue experimentally.

Simplifying a model of spurious differentiation Our model introduces format decisions in the established and flexible model of competition of [Salop and Stiglitz \(1977\)](#); [Perloff and Salop \(1985\)](#). Noisy estimate of the utility of each products ([Salop and Stiglitz, 1977](#)) is translated into a binary error term in the evaluation of products: e can take only two values, 0 or 1, and is perfectly negatively correlated across firms. One firm, firm A , cannot change its format so that other firms are sure that by choosing format A then their product is comparable to that of firm A .¹ Simplifying the model in this way made it possible to explain the game to the subjects in the laboratory.

Preference for offers expressed in a common format In our model, a firm is not able to unilaterally “unshroud” the whole market. Firms with their own idiosyncratic format may cohabit with firms that adopted a common format.² From our own preliminary study of the behavior of consumers in a similar setting ([Crosetto and Gadeul, 2014](#)) and from the literature on the attraction (*a.k.a.* decoy or asymmetric dominance) effect ([Huber et al., 1982](#); [Huber and Puto, 1983](#); [Simonson, 1989](#); [Tversky and Simonson, 1993](#)), consumers will not treat the product of a firm with its own idiosyncratic format in the same way as the dominant offer of two comparable alternatives. This is why parameter λ was introduced to measure the strength of the preference of savvy consumers for comparable offers. $\lambda = 0$ means that

savvy consumers do simple *dominance editing*, which is what [Sugden and Zheng \(2015\)](#) observe in a purchasing experiment. $\lambda > 0$, as observed in [Crosetto and Gaudeul \(2014\)](#), means that savvy consumers perform *asymmetric dominance editing*.³ Modeling demand in this way, we manipulate not only *how many* consumers compare products based on prices when the products are comparable (μ), but also by *how much* they prefer comparable to non-comparable offers (λ). We therefore precisely manipulate consumers' "sensitivity to frames" ([Spiegler, 2014](#)).

Focusing on the issue of comparability, not complexity Rather than letting firms present offers that are inherently difficult to evaluate, they have the choice to make their offers either easy or difficult to compare with the competition. This modeling therefore differs from the existing experiments that all focus on the impact of product complexity. In choosing to focus on comparability, our inspiration is in the line of [Piccione and Spiegler \(2012\)](#) rather than of [Carlin \(2009\)](#). Choosing different formats could be assimilated to making one's product more complex in models of product complexity. The difference is that rather than "complexity", we consider "difficulty in comparing product". By choosing the same format as another firm, a firm makes both of their products easier to evaluate *in comparison with* each other, but not necessarily easier to evaluate on their own.

Complexity experiments include [Kalayci \(2015b\)](#), which varies complexity exogenously by manipulating the time pressure for consumers to make choices and [Sitzia and Zizzo \(2011\)](#), which does so via lottery compounding. [Sluijs et al. \(2011\)](#) and [Henze et al. \(2014\)](#) give out noisy information about the quality of products in some of their treatments. Finally, [Kalayci and Potters \(2011\)](#) and [Shchepetova \(2012\)](#) let firms vary complexity endogenously *via* their choice of the number of parts in a tariff. In [Kalayci \(2015a\)](#), the quality attributes of a product can also be multiplied. Those experiments, by focusing on the issue of complexity, were left with the difficult issue of choosing what form of complexity they wanted to investigate, and indeed the forms of complexity differ in all those experiments.

This is why we focus on the issue of comparability rather than that of complexity. It is easier to apply and operationalize this concept in many different settings. Indeed, a great many products that are in common use nowadays are very complex, to an extent that it is often impossible for a consumer to understand how they work. However, even a very complex product can still be made comparable to a product in the same category sold by another firm. Furthermore, while it is difficult to determine by how much a two part tariff is more complex than a three part tariff, for example, it is easy to see that they are not directly comparable, in the same way that a price in € is not directly comparable to a price in ¥. Findings from an experiment which like ours varies whether products are comparable or not are therefore easier to generalize than findings from experiments that vary the complexity of the products on offer.

Exploring the model experimentally We decided to explore the workings of this model by running an experiment where human participants play the role of firms. There is a long tradition of experiments in industrial organization whereby demand is computerized while human subjects are asked to play the role of firms (Holt, 1995). Reciprocal behavior and other moral codes that subjects display in many experimental games are rarely found in experimental markets, where incentives and a certain “market moral code” seem to crowd out other behavioral principles (Roth et al., 1991). Participants were university students, but professionals have generally been shown not to behave in ways that are significantly or systematically different from students in experiments that are relevant to their field (Siegel and Harnett, 1964; Abbink and Rockenbach, 2006; Frechette, 2011) – see Potters and van Winden (2000) for an exception.

There are two main reasons for running an experiment rather than solving the model using various equilibrium concepts or exploring the question empirically. From a theoretical point of view, it is difficult to assess what behavior may emerge when subjects play this market game. This depends on factors that are difficult to explore theoretically, such as the ability of firms to maintain tacit collusion or the strategies that firms may follow in settings with incomplete information. Exploring the question empirically is also difficult because it is hard to assess whether some product differentiation is truly spurious (Perloff and Salop, 1985). Some of the variety and complexity of products may appear to be designed to confuse consumers but actually serve to better fit their demand.

2.4. Choice of treatments

Share of savvy consumers and strength of their preference First, we explore behavior when faced with different shares μ of *savvy* consumers and with different intensities λ of their preferences for comparable offers. The baseline is a market with no savvy consumers ($\mu = 0$). The subjects in this baseline treatment could still choose the format for their product but were told that consumers did not care about formats. Combinations of $\mu = 10\%$ or $\mu = 20\%$ and $\lambda = 10\%$ or $\lambda = 20\%$ are then considered. Low values of the parameters were adopted in order to minimize difference from the baseline and thus isolate the strategic effect of introducing a preference for comparable offers. Low values also address the possibility that only few consumers do comparison shopping. Indeed, there are markets where consumers are very set in their ways and not sensitive to objective comparisons across products. Finally, various combinations of values μ and λ are considered in order to identify more robustly the effect of changes in the values of the parameters. For example, the effect of an increase in μ from 10% to 20% is more robustly identified if the effect of this increase is measured for both $\lambda = 10\%$ and $\lambda = 20\%$.

Information available to firms Second, we explore the effect of the availability of information about prices and sales of the other firms on behavior, especially on tacit collusion. The information manipu-

lation covered two different regimes: *full information* about the past prices, choice of format, sales and profits of competitors, or *limited information* where one learns only one's own past sales and profit. Information about other firms is a factor in tacit collusion and the long-run survival of idiosyncratic formats "may require collusion among firms, with some form of tacit agreement that firms do not replicate one another's formats" (Gaudeul and Sugden, 2012). This is why we vary the ease with which firms can monitor the adherence of other firms to this possible tacit agreement. Since mutual monitoring by firms is generally held to favor tacit collusion, differences between full and limited information treatments help to assess the tacit collusion hypothesis. The link between information and collusion is discussed in a more detailed way on page 16.

Labeling of treatments There were thus 10 treatments in total, as summarized in table 1 along with their labels. L treatments feature Limited information; F treatments Full information; the numbers in subscript indicate the values of μ and of λ .

[Table 1 about here.]

3. Theoretical benchmarks

In the following, we consider a range of possible behavior by firms in the market and consider their implications in terms of average price level, price evolution and formats chosen. We consider Nash equilibria, myopic price adjustments and collusion, and also discuss imitation strategies and adaptive (reinforcement) learning.

3.1. Nash equilibrium

Figure 2 shows the best response function⁴ ("BRF") of firm B in a duopoly as a function of the level of the price of firm A . There are two dimensions to the choices by firm B , ft_B , the choice of format, and p_B , the price chosen. The case that is represented assumes $\mu = 40\%$.

[Figure 2 about here.]

For low prices of firm A then firm B chooses to target naive consumers by setting price $p_A + e - \zeta$ (with ζ the smallest allowable price unit, 0.01 ECU in the experiment), and sets its own idiosyncratic format B . It then sell to mass 1 of consumers. For medium prices of firm A then firm B chooses to target savvy consumers of firm A by adopting format A and pricing at $p_A - \zeta$. It then sells to mass $1 + \mu$ of consumers. Finally, for high prices of firm A then firm B takes all demand from the market by setting price $p_A - e - \zeta$ and selling to mass 2 of consumers. In this case, it is indifferent between setting format A or B because both naive and savvy consumers buy from it anyway.

The BRF of firm A can be drawn as well and depends on whether firm B chose format A or format B . There is no Nash equilibrium in pure strategies (“PSNE”). Suppose indeed that a PSNE exists with price p_A set by firm A . Then firm B either sets price $p_B = p_A + e - \zeta$ under its own format, or price $p_B = p_A - \zeta$ under format A , or price $p_B = p_A - e - \zeta$, where the choice of format is indifferent. The best response by firm A to such prices by B is either to undercut B by $e + \zeta$ or by ζ or to increase prices by $e - \zeta$. The best response by firm A to the best response by firm B to a given price p_A of firm A is therefore never p_A . This implies that Nash equilibria are in mixed strategies (“MSNE”).

The best response function of firms are very similar in the triopoly. We used Gambit, a software tool for game theory (McKelvey et al., 2014), to find the distribution of prices in Nash equilibria in the triopoly (Figure 8 in appendix A). Firms set prices in a range from 0.2 to 2.7 ECU and prices when they choose format A are generally lower than prices without a common format – setting a common format is thus analogous to having sales in Varian (1980). The distribution of prices moves to the left (lower prices) as μ increases.

Table 2 gives us expected profits in each treatment as well as the frequency with which format A is chosen by firms B and C . μ and λ in the table cover a range of conditions. $\lambda = 0$ indicates that savvy consumers adopt dominance editing and $\lambda = 100$ guarantees that savvy consumer never choose firms that adopt idiosyncratic formats. Higher μ and λ decrease profits. Higher λ encourages the use of format A , while higher μ discourages it.

[Table 2 about here.]

To summarize, if firms follow a MSNE, then profits are lower with higher μ and λ , and use of format A increases with lower μ and with higher λ . Prices when a firm adopt format A are lower on average than when it adopts its own format. Prices and format do not depend on decisions of others or of oneself last period. There is no prolonged trends in prices over time, and changes in prices are not correlated with changes in formats.

3.2. Myopic best response dynamics

Suppose that firms best respond to the strategies other firms adopted last period (Matsui, 1992; Fudenberg and Kreps, 1993; Fonseca and Normann, 2013; Mäs and Nax, 2016). If there is no differentiation ($e = 0$), then firms lower prices until prices equal zero. If $e > 0$ however, then prices do not converge to zero as a firm can always set its price at the level of the minimum price in the market plus differentiation parameter e . It then sells to consumers of its own type only but makes positive profits. There is then a constant cycle of price wars leading to low prices, which are followed by abrupt unilateral increases in prices. Prices rise like a rocket but fall like feathers (Tappata, 2009), as happens in Edgeworth price cycles (Maskin and Tirole, 1988; Kruse et al., 1994; Fonseca and Normann, 2013; Noel, 2015; Doyle et al.,

2010; Noel, 2008). Figure 9 in appendix B shows an example of such best response dynamics in the triopoly when $\mu = 50\%$ and $\lambda = 20\%$. If prices are high, then firms adopt format A and undercut each other by small amounts ϵ . Those downward price spirals are broken when a firm decides to raise its price by a large amount, adopt its own format and focus on its own customer types. This is followed by other firms until prices reach such a high level that it is again more profitable to adopt format A and undercut other firms, thus completing the cycle.

Simulations were performed to obtain the average profits in each treatment if firms follow myopic best response, as well as the frequency with which firms B and C adopt format A. Results are shown in Table 3.⁵ As under MSNE, higher μ and λ decrease profits. Unlike under MSNE, both higher μ and higher λ encourage the use of format A – higher μ leads firms to be stuck into longer lasting downward price spirals as attracting savvy consumers is then more profitable. Prices are on average higher in periods with no common format.⁶

[Table 3 about here.]

To summarize, *if firms follow myopic best response dynamics*, both higher μ and λ decrease profits and promote the use of format A. Prices when a firm adopts format A are lower on average than when it adopts its own format. Increases in prices occur over short periods of time with big increments, while declines in prices occur over longer periods of time with small increments. Finally, increases in prices are associated with the use of own formats, and decreases in prices are associated with use of format A.

3.3. Imitation dynamics

Imitation is an alternative way for participants in the experiment to play the game (Huck et al., 1999; Alós-Ferrer et al., 2000; Offerman et al., 2002; Selten and Apesteguia, 2005; Apesteguia et al., 2007). Consider the outcome of an “imitate the best” dynamic, whereby firms imitate the firm that made the highest profit last period. An equilibrium of this imitation dynamics, if it exists, has to be such that all firms make the same profit – otherwise, the low-earning firms imitate the better performing firm. This equilibrium is robust only if any small change in the decision by any one firm (an “experimentation”) leads that firm to earn lower profits than other firms. Appendix C shows that there is no such robust equilibrium under imitation. Figure 10 illustrates the price and format dynamics in the triopoly, whereby firms make small adjustments in prices and formats change with some small probability every period.⁷ Periods with no common format are associated with increases in price but a firm can gain by experimenting with format A and a lower price. If successful, this change in format is imitated. The lowest priced firm then makes the highest profit. Prices thus decrease until they are low enough that a firm can gain by experimenting with its own format.

To summarize, *if firms follow imitation dynamics*, then for any $\mu > 0$, profits and use of format A do

not depend on either μ or λ . If $\mu = 0$, then prices converge to 5. Prices set by a firm when it adopts format A are on average equal to prices when it adopts its own format. Increases in prices occur over the same length of time as declines in prices, and increases are of the same magnitude as decreases in prices. Finally, increases in prices are associated with the use of own formats, and decreases in prices are associated with the use of format A .

3.4. Adaptive (reinforcement) learning

Under an adaptive learning dynamic (Erev and Roth, 1998), a firm considers only its own past experience. “Players apply ex post rationality”, that is, they “assess the success of their previously chosen action ex post and adapt the strategy accordingly” (Köke et al., 2015). Impulse balance learning (Selten and Chmura, 2008; Chmura et al., 2012) is an example of such learning where the probability to choose an action is proportional to the profit it generates on average. The probability to choose price and format (p, ft) in iteration t of the learning dynamic is $pr_t(p, ft) = E(\pi_{t-1}(p, ft)) / \sum_{(p, ft)} E(\pi_{t-1}(p, ft))$ with $\pi_{t-1}(p, ft)$ the profit generated in period $t - 1$ of the learning dynamic. Actions that generate high profits are thus played with high probability, but any action that generates any profit is played with some positive probability. Table 4 summarizes results of the simulations of this learning dynamic in terms of average profit and frequency of choice of format A .⁸ Profits are lower on average than profits under myopic best response dynamics or mixed strategies. This is because unlike under mixed strategies, even lower earning actions are played with some probability and, unlike under best response, there is no automatic correction of prices upward when prices are too low. As in MSNE and best response, profits decrease with μ . However, higher λ lowers profits only up to a certain point. The frequency of use of common format A increases with λ and decreases with μ as long as λ is not too high, which is consistent with the MSNE.

[Table 4 about here.]

To summarize, *if firms follow reinforcement learning*, higher μ decreases profits and discourages the use of format A for the range of λ in the experiment. For that same range, higher λ decreases profits and promotes the use of format A . Prices when a firm adopts format A are lower on average than when it adopts its own format and, as in the mixed strategy Nash equilibria, there are no prolonged increases and decreases in prices over time, while increases and decreases in prices are not correlated with adoption or rejection of format A .

3.5. Collusion

3.5.1. Conditions under which collusion can be established

From the “folk theorem”, collusion is more likely to emerge when the profits generated under competition are the lowest. Indeed, the standard model of collusion relies on harsh punishment being available in case of deviation by any one party (Friedman, 1971; Aumann and Shapley, 1976; Fudenberg and Maskin, 1986; Abreu, 1988). The harsher the punishment, the less likely deviation occurs. A number of experiments have shown that collusion is likelier to emerge under fixed matchings (Huck et al., 2001) and with few firms (Huck et al., 2004). Suetens and Potters (2007) summarizes evidence that collusion in experimental markets is especially likely to emerge under Bertrand competition. From this literature, collusion is likely to occur in our experimental setting (fixed matching, few firms, Bertrand competition). Consider now the impact of changes in the treatment variables: the share of savvy consumers and the information conditions.

Share of savvy consumers. More savvy consumers makes demand more elastic when firms adopt a common format. This ought to encourage collusion since firms have more to lose by competing (Møllgaard and Overgaard, 2001). However, Petrikaitė (2016) shows that increased transparency on the consumer side (more savvy consumers) makes collusion more likely only up to a certain point, after which it makes it less likely. This is also the case in our model, as shown in appendix E. Given the range of parameters used in the experiment however, higher μ always make collusion easier to sustain. Indeed, there are no treatments with the very high values of μ after which increases in μ make collusion less likely.

Information condition. Experimental research generally supports the hypothesis that better information about competitors facilitates collusion (Dolbear et al., 1968; Feinberg and Snyder, 2002; Aoyagi and Fréchette, 2009; Fonseca and Normann, 2012), and this insight is used in policy formulation (Kühn, 2001). However, collusion can still be sustained even with imperfect monitoring (Stigler, 1964; Green and Porter, 1984; Abreu et al., 1986) and Compte and Postlewaite (2015) provide a psychological model of “plausible” cooperation in such a setting. Conversely, Vega-Redondo (1997) argues that more information can lead to more competitive outcomes if firms imitate each other and Huck et al. (2000) provides supporting experimental evidence. The general argument is however that in an environment with limited information, where firms only know their own decisions, breaks in tacit collusion have to be inferred from one’s own sales and since own sales are an imperfect signal of the actions of others, punishment may come too early or too late. Both too early break-down or late penalties mean that collusion is expected to be less likely to establish itself or be maintained in treatments with limited information.

3.5.2. How collusions may establish itself

Unlike under the standard model of Bertrand competition with no product differentiation, where a firm that wants to collude indicates wanting to do so by setting a given high price that can act as a focal point (usually, the maximum allowable price), safer strategies involving price leadership are available in our setting where products are (spuriously) differentiated. Price leadership can facilitate collusion (Mouraviev and Rey, 2011; Dijkstra, 2015) and can allow a firm to exploit imitation by other firms by gradually raising prices. Tacitly colluding firms gradually converge towards the maximum allowed price v without having to risk losing sales if other firms do not follow increases in prices. Consider indeed a candidate collusive pure strategy equilibrium of the repeated game with price profile (p_A, p_B, p_C) . If one of those prices is less than v then the firm with that price can increase it. If this new price does not exceed the minimum existing price by more than ϵ , then the firm that raised its price still makes sales – and may indeed increase profits if no firm adopted format A – while not lowering profits for others. Other firms have therefore no reason to resent that move. Rather, they ought to follow such a move by increasing their prices – especially so if the firm raising its price increased its profits. As long as all firms do not at any point increase prices by more than ϵ over the minimum price last period, then none runs any risk to either make zero sales or take sales away from other firms. Prices can thus easily converge to v .

Firms will find it easier to increase prices over time if they do not use a common format. Indeed, they then run less risk of losing or gaining market shares at the expense of others. Once collusion is established, not adopting format A at least weakly reduces the profits of a deviating firm and increases one's profit in case someone else deviates. Conversely, a firm deviating from collusion and thus lowering prices at least weakly benefits from adopting format A . We therefore expect collusion to be associated with the use of idiosyncratic formats.

To summarize, if firms tacitly collude, then higher μ and λ are associated with higher frequency of collusion and thus higher average profits and lower frequency of use of format A . Increases in prices occur over longer periods of time (as trust establishes itself), while declines in prices occur over short periods of time (this happens when a firm deviates and other firms retaliate). Increases are of a small magnitude while decreases are of a large magnitude. We expect collusion to be associated with the use of own formats and increases in prices while breaks from collusion are associated with the use of format A and decreases in prices.

3.6. Hypotheses

Hypotheses can be summarized in the form of tables, starting with hypotheses about the relation between profits and use of format A and the levels of μ and λ (Table 5).

[Table 5 about here.]

From this table, the following hypotheses can be expressed, with the type of behavior supporting them in parenthesis:

- H1: Profits are higher on average in treatments with high μ and λ (tacit collusion).
 - H1a: Profits are lower on average in treatments with high μ and λ (MSNE, imitation, best response, learning).
- H2: Profits are higher in the full information treatment (tacit collusion).
 - H2a: Average profit is equal across information treatments (MSNE, imitation, best responses, learning).
- H3: Adoption of format *A* decreases with μ (MSNE, learning, tacit collusion) and increases with λ (best response, MSNE, learning).
 - H3a: Adoption of format *A* increases with μ (best response).
 - H3b: There is no difference in adoption of format *A* depending on μ (imitation).
- H4: Prices are higher on average in periods with no common format (best response, MSNE, learning).

Another set of hypotheses concerns the relation between prices when format *A* is chosen and when own formats are used, and the dynamics of prices – length of phases with price increases, increments upwards or downwards and association of price changes with changes in formats (Table 6).

[Table 6 about here.]

From this table, the following hypotheses can be expressed:

- H5: Increases in prices are associated with switches away from the common format and decreases in prices are associated with switches to a common format (best response, imitation, collusion).
- H6: Increases in prices occur slower (over more periods, with smaller steps) than decreases in prices (tacit collusion).
 - H6a: Increases in prices occur faster (over fewer periods, with bigger steps) than decreases in prices (best response).
 - H6b: Both increases and decreases in prices are of the same length / steps (imitation).

4. Experimental procedure

The experiment was run in November and December 2013 at the laboratory of the Max Planck Institute in Jena. The experiment involved 300 subjects over 10 sessions, one for each treatment. The experimental sessions lasted about 1 hour and 30 minutes. Participants earned €11.50 on average (min=€5, max=€42). This includes a €2.50 show-up fee and a payment proportional to individual profit in one

randomly selected period in the experiment, different for each participant. The experiment was computerized using the Zurich Toolbox for Ready-made Economic Experiments (z-Tree, [Fischbacher, 2007](#)) and subjects were recruited via the Online Recruitment System for Economic Experiments (ORSEE, [Greiner, 2004](#)). 92% of the participants were German, the rest coming mainly from Eastern Europe and countries of the former Soviet Union. 58% of the subjects were women. Age was 24 on average and ranged from 17 to 41. 81% of the subjects were full-time students, about half of whom studied social sciences. There were no noticeable differences in the composition of the subject pool across treatments.

The experiment was framed as a market game whereby firms could produce different models of the same good. The participants acted as managers of one of three firms. v was set equal to 5 ECU (experimental currency unit) and e was set equal to 1 ECU, with 1 ECU=0.05€. The demand side of the economy was computerized, with 100 virtual consumers favoring firm A , B or C , for a grand total of 300 consumers, each buying one unit from one firm. Subjects had to decide what price p_i to set for their product, between 0 and 5 in steps of 1¢ of 1 ECU. Furthermore, managers of firms B and C also had to decide whether to produce their own model or produce model A .

Instructions are reported in the online appendix I. Understanding was checked with control questions that had to be answered correctly by all before the experiment could continue (Online appendix II). Subjects were also given the opportunity to practice setting prices and formats in a variety of different, pre-defined market situations (Online appendix III).

In a *first phase*, the subjects were assigned to a group with two other players and played the stage game (choice of price and format) over several periods within the same group. Subjects were told that at the end of each period, the game continued with the same group with 90% probability while with 10% probability the group would be dissolved. When the first groups dissolved, subjects were matched in another group of three (*second phase*), and then in another (*third phase*). To prevent contagion of behavior across repetitions, perfect stranger matching was implemented, which ensured that subjects never played with the same opponents twice and that the opponents they met would not meet each other in subsequent matches. Subjects were informed of this. Subjects also changed firm (A , B or C) in each phase. In order to simplify the running of the experiment, all groups dissolved at the same time and the number of periods for each phase was determined in advance by drawing a binary random variable taking value 0 with probability 10%, and counting the number of periods until the first draw of 0. This resulted in the first phase lasting 22 periods, the second phase 9 periods and the third phase 16 periods.

5. A first look at the data

Before presenting aggregate statistics, let us first look directly at the prices and formats chosen by subjects over time. Graphs for all groups in all phases of each treatment can be consulted in online appendix IV. Two examples below are only used for illustration, and represent only a small part of the total number of phases and treatments available.

[Figure 3 about here.]

Figure 3 shows the evolution of prices and adoption of format *A* in the last phase of treatments F_{22} . In this treatment, there are episodes in which prices of competing firms remain within a narrow range and prices increase over time. This does not correspond to simulated myopic best response behavior (Figure 9 in appendix B), whereby prices decrease in stages until one firm decides to raise its price. In groups 3 and 6, prices are tightly correlated and increase up to the maximum price of 5, which is maintained until the end. Those groups maintaining high prices also did not adopt format *A*. This is what was expected to happen if firms tacitly colluded, but this could also be consistent with imitation. In groups 5 and 8, prices reach a very high level in the same fashion, but then a firm breaks from the others and decreases its price. Those breaks are brutal, as predicted following deviation from tacit collusion, but are followed by renewed gradual increases in prices. Finally, in groups 7 and 9, prices are closely correlated and reach high levels before going down and evolving in an aphaazard fashion, with no subsequent consistent increases in prices. There are also some instances of subjects setting very high prices at the beginning (group 9 and 10), but they are not followed by others and must then decrease their prices. Those crude attempts at collusion are not an isolated instance. In their feedback, some subjects indeed complained that they were not followed when they set very high prices in this fashion. Other participants underlined that price increases had to be gradual to be followed. Those who set very high prices right at the beginning may have been too clever for their own good, in that they overestimated the ability of others to understand their aim.⁹

[Figure 4 about here.]

Figure 4 shows the same visualization of the data for treatment L_{22} . In this case, there is less variation in behavior across groups than in the full information treatment. Prices are on average lower than in the treatment with full information, and they remain within a more limited range. There is also more use of format *A*. Variations in price within groups are also less pronounced and prices never reach the higher levels observed in some groups in the full information treatments.

Having made those observations, we consider how they translate in terms of aggregate statistics and interpret the results.

6. Testing treatment effects on prices and adoption of common format

This part tests the hypotheses 1, 2 and 3 that deal with comparative statics. Experimental findings are summarized in table 7, which shows average profit in each treatment and the frequency with which firms *B* and *C* adopted format *A*.

[Table 7 about here.]

Table 10 in appendix F shows the results of bootstrapped linear regressions relating individual profits and format adoption in each period to the values of μ and λ , for each information treatment. Bootstrapping is stratified both at the individual and group level.

In treatments with *full information*, average profits when $\mu = 20\%$ are significantly higher than in other treatments (+25 ECU, $p < 1\%$). Format *A* is more frequently used when $\mu > 0$ than when $\mu = 0$ (+9% on average, $p < 1\%$). Higher λ does not affect profits or choice of format. Profits are significantly lower in treatments with *limited information* than in treatments with full information (−27 ECU, $p < 1\%$) and use of format *A* is more frequent (+9%, $p < 1\%$). In the limited information treatment, profits tend to be lower in treatments with higher μ (−7 ECU when $\mu = 10\%$ vs. $\mu = 0\%$, $p < 5\%$, and −5 ECU when $\mu = 20\%$ vs. $\mu = 10\%$, $p < 10\%$), but profits are not influenced by the level of λ . The frequency of adoption of format *A* increases with higher λ (+10% when $\lambda = 20\%$ vs. $\lambda = 10\%$, $p < 1\%$), while higher μ also leads to more frequent use of format *A* (+9% when $\mu = 10\%$ vs. $\mu = 0\%$, $p < 1\%$, +5% when $\mu = 20\%$ vs. $\mu = 10\%$, $p < 1\%$).

Tables 11 and 12 in appendix G show results when restricting attention to individual profits and format adoption in the third phase, where subjects were more experienced. Experience did not significantly change the frequency of use of format *A* or profits in treatments with limited information. However, experience led to less frequent use of format *A* and to higher profits in treatments with full information when $\mu = 20\%$. When looking at the overall effect of experience, average profits increased by an average of 20 ECU between the first and the second phase in the limited information treatments ($p < 1\%$) but then dropped down by 12 ECU in the third phase vs. the second phase ($p < 1\%$). Profits in the full information treatment remained higher than in the first phase (+19 ECU in the second phase vs. first, $p < 1\%$, +18 ECU in the third phase vs. first, $p < 1\%$).

Statistics on average group profits and format adoption (30 observations per treatment) are presented in tables 13 and 14 in appendix G. All effects remain consistent with individual per period statistics, and treatments with $\mu = 20\%$ generate higher profits in the full information treatment while treatments with $\lambda = 20\%$ encourage use of format *A* in the limited information treatments.

We conclude that profits are higher when there is a sufficient number of savvy consumers in treatments with full information ($\mu = 20\%$), while profits are not affected by μ in treatments with limited information. Profits are lower and use of format *A* more frequent in treatments with limited informa-

tion. As per the definition of tacit collusion in [Holt \(1995, p.392\)](#), the observation that average profit in the full information treatment is higher than theoretically predicted and also higher than profits in the limited information environment indicates that tacit collusion may have occurred in the full information treatment (*hypothesis H2*). Giving more weight to this argument, only the analysis of tacit collusion predicted that profits could be increasing with μ , which is what happened in the full information treatment (*hypothesis H1*). Furthermore, the observation that profits were significantly lower in the first phase of the full information treatment and then increased and were maintained at a higher level supports the hypothesis that subjects experienced harder competition in the first phase, which would lead them to try to cooperate in the next phases. This contrasts with treatments with limited information, where higher profits in the second phase were not maintained in the third phase. However, as noted in [Potters and Suetens, 2013, p. 448](#), “intentions are hard to identify” and “it is not obvious that such outcomes [higher profits–Ed.] are always due to ‘conscious’ collusion”. The evidence is consistent with tacit collusion, but it cannot be proved that participants had the intention to collude.

The frequency of adoption of format A decreased with experience in treatments with full information, which is consistent with *hypothesis H3*. However the frequency of adoption of format A increased with λ , and less significantly with μ , in treatments with limited information, which is consistent with *hypothesis H3a*. This is surprising as best response seems to be a bad candidate for explaining behavior under limited information. Softened best response dynamics may however explain the result (note 6 of section 3.2). It is still surprising that more frequent use of format A did not consistently lead to lower profits in treatments with limited information.

Consider now the predictions about the strategies that underlie price and format choices. The next part shows a link between use of format A and lower prices, and shows that prices increases were more gradual than price decreases. This is consistent with collusion but not with imitation or best response.

7. Testing the dynamics and strategies in competition

This part tests hypotheses 4, 5 and 6, which deal with the dynamics of competition. Regularities in the behavior of participants are identified, in particular in their use of format A, in the patterns of price increases and decreases, and in how pricing and format choices differed from myopic best response or imitation.

7.1. Price distributions and adoption of common format

Figure 5 shows the distribution of prices depending on the choice of format, by information treatment, for firms B and C.

[Figure 5 about here.]

Prices were higher – the distribution of prices is to the right – when the firm did not use format *A*. We run Kolmogorov-Smirnov tests for differences in distributions and t-tests for differences in means. All tests are bootstrapped with stratification at the individual and group level and are thus based on bootstrapped standard errors. Differences are significant with p -values $< 1\%$, so that *hypothesis H4* cannot be rejected. The difference in the distribution of prices by choice of format was particularly large in treatments with full information. Indeed, while the mean of prices when format *A* was chosen did not significantly differ across information treatments (1.69 ECU *vs.* 1.65 ECU, $p = 0.051$), the mean of prices when an idiosyncratic format was chosen was significantly higher in the full information treatment (2.34 ECU *vs.* 2.06 ECU, $p < 1\%$). Finally, there is a positive mass of prices equal to the maximum possible price in treatments with full information. This mass is associated with use of own format, as hypothesized in the analysis of collusion.

The difference between prices with and without common format suggests a link between pricing low and choosing a common format, which is likely to result in attracting savvy consumers, and a link between pricing high and choosing an idiosyncratic format, which is likely to result in maintaining a monopoly on one's own type of consumers. At the least, this shows that participants in the experiment understood the use of formats as a tool for differentiation and the implications of choosing a common format.

Figure 6 shows changes in prices as a function of changes in format.

[Figure 6 about here.]

Switching to a common format is associated with a decrease in prices – presumably to gain sales or better compete if some firms already adopted format *A*. Switching to an idiosyncratic format, on the other hand, is associated with increases in prices – adopting one's own format is thus associated with breaking away from competition. All Kolmogorov-Smirnov tests for differences in distributions and t-tests for differences in means obtain p -values $< 1\%$. *Hypothesis H5* cannot therefore be rejected. The association between changes in prices and changes in formats is particularly strong in treatments with limited information. In the absence of information about other firms' prices, firms presumably changed both price and format at the same time to maximize the effect of their changes – they adopted a common format when decreasing prices to gain as many consumers as possible, and they adopted their own format when increasing prices to lose as few consumers as possible. This also suggests that firms adopted idiosyncratic formats when trying to soften competition and support higher prices, since this protected them from losing too many consumers if other firms did not follow, and they adopted format *A* when initiating or following decreases in prices because this gave them an opportunity to gain savvy consumers. Not adopting format *A* was thus associated with softened competition and overall

increases in prices, while adopting format *A* was associated with strong competition and decreases in prices.

This observation is confirmed in table 8, whereby the average price change under one's own format was small and positive, while it was large and negative under format *A*.

[Table 8 about here.]

All means in the table are significantly different from 0 ($p < 1\%$, t-tests, bootstrapped standard errors). Prices decreased by a larger amount on average under format *A* than they increased under idiosyncratic formats. This patterns contradicts the hypothesis that participants adopted best responses. Indeed, best response implies an association between infrequent and large increases in price and use of own format, and frequent small decreases in prices and use of a common format. The direction of prices changes is therefore consistent with best response, but not their frequency nor their magnitude. This pattern does not fit with imitation either, as the price changes are significantly larger when format *A* is used and the frequency of use of own format is also significantly higher than that of format *A*. Overall, this pattern is only consistent with the establishment of collusion through use of own format and progressive increases in prices, and the breakdown in collusion through use of format *A* and large decreases in prices. The next section confirms the existence of longer phases of price increases than of price decreases (*Hypothesis H6*).

7.2. Speed of increases and decreases in prices

Figure 7 shows the distribution of the length of phases of increases and decreases in prices across information treatments. The length of a phase of increases in price is indicated by a positive number, while the length of a phase of decreases in prices is indicated by a negative number.

[Figure 7 about here.]

Compared to firms in the treatment with limited information, firms with full information changed their price more often and in a more sustained way. Treatments with limited information exhibited lower frequency of either increases or decreases in prices, and this for every phase length other than 0, where a firm does not change its price. The average length of a phase was 0.55 in treatments with full information and 0.40 in treatments with limited information (both significantly higher than 0, $p < 1\%$, bootstrapped standard errors). This means that in both information treatments, phases of increases in prices lasted longer than phases of decreases in prices – the distribution is skewed to the right. The difference in the distributions of length of phases between information treatments is also significant (Kolmogorov-Smirnov test), as is their difference in means ($p < 1\%$, bootstrapped standard errors).

[Table 9 about here.]

Table 9 shows that price increases were more frequent than price decreases in both treatment (47% vs. 35% under limited information, 54% vs. 36% under full information, $p < 1\%$, b.s.e.), and that price decreases were larger on average than price increases in both information treatments ($p < 1\%$, b.s.e.). This supports *hypothesis H6 (collusion)* whereby increases in prices last longer and are slower than phases of decreases in prices. This is a pattern that is not consistent with either the use of best response strategies (the pattern would be opposite) or with the use of imitation strategies (there would be no pattern). This is however consistent with collusive behavior, whereby firms build trust by slowly increasing prices, until one or more firms decide to undercut others, which is quickly followed up. Prices then quickly reach a level that is low enough for one firm to decide to increase its price again.

7.3. Imitation, best reply or tacit collusion?

There was an association between change in prices and changes in format. Furthermore, individual prices were significantly auto-correlated in all treatments. The hypothesis that participants followed mixed strategies can therefore be excluded. Behavior also differed from best response. Comparing best response in terms of prices and choice of format with actual behavior in the full information treatment, own format was adopted in 73% of the cases where the best response was to adopt format A, to be compared with 77% adoption of own format when that was indeed the best response. The unwillingness of subjects to adopt format A is consistent with an unwillingness to compete strongly with others. Even when subjects adopted the format predicted by best response, actual prices did not fit well with best responses ($R^2 \leq 10\%$, more details in online appendix V).

Imitation does not predict format choice much better than best reply in the full information treatment: own format was adopted in 59% of the cases where the best performing firm last period adopted format A, to be compared with 82% adoption of own format when the best performing firm last period adopted its own format. However, the fit between best price last period and price in the current period was high when format choice corresponded to the best format last period ($R^2 = 62\%$ when adopting own format, $R^2 = 47\%$ when adopting format A, more details in online appendix VI). The fit between imitation and chosen prices is also high in the limited information treatment, which is because the prices of competing firms were close and firms did not vary their prices much across periods. Conversely, bad fit with best response is in part due to how best response requires constant and sometime large changes in prices.

Finally, prices that were observed to be equal to the maximum v cannot be driven by best response as the best response to a price of v is always to set a price of $v - e$ given the value of parameters in the experiment. However, very high prices (more than $v - e$) without use of format A are well predicted by imitation, whereby firms set a high price and adopt their own format when the best performing price also set a high price and adopted its own format last period. Part of what we deem to be collusive behavior may therefore be driven by imitation. It may be that strategic players promoted collusion

by exploiting the tendency of less savvy participants to imitate the best performing firms. From the feedback of subjects, some subjects exploited the tendency of other participants to imitate each other in order to progressively raise prices. A combination of imitation and leadership can therefore explain how some groups were able to raise prices over time without any one firm deviating.

8. Discussion and extensions

The analysis focused mainly on the full information treatment. Behavior in the limited information treatment appears to be an attenuated version of behavior in the full information treatments, whereby phases of increases or decreases in prices were shorter and changes in prices were of smaller magnitude. Firms used format A less often in treatments with full information, which is consistent with coordination on not using format A in order to weaken competition. More frequent use of format A in treatment with $\mu > 0$ under limited information is consistent only with myopic best response dynamics, but those are difficult to sustain with limited information about competitors. However, note 6 of section 3.2 discusses an extension of myopic best response dynamics whereby firms adapt their prices with some inertia but in the direction mandated by best response. Such softened dynamics can be a good explanation for behavior under limited information.

Extensions of the research exposed in this paper could focus on the dynamics of Bertrand competition with product differentiation. Product differentiation gives firms some leeway to increase prices without losing sales. This allows firms to costlessly signal a readiness to increase prices and to set in motion imitation dynamics that lead to gradual increases in prices. It would also be interesting to run treatments that vary μ when μ is high. Indeed, the analysis of collusions predicts that increases in the share of savvy consumers if its level is originally low promotes collusion, while increases in μ if its level is originally high makes collusion more difficult.

9. Conclusion

This paper analyzed experimentally a model of competition with spurious differentiation by varying the degree of sophistication of consumers and the amount of information managers had about their competitors. Firms could choose how transparent their offers would be to a portion of savvy consumers. Observations are consistent with the hypothesis that firms were able to tacitly collude in shrouding their offers when information about the behavior of their competitors was available. They were then able to avoid the low prices and profits that would be triggered if they made their offers comparable. Along the lines of Møllgaard and Overgaard (2001), transparency was a double-edged sword: being able to choose to make prices transparent and products easily comparable helped sustain tacit collusion. More

transparency on the consumer side (more consumers being sensitive to price differences when those are easy to identify) can therefore have a pro-collusive effect, but only if there is transparency on the firm side (firms being able to observe each other). Indeed, when firms could only observe their own prices, formats and sales, then prices and profits were maintained at a low level and firms were driven to adopt common formats more often in treatments with more savvy consumers. This indicates that the well established competition policies against information sharing ([Kühn, 2001](#)) may be sufficient to prevent collusion when firms compete both on prices and formats.

From a policy perspective, this experiment indicates that educating consumers so that they learn to favor comparable offers can have an adverse effect on consumer welfare if one does not also limit the ability of firms to check each other's prices and choice of formats. If that is not possible, then it may not be a good idea to subsidize services that help consumers make choices or to teach consumers to favor offers that are easy to understand ([Agnew, 1934](#); [Beales et al., 1981](#); [Garrod et al., 2009](#); [Köszegi, 2014](#); [Gu and Wenzel, 2014](#)). This "hidden welfare cost of education" ([Kosfeld and Schüwer, 2011](#)) occurs if the regulator cannot ensure sufficient levels of opacity on the supply side of the market. This is likely to be the case, as it is particularly difficult to prevent firms from observing the formats adopted by the competition, especially in consumer markets where there is generally no potential for hidden one-to-one negotiation between firms and consumers. Indeed, firms in consumer markets often do not have direct contact with consumers since their sales are often handled by intermediaries. This makes it easy for competing firms to simply shop the product of competitors and check that they do not engage in direct comparisons with the alternatives. This makes it very difficult for a firm to make its product comparable with others or otherwise help consumers compare products without this being noticed and retaliated against.

Since it is difficult to prevent firms from monitoring each other, the regulator may also need to promote the use of common formats in the presentation of offers to consumers. This goes along with better specifications and labeling for consumer goods ([Agnew, 1934](#)), as already implemented in some markets for some aspects of product information. Indeed, unit price information is generally available or even mandated in supermarkets. Some standardization is also present at the national level for presenting lending rates in terms of annual percentage rate of charge. There is however a lot of progress to be made, for example in the automobile market where fuel economy information is often misleading and conveyed in the wrong way ([Larrick and Soll, 2008](#)). Consumer protection policies therefore involve encouraging, guiding or even mandating the elaboration and use of common formats for measuring the performance and prices of competing products in an industry. This strengthening of regulation in terms of how products are presented and in terms of the information that is given along with them is however costly and intrusive. Intervention might therefore best be limited to the category of those products that have well-understood, measurable and relatively stable characteristics.

Notes

¹An alternative way to present the model to participants could have been to let firms adopt different locations, whereby choosing the same format is equivalent to choosing the same location (Dudey, 1990; Brown-Kruse et al., 1993; Non, 2010). The 3-firm location problem (Collins and Sherstyuk, 2000; Shaked, 1982) would be avoided by preventing one firm from changing its location.

²A firm could unilaterally decide to make its product comparable with all other products if for example it did comparative advertising that showed the superiority of its product *vs.* the competition. This does not require it to adopt the same format as them. Morgan et al. (2006) presents a model in that spirit, where some consumers always choose the product of their preferred firm and others always choose the lower priced. This allows the authors to solve explicitly for mixed strategy equilibria.

³Gaudeul and Sugden (2012) argue that it is rational for consumers to penalize those firms that adopt idiosyncratic formats. Indeed, competition is tougher among firms with a common formats, so their prices are lower than those of firms with idiosyncratic formats. Crosetto and Gaudeul (2014) give further statistical arguments in favor of following such a heuristic.

⁴*a.k.a.* reaction function, cf. Tirole (1988).

⁵The code for the simulations, performed in R, is available at <http://github.com/alescia/CS2-Simulations/blob/master/simulations.R>. Firms take turn to revise their strategies according to a random process (Blume, 1995) and starting prices are randomized as well.

⁶This analysis can be extended by assuming that firms do not adapt their prices and format immediately, but rather do so slowly and generally “in the right direction”. They raise their price if the best response to last period’s play called for a higher price than last period, and they change format with some probability if the best response called for it (Zusai, 2013). Formally, if $A_{it} = (p_{it}, ft_{it})$ was the strategy of subject i in period t (with p_{it} the price and ft_{it} the choice of format), and $A^*_{it+1} = (p^*_{it+1}, ft^*_{it+1})$ is the best response by i to the strategies adopted by other firms in period t , then A_{it+1} , the action adopted by i in period $t + 1$ is $ft_{it+1} = ft_{it}$ with probability ϕ and $ft_{it+1} = ft^*_{it+1}$ with probability $1 - \phi$, while price is $p_{it+1} = \gamma \cdot p_{it} + (1 - \gamma) \cdot p^*_{it+1}$. Results of simulations with this type of behavior show that the general patterns of myopic best responses are maintained: price increases occur over shorter time spans than price decreases, and the influence of μ and λ on profits and use of format A are similar.

⁷The code for performing the imitation dynamics, written in R, is available at http://github.com/alescia/CS2-Simulations/blob/master/simulations_imitation.R

⁸The code for the simulations, performed in R, is available at http://github.com/alescia/CS2-Simulations/blob/master/simulation_reinforcement_learning.R

⁹This behavior is similar to that of subjects who bid 0 in the guessing game (Nagel, 1995) without thinking that many other participants do not push the logic to that extreme.

References

- Abbink, K. and Rockenbach, B. (2006). Option pricing by students and professional traders: a behavioural investigation. *Managerial and Decision Economics*, 27(6):497–510. 11
- Abreu, D. (1988). On the theory of infinitely repeated games with discounting. *Econometrica: Journal of the Econometric Society*, 56(2):383–396. 16
- Abreu, D., Pearce, D., and Stacchetti, E. (1986). Optimal cartel equilibria with imperfect monitoring. *Journal of Economic Theory*, 39(1):251–269. 16
- Adams, S. (1997). *The Dilbert Future: Thriving on Stupidity in the 21st Century*. New York: HarperCollins Publishers. 5
- Agnew, P. G. (1934). The movement for standards for consumer goods. *The ANNALS of the American Academy of Political and Social Science*, 173(1):60–69. 27

- Alós-Ferrer, C., Ania, A. B., and Schenk-Hoppé, K. R. (2000). An evolutionary model of Bertrand oligopoly. *Games and Economic Behavior*, 33(1):1–19. [14](#)
- Aoyagi, M. and Fréchette, G. (2009). Collusion as public monitoring becomes noisy: Experimental evidence. *Journal of Economic Theory*, 144(3):1135–1165. [16](#)
- Apesteguia, J., Huck, S., and Oechssler, J. (2007). Imitation–theory and experimental evidence. *Journal of Economic Theory*, 136(1):217–235. [14](#)
- Armstrong, M. (2015). Search and ripoff externalities. *Review of Industrial Organization*, 47:273–302. [4](#)
- Aumann, R. and Shapley, L. (1976). Long term competition: A game theoretic analysis. mimeo, Hebrew University. Reprinted in N. Megiddo, (ed.) (1994): *Essays in Game Theory in Honor of Michael Maschler*, 1-15, Springer Verlag, Berlin. [16](#)
- Bar-Isaac, H., Caruana, G., and Cuñat, V. (2010). Information gathering and marketing. *Journal of Economics & Management Strategy*, 19(2):375–401. [5](#)
- Barigozzi, F. and Peitz, M. (2007). Comparative advertising and competition policy. In Jay Pil Choi, editor, *Recent Developments in Antitrust: Theory and Evidence*, CESifo Seminar Series. MIT Press. [4](#)
- Baye, M. R. and Morgan, J. (2002). Information gatekeepers and price discrimination on the internet. *Economics Letters*, 76(1):47–51. [4](#)
- Beales, H., Craswell, R., and Salop, S. (1981). Information remedies for consumer protection. *American Economic Review*, 71(2):410–413. [4](#), [27](#)
- Beard, F. (2010). Comparative advertising wars: An historical analysis of their causes and consequences. *Journal of Macromarketing*, 30(3):270–286. [4](#)
- Blume, L. E. (1995). The statistical mechanics of best-response strategy revision. *Games and Economic Behavior*, 11(2):111–145. [28](#)
- Brown-Kruse, J., Cronshaw, M. B., and Schenk, D. J. (1993). Theory and experiments on spatial competition. *Economic Inquiry*, 31(1):139–165. [28](#)
- Carlin, B. I. (2009). Strategic price complexity in retail financial markets. *Journal of Financial Economics*, 91(3):278–287. [5](#), [10](#)
- Célérier, C. and Vallée, B. (2013). What drives financial complexity?: A look into the European retail structured products market. *HEC Paris Research Paper*. FIN-2013-1013. [5](#)
- Chioveanu, I. and Zhou, J. (2013). Price competition with consumer confusion. *Management Science*, 59(11):2450–2469. [5](#)
- Chmura, T., Goerg, S. J., and Selten, R. (2012). Learning in experimental games. *Games and Economic Behavior*, 76(1):44–73. [15](#)
- Collins, R. and Sherstyuk, K. (2000). Spatial competition with three firms: An experimental study. *Economic Inquiry*, 38(1):73–94. [28](#)
- Compte, O. and Postlewaite, A. (2015). Plausible cooperation. *Games and Economic Behavior*, 91:45–59. [16](#)
- Cristol, S. M. and Sealey, P. (2000). *Simplicity Marketing: End Brand Complexity, Clutter, and Confusion: Relieving Stress in the Digital Age*. New York, Free Press. [5](#)
- Crosetto, P. and Gaudeul, A. (2014). Testing the strength and robustness of the attraction effect in consumer decision making. JERP 2014-021, INRA-GAEL, Université Grenoble Alpes and Friedrich-Schiller-Universität, Jena. [9](#), [10](#), [28](#)
- Dijkstra, P. T. (2015). Price leadership and unequal market sharing: Collusion in experimental markets. *International Journal of Industrial Organization*, 43:80–97. [17](#)

- Dolbear, F. T., Lave, L. B., Bowman, G., Lieberman, A., Prescott, E., Rueter, F., and Sherman, R. (1968). Collusion in oligopoly: An experiment on the effect of numbers and information. *The Quarterly Journal of Economics*, 82(2):240–259. [16](#)
- Doyle, J., Muehlegger, E., and Samphantharak, K. (2010). Edgeworth cycles revisited. *Energy Economics*, 32(3):651–660. [13](#)
- Dudey, M. (1990). Competition by choice: The effect of consumer search on firm location decisions. *The American Economic Review*, 80(5):1092–1104. [28](#)
- Edward Kasabov (2015). What we know, don't know, and should know about confusion marketing. *European Journal of Marketing*, 49(11/12):1777–1808. [5](#)
- Ellison, G. (2005). A model of add-on pricing. *Quarterly Journal of Economics*, 120(2):585–637. [5](#)
- Ellison, G. and Ellison, S. (2009). Search, obfuscation, and price elasticities on the Internet. *Econometrica*, 77(2):427–452. [5](#)
- Ellison, G. and Wolitzky, A. (2012). A search cost model of obfuscation. *The RAND Journal of Economics*, 43(3):417–441. [5](#)
- Erev, I. and Roth, A. (1998). Predicting how people play games: Reinforcement learning in experimental games with unique, mixed strategy equilibria. *The American Economic Review*, 88(4):848–881. [15](#)
- Ericson, K. M. M. and Starc, A. (2013). How product standardization affects choice: Evidence from the Massachusetts Health Insurance Exchange. *NBER Working Paper*, 19527. [5](#)
- Feinberg, R. and Snyder, C. (2002). Collusion with secret price cuts: An experimental investigation. *Economics Bulletin*, 3(6):1–11. [16](#)
- Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2):171–178. [19](#)
- Fonseca, M. A. and Normann, H.-T. (2012). Explicit vs. tacit collusion — the impact of communication in oligopoly experiments. *European Economic Review*, 56(8):1759–1772. [16](#)
- Fonseca, M. A. and Normann, H.-T. (2013). Excess capacity and pricing in Bertrand-Edgeworth markets: Experimental evidence. *Journal of Institutional and Theoretical Economics JITE*, 169(2):199–228. [13](#)
- Frechette, G. R. (2011). Laboratory Experiments: Professionals Versus Students. SSRN Scholarly Paper ID 1939219, Social Science Research Network, Rochester, NY. [11](#)
- Friedman, J. W. (1971). A non-cooperative equilibrium for supergames. *Review of Economic Studies*, 38(1):1–12. [16](#)
- Fudenberg, D. and Kreps, D. M. (1993). Learning mixed equilibria. *Games and Economic Behavior*, 5(3):320–367. [13](#)
- Fudenberg, D. and Maskin, E. (1986). The folk theorem in repeated games with discounting or with incomplete information. *Econometrica*, 54(3):533–554. [16](#)
- Gabaix, X. and Laibson, D. (2006). Shrouded attributes, consumer myopia, and information suppression in competitive markets. *The Quarterly Journal of Economics*, 121(2):505–540. [5](#)
- Garrod, L., Hviid, M., Loomes, G., and Price, C. W. (2009). Competition remedies in consumer markets. *Loyola Consumer Law Review*, 21:439–495. [4, 27](#)
- Gaudeul, A. (2010). Software marketing on the Internet: the use of samples and repositories. *Economics of Innovation and New Technology*, 19(3):259–281. [4](#)
- Gaudeul, A. and Sugden, R. (2012). Spurious complexity and common standards in markets for consumer goods. *Economica*, 79(314):209–225. [4, 5, 12, 28](#)
- Green, E. J. and Porter, R. H. (1984). Noncooperative collusion under imperfect price information. *Econometrica*, 52(1):87–100. [16](#)

- Greiner, B. (2004). An online recruitment system for economic experiments. In Kremer, K. and Macho, V., editors, *Forschung und Wissenschaftliches Rechnen, GWDG-Bericht Nr. 63*, pages 79–93. Gesellschaft für Wissenschaftliche Datenverarbeitung, Göttingen. [19](#)
- Grubb, M. D. (2015). Failing to choose the best price: Theory, evidence, and policy. Working Papers 878, Boston College Department of Economics. [4](#)
- Gu, Y. and Wenzel, T. (2014). Strategic obfuscation and consumer protection policy. *The Journal of Industrial Economics*, 62(4):632–660. [27](#)
- Heidhues, P., Koszegi, B., and Murooka, T. (2012). The market for deceptive products. Working Paper, University of California, Berkeley. [5](#)
- Henze, B., Schuett, F., and Sluijs, J. P. (2014). Transparency in markets for experience goods: Experimental evidence. *Economic Inquiry*, 53(1):640–659. [10](#)
- Holt, C. A. (1995). Industrial organization: A survey of laboratory research. In Kagel, J. and Roth, A., editors, *The handbook of experimental economics*, pages 349–443. Princeton, New Jersey: Princeton University Press. [11](#), [22](#)
- Hossain, T. and Morgan, J. (2007). ...plus shipping and handling: Revenue (non) equivalence in field experiments on eBay. *The B.E. Journal of Economic Analysis & Policy*, 6(2). [5](#)
- Huber, J., Payne, J. W., and Puto, C. (1982). Adding asymmetrically dominated alternatives: Violations of regularity and the similarity hypothesis. *Journal of Consumer Research*, 9(1):90–98. [9](#)
- Huber, J. and Puto, C. (1983). Market boundaries and product choice: Illustrating attraction and substitution effects. *Journal of Consumer Research*, 10(1):31–41. [9](#)
- Huck, S., Müller, W., and Normann, H.-T. (2001). Stackelberg beats Cournot: On collusion and efficiency in experimental markets. *Economic Journal*, pages 749–765. [16](#)
- Huck, S., Normann, H.-T., and Oechssler, J. (1999). Learning in Cournot oligopoly — an experiment. *The Economic Journal*, 109(454):80–95. [14](#)
- Huck, S., Normann, H.-T., and Oechssler, J. (2000). Does information about competitors’ actions increase or decrease competition in experimental oligopoly markets? *International Journal of Industrial Organization*, 18(1):39 – 57. [16](#)
- Huck, S., Normann, H.-T., and Oechssler, J. (2004). Two are few and four are many: Number effects in experimental oligopolies. *Journal of Economic Behavior & Organization*, 53(4):435 – 446. [16](#)
- Kalaycı, K. (2015a). Confusopoly: competition and obfuscation in markets. *Experimental Economics*, pages 1–18. [5](#), [6](#), [10](#)
- Kalaycı, K. (2015b). Price complexity and buyer confusion in markets. *Journal of Economic Behavior & Organization*, 111:154–168. [5](#), [6](#), [10](#)
- Kalaycı, K. and Potters, J. (2011). Buyer confusion and market prices. *International Journal of Industrial Organization*, 29(1):14–22. [5](#), [6](#), [7](#), [10](#)
- Köke, S., Lange, A., and Nicklisch, A. (2015). Adversity is a school of wisdom: Experimental evidence on cooperative protection against stochastic losses. WiSo-HH Working Paper Series 22, Universität Hamburg. [15](#)
- Kosfeld, M. and Schüwer, U. (2011). Add-on pricing, naive consumers, and the hidden welfare costs of education. Working Paper, Forschungsinstitut zur Zukunft der Arbeit. [27](#)
- Köszegi, B. (2014). Behavioral contract theory. *Journal of Economic Literature*, 52(4):1075–1118. [27](#)
- Kruse, J. B., Rassenti, S., Reynolds, S. S., and Smith, V. L. (1994). Bertrand-Edgeworth competition in experimental markets. *Econometrica*, 62(2):343–371. [13](#)
- Kühn, K.-U. (2001). Fighting collusion by regulating communication between firms. *Economic Policy*, 16(32):168–204. [16](#), [27](#)

- Kula, W. (1986). *Measures and Men*. New Jersey: Princeton University Press. [3](#)
- Larrick, R. P. and Soll, J. B. (2008). The MPG Illusion. *Science*, 320(5883):1593–1594. [27](#)
- Mäs, M. and Nax, H. H. (2016). A behavioral study of “noise” in coordination games. *Journal of Economic Theory*, 162:195–208. [13](#)
- Maskin, E. and Tirole, J. (1988). A theory of dynamic oligopoly, II: Price competition, kinked demand curves, and Edgeworth cycles. *Econometrica*, 56(3):571–99. [13](#)
- Matsui, A. (1992). Best response dynamics and socially stable strategies. *Journal of Economic Theory*, 57(2):343–362. [13](#)
- McDonald, S. and Wren, C. (2013). Multiple price posting and consumer search obfuscation: Evidence from an online market. Presented at the 40th EARIE Annual Conference. [5](#)
- McKelvey, R. D., McLennan, A. M., and Turocy, T. L. (2014). Gambit: Software tools for game theory, version 14.1.0. <http://www.gambit-project.org>. [13](#)
- Møllgaard, H. P. and Overgaard, P. B. (2001). Market transparency and competition policy. *Rivista di Politica Economica*, 91(4):11–64. [5](#), [16](#), [26](#)
- Morgan, J., Orzen, H., and Sefton, M. (2006). An experimental study of price dispersion. *Games and Economic Behavior*, 54(1):134–158. [28](#)
- Mouraviev, I. and Rey, P. (2011). Collusion and leadership. *International Journal of Industrial Organization*, 29(6):705–717. [17](#)
- Muir, D., Seim, K., and Vitorino, M. (2013). Price obfuscation and consumer search: An empirical analysis. *Working Paper, University of Pennsylvania and University of Minnesota*. [5](#)
- Nagel, R. (1995). Unraveling in guessing games: An experimental study. *The American Economic Review*, 85(5):1313–1326. [28](#)
- Noel, M. D. (2008). Edgeworth price cycles and focal prices: Computational dynamic Markov equilibria. *Journal of Economics & Management Strategy*, 17(2):345–377. [14](#)
- Noel, M. D. (2015). Do Edgeworth price cycles lead to higher or lower prices? *International Journal of Industrial Organization*, 42:81–93. [13](#)
- Non, M. (2010). Isolation or joining a mall? On the location choice of competing shops. MPRA Paper 20044, University Library of Munich, Germany. [4](#), [28](#)
- Offerman, T., Potters, J., and Sonnemans, J. (2002). Imitation and belief learning in an oligopoly experiment. *The Review of Economic Studies*, 69(4):973–997. [14](#)
- Perloff, J. M. and Salop, S. C. (1985). Equilibrium with product differentiation. *The Review of Economic Studies*, 52(1):107–120. [7](#), [9](#), [11](#)
- Petrikaitė, V. (2016). Collusion with costly consumer search. *International Journal of Industrial Organization*, 44:1–10. [16](#), [36](#)
- Piccione, M. and Spiegler, R. (2012). Price competition under limited comparability. *The Quarterly Journal of Economics*, 127(1):97–135. [5](#), [10](#)
- Potters, J. and Suetens, S. (2013). Oligopoly experiments in the current millennium. *Journal of Economic Surveys*, 27(3):439–460. [22](#)
- Potters, J. and van Winden, F. (2000). Professionals and students in a lobbying experiment: Professional rules of conduct and subject surrogacy. *Journal of Economic Behavior & Organization*, 43(4):499–522. [11](#)
- Roth, A. E., Prasnikar, V., Okuno-Fujiwara, M., and Zamir, S. (1991). Bargaining and market behavior in Jerusalem, Ljubljana, Pittsburgh, and Tokyo: An experimental study. *American Economic Review*, 81(5):1068–95. [11](#)

- Salop, S. and Stiglitz, J. (1977). Bargains and ripoffs: A model of monopolistically competitive price dispersion. *The Review of Economic Studies*, 44(3):493–510. [4](#), [7](#), [9](#)
- Scitovsky, T. (1950). Ignorance as a source of oligopoly power. *The American Economic Review*, 40(2):48–53. [3](#), [4](#)
- Selten, R. and Apesteguia, J. (2005). Experimentally observed imitation and cooperation in price competition on the circle. *Games and Economic Behavior*, 51(1):171–192. [14](#)
- Selten, R. and Chmura, T. (2008). Stationary concepts for experimental 2x2-games. *The American Economic Review*, 98(3):938–966. [15](#)
- Shaked, A. (1982). Existence and computation of mixed strategy Nash equilibrium for 3-firms location problems. *The Journal of Industrial Economics*, 31(1/2):93–96. [28](#)
- Shchepetova, A. (2012). Strategic limitation of price comparison by competing firms: An experimental study. Working Paper, Toulouse School of Economics. [5](#), [6](#), [10](#)
- Shiller, G. A. A. . R. J. (2015). *Phishing for Phools: The Economics of Manipulation and Deception*. New Jersey: Princeton University Press. [4](#)
- Siegel, S. and Harnett, D. L. (1964). Bargaining Behavior: A Comparison Between Mature Industrial Personnel and College Students. *Operations Research*, 12(2):334–343. [11](#)
- Simonson, I. (1989). Choice based on reasons: The case of attraction and compromise effects. *Journal of Consumer Research*, 16(2):158–174. [9](#)
- Sitzia, S. and Zizzo, D. J. (2011). Does product complexity matter for competition in experimental retail markets? *Theory and Decision*, 70(1):65–82. [10](#)
- Sluijs, J. P., Schuett, F., and Henze, B. (2011). Transparency regulation in broadband markets: Lessons from experimental research. *Telecommunications Policy*, 35(7):592–602. [10](#)
- Spenner, P. and Freeman, K. (2012). To keep your customers, keep it simple. *Harvard Business Review*. May. [5](#)
- Spiegler (2006). Competition over agents with boundedly rational expectations. *Theoretical Economics*, 1(2):207–231. [5](#)
- Spiegler, R. (2014). Competitive framing. *American Economic Journal: Microeconomics*, 6(3):35–58. [3](#), [5](#), [10](#)
- Spiegler, R. (2015). Choice complexity and market competition. Working Paper, Tel Aviv University, University College London and CFM. [4](#)
- Stigler, G. J. (1964). A theory of oligopoly. *Journal of Political Economy*, 72(1):44–61. [16](#)
- Suetens, S. and Potters, J. (2007). Bertrand colludes more than Cournot. *Experimental Economics*, 10(1):71–77. [16](#)
- Sugden, R. and Zheng, J. (2015). Do consumers take advantage of common pricing standards? An experimental investigation. CBESS discussion paper 15-12, University of East Anglia, Norwich. [10](#)
- Tappata, M. (2009). Rockets and Feathers: Understanding Asymmetric Pricing. *RAND Journal of Economics*, 40(4):673–687. [13](#)
- Tirole, J. (1988). *The Theory of Industrial Organization*. MIT Press. [28](#)
- Tversky, A. and Simonson, I. (1993). Context-dependent preferences. *Management Science*, 39(10):1179–1189. [9](#)
- Varian, H. (1980). A model of sales. *American Economic Review*, 70(4):651–659. [4](#), [7](#), [13](#)
- Vega-Redondo, F. (1997). The evolution of Walrasian behavior. *Econometrica*, 65(2):375–384. [16](#)
- Wenzel, T. (2013). Naive consumers, banking competition, and ATM pricing. *Review of Network Economics*, 12(3). [5](#)

- Wenzel, T. (2014). Consumer myopia, competition and the incentives to unshroud add-on information. *Journal of Economic Behavior & Organization*, 98:89–96. 4, 5
- White, M. C. (2015). Seeking more bookings, airlines limit sites that show their fares. *The New York Times*. June 8, <http://www.nytimes.com/2015/06/09/business/pulling-fare-data-from-travel-sites-some-airlines-look-to-book-more-flights.html>. 4
- Wilson, C. (2010). Ordered search and equilibrium obfuscation. *International Journal of Industrial Organization*, 28(5):496–506. 5
- Woodward, S. E. and Hall, R. E. (2010). Consumer Confusion in the Mortgage Market: Evidence of Less than a Perfectly Transparent and Competitive Market. *American Economic Review*, 100(2):511–515. 5
- Zusai, D. (2013). Tempered best response dynamics. DETU Working Paper 1301, Department of Economics, Temple University. 28

A. Mixed strategies

[Figure 8 about here.]

B. Myopic best response simulations.

[Figure 9 about here.]

C. Robust equilibrium and dynamics under imitation

We prove in this section that there is no robust equilibrium under imitation dynamics and we characterize the dynamics of price and format adoption under imitation.

No robust equilibrium

Assume $\mu > 0$ and consider a candidate equilibrium with prices $P = (p_A, p_B, p_C)$.

Suppose there is no common format, $F = (A, B, C)$ (firm A adopts format A, other firms do not). In this case, equal profits means that $p_A = p_B = p_C$. This equilibrium is not robust to an arbitrarily small ϵ increase in price by one firm, for example firm B, such that $P' = (p_A, p_B + \epsilon, p_C)$. Indeed, firm B now makes higher profits than others and is therefore imitated. If such a deviation occurs, firms A and C imitate firm B, overall prices increase and there is no common format.

Suppose now that $F = (A, A, C)$.

- If $p_A = p_B$ then one of the two firms A or B may experiment with a decrease in its price by ϵ and gain higher profit than the other by attracting its savvy consumers. This will be then imitated by others.
- If $p_A > p_B$ then we have two possibilities,
 - Firm B sells to all savvy consumers, in which case we must have $p_B \cdot (1 + 2\mu) = p_A \cdot (1 - \mu) = p_C \cdot (1 - \mu)$ (equality of profits). This equilibrium is not robust to an experimentation by firm B such that it increases its price by arbitrarily small ϵ and make profit $(p_B + \epsilon) \cdot (1 + 2\mu)$. If such a deviation occurs indeed, firm C imitates firm B by adopting the new higher price of firm B and also adopts the format adopted by firm B (format A). Firm A also adopts the new price of firm B.
 - Firm B sells only to savvy consumers of firm A, in which case we must have $p_B \cdot (1 + \mu) = p_A \cdot (1 - \mu) = p_C$ (equality of profits). As above, firm B may increase its price by ϵ and make higher profit, so this equilibrium is not robust to experimentation.
- If $p_A < p_B$, then the same type of reasoning as above holds, i.e. firm A will benefit if it experiments by raising its price by ϵ . Furthermore, firm B may gain by randomly switching to its own format B.

Suppose finally that $F = (A, A, A)$. Again, equal profits means that $p_A = p_B = p_C$. This equilibrium is not robust to an arbitrarily small ϵ decrease in price by one firm, for example firm B, such that $P' = (p_A, p_B - \epsilon, p_C)$. Indeed, firm B now makes higher profits than others by attracting all savvy consumers and will therefore be imitated. Prices thus decrease and all firms maintain format A.

Dynamics

From the above, the dynamics of the imitation strategy when $\mu > 0$ are as follows:

1. Whenever $F = (A, B, C)$, then prices increase and firms maintain their own format.
 2. Experimentation in terms of format may however lead one firm, for example firm B, to adopt format A, so that $F = (A, A, C)$. However, $F = (A, A, C)$ cannot lead to stable prices.
 - a) if $F = (A, A, C)$ and $p_A < p_B$, then firm B may experiment by switching to its own format (so we go back to $F = (A, B, C)$) or by increasing its price — which is imitated by firm C if this leads to higher profits, leading to $F = (A, A, A)$. Finally, firm A may experiment by raising its price (up to p_B). This increases its profit and is thus maintained. We are then led to the situation where:
 - b) $F = (A, A, C)$ and $p_A > p_B$, and then firm B may experiment by increasing its prices (up to p_A), in which case firm B is imitated by firm C so $F = (A, A, A)$ in the next period.
- Any situation where $F = (A, A, C)$ or $F = (A, B, A)$ is therefore not robust to experimentation.

3. Finally, if $F = (A, A, A)$ then experimentation leads to price decreases while firms maintain format A. This can be broken however when one firm experiments by switching to its own format. This will raise its profit – and thus be imitated – if prices are low enough. Finally, if $\mu = 0$, then the choice of format is indifferent and we get the dynamics of the case where $F = (A, B, C)$. Prices gradually increase until they are equal to 5. $p = (5, 5, 5)$ is therefore a stable imitation equilibrium when $\mu = 0$.

D. Dynamics under imitation

[Figure 10 about here.]

E. Sustainable collusion

We show that higher μ and λ make punishment harder when a firm breaks a (tacit) collusive agreement, but also make deviations more profitable. As in [Petrikaitė \(2016\)](#), the balance first makes collusion easier to sustain, then makes it less likely. Formally, denote $C(\mu, \lambda)$ the maximum profit attainable if firms compete normally (either best responding, adopting mixed strategies or learning over time, cf. sections above), and denote $D(\bar{p}, \mu, \lambda)$ the maximum profit that can be obtained by a deviating firm when collusion is at price \bar{p} . Collusion will be sustainable in a context with full information about the past action of others if

$$\frac{\bar{p}}{1 - \delta} \geq D(\bar{p}, \mu, \lambda) + \delta \cdot \frac{C(\mu, \lambda)}{1 - \delta} \quad (1)$$

where discount factor δ may reflect the level of patience of subjects, and also reflects the probability with which a pairing is maintained next period in the experiment (set at 90% in our sessions).

We saw that $C(\mu, \lambda)$ was decreasing in both μ and λ in all scenarios for competition that we considered (except imitation, where no prediction could be made). We now show that $D(\mu, \lambda)$, the deviation profit, is at least weakly increasing in μ and λ . $D(\bar{p}, \mu, \lambda)$ is the maximum profit out of three options:

1. set price $p < \bar{p} - e$ in which case the deviating firm gains the whole market. Its profit can then be made arbitrarily close to $3 \cdot (\bar{p} - e)$.
2. adopt format A set $p \in [\bar{p} - e, \min[(1 + \lambda) \cdot \bar{p} - e, \bar{p}]]$ and gain all savvy consumers. Profit of the deviating firm can then be made arbitrarily close to $(1 + 2\mu) \cdot \min[(1 + \lambda) \cdot \bar{p} - e, \bar{p}]$.
3. adopt format A and set $p \in [\min[(1 + \lambda) \cdot \bar{p} - e, \bar{p}], \bar{p}]$. The deviating firm then gains savvy consumers of firm A but its price is not low enough to gain savvy consumers of firm C (if the deviating firm is B) or savvy consumers of firm B (if the deviating firm is C). Its profit can then be made arbitrarily close to $(1 + \mu) \cdot \bar{p}$.

$D(\mu, \lambda)$ being the maximum of three options, two of which are increasing in μ and one being weakly increasing in λ , we see that deviation profit is at least weakly increasing in μ and λ .

Graph 11 shows the range of δ where collusion will be sustained, as a function of \bar{p} , the collusive price, in abscissa, for different levels of μ and given $\lambda = 30\%$. $C(\mu, \lambda)$ is taken from best response predictions. We see that higher μ and λ do not always make collusion easier to sustain, and lower \bar{p} does not necessarily make it more difficult. In particular, high levels of μ make deviation so profitable – one only needs to decrease price by ϵ to gain almost the whole market – that this counteracts how low competitive profits subsequently are.

[Figure 11 about here.]

F. Regression

[Table 10 about here.]

G. Robustness

[Table 11 about here.]

[Table 12 about here.]

[Table 13 about here.]

[Table 14 about here.]

ONLINE APPENDIX

H. Instructions

Welcome and thank you for your participation! You can earn an amount of money which depends on your decisions and the decisions of the other participants in this experiment. It is therefore very important that you thoroughly read through these instructions.

From now on, all communication with other participants is prohibited. If you have a question, please raise your hand. We will then come to you and answer your question. If you violate this rule, we will be forced to exclude you from the experiment.

PLEASE TURN OFF YOUR MOBILE PHONE NOW!

You will make decisions in the course of the experiment. There are no right or wrong decisions. Decide the way you think is best. All results of the study will be kept strictly confidential.

Your earnings will be calculated in ECU (Experimental Currency Units). 1 ECU corresponds to 0.05€. That is 100 ECU is equivalent to 5€. At the end of the experiment your total earnings will be converted in euros and paid to you confidentially and in cash.

For your punctual arrival you will receive a base payment of 50 ECU (2.5€).

EXPLANATIONS

The experiment consists of four phases.

1. Phase 1: In this phase, we will read the instructions aloud and make sure that all participants understand the rules of the experiment.

After reading the instructions completely, you will answer control questions to check your understanding of the experiment. Only when all participants have answered the control questions correctly will you be able to move to the next phase of the experiment.

2. Phase 2: You will have the opportunity to explore how different combinations of your decisions and those of other participants impact on your earnings. There will be four different scenarios. You will have three minutes time to go to each scenario.

3. Phase 3: When phase 2 and thereby the scenario exploration is completed, the main part of the experiment start. The next sections explains how Phase 3 works.

4. Phase 4: In phase 4, you will fill in two questionnaires.

Your earnings will be determined at the end of the experiment. Right after this we will pay your earnings in cash and confidentially and you will be able to leave.

EXPLANATION OF THE MAIN PART OF THE EXPERIMENT (PHASE 3)

In the experiment, you assume the role of a manager. You are matched with two other randomly selected participants. Each of you is assigned to be the manager of one company. The three companies in your market area are called A, B, C and manufacture different models of the same type of product. Company A manufactures Model A, Company B manufactures Model B or Model and Company C manufactures Model C or Model A.

There are a total of 300 customers who want to buy a product in this market. As managing director of your company, your job is to maximize profit. You make a profit by selling your product in your market area. It is your responsibility to decide how you want to market your product in order to maximize profit. You can choose the price of your product and the model you manufacture.

1. Price: You can select the price for your product. You can set any price between 0 and 5, with an accuracy of up to two decimal places.
2. Model: If you manage business B or C, you can decide whether you want to either make your own model (Model B and Model C) or whether you want to produce the same model as Company A (Model A). If you manage business A, you cannot decide which model to produce. You need to produce your own model A.

You will make both of these decisions on your own and at the same time as the other two companies in your market area. You will not see the decisions of others when you make your decisions. Likewise, the others can not see your choices. Once choices are made, then consumers choose among your products.

Your profit is derived from the number of units you sold multiplied by the price you set. There are no costs in producing your product.

In choosing their products, not all of the 300 clients have the same preferences. 100 of 300 customers prefer to buy from company A. 100 customers prefer to buy from companies B and 100 customers prefer to buy from Company C.

- If all companies produce their own model, customers would rather pay 1 ECU more to obtain the product of their preferred company than buying from another company. In other words, the customers buy from their favorite business as long as its price is not more than 1 ECU higher than the lowest price at the other companies. If the product of their preferred company is more than 1 ECU more expensive than the cheapest product at the competition, then they prefer to buy the cheapest product rather than the product of the preferred company.
- If two or more companies produce Model A, Model A is the standard in the market. In this case, 20% of customers (20 per company) tend to buy the cheapest model A rather than a non-standard model. For example:
 - If all firms produce the Model A, those 20% of customers buy the cheapest model A, even if it is not made by their preferred company.
 - If only two companies produce model A, those 20% of customers compare the cheapest model A and the non-standardized product. They never buy the more expensive model A. Those customers are willing to pay 20% more for the cheapest model A than for a non-standard model. This is the extent by which these customers dislike the non-standard model.
 - If every company produces its own model, those 20% of customers behave exactly like the other 80% of customers
 - The rest of the customers (80 per company) are not interested in whether another company sells the same model as their preferred firm or not. They keep on buying from their favorite business as long as its price is not more than 1 ECU above the lowest price at the other companies.

In summary: Every company has 100 customers who are willing to pay more for their product than for the product of another company. However, if two or more firms produce model A, 20% of those customers tend to buy the cheapest model A instead of a non-standard model. The remaining 80% of customers do not care whether some companies manufacture the same model or not.

Once all companies have made their pricing decision and their model selection, the customers look at the prices and models on the market and make their purchase decision. The decisions of the 300 customers are made by the computer according to the rules described above.

Once the computer has calculated your sales and profits, you will see reminder information on the screen showing your chosen price and model, along with your sales and profits as well as the prices, model, sales and profits of your competitors. The other participants in your group will receive the same information as you.

Once all of the companies in the market have had the chance to look at the results, the market closes with a probability of 10%, otherwise there is a new market period with the same competitors in your marketplace. If the market closes, then you enter a new market with new participants and manage a new company.

- If the market continues, you will enter a new period with the same competitors as in the last round and act as manager of the same company. The new market period works just like the previous one. You will see the progress of the past actions, the sales and profits of all three companies on the market when you make your decisions.
- If the market closes, you will be randomly assigned to a new market with two new participants and manage a new business. This random assignment guarantees that you never meet again the same two managers in the course of the experiment. In other words, the members of each market to which you are assigned are people with whom you never were in competition previously in this experiment. In addition, none of the competitors with whom you have interacted in a market will ever meet a competitor you also met.

In the course of the experiment you will participate in three different markets, each time with all-new competitors, and without knowing which company you will be assigned to (A, B or C).

DETERMINATION OF PAYOUTS

At the end of the experiment, the computer will randomly select a time period of one of the three markets you took part in as relevant. You will not know in advance which period and which market will

determine your payout. You should therefore make your decisions in all three markets and all periods carefully, as each of them could decide on the amount of your payment at the end of the experiment.

Once a period has been selected from a market for payment, the program will show your choices in that period and how much revenue and profit you made in that period. You will see as well the decisions, sales and profits of your competitors in that period.

The profits that you made in the selected period will be converted into euro and paid to you in cash and confidentially at the end of the experiment.

SUMMARY

1. After reading the instructions you will answer quiz questions and will have the opportunity to consider four market scenarios.
2. You will then participate in three different markets. Each market will last a certain number of periods. Each period has a probability of 10% of being the last period of the market. This means that you do not know how long each market will last. In addition, not every market lasts the same number of periods. You will be assigned to a completely new group of competitors in each market.
3. You will be asked a series of background questions and questions regarding your choices at the end of the experiment.
4. Once all decision-making situations are over and you have answered all questions, then the computer will determine which market and which period in that market will be relevant for your payout. Thereupon details of your payoff calculation will be displayed.
5. Your profits in the randomly selected market and period will be paid to you at the end of the experiment in cash and confidentially.

I. Control questions

1. Suppose you are firm B. How many consumer favor your product over others? (A: 100)
2. How many consumers can you sell to at most? (A: 300)
3. Can you choose what model to offer if you are firm A? (A: No)
4. How much more is a consumer who favors your product ready to pay to get your product rather than a competing product? (A: 1 ECU)
5. How many consumers are there who prefer to get a standard model? (A: 20, 10 or 0 depending on the treatment)
6. In how many markets with different competitors will you be active? (A: 3)
7. How many periods will each markets last? (A: It depends)
8. Will you interact with the same participants in each market? (A: No)

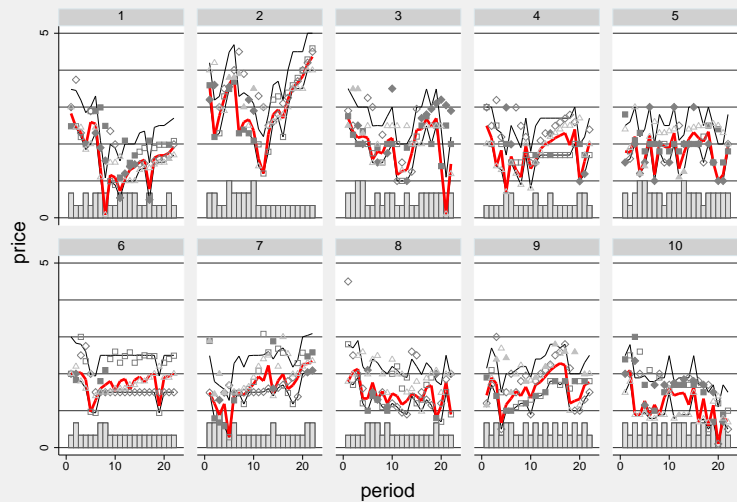
J. Scenarios to be explored

[Table 15 about here.]

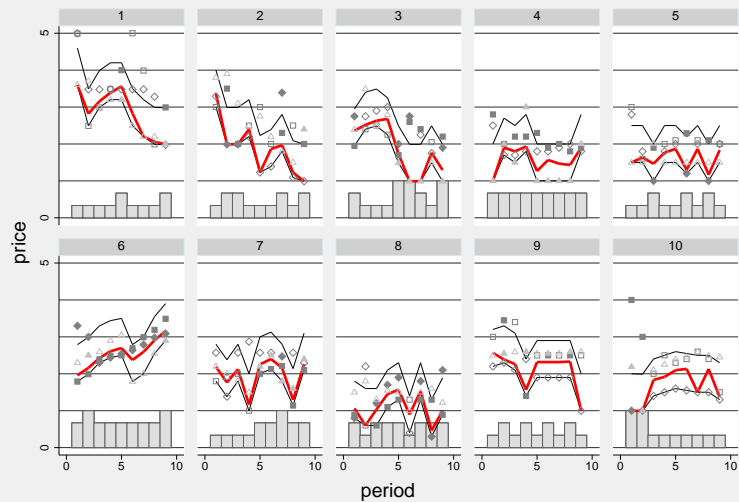
Scenarios are presented by order of difficulty. In the first scenarios, the subject is firm A and faces a situation with all firms adopting format A. The best choice is to set $p_A = 2.69$. In the second scenario, firm A faces firms with all their own format. The best choice is to set $p_A = 2.49$. In the third scenario, firm B faces firms that adopted format A and can choose both its price and its format. The best choice is to set $p_B = 2.89$ if $\mu = 0$ and to set $p_B = 0.89$ otherwise (the choice of format is indifferent in that case). In the fourth scenario, firm C is best of setting format C and price $p_C = 3.09$.

K. Evolution of prices and adoption of format *A* over time, by treatment, phase and groups

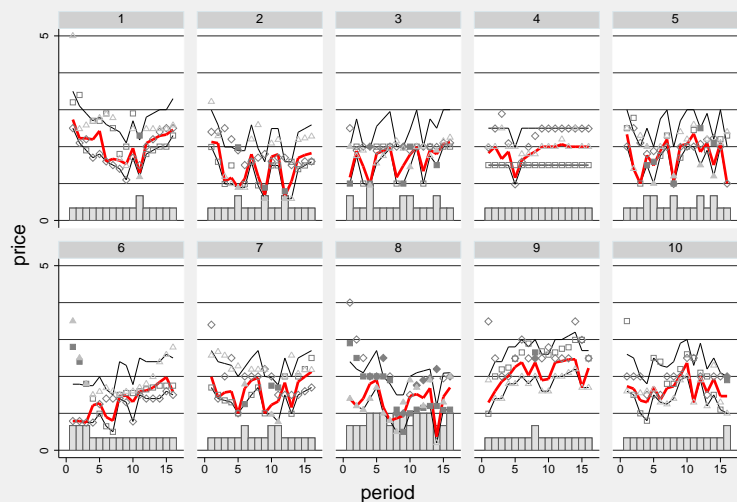
Each point (square, lozenge, triangle) corresponds to a firm, with firm *A* shown with squares. Full shapes indicate the firm chose format *A* (firms *B* and *C*) or that format *A* was a common format (firm *A*). Empty shapes indicate the firm chose its own format (firms *B* and *C*) or that only firm *A* adopted format *A* (firm *A*). The grey bars represent the proportion of firms with format *A* in each period (from $1/3$ - firm *A* only - to 1 - all firms). The lower lines indicate the lowest price in the market in the period, and the upper lines the highest price at which sales can be made in that period (= lowest price plus e). The middle line shows the average profit per consumer in the period.



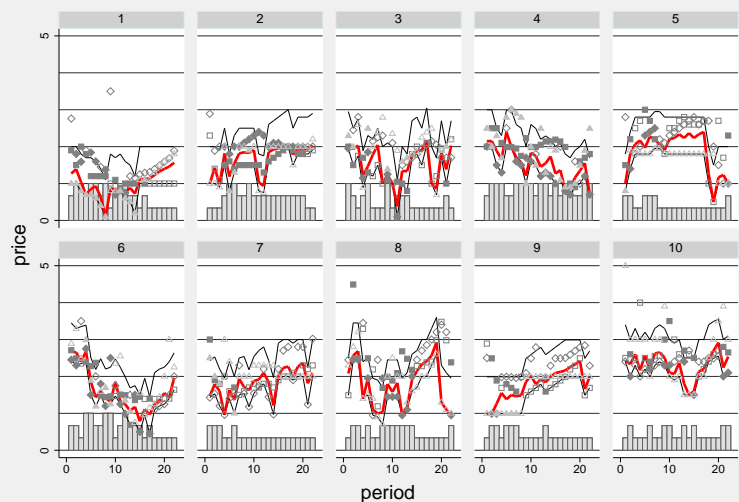
Treatment L00 Phase 1



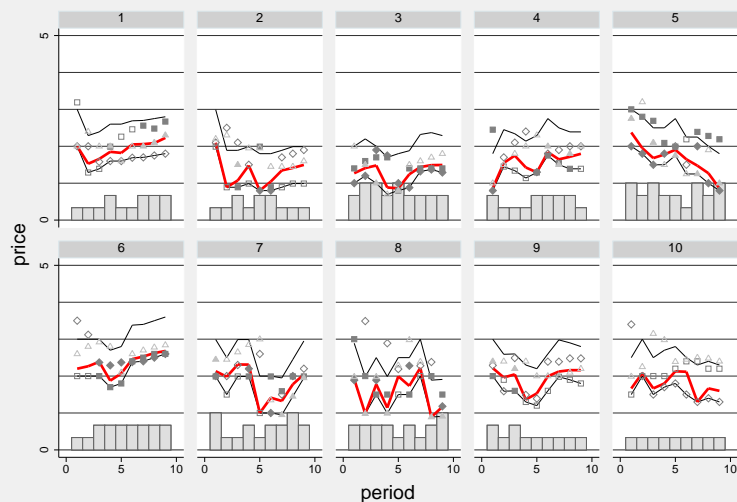
Treatment L00 Phase 2



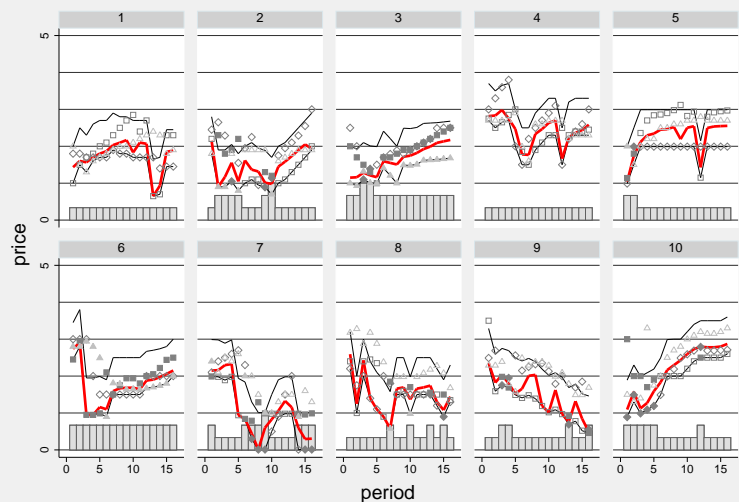
Treatment L00 Phase 3



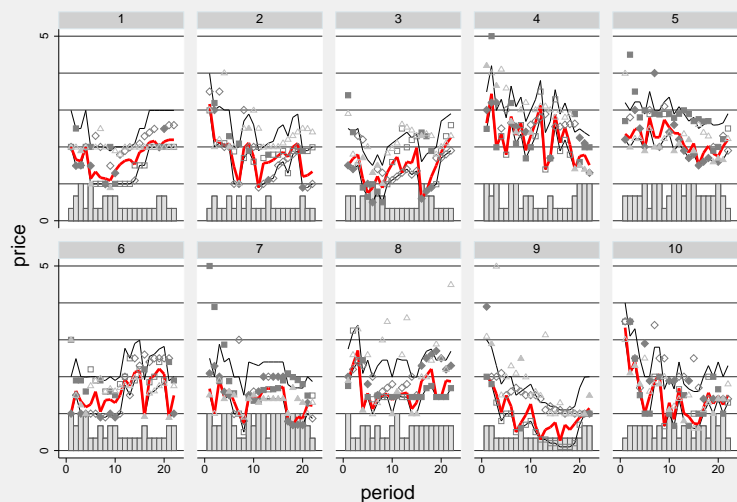
Treatment L11 Phase 1



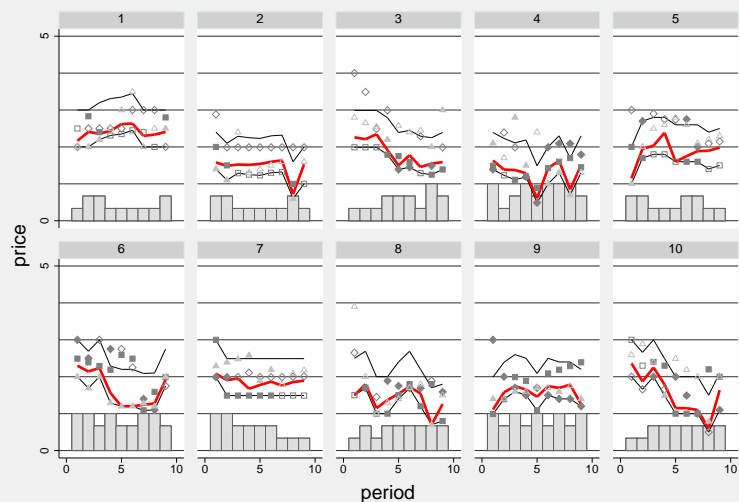
Treatment L11 Phase 2



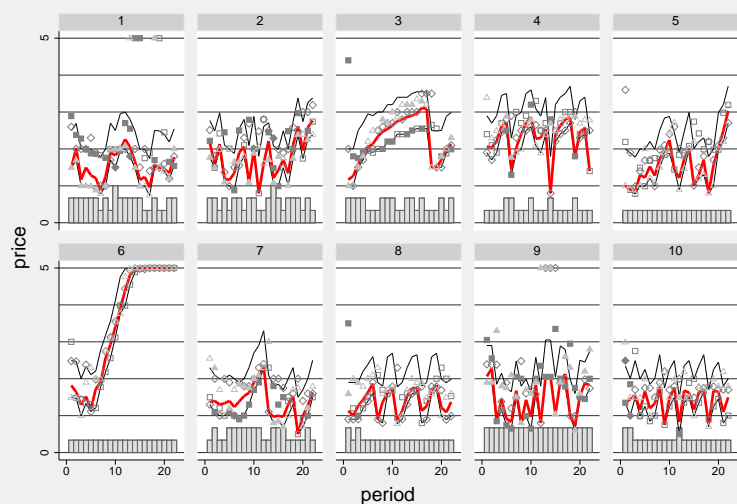
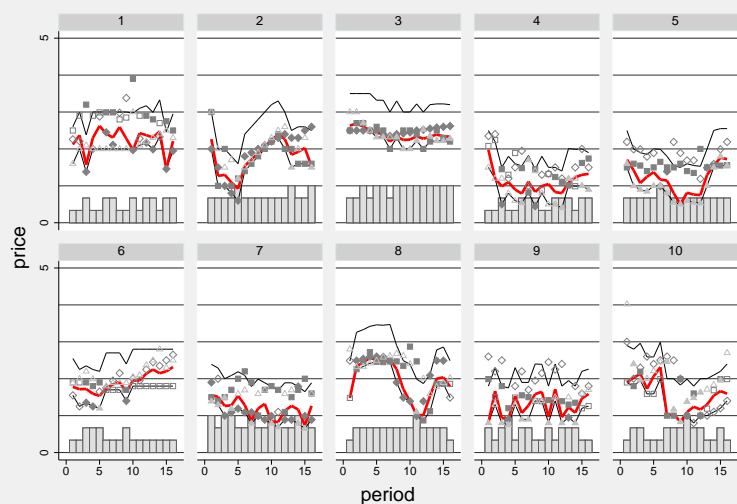
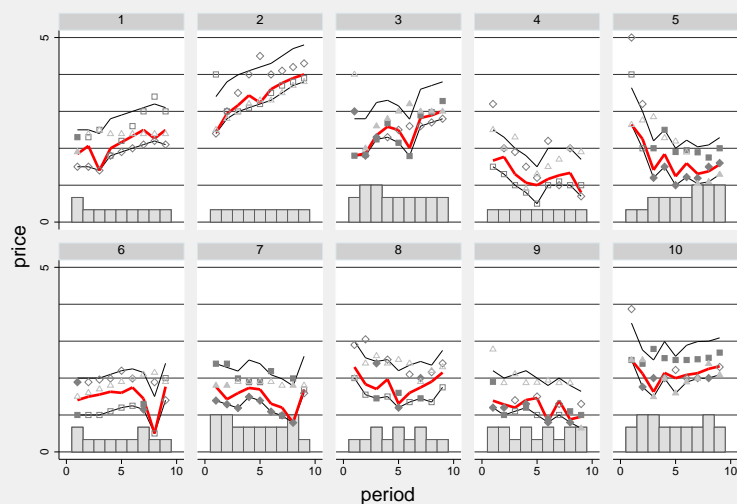
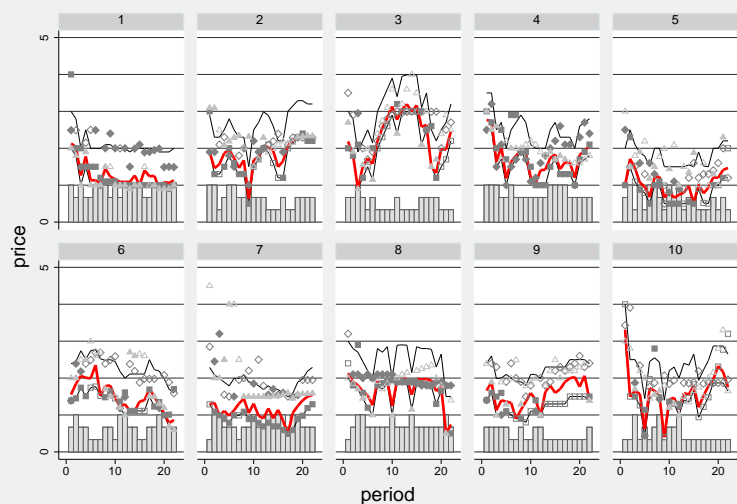
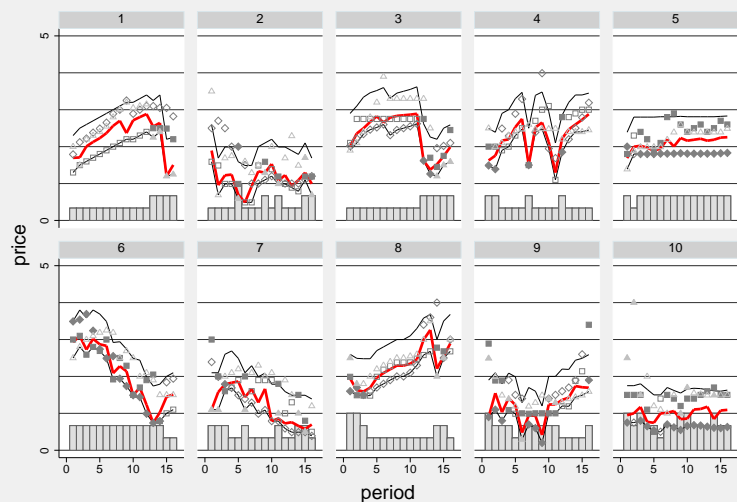
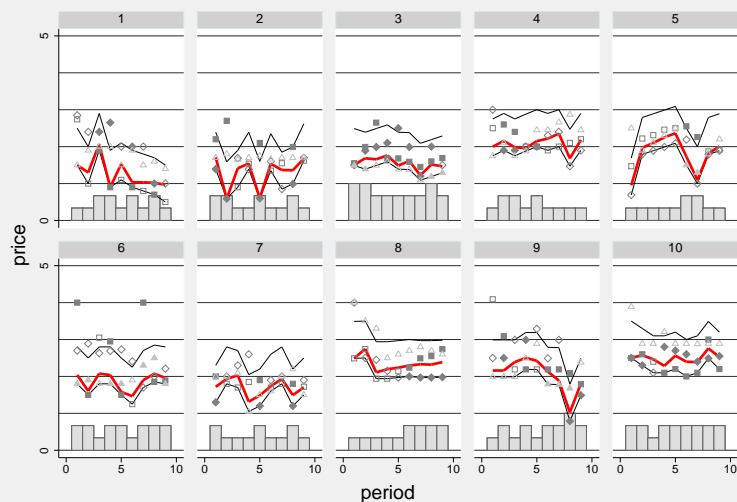
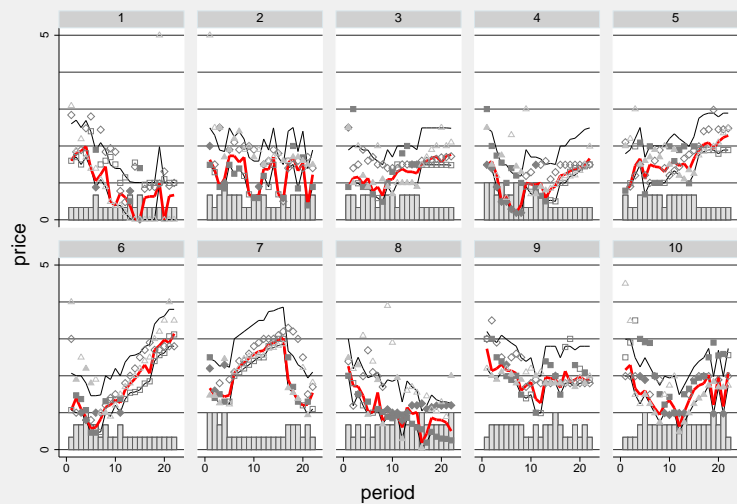
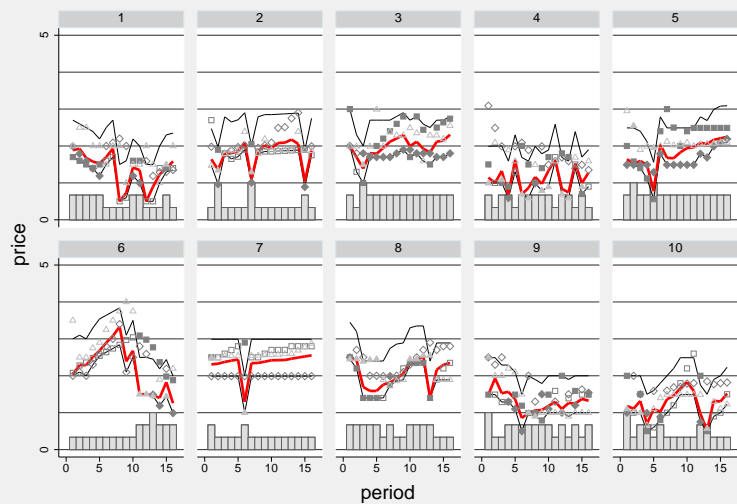
Treatment L11 Phase 3

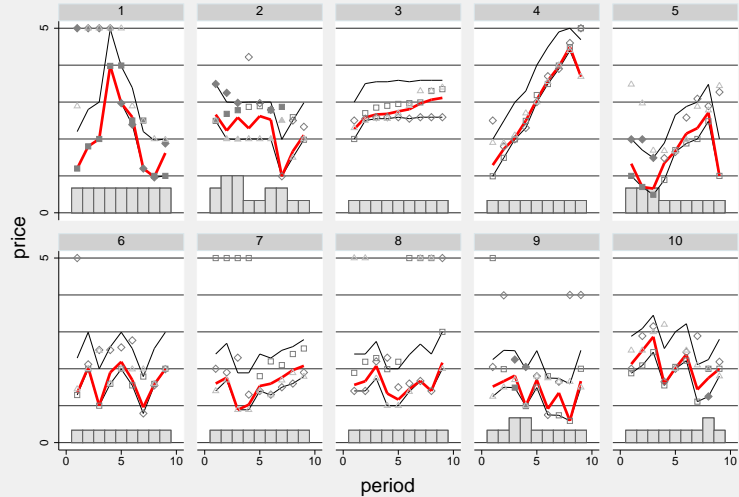


Treatment L12 Phase 1

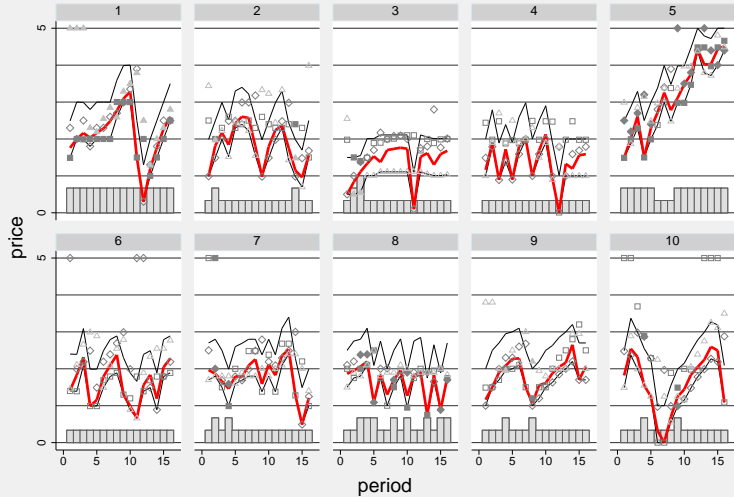


Treatment L12 Phase 2

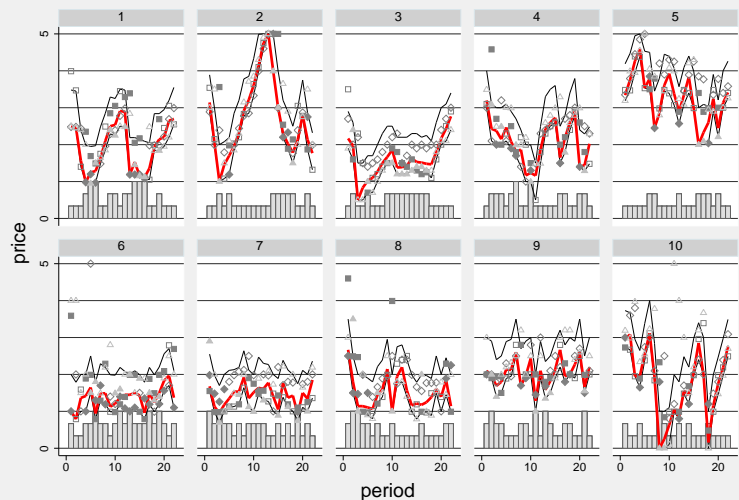




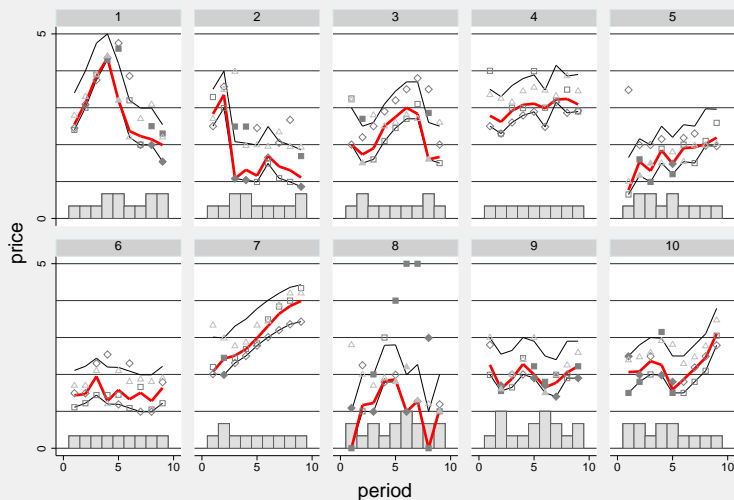
Treatment F00 Phase 2



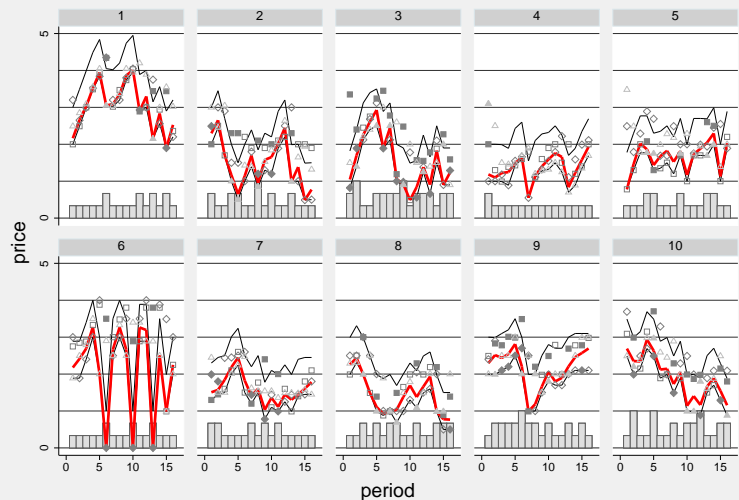
Treatment F00 Phase 3



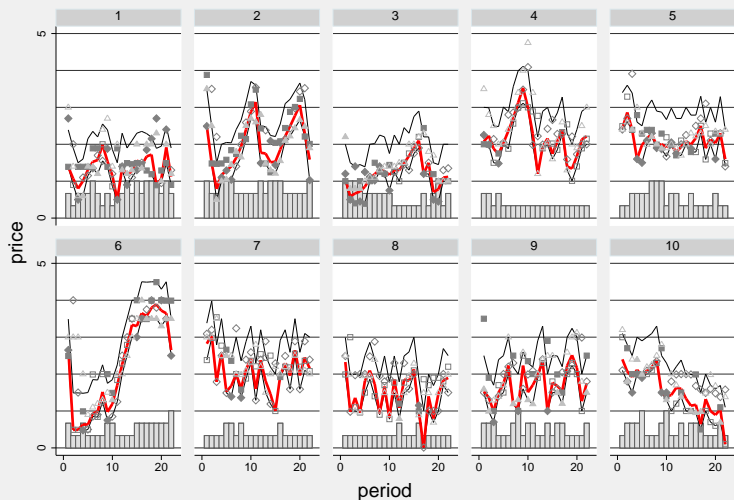
Treatment F11 Phase 1



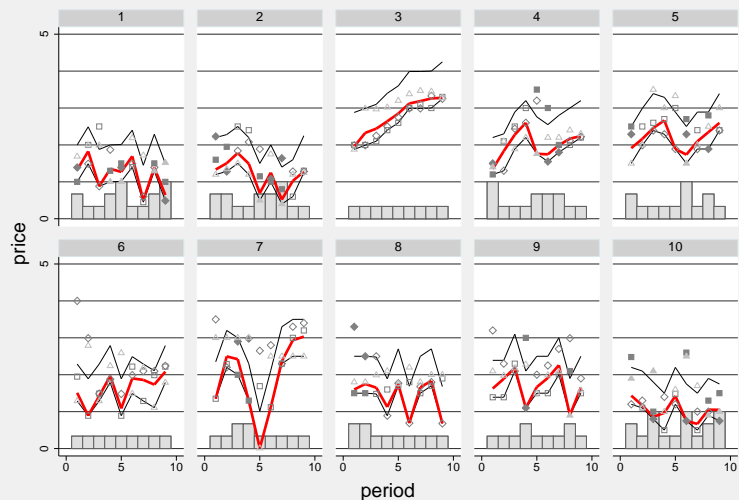
Treatment F11 Phase 2



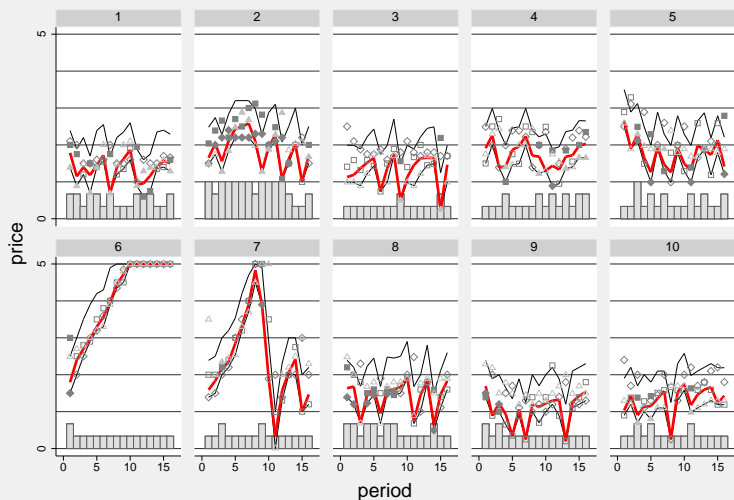
Treatment F11 Phase 3



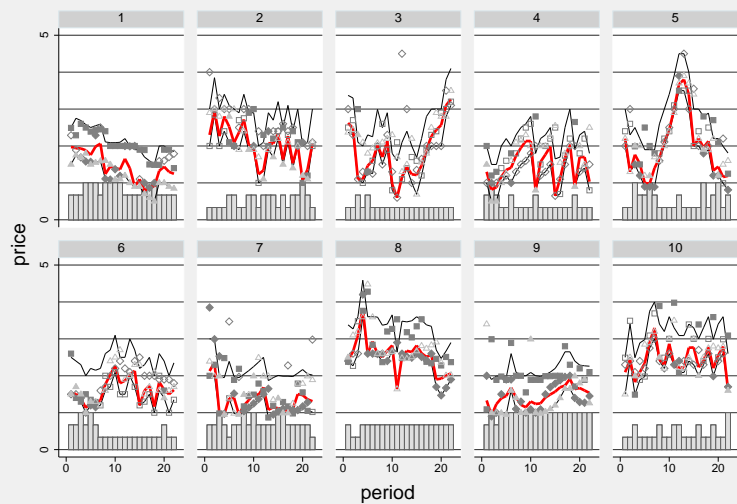
Treatment F12 Phase 1



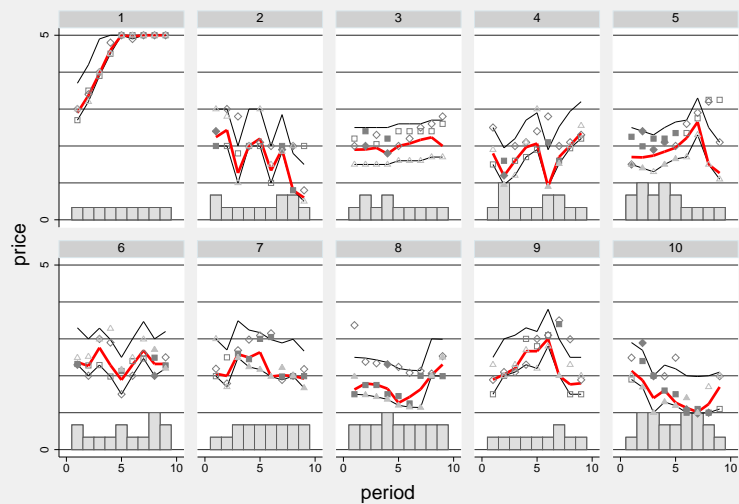
Treatment F12 Phase 2



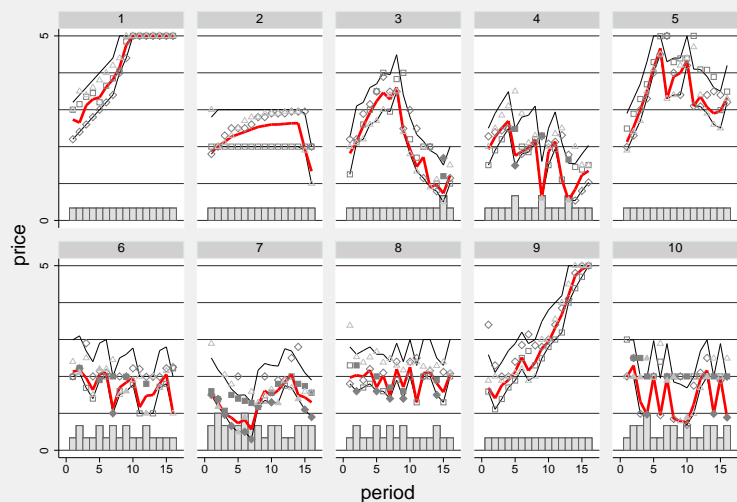
Treatment F12 Phase 3



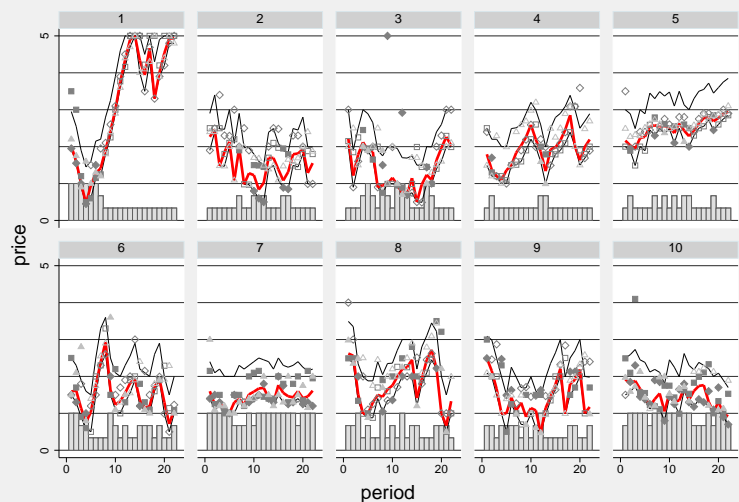
Treatment F21 Phase 1



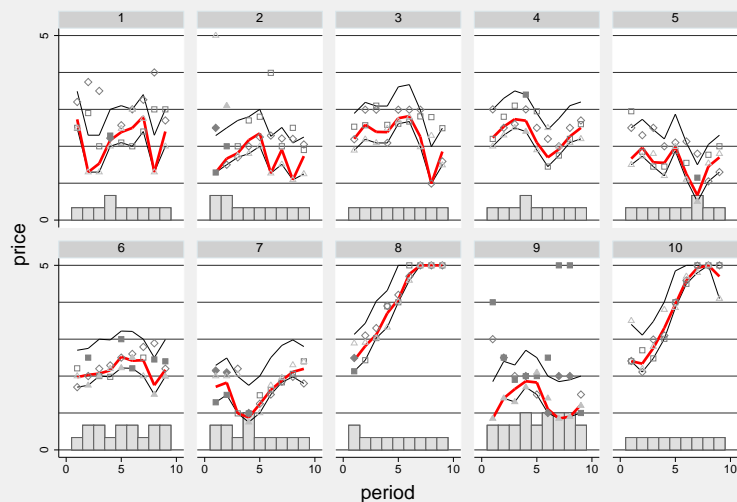
Treatment F21 Phase 2



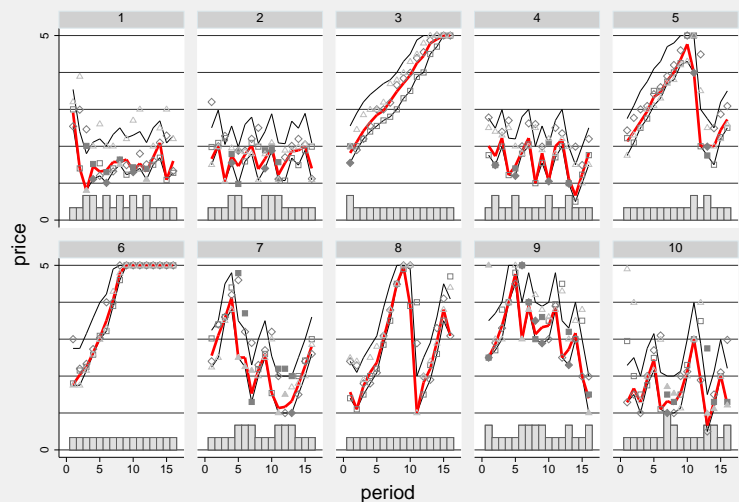
Treatment F21 Phase 3



Treatment F22 Phase 1



Treatment F22 Phase 2



Treatment F22 Phase 3

L. Individual behavior, comparison with best response

[Figure 12 about here.]

[Table 16 about here.]

M. Individual behavior, comparison with best choice last period

[Figure 13 about here.]

[Table 17 about here.]

Tables

				μ	
			0%	10%	20%
Limited information	λ	10%	L_0	L_{11}	L_{21}
		20%		L_{12}	L_{22}
Full information	λ	10%	F_0	F_{11}	F_{21}
		20%		F_{12}	F_{22}

Table 1: Treatments in the experiment, with labels

Table 2: Profits and choice of common formats in MSNE

<i>Average profits (in ECU)</i>					<i>Adoption of format A (firms B and C)</i>				
μ					μ				
	0%	30%	70%	100%		0%	30%	70%	100%
λ	0	149	131	131	λ	0	37%	26%	18%
	0.3	161	146	102		0.3	50%	39%	33%
	100		124	84		100	67%	43%	48%

Table 3: Results of the myopic best response simulations.

<i>Average profits (in ECU)</i>					<i>Adoption of format A (firms B and C)</i>				
μ					μ				
	0%	30%	70%	100%		0%	30%	70%	100%
λ	0	144	138	113	λ	0	31%	43%	50%
	0.3	166	142	110		0.3	55%	72%	73%
	100		122	80		100	78%	87%	100%

Table 4: Results of the reinforcement learning simulations.

Average profits (in ECU)					Adoption of format A (firms B and C)						
μ					μ						
0% 30% 70% 100%					0% 30% 70% 100%						
λ	0		94	82	75	λ	0	indif-	46%	40%	33%
	0.3	103	92	77	68		0.3	ferent	49%	45%	40%
	100		98	89	72		100		55%	65%	77%

	$\frac{\partial Profit^b}{\partial \mu}$	$\frac{\partial Profit^b}{\partial \lambda}$	$\frac{\partial Format\ A^c}{\partial \mu}$	$\frac{\partial Format\ A^c}{\partial \lambda}$	Average prices under format A
MSNE	—	—	—	+	Lower
Myopic Best Response	—	—	+	+	Lower
Imitation dynamics	High if $\mu = 0$, else no relation	No relation	No relation	No relation	Same
Reinforcement learning ^a	—	—	—	+	Lower
Collusion ^a	+	+	+	+	Lower

Table 5: Treatment effects on profits and use of format A, by hypothesized behavior.

^a Within the range of the experimental parameters. ^b Change in average profit as a function of changes in treatment parameters μ and λ . ^c Change in average frequency of use of format A as a function of changes in treatment parameters μ and λ .

	$\frac{\partial p}{\partial \text{Format A}}$ ^a	Upward price trends			Downward price trends		
		Length	Increment	Format	Length	Increment	Format
MSNE	NA	NA	NA	NA	NA	NA	NA
Myopic Best Response	decrease	short	big	own	long	small	Format A
Imitation dynamics	decrease	long	small	own	long	small	Format A
Reinforcement learning	NA	NA	NA	NA	NA	NA	NA
Collusion	decrease	long	small	own	short	big	Format A

Table 6: Relation between prices and use of format A, and trends in prices, by hypothesized behavior.

^a Change in price associated with the adoption of format A.

Table 7: Mean and standard deviation of profit and mean adoption of format A.

<i>Average profits (in ECU)</i>						<i>Adoption of format A (firms B and C)</i>				
			0%	μ 10%	20%			0%	μ 10%	20%
Limited information	λ	10% 20%	176 (107)	171 (91) 167 (99)	162 (98) 166 (96)	λ	10% 20%	23%	29% 35%	31% 44%
Full information	λ	10% 20%	186 (128)	195 (133) 177 (115)	205 (122) 214 (141)	λ	10% 20%	17%	25% 25%	28% 24%
<i>N=1410 observations per treatment</i>						<i>N=940 observations per treatment</i>				

		<i>Own format</i>	<i>Format A</i>
Limited	mean (sd)	0.05 (0.53)	-0.21 (0.61)
information	N (%)	2999 (68%)	1401 (32%)
Full	mean (sd)	0.09 (0.65)	-0.33 (0.79)
information	N (%)	3335 (76%)	1045 (24%)

Table 8: Average magnitude and frequency of change in prices, by choice of format (firms B and C)

		<i>Price decreases</i>	<i>No change</i>	<i>Price increases</i>
Limited information	mean (sd)	-0.55 (0.52)	0 (0)	0.34 (0.37)
	N (%)	1543 (35%)	770 (18%)	2087 (47%)
Full information	mean (sd)	-0.68 (0.64)	0 (0)	0.44 (0.41)
	N (%)	1599 (36%)	436 (10%)	2365 (54%)

Table 9: Average magnitude and frequency of change in prices, by direction of change (firms B and C)

Table 10: Panel regressions (linear and logistic), profit and format adoption, by information treatment

	profits		format	
	limited info	full info	limited info	full info
$\mu = 10\%$	-7.13* [-13.45,-0.82]	1.44 [-6.42,9.30]	0.25** [0.10,0.40]	0.53*** [0.37,0.69]
$\mu = 20\%$	-12.06*** [-18.31,-5.81]	24.81*** [17.47,32.16]	0.48*** [0.33,0.64]	0.59*** [0.45,0.74]
$\lambda = 20\%$	-0.50 [-4.93,3.92]	-4.01 [-9.56,1.55]	0.44*** [0.33,0.55]	-0.08 [-0.20,0.05]
Constant	176.45*** [171.38,181.53]	186.45*** [180.73,192.17]	-1.23*** [-1.35,-1.12]	-1.60*** [-1.71,-1.49]
$\mu = 20\%$ vs. $\mu = 10\%$	-4.93+ [-10.36,0.50]	23.36*** [16.63,30.11]	0.23*** [0.10,0.36]	0.06 [-0.08,0.21]
N observations	7050.00	7050.00	4700.00	4700.00
ll	-42379.69	-44230.97	-2901.87	-2557.64
chi2	18.08***	90.78***	168.64***	68.15***

Base categories: $\mu = 0\%$, $\lambda = 10\%$

Bootstrapped estimations, 1000 repetitions, stratified by group and subjects

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.

Table 11: Mean and standard deviation of profit and mean adoption of format A, in Phase 3.

<i>Average profits (in ECU)</i>						<i>Adoption of format A (firms B and C)</i>				
				μ				μ		
		0%		10%	20%	0%		10%	20%	
Limited information	λ	10%	168 (91)	175 (92)	178 (98)	λ	10%	15%	21%	29%
		20%		172 (87)	165 (87)		20%	30%	45%	
Full information	λ	10%	182 (122)	182 (128)	230 (143)	λ	10%	15%	22%	12%
		20%		182 (129)	253 (167)		20%	20%	12%	
<i>N=480 observations per treatment</i>						<i>N=320 observations per treatment</i>				

Table 12: Panel regressions (linear and logistic), profit and format adoption, phase 3, by information treatment

	profits		format	
	limited info	full info	limited info	full info
$\mu = 10\%$	9.68* [0.33,19.04]	-5.64 [-19.10,7.82]	0.33* [0.05,0.61]	0.43** [0.14,0.72]
$\mu = 20\%$	8.13+ [-1.30,17.56]	53.65*** [40.38,66.91]	0.90*** [0.61,1.19]	-0.22 [-0.52,0.07]
$\lambda = 20\%$	-7.73* [-14.59,-0.88]	11.03* [0.26,21.80]	0.60*** [0.41,0.78]	-0.09 [-0.35,0.16]
Constant	167.55*** [160.38,174.72]	182.21*** [172.55,191.87]	-1.73*** [-1.97,-1.50]	-1.73*** [-1.92,-1.55]
$\mu = 20\%$ vs. $\mu = 10\%$	-1.55 [-9.83,6.72]	59.28*** [46.72,71.85]	0.57*** [0.35,0.79]	-0.66*** [-1.00,-0.31]
N observations	2400.00	2400.00	1600.00	1600.00
ll	-14232.91	-15246.54	-907.81	-694.04
chi2	6.60+	146.44***	136.43***	22.50***

Base categories: $\mu = 0\%$, $\lambda = 10\%$

Bootstrapped estimations, 1000 repetitions, stratified by group and subjects

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. 95% confidence intervals in brackets.

Table 13: Mean and standard deviation of profit and mean adoption of format A, group averages

<i>Average profits (in ECU)</i>						<i>Adoption of format A (firms B and C)</i>				
			0%	μ 10%	20%			0%	μ 10%	20%
Limited information	λ	10% 20%	179 (43)	172 (34) 168 (37)	168 (49) 170 (51)	λ	10% 20%	24%	29% 37%	30% 41%
Full information	λ	10% 20%	188 (57)	197 (59) 176 (61)	209 (76) 220 (84)	λ	10% 20%	16%	23% 24%	26% 22%
<i>N=30 observations per treatment</i>						<i>N=30 observations per treatment</i>				

Table 14: Linear regressions, average group profit and format adoption, by information treatment

	profits		format	
	limited info	full info	limited info	full info
$\mu = 10\%$	-8.56 [-27.96,10.84]	0.90 [-28.27,30.07]	0.04 [-0.05,0.14]	0.09* [0.01,0.16]
$\mu = 20\%$	-8.85 [-30.09,12.40]	28.91+ [-2.13,59.95]	0.07+ [-0.01,0.16]	0.09+ [-0.01,0.19]
$\lambda = 20\%$	-0.79 [-16.25,14.68]	-4.86 [-29.89,20.17]	0.09* [0.02,0.17]	-0.02 [-0.09,0.05]
Constant	178.62*** [162.92,194.32]	188.16*** [166.88,209.43]	0.24*** [0.17,0.30]	0.16*** [0.10,0.22]
$\mu = 20\%$ vs. $\mu = 10\%$	-0.28 [-18.76,18.20]	28.01+ [-4.06,60.08]	0.03 [-0.06,0.12]	0.01 [-0.08,0.10]
N observations	150.00	150.00	150.00	150.00
ll	-775.89	-844.88	28.69	30.16
chi2	1.04	5.23	13.38**	4.94

Base categories: $\mu = 0\%$, $\lambda = 10\%$

Bootstrapped estimations, 1000 repetitions, 95% confidence intervals in brackets.

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	Role Played	Format A	Format B	Format C	Price A	Price B	Price C
Scenario 1	Firm A	-	A	A	Free Choice	2.7	4
Scenario 2	Firm A	-	B	C	Free Choice	1.5	1.6
Scenario 3	Firm B	A	Free Choice	A	2	Free Choice	1.9
Scenario 4	Firm C	A	B	Free Choice	4.1	4.5	Free Choice

Table 15: Table of the four scenarios to be explored prior to starting with real decisions

			Best response	
			<i>Adopt own format</i>	<i>Adopt format A</i>
Limited information	Actual behavior	Adopt format A	$p = 0.01 \times p^* + 1.52$ $N = 1219, R^2 = 0.00$	$p = 0.51 \times p^* + 0.98$ $N = 788, R^2 = 0.12$
		Adopt own format	$p = 0.21 \times p^* + 1.50$ $N = 2215, R^2 = 0.03$	$p = 0.54 \times p^* + 1.40$ $N = 1298, R^2 = 0.15$
Full information	Actual behavior	Adopt format A	$p = 0.12 \times p^* + 1.28$ $N = 765, R^2 = 0.01$	$p = 0.40 \times p^* + 1.07$ $N = 609, R^2 = 0.10$
		Adopt own format	$p = 0.46 \times p^* + 1.20$ $N = 2499, R^2 = 0.10$	$p = 0.92 \times p^* + 0.94$ $N = 1647, R^2 = 0.46$

Table 16: Best response *vs.* actual behavior in the experiment (firm B, excluding baseline treatment)

			Best choice last period	
			<i>Adopt own format</i>	<i>Adopt format A</i>
Limited information	Actual behavior	Adopt format A	$p = 0.45 \times p^* + 0.89$ $N = 1470, R^2 = 0.19$	$p = 0.72 \times p^* + 0.55$ $N = 882, R^2 = 0.46$
		Adopt own format	$p = 0.59 \times p^* + 0.90$ $N = 3786, R^2 = 0.37$	$p = 0.43 \times p^* + 1.36$ $N = 762, R^2 = 0.16$
Full information	Actual behavior	Adopt format A	$p = 0.51 \times p^* + 0.69$ $N = 998, R^2 = 0.23$	$p = 0.74 \times p^* + 0.46$ $N = 526, R^2 = 0.47$
		Adopt own format	$p = 0.78 \times p^* + 0.63$ $N = 4631, R^2 = 0.62$	$p = 0.67 \times p^* + 1.06$ $N = 755, R^2 = 0.46$

Table 17: Best last period *vs.* behavior in the experiment (firm B)

Figures

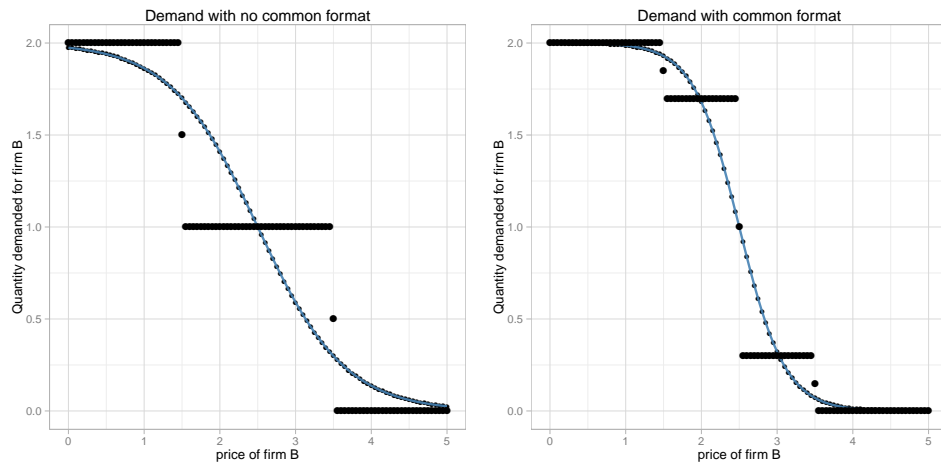


Figure 1: Demand for firm B in a duopoly given $v = 5$, $e = 1$, $\mu = 0.3$ and $p_A = 2.5$. The step black lines are the demand for firm B as a function of its price. The continuous blue line is a logistic approximation.

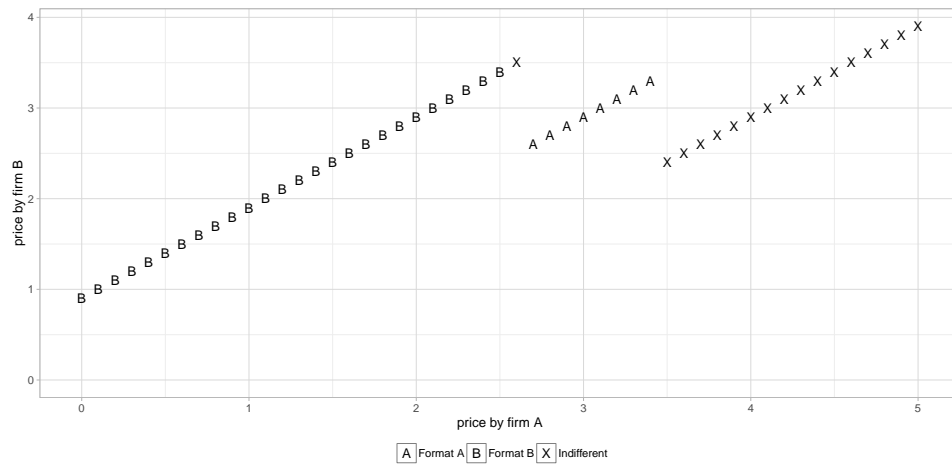


Figure 2: Best response function of firm *B* in a duopoly

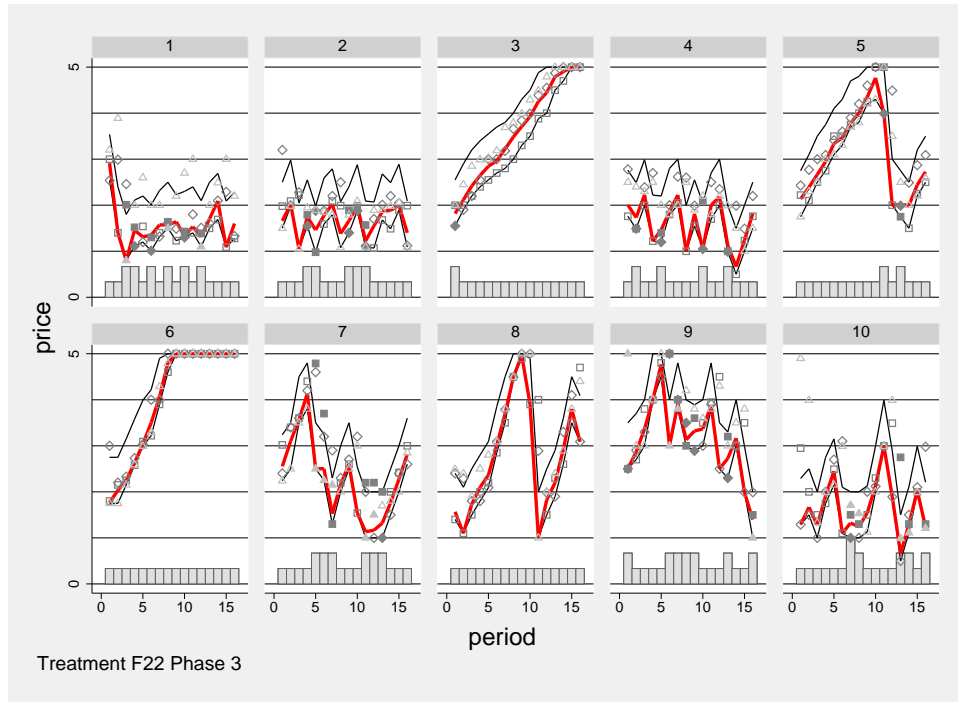


Figure 3: Prices and fraction of firms with format *A* over time, Treatment F_{22} , Phase 3. Each point (square, lozenge, triangle) corresponds to a firm's price in a given period, with firm *A* shown with squares. Full shapes indicate the firm chose format *A* (firms *B* and *C*) or that format *A* was a common format (firm *A*). Empty shapes indicate the firm chose its own format (firms *B* and *C*) or that only firm *A* adopted format *A* (firm *A*). The grey bars represent the proportion of firms with format *A* in each period (from 1/3 - firm *A* only - to 1 - all firms). The lower lines indicate the lowest price in the market in the period, and the upper lines the highest price at which sales can be made in that period (= lowest price plus e). The middle line shows the average profit per consumer in the period.

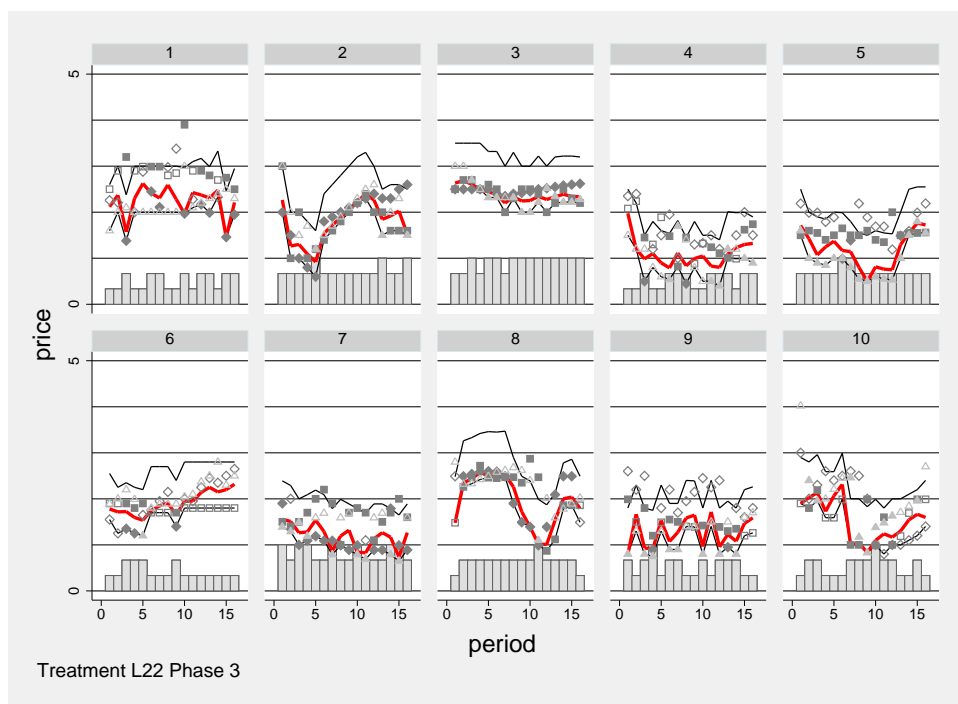


Figure 4: Prices and fraction of firms with format A over time, Treatment L_{22} , Phase 3.

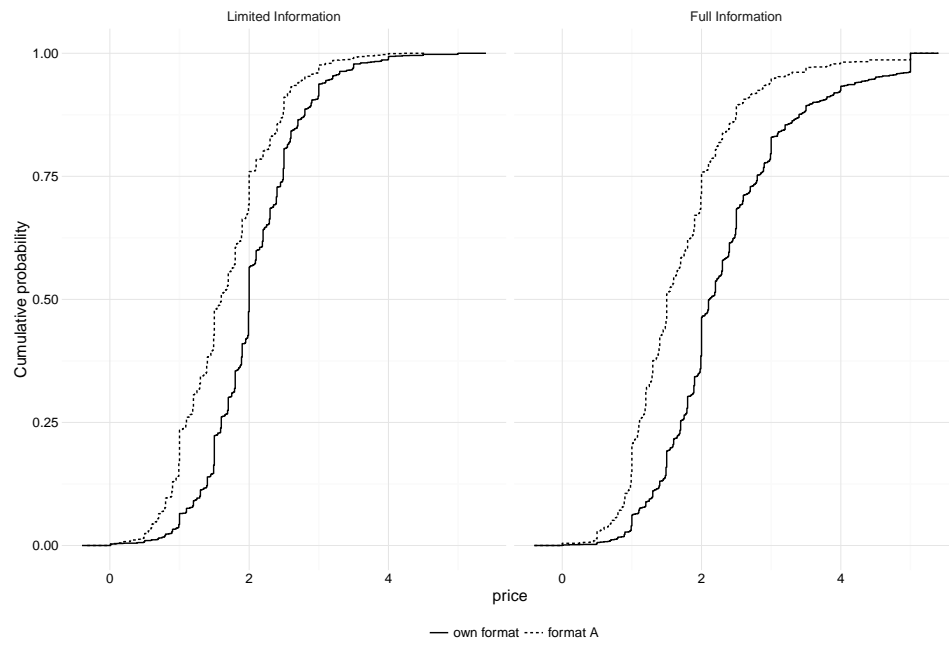


Figure 5: Distribution of prices by adoption of format *A* under limited and under full information (firms *B* and *C*).

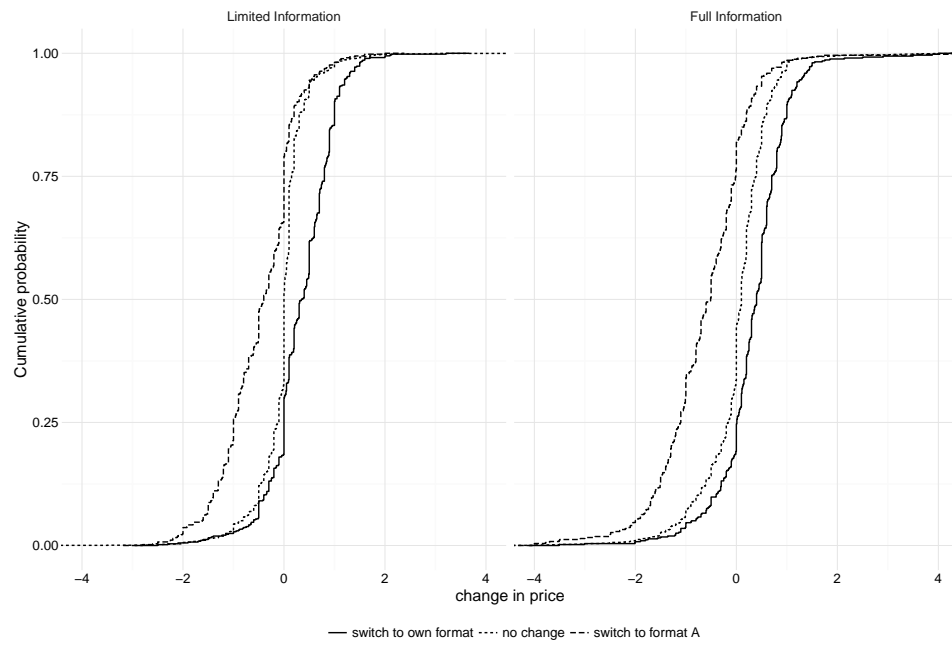


Figure 6: Changes in prices by changes in format A under limited and under full information (firms B and C).

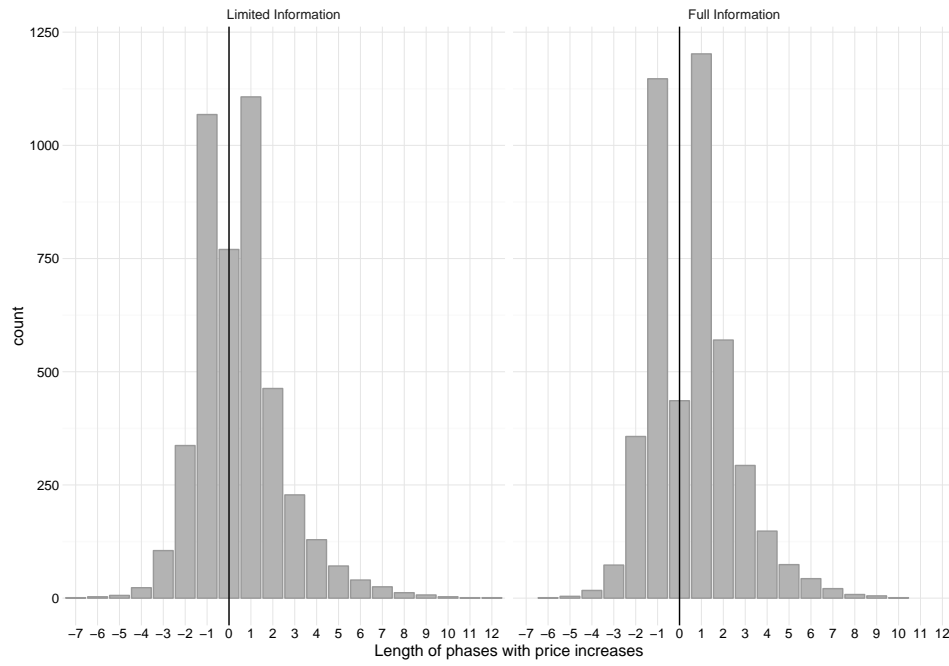


Figure 7: Distribution of the length of phases of increases and decreases in prices.

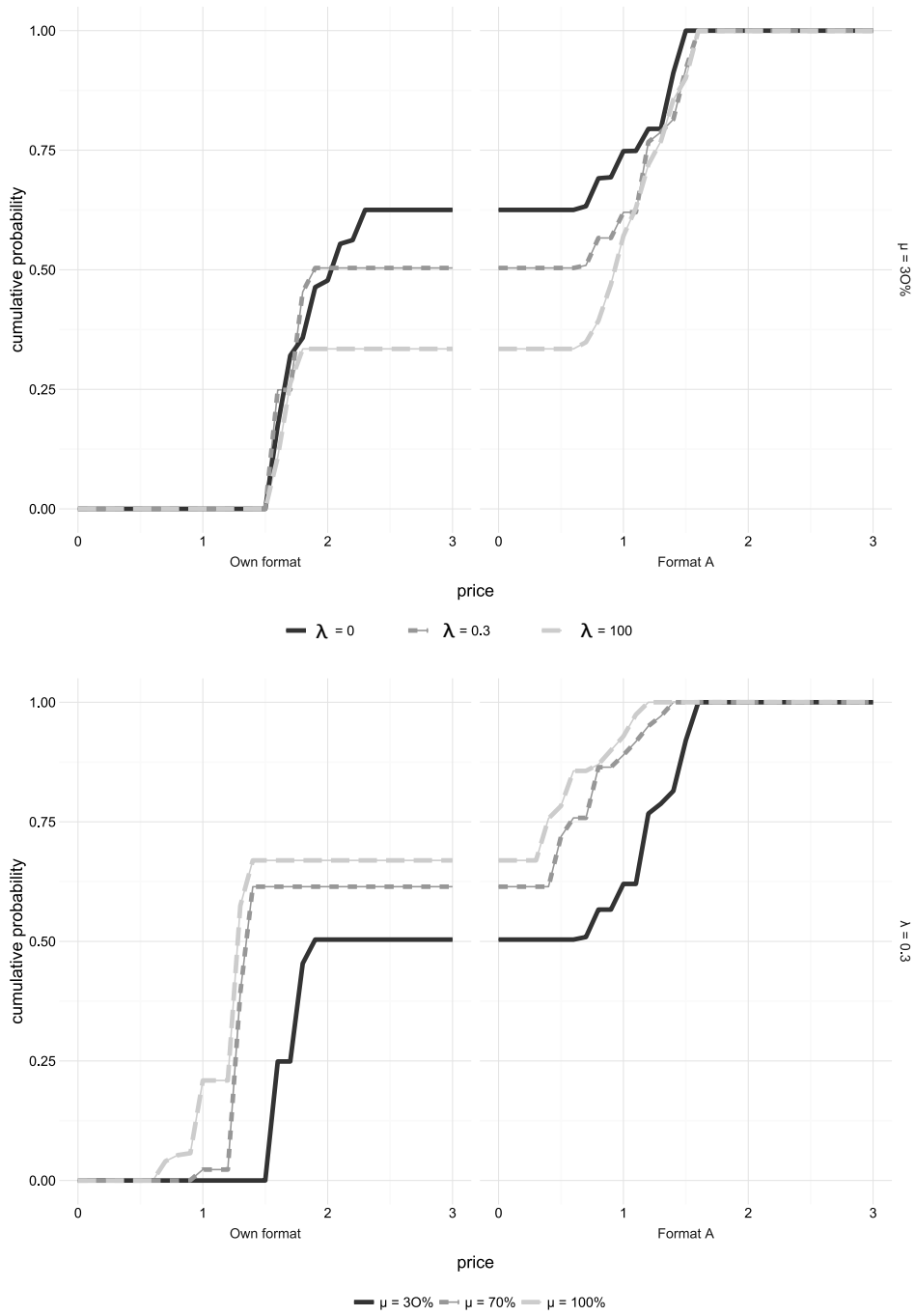


Figure 8: Cumulative probability distribution function of prices under mixed strategies
 We show both the cdf of prices when a firm chooses not to adopt format A ("NCS"), starting from the origin, and the cdf of prices when a firm chooses to adopt format A ("CS"), starting from the probability that the firm does not adopt format A. The maximum value of the first cdf is therefore the cumulative probability that the firm does not adopt format A.

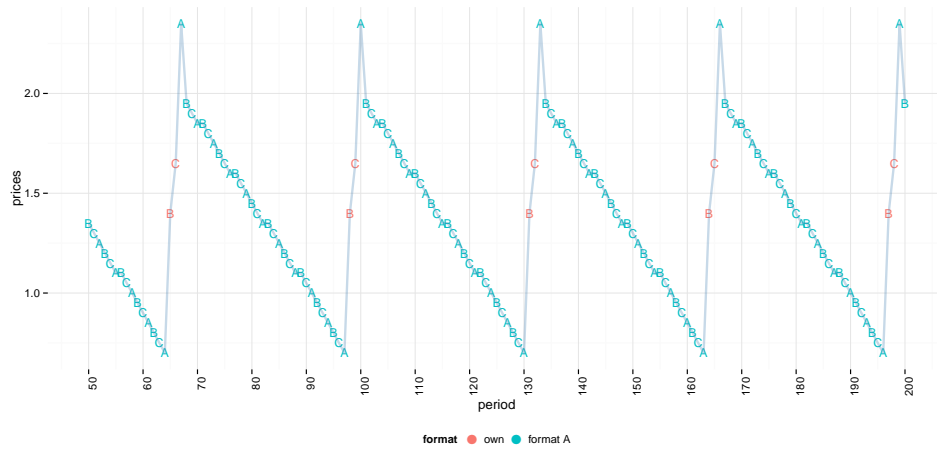
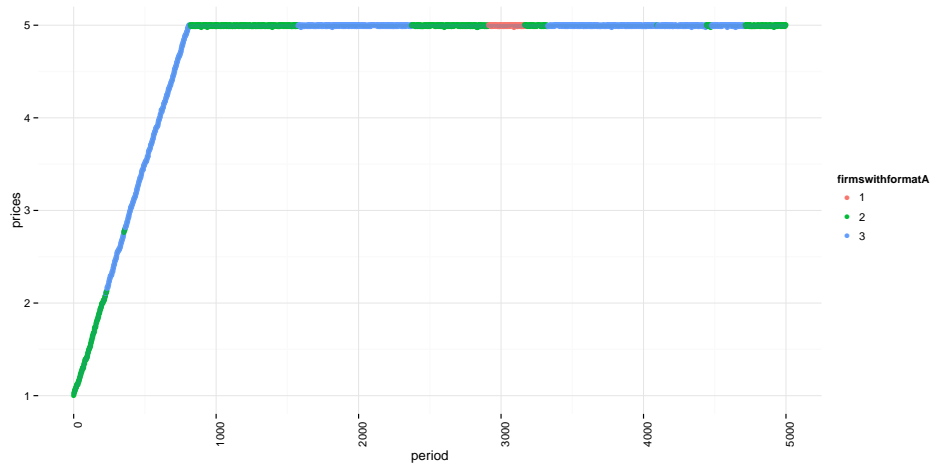
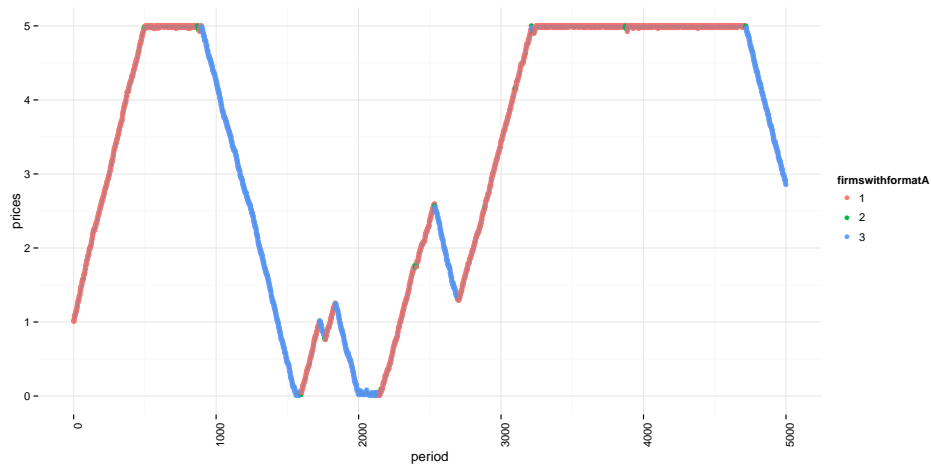


Figure 9: Simulated evolution of prices and choice of format in the triopoly under myopic best response dynamics when $\mu = 50\%$ and $\lambda = 20\%$.

The figure shows the price and format chosen by each firm over time. Firms are indicated by their letter, colors indicate the format chosen (blue means the firm chose format A, red means the firm chose its own format).



(a) Case with $\mu = 0$



(b) Case with $\mu > 0$

Figure 10: Simulated evolution of prices and number of firms with format A in the triopoly under imitation dynamics.

The figure shows the price set by firm A. This is the price set by the firm that obtained the highest profits last period, plus or minus $\epsilon \hookrightarrow U[-0.01, 0.01]$ (experimentation). Firms adopt the format of the most successful firm (other than firm A) each period, otherwise maintain their standard of the preceding period. They additionally randomly switch format with probability 1% each period.

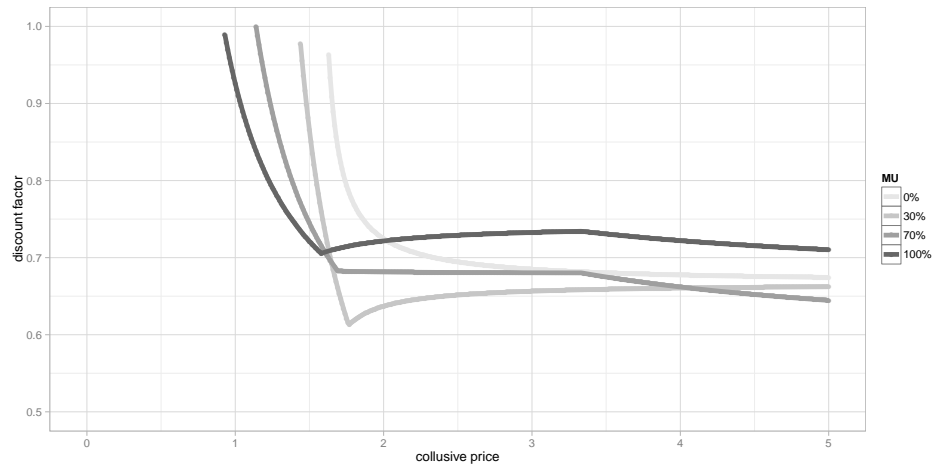


Figure 11: Range (δ, \bar{p}) with sustainable collusion.
 $\mu \in [0, 0.3, 0.7, 1]$ and $\lambda = 0.3$

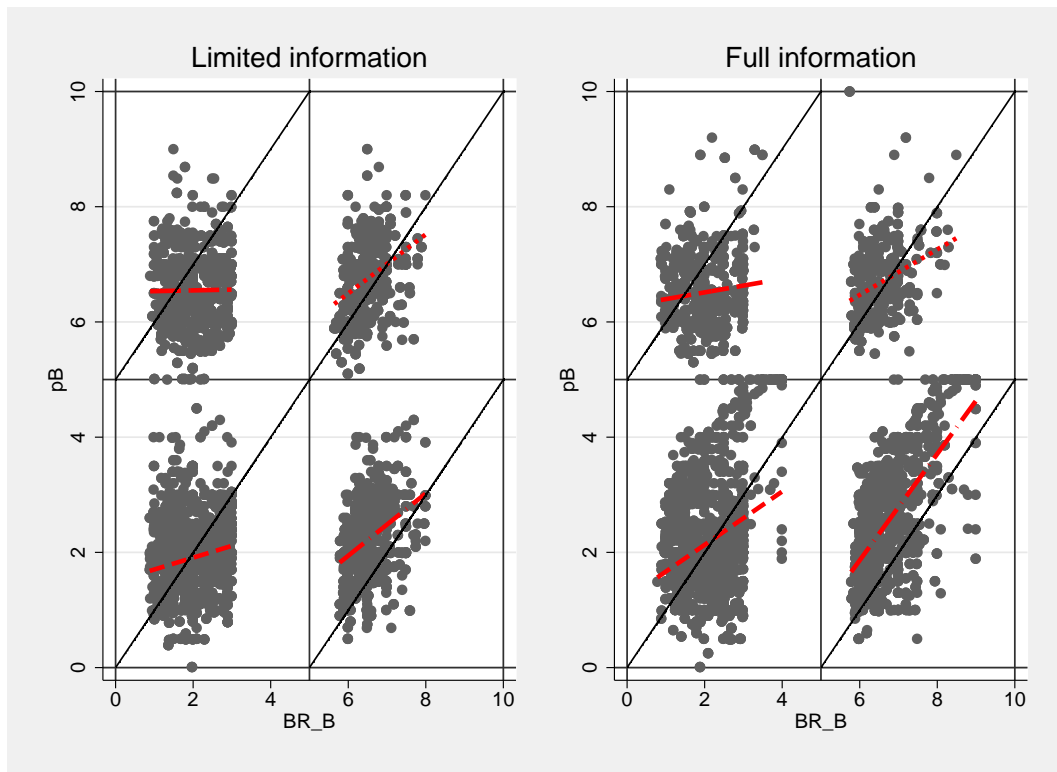


Figure 12: Actual behavior vs. predicted best response, firm B, excluding baseline treatments.
 Note: For ease of graphical presentation, prices from 0 to 5 are prices with own format, prices from 5 to 10 are prices with format A to which are added 5.

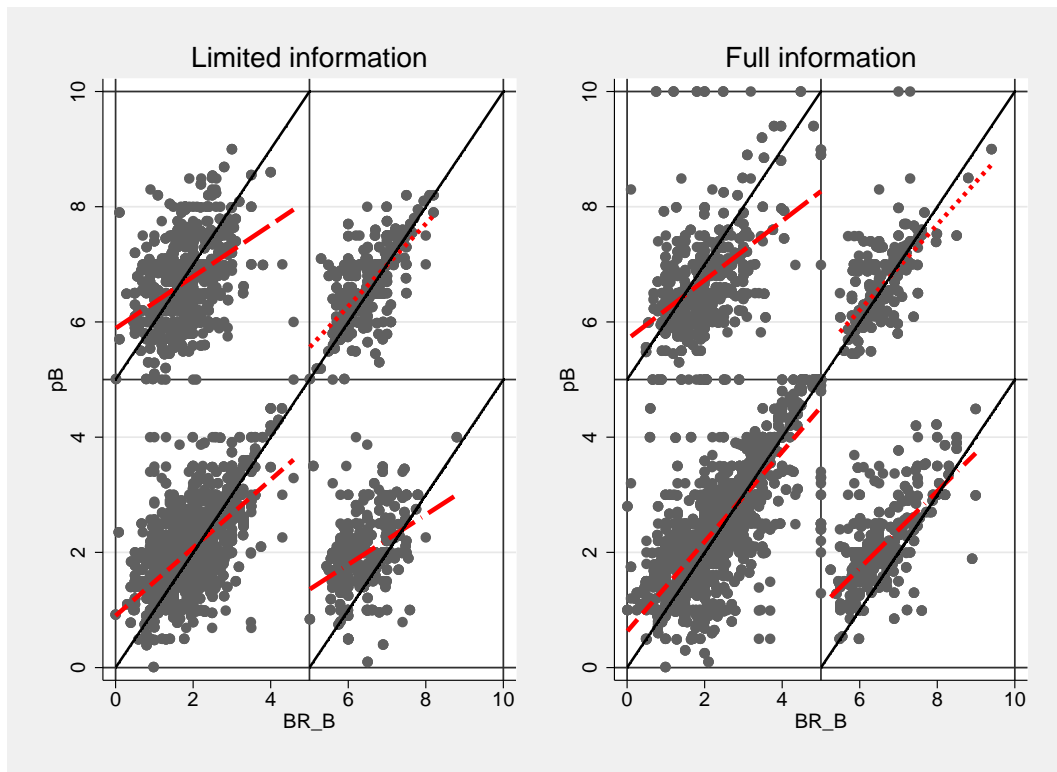


Figure 13: Actual behavior vs. best choice last period, firm *B*.

Note: For ease of graphical presentation, prices from 0 to 5 are prices with own format, prices from 5 to 10 are prices with format A to which are added 5.