CSEF
Centre for Studies in Economics and Finance

WORKING PAPER NO. 457

Consumer Loss Aversion, Product Experimentation and Implicit Collusion

Salvatore Piccolo and Aldo Pignataro

November 2016

University of Naples Federico II | University of Salerno | Bocconi University, Milan

CSEF - Centre for Studies in Economics and Finance
DEPARTMENT OF ECONOMICS – UNIVERSITY OF NAPLES
80126 NAPLES - ITALY
Tel. and fax +39 081 675372 – e-mail: csef@unisa.it

WORKING PAPER NO. 457

Consumer Loss Aversion, Product Experimentation and Implicit Collusion

Salvatore Piccolo[♦] **and Aldo Pignataro**[♣]

Abstract
Two firms supplying experience goods compete to attract loss averse consumers that are uncertain about how well these goods fit their needs. To resolve valuation uncertainty, firms can allow perspective customers to test (experiment) their products before purchase. We investigate firms' dynamic incentives to allow experimentation and analyze the resulting effects on the profitability and the stability of horizontal price fixing. The analysis shows that, depending on the regulatory regime in place | i.e., whether experimentation is forbidden, mandated or simply allowed but not imposed (laissez-faire) | the degree of consumer loss aversion has ambiguous effects both on the profits that firms can achieve through implicit collusion and on the extent to which these agreements can be sustained. Moreover, we also show that while in static environments consumer welfare is always maximized by a policy that forbids experimentation, the opposite might happen in a dynamic environment.

Classification JEL: L12, L15, L44, M30

Keywords: Collusion, Loss Aversion, Product Experimentation, Vertical Differentiation

Acknowledgement: We are particularly grateful to Margaret Meyer for insightful suggestions and detailed comments. For extremely helpful comments, we also would like to thank Piergiorgio Carapella, Stefano Colombo, Elisabetta Iossa, Bruno Jullien, Marco Ottaviani, Alexei Parakhonyak, Pasquale Schiraldi, Piero Tedeschi, Michele Tettamanzi, Andre Veiga and seminar participants at Postdoctoral & DPhil Research Workshop (Oxford) and PhD seminar at Università Cattolica del Sacro Cuore (Milan).

♦ Università Cattolica del Sacro Cuore (Milano) and CSEF. Email: salvapiccolo@gmail.com

♣ Università Cattolica del Sacro Cuore (Milano). Email: aldo.pignataro@unicatt.it

Table of contents

1 Introduction

People often refrain from consuming experience goods because they are afraid of buying products not worth their price. The fear of making a bad purchase is particularly strong for loss averse consumers — i.e., individuals that prefer avoiding losses to making gains (e.g., Kahneman, Knetsch and Thaler, 1991, Kahneman and Tversky, 1979 and 1991). A recent and growing literature has started to study the implications of loss aversion both for consumer and firm behavior (see, e.g., Köszegi and Rabin, 2006 and 2007, Heidues and Köszegi, 2008, Karle and Peitz, 2014, Rosato, 2016, and Zhou, 2011, among others). But, these models mostly focus on static environments, while little is known on how firms react to consumer loss aversion in dynamic environments (Grubb, 2015). To contribute filling this hole, in this paper we analyze how consumer loss aversion affects the strategic use of product experimentation in a repeated game where firms selling products with uncertain (but ex post verifiable) characteristics compete to attract loss averse consumers.

Tests, product demonstrations, free-trial policies, return policies and any other marketing initiative that allows consumers to learn product characteristics and resolve valuation uncertainty before purchase, are usually seen as 'customer friendly' practices because they reduce (or even eliminate) the risk of bad purchases (e.g., Roberts and Urban, 1988). In the real world, consumers can often test many high-tech products — e.g., software, smartphones, tablets, laptops, printers, video-games, consoles and all their components, etc. (e.g., Heiman and Muller, 1996, Heiman, McWilliams and Zilberman, 2001, and Hahn, 2005). Similarly, in the car industry, many dealers regularly avail free drive-tests to their customers (e.g., Heiman *et al.*, 2001 and Roberts and Urban, 1988). Food and wine tasting initiatives are further notable examples (e.g., Hahn., 2005).

Yet, even if consumers are typically not charged for testing products before purchase, the information they are able to collect through these services might have hidden costs. The reason is simple: besides allowing people to better ground their choices, experimentation also creates (vertical) product differentiation by changing consumers' relative taste between products that, *behind the veil of ignorance*, appear as close (or even perfect) substitutes. Clearly, this softens competition and allows firms to charge non-competitive prices in equilibrium, whereby expropriating the informative benefits of experimentation (e.g., Hahn, 2005). Hence, regulatory rules that force experimentation may not necessarily benefit consumers, at least from a static standpoint.

To what extent this logic carries over to a dynamic environment in which firms interact repeatedly over time? Does experimentation facilitate or hinder collusion? How these incentives are affected by consumer loss aversion? To address these issues we study a simple (infinitely) repeated game in which two firms supplying experience goods compete to attract loss averse consumers that are (ex ante) uncertain about the fit between the characteristics of the products on sale and their needs (in brief, quality). To resolve this uncertainty, before the price-setting stage, firms can commit to allow consumers to freely test their products prior to sales (experimentation). When both firms do so (comparative experimentation) consumers can make purchasing decisions based not only on price differences, but also on the relative fit between product characteristics and their needs (in other words, on their relative taste). Within this framework, we investigate how consumer loss aversion influences firms' incentive to use experimentation as a collusive device, and analyze the resulting effects on consumer welfare.

Loss aversion has interesting effects already in the static environment. We show that, for low degrees of loss aversion, the stage game features a unique symmetric equilibrium in which firms randomly choose their experimentation policy. By contrast, for high degrees of loss aversion, the game features a unique symmetric equilibrium in which firms allow experimentation with certainty. The intuition is straightforward. When consumers are sufficiently loss averse, a firm has no incentive to deviate from a candidate equilibrium with comparative experimentation because consumers require a substantial price discount to buy a product with unknown characteristics. Hence, a deviation to a non experimentation policy must be followed by a considerable price discount in order to attract customers. By contrast, if the degree of loss aversion is not too high, the same deviation becomes profitable because the deviating firm can successfully exploit monopoly power *vis-à-vis* customers, who after having tested the rival's product, find it not appealing. As explained before, consumers are always harmed by comparative experimentation in the stage game (see, Hahn, 2005, for a result in this spirit).

The existence of a mixed strategy equilibrium provides a novel managerial insight: it partly explains why firms producing similar products may adopt different experimentation policies. Notably, in contrast to some of their competitors, Apple, Samsung and Microsoft usually allow potential customers to test their new devices in dedicated showrooms (Boleslavsky *et al.*, 2016). Similarly, in the car and the software industries not all companies allow customers to test their products.

The picture becomes considerably more complex when considering the repeated game. The analysis shows that, depending on the regulatory regime in place — i.e., whether experimentation is forbidden, mandated or allowed but not imposed (*laissez-faire*) — the degree of consumer loss aversion has ambiguous effects both on the profits that firms can achieve through implicit collusion, and on the stability of these agreements.

Concerning stability, we derive the following results. First, we show that implicit collusion is easier to sustain when experimentation is mandated relative to the regime in which it is forbidden. The reason is that deviating in the regime with mandatory tests is (other things being equal) less profitable than in the regime in which tests are forbidden. Indeed, while in the latter case a deviating firm is able to obtain the monopoly profit (due to a standard undercutting logic), in the former it earns less than the monopoly profit due to product differentiation — i.e., it is harder to attract consumers that value relatively more the rival's product. Second, other things being equal, we show that collusion is easier to sustain when experimentation is mandated relative to the *laissez-faire* regime. The reason is again straightforward: under *laissez-faire*, firms can deviate not only by undercutting the collusive price, but also by changing experimentation policy, which (by revealed preferences) secures a higher deviation profit. Third, when comparing the *laissez-faire* regime with that in which experimentation is forbidden we show that, ceteris paribus, collusion is easier to sustain under *laissez-faire* if and only if consumers are sufficiently loss averse (the opposite result holds otherwise).

Therefore, the regulatory regime that maximizes the scope for firms' cooperation is the one in which tests are compulsory. However, this regime is not necessarily the one that also maximizes firms' joint profit. Specifically, the analysis highlights a trade off between stability and profitability of collusion. We show that the regime that maximizes firms' joint profit from cooperation is the one in which experimentation is forbidden when consumers are not too loss averse. By contrast, when consumers are sufficiently loss averse, joint profit is higher when comparative experimentation is viable. This shows that implicit collusion is more likely to involve experimentation when consumers are particularly loss averse — i.e., when other things being equal, the benefits of experimentation are considerably important for them. By contrast, cooperation does not require experimentation when consumers are not too loss averse. Hence, our analysis suggests that tests, product demonstrations, free-trial policies etc., might be interpreted as a signal of price fixing in markets where consumers are particularly loss averse and product characteristics are difficult to ascertain before consumption — e.g., high-tech products, electronic devices, organic food, dietary supplements, etc. Overall, firms' equilibrium profits from collusion are (weakly) decreasing with the degree of consumer loss aversion.

Finally, as a normative exercise we study the effects of experimentation on consumer surplus. We show that the optimal policy for an Antitrust Authority, whose objective is to maximize consumer welfare, depends in an ambiguous manner on the model parameters. Forcing experimentation is harmful to consumers when firms are unable to collude regardless of the regulatory regime in place — i.e., for sufficiently low discount factors. The reason is simple, (vertical) product differentiation, as induced by comparative experimentation, conveys monopolistic power to firms, which charge prices above marginal costs in equilibrium. Hence, when firms are expected to play the static outcome of the game, the best policy from the consumers' point of view is to forbid experimentation so as to intensify competition and implement the Bertrand outcome. By contrast, when collusion is sustainable with a ban on experimentation, the optimal policy cannot forbid tests because, otherwise, firms would fully extract the surplus of the uninformed consumers.

In this case, forcing experimentation is an optimal policy when the consumer is not too loss averse and the discount factor is large enough. Conversely, a *laissez-faire* approach is optimal as long as firms collude through experimentation.

All our results are derived under the hypothesis that, in every regulatory regime, collusion is sustained by Nash reversion during the punishment phase. In an extension we show that when firms can punish deviations with harsher and more complex penal codes, *laissez-faire* is actually the regime that maximizes stability of collusive agreements, so it is never optimal for consumers. As a result, whenever experimentation maximizes consumer surplus, it must be mandated.

The rest of the paper is structured as follows. Section 2 relates our contribution to the existing literature. Section 3 sets up the baseline model. In Section 4 we report some preliminary results that will be useful for the equilibrium analysis both in the stage game and in its infinitely repeated version. In Section 5 we characterize the equilibrium of the model. For each regulatory regime we determine the critical discount factor above which firms are able to enforce joint profit maximization, and then analyze how product experimentation affects both stability and profitability of collusion. Finally, in Section 6, we study how the expected consumer surplus is affected by comparative experimentation. Section 7 extends the analysis to harsher punishments. Section 8 concludes. All proofs are in the appendix.

2 Related literature

Our paper contributes and is related to several strands of literature.

Loss-aversion and oligopolistic markets. Many recent papers analyze the effects of loss aversion on firm conduct in oligopolistic markets — see, e.g., Heidues and Köszegi (2008), Karle and Peitz (2014) and Zhou (2011) among others. This literature highlights the implications of loss aversion on strategic aspects such as firms' advertising and pricing behavior, and shares with us the idea that loss averse consumers must be either offered price discounts when they buy products with uncertain characteristics, or they need to be persuaded about the quality of the products they purchase through informative and/or persuasive advertising. Yet, all these models focus on static environment and little is known on the link between loss aversion and collusion (see, e.g., Grubb, 2015, for a survey). We complement this bulk of work precisely by studying how loss aversion affects firms ability to collude and the implications on their experimentation strategies.

Collusion and product differentiation. By studying how experimentation affects firms' ability to sustain implicit collusion, our paper is also related to the traditional IO literature dealing with price fixing under product differentiation. Starting with Deneckere (1983, 1984) and Wernefelt (1989), many models have shown that product differentiation helps firms to enforce implicit collusion.[1] These models do not consider loss aversion and usually take the degree of product differentiation as given, while in our model firms choose whether or not differentiate their products by means of experimentation. In contrast to these models, product differentiation has ambiguous effects in our environment. Specifically, it helps collusion only when comparing the regime with mandatory experimentation with that in which tests are forbidden. But, the opposite result obtains when considering the *laissez-faire* regime — i.e., the case in which firms are free to choose experimentation policy at any point in time. In this case, experimentation hinders collusion when consumers are sufficiently loss averse, and the opposite holds otherwise.

Gupta and Venkatu (2002) and Matsumura and Matsushima (2005) also obtain ambiguous results in a context of delivered pricing policies where collusion is sustained by Nash reversion.[2] Thomadsen and Rhee (2007) and Colombo (2013), instead, show that a negative relationship between firms' ability to collude and product differentiation obtains when firms need to invest sufficiently large resources in monitoring and coordination activities to enforce collusion.

Information disclosure and advertising. Our analysis also adds to the theoretical and policy debate on quality disclosure. There are many papers that deal with this issue. The main question they address is whether firms have an incentive to disclose information about product quality and how this information affects consumer welfare. It turns out that an important aspect of the problem is whether products are vertically or horizontally differentiated.

When products are vertically differentiated the unraveling result establishes that firms selling products of quality above the average will truthfully disclose the quality of their products to consumers. Hence, also firms below the average will disclose their quality, so that all private information is revealed in equilibrium through voluntary disclosure — see, e.g., Viscusi (1978), Grossman (1981), Grossman and Hart (1980), Jovanovic (1982), and Fishman and Hagerty (2003). By contrast, the unraveling logic might fail when frictions, such as disclosure costs, consumer cognitive costs etc., are taken into consideration — see, e.g., Grossman and Hart (1980), Jovanovic (1982), and Fishman and Hagerty (2003). In these cases a pooling equilibrium can emerge — i.e., quality is not disclosed and the market might break down. Recently, Janssen and Roy (2015) have shown that nondisclosure can also be explained by a combination of market competition and the availability of signaling as an alternative means (to disclosure) of communicating private information.

[1] See, for example, Chang (1991), Lambertini and Sasaki (1999), Østerdal (2003), Ross (1992), Rothschild (1992) and Tyagi (1999) among many others.

[2] In the same framework, Miklós-Thal (2008) came to an opposite conclusion with optimal punishment.

With horizontal differentiation the unraveling result might fail even without frictions — see, e.g., Anderson and Renault (2006, 2009), Celik (2014), Ivanov (2013), Janssen and Teteryatnikova (2016) Johnson and Myatt (2006), Koessler and Renault (2012) and Sun (2011).

Although these models share with us the idea that quality disclosure might have important effects on competition by changing consumers' perception of competing product brands, they only take a static perspective. The only exception is Levin *et al.* (2009). As we do, they also set up a repeated game in which two cartel members must decide how much information to disclose about product quality. They show that cartels tend to be more transparent than competitive industries since (on equilibrium path) colluding firms can afford more easily the fixed cost of disclosure. By contrast, in our model, experimentation has ambiguous effects on consumer welfare, which depend (among other things) on the regulatory regime in place. Overall, all these models are silent on the impact of consumer loss aversion. One important difference between our set-up and this stream of literature is that firms are uninformed about the quality of their products in our model: in this sense, experimentation can be viewed as a form of informative advertising, even though in such a framework disclosure cannot not be driven by an unraveling logic, but rather by dynamic considerations.

Return policies. Finally, there exists a literature in marketing and IO studying the cost and benefits of return policies and money back guarantees. These instruments can be obviously seen as a specific forms of experimentation. In these models customers purchase items with incomplete information that is later resolved via postpurchase inspection. Return policies reduce customer risk, which allows retailers to raise prices, but a customer will return an item if the price exceeds her ex post valuation, which will reduce demand. Che (1996) and Shulman *et al.* (2009) show that retail information about product fit (i.e., tests, product demonstrations etc.) can serve the same role as postpurchase inspection (see, also, Davis *et al.*, 1995, for an application to money back guarantees). As a result, customers may have a higher willingness to pay in the absence of product information than with additional information. Again, all these models are static, do not consider consumer loss aversion and neglect the effect of return policies on collusion.

3 The model

Players. Consider an infinitely repeated game in which two firms ($i = 1, 2$) compete by setting prices. For simplicity, and with no loss of insights, assume that in every period ($\tau = 1, 2, .., +\infty$) there is only one (representative) consumer willing to purchase at most one unit of product. Consumers exit the market after consumption and are uncertain about how well the goods on sale satisfy their needs: each consumer only knows that, in period τ, consuming firm i's product yields utility θ_i^τ, which distributes on the support $[0,1]$ with cdf $F(\theta_i^\tau)$. For brevity, we will sometimes refer to θ_i^τ as to quality.

Following the literature — e.g., Köszegi and Rabin (2006) and Heidhues and Köszegi (2008) — we assume that consumers are loss averse. Hence, *behind the veil of ignorance* — i.e., when buying a product of unknown characteristics — the preferences of a consumer who purchases firm i's product at price p_i^τ are described by the following gain-loss utility

$$u^N(p_i^\tau) \equiv \underbrace{\int_{p_i^\tau}^1 (\theta_i^\tau - p_i^\tau)\, dF(\theta_i^\tau)}_{\text{Expected gain from purchase}} + \alpha \underbrace{\int_0^{p_i^\tau} (\theta_i^\tau - p_i^\tau)\, dF(\theta_i^\tau)}_{\text{Expected loss from purchase}}, \quad i = 1,2 \quad \tau = 1,2,..,+\infty. \tag{1}$$

The first integral in the left-hand-side of (1) reflects the gain in product satisfaction that occurs when quality exceeds the price — i.e., $\theta_i^\tau \geq p_i^\tau$. By contrast, the second integral in the left-hand-side of (1) reflects the expected loss that occurs when quality is not worth the price — i.e., $\theta_i^\tau < p_i^\tau$. Essentially, since consumers are ex ante uncertain about product quality, but learn it after consumption, their willingness to pay is determined by the comparison between the gain and the loss they expect to experience after purchase. The parameter $\alpha \geq 1$ represents the degree of loss aversion: the higher α, the more loss averse consumers are. For simplicity, we assume that α is time invariant, so that it is the same for all consumers.

Nevertheless, firms can allow consumers to test their products before purchase, which drastically changes consumers' expected utility. For simplicity, we posit that, once consumers test a product, valuation uncertainty resolves completely. That is, when allowed to test (experiment) a product (say firm i's product), consumers learn its quality. Hence, the expected utility that a consumer obtains when he tests a product i is

$$u^T(p_i^\tau) \equiv \int_0^1 \max\{0, \theta_i^\tau - p_i^\tau\}\, dF(\theta_i^\tau), \quad i = 1,2 \quad \tau = 1,2,..,+\infty.$$

Without loss of generality, we normalize consumers' outside option to zero, and assume that when indifferent between accepting and refusing an offer, consumers break the tie by choosing the former option.

Regulatory environment. To better highlight the policy implications of the model, we consider three alternative regulatory regimes: the first in which experimentation is banned; the second in which experimentation is mandated; the third in which firms face no restrictions on the use they make of experimentation (*laissez-faire*). Hence, under *laissez-faire* firms can potentially change experimentation policy at any period of the game or, to foster cooperation, they might adopt different policies in the collusive and the punishment phases (as we will see below).

Timing. In each period $\tau \geq 1$ the stage game is as follows:

T = 1 Firms decide simultaneously, and publicly, whether to allow experimentation (provided that it is legal).

T = 2 Firms simultaneously post prices.

T = 3 Consumers observe prices and experimentation choices, and decide whether to test or not products (if legal). Then, they decide whether to buy or not, and which firm to patronize.

This sequential timing applies to environments in which prices are relatively more flexible than experimentation policies (see e.g., Boleslavsky *et al.*, 2016). In practice, planning product experimentation usually require time and effort, while prices can quickly and easily adjust in response to own and rivals' testing policies.

Assumptions. Firms are long lived and maximize the discounted sum of future profits over an infinite horizon, using the common discount factor $\delta \in (0, 1)$. There is perfect monitoring: any price deviation is detected in the next stage of the game following the one in which it occurred. Notice that our model is a repeated extensive-form (rather than normal-form) game since experimentation choices are observed before the price-setting stage. Hence, punishments of first-stage deviations might begin within the deviation period, which implies that the details of the punishment code can affect the price that the deviating firm can charge in the second stage. We discuss more in detail the punishment code as we go along the analysis. The equilibrium concept is Subgame Perfect Nash Equilibrium (SPNE).

To simplify exposition we also impose the following additional assumptions.

A1 Tests are costless both for the firms and the consumers.

Assumption **A1** allows us to focus exclusively on the strategic aspects of experimentation. Introducing fixed costs of experimentation would not alter qualitatively our conclusions.

A2 Qualities are drawn from independent uniform distributions — i.e., $F(\theta_i^\tau) = \theta_i^\tau$ for $i = 1, 2$ and $\tau = 0, 1, .., +\infty$.

Assumption **A2** allows us to obtain tractable closed-form solutions.

A3 Firms are uninformed about how well their products fit consumers' needs — i.e., at any stage $\tau \geq 1$, they do not know how well their goods satisfy the consumers' needs.

This assumption reflects the idea that, often in real life, 'quality' is a subjective assessment that each consumer makes of the characteristics of a product once it has experienced it. Formally, **A3** rules out signaling issues: firms cannot signal quality since they do not know it. The strategic aspects of signaling through advertising and/or prices has been largely addressed in the literature (see, e.g., Piccolo *et al.*, 2015 and 2016 for a competitive model and Rhodes and Whilson, 2016, for the monopoly case)

A4 Firms' technologies feature constant returns to scale. Marginal costs are normalized to zero.

4 Preliminaries

To begin with, we first establish some useful properties of consumer and firm behavior in the stage game.

Lemma 1 *Consumers always test products when they are entitled to do so.*

The intuition is straightforward. For given prices, consumers cannot be harmed by testing products: tests are costless and allow consumers to avoid buying products not worth their price. Hence, we can focus (without loss of generality) on equilibria in which consumers always test products when they are entitled to do so.

Next, for given experimentation policies, we derive the equilibrium prices of the corresponding price-setting subgame.

Proposition 1 *If both firms impede experimentation, the price-setting subgame has a unique Nash equilibrium in which the price is equal to the marginal cost — i.e.,* $p^{N,N} = 0$.

When experimentation is forbidden by both firms, the consumer perceives the two goods as perfect substitutes. Hence, a standard undercutting logic leads to the Bertrand outcome.

By contrast, when both firms allow experimentation, the consumer patronizes firm i if and only if his participation constraint is satisfied — i.e.,

$$u(\theta_i, p_i) \geq 0 \quad \Leftrightarrow \quad \theta_i \geq p_i \quad i = 1, 2,$$

and the product offered by firm i is preferred to the rival's one — i.e.,

$$u(\theta_i, p_i) \geq u(\theta_j, p_j) \quad \Leftrightarrow \quad \theta_i - \theta_j \geq p_i - p_j, \quad i, j = 1, 2.$$

Firm i's expected profit is:

$$\pi_i^{T,T}(p_i, p_j) = p_i \times \underbrace{\int_{p_i}^{1} (\theta_i + p_j - p_i)\, d\theta_i}_{\Pr[\theta_i - \theta_j \geq p_i - p_j] \cap \Pr[\theta_i \geq p_i]}, \quad i, j = 1, 2,$$

whose maximization yields the following upward-sloping best-reply function

$$p_i^T(p_j) \equiv \frac{2}{3}(1 + p_j) - \frac{1}{3}\sqrt{2p_j + 4p_j^2 + 1} \quad i, j = 1, 2.$$

Therefore:

Proposition 2 *If both firms allow experimentation, the price-setting subgame has a unique Nash equilibrium in which both firms charge* $p^{T,T} \equiv \sqrt{2} - 1 > 0$.

When both products can be tested, the equilibrium price does not depend on α since quality is revealed before purchase — i.e., uncertainty about product characteristics is resolved before purchase. The equilibrium price is larger than marginal cost because comparative experimentation generates (vertical) product differentiation. Hence, each firm can extract some surplus from the consumer when he likes relatively more its product.

Finally, when only one firm (say firm i) allows experimentation, the consumer patronizes that firm if and only if

$$u(\theta_i, p_i) \geq 0, \quad i = 1, 2,$$

and

$$u(\theta_i, p_i) \geq u(p_j) \quad \Leftrightarrow \quad \theta_i \geq \underline{\theta}(p_i, p_j) \equiv \frac{1}{2} + p_i - p_j - \frac{(\alpha - 1)\, p_j^2}{2}, \quad i, j = 1, 2.$$

Hence, firm i's expected profit is

$$\pi_i^{T,N}(p_i, p_j) = p_i \times \underbrace{\left(p_j - p_i + \frac{1}{2} + \frac{(\alpha - 1)\, p_j^2}{2}\right)}_{\Pr[\theta_i \geq \underline{\theta}(p_i, p_j)]}, \tag{2}$$

whose maximization yields an upward-sloping best-reply function

$$p_i^{T,N}(p_j) \equiv \frac{2p_j + p_j^2(\alpha-1)+1}{4}. \tag{3}$$

By the same token, it can be readily shown that firm j's expected profit is

$$\pi_j^{N,T}(p_j,p_i) \equiv p_j \times \underbrace{\left(p_i - p_j + \frac{1}{2} - \frac{(\alpha-1)\,p_j^2}{2}\right)}_{\Pr[\theta_i \leq \underline{\theta}(p_i,p_j)]}, \tag{4}$$

whose maximization yields the following upward-sloping best-reply function

$$p_j^{N,T}(p_i) \equiv \frac{\sqrt{3\alpha + 6p_j(\alpha-1)+1} - 2}{3(\alpha-1)}. \tag{5}$$

Taken together, conditions (3) and (5) imply the following result.

Proposition 3 *If only firm i allows experimentation, the price-setting subgame has a unique Nash equilibrium in which*

$$p_i = p^{T,N} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha-2} - 13}{25(\alpha-1)} \geq p_j = p^{N,T} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha-2} - 13}{5(\alpha-1)} - 2. \tag{6}$$

The firm that allows experimentation charges a higher price in equilibrium because, by testing the product before purchase, the consumer does not bear the risk of a bad purchase. Figure 1 shows that both prices are decreasing in α.

The reason why the price charged by the firm that does not allow experimentation is also decreasing in α is fairly intuitive: the more loss averse the consumer is, the higher is the price discount that firms must offer in order to induce the consumer to purchase a product of uncertain quality. Since prices are strategic complements, this explains why the price of the firm that allows experimentation is decreasing in α too.

5 Equilibrium analysis

5.1 Static outcome

We now characterize the equilibrium of the stage game, which determines the punishment profit under Nash reversion. A first obvious observation is that there cannot exist an equilibrium in pure

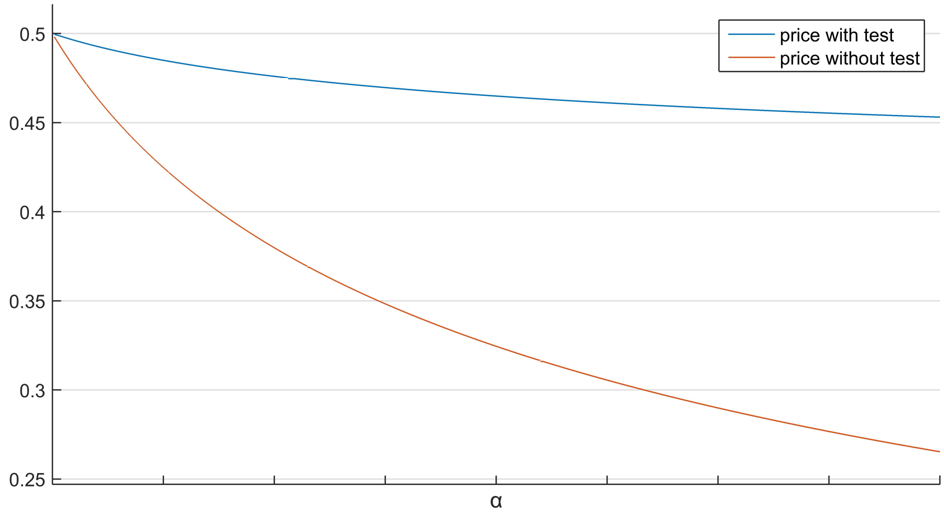


Figure 1: Equilibrium prices with asymmetric testing strategies

strategies without experimentation. Indeed, if the consumer cannot test products before purchase, he perceive the two brands as perfect substitutes and Bertrand competition leads firms to price at marginal cost. As a consequence, a firm has an incentive to deviate by allowing experimentation and charge a price (slightly) larger than marginal cost. This is profitable because the probability of making a sale is always larger than zero for the deviating firm, and when this occurs it makes positive profits.

Consider now the candidate equilibrium in which both firms allow experimentation. In the previous section, we have already characterized the price emerging in this scenario. Substituting $p^{T,T}$ into the profit function we have

$$\pi^{T,T} \equiv 3 - 2\sqrt{2}.$$

In order to check that this is an equilibrium, $\pi^{T,T}$ has to be compared with the profit that a firm obtains by deviating to no experimentation in the first stage. Substituting the prices obtained in (6) into the profit function (4), we have

$$\pi^{N,T} \equiv \frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha - 2})(\sqrt{3}\sqrt{5\alpha - 2} - 3)}{250\,(\alpha - 1)^2}. \tag{7}$$

It can be shown that $\pi^{N,T}$ is decreasing in α: the deviating firm must offer a higher discount as the consumer becomes more loss averse in order to induce him to buy a product with unknown characteristics. We can thus establish the following:

Lemma 2 *There exists a threshold $\alpha^* > 1$ such that $\pi^{T,T} \geq \pi^{N,T}$ if and only if $\alpha \geq \alpha^*$.*

Hence, the stage game features a pure strategy SPNE with comparative experimentation as long as the consumer is sufficiently loss averse. In this region of parameters, a deviation from the equilibrium candidate in the first stage must be followed by a considerable price discount in the second stage to attract the consumer. By contrast, if the degree of loss aversion is not too high, the deviation is profitable because it is sufficient to allow the consumer to test only one product in order to create enough differentiation between the two brands. In this case, the deviating firm can exploit monopoly power in the sates of nature where the consumer finds the rival's product unappealing.

What happens when α is sufficiently low? Clearly, there are no symmetric equilibria in pure strategies because an equilibrium in which both firms impede experimentation cannot exist either (as explained before). Hence, in this region of parameters, the game may feature a symmetric equilibrium in which firms randomize in the first stage. Suppose this is true, the rule according to which they allow experimentation is determined by the following indifference condition

$$\beta\pi^{T,T} + (1-\beta)\,\pi^{T,N} = \beta\pi^{N,T}, \tag{8}$$

where $\beta \in (0,1)$ is the probability according to which firms allow experimentation.

Using the results of the previous section, is easy to check that the profit a firm obtains when it allows experimentation, while the rival does not, is

$$\pi^{T,N} \equiv \frac{(5\alpha - 20 + 3\,(5\alpha-2) + 2\sqrt{3}\sqrt{5\alpha-2})(10\alpha - 13 + \sqrt{3}\sqrt{5\alpha-2})}{1250\,(\alpha-1)^2}. \tag{9}$$

As shown in Figure 2 below, this profit is always decreasing in α. The more loss averse the consumer is, the lower the price offered by the firm that impedes experimentation will be. Since prices are strategic complements, this results in lower equilibrium prices and profits for both both firms.

Let $\beta(\alpha)$ be the solution of (8). We can state the following result.

Proposition 4 *For $\alpha \geq \alpha^*$, the stage game has a unique symmetric pure strategy SPNE in which both firms allow experimentation. By contrast, for $\alpha < \alpha^*$ the stage game features a unique symmetric SPNE in which firms play mix strategies in the first stage: each firm allows experimentation with probability $\beta(\alpha) \in (0,1)$, such that $\beta'(\alpha) > 0$ and $\beta(\alpha^*) = 1$.*

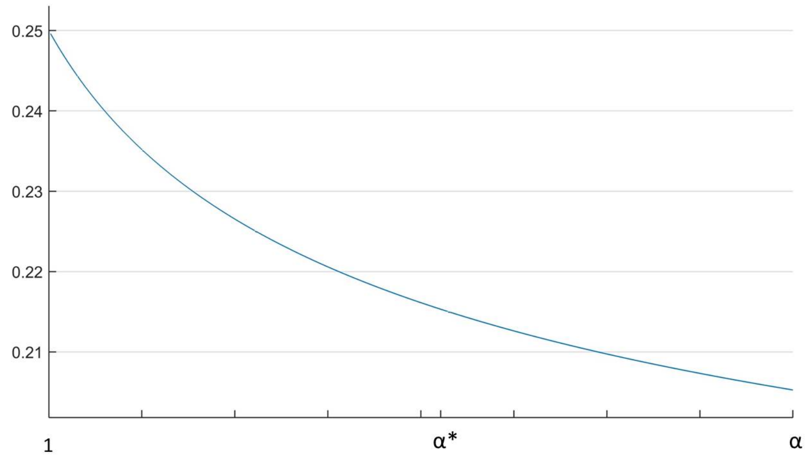


Figure 2: Firm i's profit when it is the only one to allow the test

The reason why the probability of allowing experimentation is increasing in the degree of consumer's loss aversion is straightforward. Large values of α imply that, when purchasing a product with unknown characteristics, the consumer values relatively more the expected loss than the expected gain. Hence, other things being equal, a larger α implies a lower willingness to pay for products of uncertain characteristics. This reduces equilibrium prices when only one firm allows experimentation, reduces profits, and therefore it increases the probability with which firms allow experimentation in equilibrium. Figure 3 below illustrates the relationship between $\beta(\alpha)$ and α.

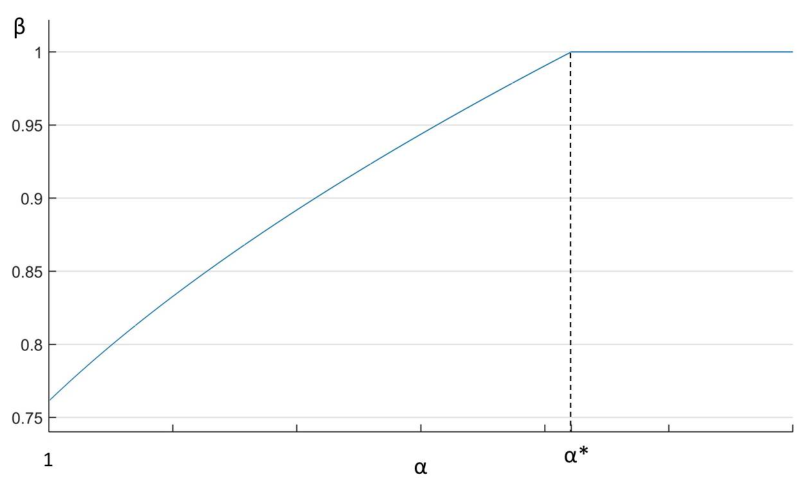


Figure 3: Relationship between $\beta(\alpha)$ and α

It is immediate to see that $\beta(\alpha) = 1$ for $\alpha \geq \alpha^* \approx 3.1$, whereas $\beta(\alpha) \in (0,1)$ for $\alpha < \alpha^*$.

Figure 4 below, instead, plots the equilibrium (expected) profit of the stage game — i.e., $\pi(\alpha) \equiv \beta(\alpha)\pi^{T,T} + (1 - \beta(\alpha))\pi^{T,N}$.

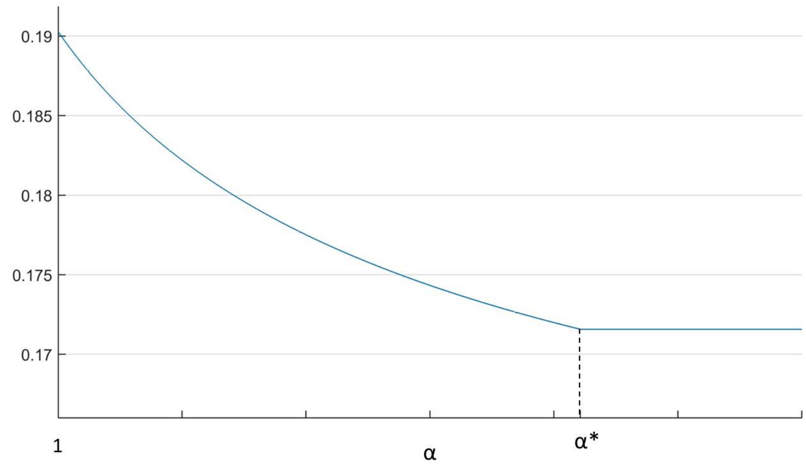


Figure 4: Profit function of the stage game

As intuition suggests, firms' equilibrium profit is weakly decreasing in α: competition is more intense when the consumer is relatively more loss averse because he needs to be offered a lower price in order to be willing to buy a product of unknown quality. Since firms randomize over the experimentation choice, also the expected (equilibrium) profit must fall as α grows large.

5.2 Repeated game

We can now turn to analyze firms' joint profit maximization behavior in the repeated game. In so doing, we restrict attention to symmetric and stationary strategies such that, depending on the regulatory regime in place, in each period firms decide whether or not allowing the consumer to test their products and quote a price that maximizes their joint profit. We assume that co-operation is sustained through 'Nash reversion'. Specifically, if a firm announces an unexpected experimentation policy, or undercuts the collusive price, both firms revert to play 'competitively' in every subgame following the deviation. Note that, since the stage game is sequential — i.e., firms observe each other experimentation policy before setting prices — a firm that deviates to an unexpected experimentation policy in period τ triggers an earlier reaction by inducing the rival to price competitively already in period τ at the price-setting stage.

5.2.1 Collusion with forbidden experimentation

As explained before, when experimentation is forbidden consumers perceive the two products as perfect substitutes. Hence, we can state the following intuitive result.

Proposition 5 *When experimentation is forbidden, joint profit maximization is sustainable if and only if* $\delta \geq \delta_{FT} \equiv \frac{1}{2}$.

On equilibrium path, firms charge a price that fully extracts the consumer's surplus — i.e.,

$$u^N(p^c) = \int_{p^c}^{1} (\theta_i - p^c)\, d\theta_i + \alpha \int_{0}^{p^c} (\theta_i - p^c)\, d\theta_i = 0,$$

yielding a price

$$p_{FT}^c \equiv \frac{\sqrt{\alpha} - 1}{\alpha - 1}. \tag{10}$$

Each firm's expected profit is

$$\pi_{FT}^c \equiv \frac{\sqrt{\alpha} - 1}{2(\alpha - 1)}. \tag{11}$$

As intuition suggests, the collusive price and profit are both decreasing in α.

5.2.2 Collusion under mandatory experimentation

Consider now the regime with mandatory experimentation — i.e., the regime in which firms are forced by an Authority to allow consumers to test their products before purchase. For any symmetric price p charged by both firms, the consumer makes a purchase if and only if

$$\max\{\theta_1, \theta_2\} \geq p.$$

Hence, the joint-profit maximization problem is

$$\max_{p\in[0,1]} p \times \Pr[\max\{\theta_1, \theta_2\} \geq p] \equiv \max_{p\in[0,1]} p \times \left(\int_p^1 \theta_1 d\theta_1 + \int_p^1 \theta_2 d\theta_2 \right).$$

Figure 5 below shows how the probability of selling one of the two products (which can be interpreted as a downward-sloping market demand curve) reacts to a change in the collusive price.

Essentially, if the collusive price is equal to zero — i.e., the lower bound of the support of the random variables θ_1 and θ_2 — the market demand is equal to 1, otherwise it is decreasing in the collusive price.

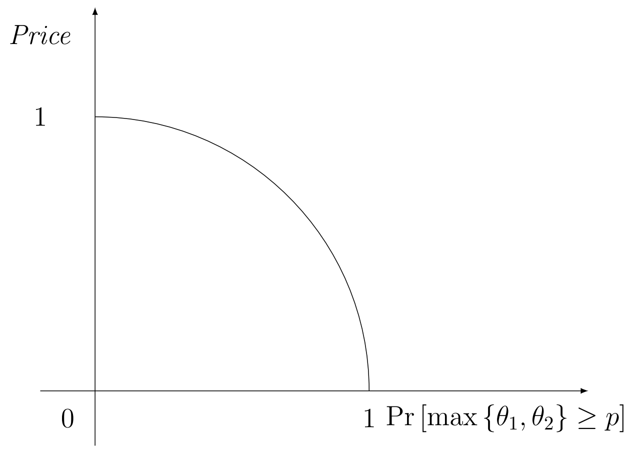


Figure 5: Demand function with mandatory tests

The price that maximizes firms' joint-profit is

$$p^c_{MT} \equiv \frac{\sqrt{3}}{3} \in (0,1). \tag{12}$$

Hence, in the collusive phase each firm's expected profit is

$$\pi^c_{MT} \equiv \frac{\sqrt{3}}{9}.$$

Exactly as in a standard monopoly problem, when experimentation is mandatory, joint profit maximization requires firms to restrict quantity and choose a price high enough to induce the consumer not to buy in some (but not all) states of nature. By contrast, firms will never charge more than 1, as this would imply market breakdown.

Next, consider a deviation. Clearly, with mandatory tests, firms can only deviate at the pricing-setting stage. Suppose that firm i deviates by charging a price different than p^c_{MT}. The optimal deviation (say p^d_{MT}) solves

$$\max_{p\in[0,1]} p \times \underbrace{\int_p^1 \left(\theta_i - p + p^c_{MT}\right) d\theta_i}_{\Pr\left[\theta_i-\theta_j>p-p^c_{MT}\right]\cap\Pr[\theta_i>p]}, \tag{13}$$

whose first-order condition immediately yields

$$p^d_{MT} \equiv \frac{2\left(1+p^c_{MT}\right) - p^c_{MT}\sqrt{7+2\sqrt{3}}}{3}. \tag{14}$$

Substituting p^d_{MT} and p^c_{MT} in equation (13), it can be shown that

$$\pi^d_{MT} \equiv p^d_{MT} \times \int_{p^d_{MT}}^{1} \left(\theta_i - p^d_{MT} + p^c_{MT}\right) d\theta_i > \pi^c_{MT}.$$

Finally, consider the punishment phase. With mandatory experimentation, following a deviation, Nash reversion implies that firms play the equilibrium of the stage game in which both allow experimentation for the rest of the game. Accordingly, they charge $p^{T,T}$ and earn $\pi^{T,T}$ during punishment.

Summing up, with mandatory experimentation, joint profit maximization is sustainable if and only if the following inequality holds

$$\frac{\pi^c_{MT}}{1-\delta} \geq \pi^d_{MT} + \frac{\delta}{1-\delta}\pi^{T,T}. \tag{15}$$

We can state the following result.

Proposition 6 *When experimentation is mandatory, joint profit maximization is sustainable if and only if $\delta \geq \delta_{MT}$, with $\delta_{MT} < \frac{1}{2}$ being the solution of (15).*

Note that joint profit maximization is easier to sustain when experimentation is mandated relative to the regime in which it is forbidden. Although deviations are punished more harshly when experimentation is forbidden (a punishment effect), deviating in the regime with mandatory tests is (other things being equal) less profitable than in the regime in which tests are forbidden (a deviation effect). This is because while in the latter regime the deviating firm is able to obtain the monopoly profit (due to a standard undercutting logic), in the former regime the deviating firm earns less than the monopoly profit because products are differentiated. The deviation effect outweighs the punishment effect.

5.2.3 Collusion under *laissez-faire*

Finally, suppose that firms face no restrictions on whether they should allow or impede tests. Do firms enforce joint-profit maximization with or without comparative experimentation? The answer to this question is not obvious. The reason is that, in this case the punishment phase might be different than in the two previous regimes. Indeed, when consumers are not too loss averse, firms play mixed strategies during punishment. Hence, a priori, it is not clear whether firms prefer to collude with or without experimentation.

Colluding via experimentation. Consider first the case in which collusion is enforced via comparative experimentation. On equilibrium path, firms allow consumers to test their products and, if a deviation occurs, they revert to the equilibrium of the stage game characterized in Proposition 4.

In this case, both firms charge a price equal to p^c_{MT} on equilibrium path, and each obtains π^c_{MT}. Yet, there are two types of deviations that a firm can envision with *laissez-faire*. First, a firm could deviate by changing experimentation policy, and then charge the equilibrium price of the subsequent price-setting stage (see, i.e., Section 4). Second, a firm can announce the expected experimentation policy, but deviate subsequently at the price-setting stage. Hence, the deviation profit is

$$\pi^d_{LF} \equiv \max\left\{\pi^d_{MT}, \pi^{N,T}\right\},$$

which leads to the following result.

Lemma 3 *There exists a threshold $\widehat{\alpha} > 1$ such that $\pi^d_{LF} = \pi^{N,T}$ if $\alpha \leq \widehat{\alpha}$, and $\pi^d_{LF} = \pi^d_{MT}$ otherwise.*

The intuition is straightforward. If consumers are sufficiently loss averse, they are (relatively) more willing to pay for products that can be tested before purchase. Hence, a deviating firm must allow experimentation, otherwise it would have to offer a considerable price discount in order to convince people to purchase a product of unknown quality — i.e., a product that cannot be tested prior to sale.

Summing up, cooperation is enforced via experimentation if and only if

$$\frac{\pi^c_{MT}}{1-\delta} \geq \pi^d_{LF} + \frac{\delta}{1-\delta}\pi(\alpha).$$

Notice that, compared with the regime in which tests are mandatory, the degree of consumer loss aversion impacts the stability of a collusive agreement under *laissez-faire*. The reason is that, in the regime under consideration, firms play mixed strategies during the punishment phase when $\alpha < \alpha^*$.

Proposition 7 *Under laissez-faire, joint-profit maximization is sustainable with experimentation if and only if $\delta \geq \delta^T_{LF}(\alpha)$, with $\delta^T_{LF}(\alpha) \in [\delta^T_{MT}, 1)$ being decreasing in α.*

While collusive profits do vary with α because there is no valuation uncertainty under comparative experimentation, deviation and punishment profits unambiguously fall as α grows large (as discussed before). Figure 6 below provides a graphical illustration of $\delta^T_{LF}(\alpha)$.

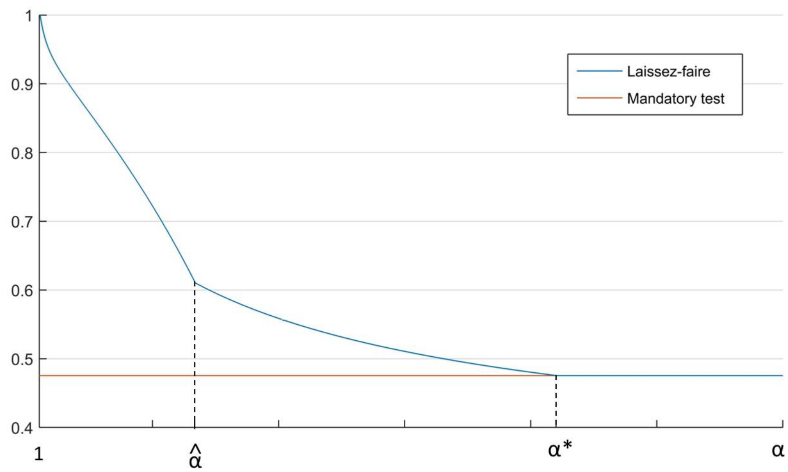


Figure 6: Critical discount factor when firms collude via comparative experimentation

Finally, collusion is easier to sustain when experimentation is mandatory relative to *laissez-faire* because: (i) under *laissez-faire*, firms can deviate not only by undercutting the collusive price, but also by changing experimentation policy; (ii) the punishment profit is higher under *laissez-faire* than under mandatory tests.

Colluding without experimentation. Consider now the case in which firms collude without experimentation. As seen before, the price that maximizes their joint profit is p^c_{FT}. So that, each firm sells with probability $\frac{1}{2}$ and earns π^c_{FT}. Off equilibrium path, there are again two feasible deviations. In defection, a firm can either change experimentation policy right away, by allowing experimentation, so to obtain $\pi^{T,N}$. Alternatively, it can stick to no experimentation and then undercut p^c_{FT} in the price-setting stage, which yields the monopoly profit $2\pi^c_{FT}$. Hence, the deviation profit is

$$\pi^d_{LF} \equiv \max\left\{2\pi^c_{FT}, \pi^{T,N}\right\},$$

which leads to the following result.

Lemma 4 *There exists a threshold* $\widetilde{\alpha} > 1$ *such that* $\pi^d_{LF} = 2\pi^c_{FT}$ *if* $\alpha \leq \widetilde{\alpha}$ *and* $\pi^d_{LF} = \pi^{T,N}$ *otherwise.*

As already explained before, the larger the degree of loss aversion, the higher the valuation that consumers assign to a product that cannot be tested. Hence, it is optimal to deviate by allowing experimentation when α is sufficiently large.

Summing up, under *laissez-faire*, cooperation is enforced without experimentation if and only if

$$\frac{\pi^c_{FT}}{1-\delta} \geq \pi^d_{LF} + \frac{\delta}{1-\delta}\pi(\alpha).$$

We can state the following result.

Proposition 8 *Under laissez-faire, there exists a threshold $\alpha^N \in (\alpha^*, \widetilde{\alpha})$ such that joint-profit maximization is sustainable without experimentation if and only if $\delta \geq \delta^N_{LF}(\alpha)$ and $\alpha \leq \alpha^N$, with $\delta^N_{LF}(\alpha) \in (\delta^T_{MT}, 1]$ being increasing in α.*

Differently than before, without experimentation it is relatively harder to collude when consumers are more loss averse (see Figure 7 below).

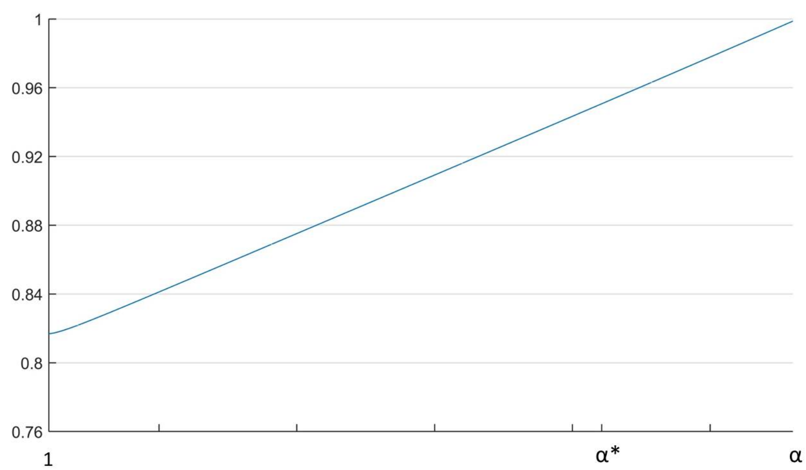


Figure 7: Critical discount factor when firms collude without experimentation

Indeed, although deviation and punishment profits drop when α increases, the prevailing effect is on the equilibrium profit: when α grows large, firms that do not allow experimentation must lower considerably the price they charge since consumers require a higher premium to buy products of uncertain quality. Figure 7 below shows how the critical discount factor $\delta^N_{LF}(\cdot)$ varies with α.

Optimal collusion. Building on the previous analysis, we can now characterize the optimal collusive scheme under *laissez-faire*. To this purpose, we first study how comparative experimentation affects firms' expected profit from cooperation, then we determine how it impacts stability — i.e., the critical discount factor above which collusion can be sustained.

Lemma 5 *There exists a threshold $\overline{\alpha} > 1$ such that $\pi^c_{MT} \geq \pi^c_{FT}$ if and only if $\alpha \geq \overline{\alpha}$.*

The intuition is straightforward. The more loss averse consumers are, the less firms can extract from them (even in collusion). Essentially, when consumers are not too loss averse, collusion without experimentation yields a higher profit to firms because the gain of preventing product differentiation more than compensates the cost of awarding discounts to consumers that purchase products of uncertain characteristics.

What about self-enforceability? In the next lemma we show that if consumers are sufficiently loss averse, collusion is not only relatively more profitable with experimentation, but it is also easier to sustain.

Lemma 6 *There exists a threshold* $\underline{\alpha} \in (1, \overline{\alpha})$ *such that, under laissez-faire, experimentation facilitates collusion if and only if* $\alpha > \underline{\alpha}$ *— i.e.,* $\delta_{LF}^{T}(\alpha) < \delta_{LF}^{N}(\alpha)$ *if and only if* $\alpha > \underline{\alpha}$*.*

There are two effects pointing in the same direction. In addition to the fact that the difference between collusive profits with and without experimentation is increasing in the degree of consumer loss aversion, deviating from an equilibrium sustained via comparative experimentation is less profitable also because (other things being equal) a firm has a lower chance to attract relatively more loss averse consumers when its product cannot be tested before purchase.

Gathering Lemma (5) and Lemma (6) together, we can state the following.

Proposition 9 *Under laissez-faire, joint-profit maximization does not require experimentation if* $\alpha \in [1, \overline{\alpha})$ *and* $\delta \geq \delta_{LF}^{N}(\alpha)$*. Otherwise, when it is feasible, collusion requires experimentation.*

Figure 8 below represents graphically firms' optimal strategies conditional on the discount factor in the industry and the degree of consumer loss aversion.

This figure highlights the region of parameters in which experimentation is used as collusive device. Provided that the discount factor is not too small, colluding via comparative experimentation is both more profitable and easier to sustain for high degrees of loss aversion. By contrast, for intermediate values of loss aversion, sustaining collusion via experimentation is easier than without experimentation, but less profitable. Finally, for low values of loss aversion, colluding without experimentation is optimal. Of course, for low values of the discount factor, the outcome of the repeated game is the same as that of the stage game — i.e., cooperation is not feasible in every regulatory regime.

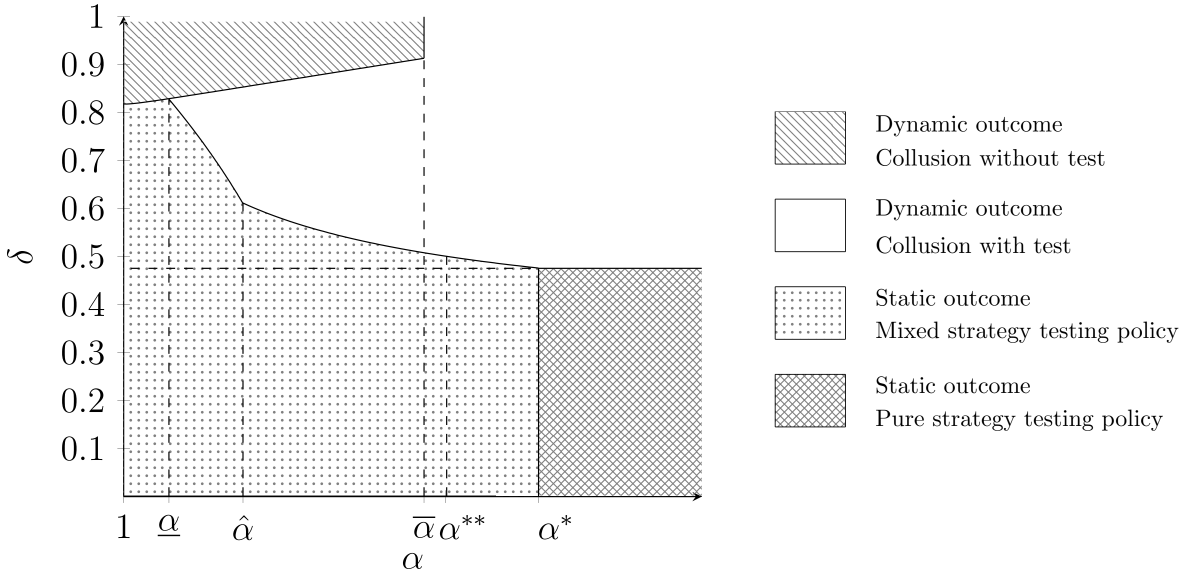


Figure 8: Optimal strategies under *laissez-faire* regime

6 Welfare implications

In this section we analyze the effects of comparative experimentation on consumers, and characterize the optimal policy for an Authority whose objective is to maximize consumer surplus.

Consider first the regime in which experimentation is forbidden. When collusion is not sustainable ($\delta < \frac{1}{2}$), firms price at marginal cost because products are perceived as perfect substitutes by the consumers. Hence, consumer welfare is simply equal to the expected quality (recall that we normalized marginal costs). Conversely, if collusion is sustainable, firms fully extract the consumer surplus. Hence, when tests are forbidden, consumer welfare is

$$u_{FT}(\delta) \equiv \begin{cases} 0 & \Leftrightarrow & \delta \geq \frac{1}{2} \\ \mathbb{E}[\theta] & \Leftrightarrow & \delta < \frac{1}{2} \end{cases} .$$

This proposition highlights an interesting trade off, which will be key for the rest of the analysis. By forbidding experimentation an Antitrust Authority maximizes consumer welfare if and only if collusion is not enforceable under this regime (since firms compete à la Bertrand). However, when collusion is viable, such a policy may actually deliver the worst possible outcome, because it enables firms to fully extract the consumer surplus.

Next, consider the regime in which experimentation is mandatory. In equilibrium, firms charge prices higher than marginal cost regardless of whether collusion can be sustained or not: comparative experimentation creates product differentiation, which relaxes competition and allows firms to exploit monopolistic power even in the static outcome. Recall that if both firms charge the same price, say p, the consumer surplus is

$$u^T(p) \equiv \int_p^1 (\theta_i - p)\,\theta_i d\theta_i + \int_p^1 (\theta_j - p)\,\theta_j d\theta_j.$$

Hence, when tests are mandatory, consumer welfare is

$$u_{MT}(\delta) \equiv \begin{cases} u^T(p^c_{MT}) = \frac{2}{3} - \frac{8}{27}\sqrt{3} > 0 & \Leftrightarrow \quad \delta \geq \delta_{MT} \\ u^T(p^{T,T}) = \frac{2}{3} - \frac{2}{3}(2-\sqrt{2}) > 0 & \Leftrightarrow \quad \delta < \delta_{MT} \end{cases},$$

where, as intuition suggests, collusion harms consumers — i.e., $u^T(p^c_{MT}) < u^T(p^{T,T})$.

There are two interesting points to highlight here. On the one hand, when collusion is not sustainable both with mandatory experimentation and in the regime where tests are forbidden, consumers are better off in the latter regime because experimentation relaxes price competition, while firms price competitively when it is banned. On the other hand, when collusion is feasible in both regimes, consumers prefer the regime with mandatory experimentation. The reason is simple: when products can be tested, consumers make more informed choices and, therefore, firms cannot fully extract their surplus as in the regime with forbidden tests — i.e., given prices, consumers purchase the product that better fits their taste.

Finally, consider the *laissez-faire* regime. This case is slightly more complex because firms can cooperate either through comparative experimentation or by preventing consumers to test products. In addition, when collusion is not sustainable, the stage game may either feature a pure strategy equilibrium in which both firms allow experimentation (if $\alpha < \alpha^*$), or an equilibrium in mixed strategies (if $\alpha \geq \alpha^*$), as shown in Proposition 4. When $\alpha < \alpha^*$ the consumer's surplus without collusion is the same as in the regime with mandatory test. By contrast, when $\alpha \geq \alpha^*$ consumer surplus must take into account firms' mixed strategies — i.e.,

$$u_{LF} = \beta(\alpha)^2 u^T(p^{T,T}) + (1-\beta(\alpha))^2 \mathbb{E}[\theta] +$$
$$+2\beta(\alpha)(1-\beta(\alpha)) \left[\int_{\underline{\theta}(p^{T,N},p^{N,T})}^1 \left(\theta - p^{T,N}\right) d\theta + \int_0^{\underline{\theta}\left(p^{T,N},p^{N,T}\right)} \left[\int_{p^{N,T}}^1 \left(\theta - p^{N,T}\right) d\theta + \alpha \int_0^{p^{N,T}} \left(\theta - p^{N,T}\right) d\theta \right] d\theta \right].$$

As illustrated in Figure 9 below, this expression (which is explicitly derived in the Appendix) is increasing in α. Again, more loss averse consumers pay lower prices to buy products of uncertain quality.

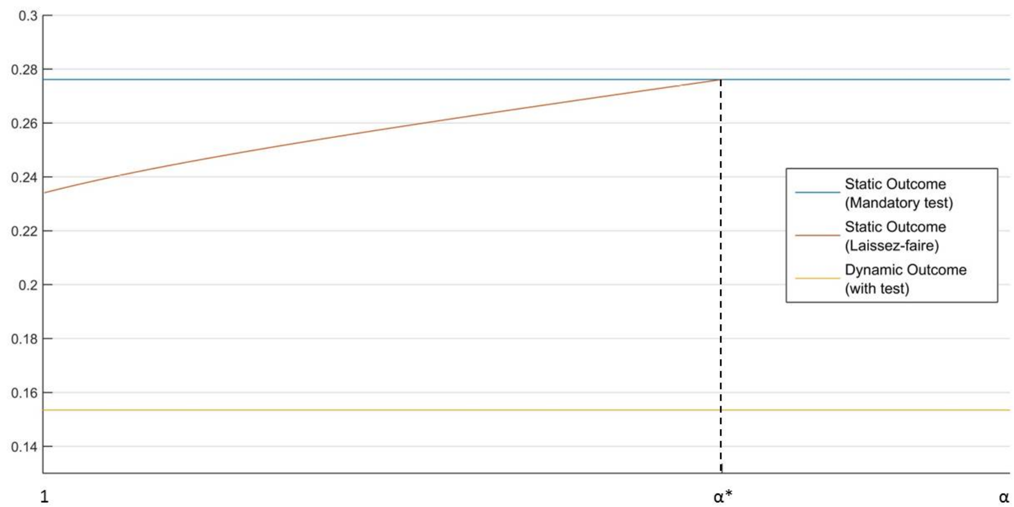


Figure 9: Expected consumer surplus if experimentations are not forbidden

Consider now the region of parameters in which firms collude. Consumer welfare depends on the optimal collusion rule, which may either require comparative experimentation or not depending on the degree of loss aversion α and the discount factor δ.

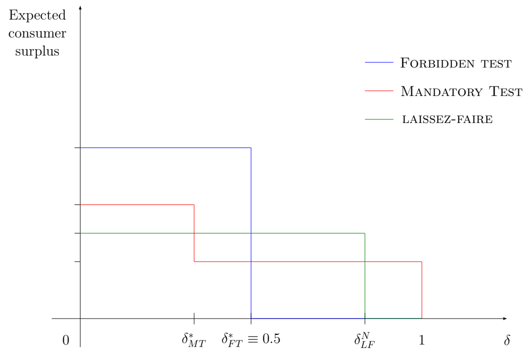
Suppose that $\alpha \in [1, \underline{\alpha}]$ and that $\delta \geq \delta_{LF}^{N}(\alpha)$. In this region of parameters joint profit maximization requires no experimentation as shown in Proposition 9. Hence, firms fully extract the consumer surplus.

Suppose now that $\alpha \in (\underline{\alpha}, \overline{\alpha})$. In this region of parameters firms maximize joint profits without experimentation. Hence, if $\delta \geq \delta_{LF}^{N}(\alpha)$, consumer surplus is still equal to zero. However, if collusion without experimentations is not enforceable — i.e., $\delta < \delta_{LF}^{N}(\alpha)$ — firms can still collude by allowing experimentation when $\delta \in \left[\delta_{LF}^{T}(\alpha), \delta_{LF}^{N}(\alpha)\right)$. In this case, consumer surplus is the same as in the case of mandatory experimentation.

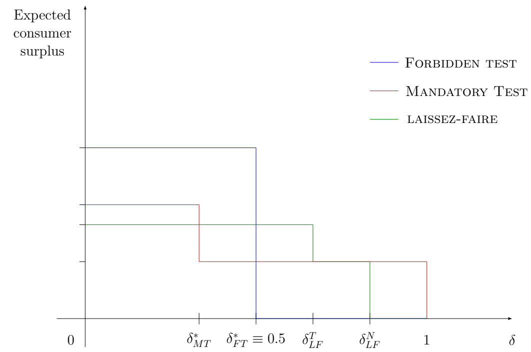
Finally, suppose that $\alpha \geq \overline{\alpha}$. In this region of parameters collusion is always enforced through experimentation because it yields higher profits and requires a lower discount factor to be self-enforceable. Hence, consumer surplus coincides with that obtained under mandatory experimentation.

What is the regulatory regime that maximizes consumers' well being? Figure 10 provides four illustrations of the consumer surplus for each parameter region of interest.[3]

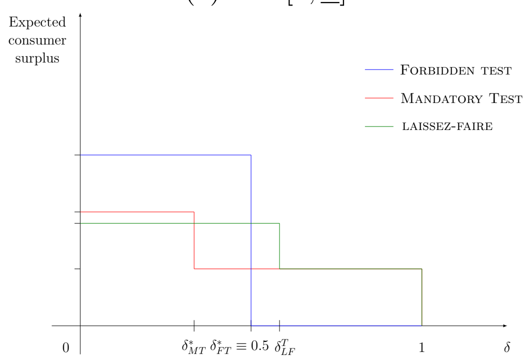
[3]We ruled out the interval of α, such that $\alpha \geq \alpha^*$. In fact, under *laissez-faire* firms have always incentive to allow the consumer to test their products. This means that this regime will coincide with that under mandatory experimentation.



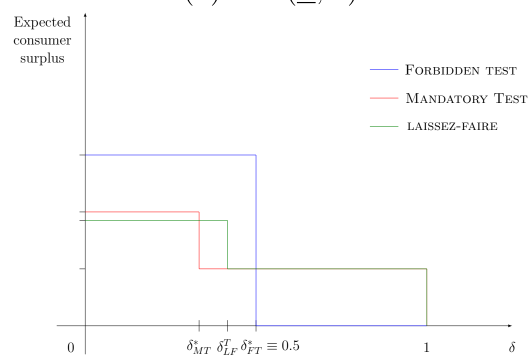
(a) $\alpha \in [1, \underline{\alpha}]$



(b) $\alpha \in (\underline{\alpha}, \overline{\alpha})$



(c) $\alpha \in [\overline{\alpha}, \alpha^{**}]$



(d) $\alpha \in (\alpha^{**}, \alpha^{*})$

Figure 10: Expected consumer surplus

This leads to the following result.

Proposition 10 *For $\delta < \frac{1}{2}$ consumer surplus is maximized by a policy that forbids experimentation regardless of α. For $\delta \geq \frac{1}{2}$ comparative experimentation has a beneficial effect on consumer surplus. Specifically, for $\alpha \in [1, \overline{\alpha})$ and $\delta \geq \delta^N_{LF}(\alpha)$, the optimal policy is to force product experimentation. Otherwise, a laissez faire approach is optimal.*

Figure 11 below represents graphically the optimal policy as a function of α and δ.

Summing up, forcing experimentation is harmful to consumers when collusion is unviable regardless of the regulatory regime in place ($\delta < \frac{1}{2}$). Indeed, product differentiation, as induced by comparative experimentation, conveys monopolistic power to the firms who charge prices above marginal costs. Instead, a policy that forbids experimentation forces the Bertrand outcome.

By contrast, when firms are able to sustain collusion under the regulatory regime that forbids experimentation ($\delta \geq \frac{1}{2}$), the optimal policy must induce experimentation in equilibrium, otherwise firms would fully extract the consumer surplus. Interestingly, when consumers are not too loss

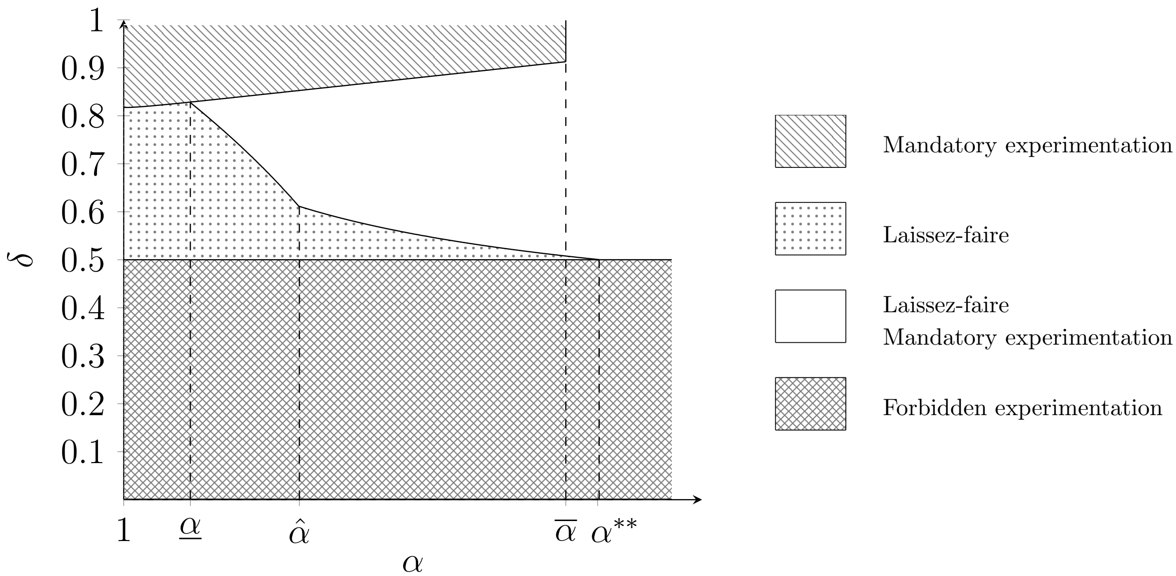


Figure 11: Optimal testing policy

averse ($\alpha < \overline{\alpha}$) and the discount factor is such that firms cooperate without experimentation in the *laissez-faire* regime ($\delta \geq \delta_{LF}^{N}(\alpha)$), the optimal policy must force experimentation. Conversely, if collusion is enforced via comparative experimentation, a *laissez-faire* approach is optimal because it hinders collusion and at the same time it avoids full surplus extraction. The dotted area of the graph represents the region of parameters in which *laissez-faire* is strictly better than any other regime: in this area it makes collusion unviable. By contrast, within the white area, firms collude via comparative experimentation under *laissez-faire*. Hence, the effect on consumer surplus coincides with that under mandatory experimentation — i.e., the two regimes yield the same consumer surplus and are thus both optimal.

7 Harsher punishment codes

In our model, Nash reversion is clearly an optimal punishment (i.e., the minmax) when consumers cannot test products before purchase. The same is not necessarily true under mandatory experimentation or *laissez-faire* since, in both these regimes, the stage game features an equilibrium in which firms make positive profits. In this section we show that, under *laissez-faire*, firms can use more complex punishment codes to sustain collusion via comparative experimentation in a wider range of discount factors relative to Nash reversion.

Before providing the result, it is important to notice that, unlike most of the existing models of tacit collusion, our model is a repeated extensive-form (rather than normal-form) game. Punishments of first-stage deviations begin within the deviation period, which implies that the details of the punishment code affect the price that the deviating firm can charge in the second stage. Unlike in repeated normal-form games where short-term deviation gains are independent of future play, the short-term deviation gain that can be achieved by means of a first-stage deviation thus depends on the exact nature of the punishment. Mailath, Nocke and White (2004) discuss the failure of simple penal codes (Abreu 1986, 1988) for repeated extensive-form games and show that it can be necessary to tailor the punishment to the nature of the deviation in order to sustain the desired equilibrium (see also Piccolo and Miklos-Thal, 2012).

To make our point in the simplest possible way, we consider the following penal code that firms use to sustain collusion via comparative experimentation:

(i) If a deviator unexpectedly does not allow experimentation in the first-stage of period τ, the rival (i.e., the punisher) prices at the marginal cost in the price-setting stage of the deviation period, while in period $\tau + 1$ both firms do not allow experimentation and price at marginal cost. If both firms obey the punishment code, they go back to collusion for the rest of the game. If a deviation occurs at $\tau + 1$ there is another round of punishment.

(ii) If a deviator does not allow experimentation in the first-stage of period τ and the punisher deviates by not charging a price equal to the marginal cost in the price-setting stage of period τ, then in periods $\tau + 1$ and $\tau + 2$ both firms do not allow experimentation and price at marginal cost. If both firms obey the punishment code, they go back to collusion for the rest of the game. Otherwise, there is another round of punishment.

(iii) If both firms allow experimentation but a price deviation occurs in the price-setting stage of period τ, then in period $\tau + 1$ both firms do not allow experimentation and price at marginal cost. If both firms obey the punishment code, they go back to collusion for the rest of the game. Otherwise, there is another round of punishment.

This penal code has a very simple and intuitive structure. The main difference with the approach taken in repeated normal-form games is that the punisher can now deviate even at the price-setting stage of a period in which there has been a first-stage deviation. A penal code that does not hinge on Nash reversion needs to cope with this additional deviation from the punishment phase. Hence:

Proposition 11 *When firms use the penal code described by $(i) - (iii)$, they can sustain collusion with experimentation for some values of the discount factor (strictly) lower than $\frac{1}{2}$.*

This result has two interesting implications. First, the same logic can be applied to show that firms' ability to enforce collusion can also improve without experimentation when moving away from Nash reversion. Second, from a policy perspective, it implies that with punishment codes harsher than Nash reversion, a *laissez-faire* approach never improves consumer welfare relative to the other regimes. As explained before, under Nash reversion consumers prefer *laissez-faire* because (in this regime) punishment and deviation profits are (weakly) larger than in any other regime. Other things being equal, this clearly makes collusion more difficult to sustain. However, more complex punishment codes allow firms to actually play with the degree of flexibility offered by *laissez-faire* to reduce profits in the punishment phase, and make first-stage deviations less appealing by means of instantaneous price reactions harsher than simple Nash reversion. Clearly, this facilitates collusion and harms consumers.

8 Concluding remarks

The recent literature studying the link between consumer loss aversion and firm behavior has shown that surprising results on how companies price and market their products may emerge when behavioral aspects, such as loss minimization, are introduced in standard IO problems. In this article, we have contributed to this growing literature by highlighting novel aspects of the relationship between loss aversion and firm behavior in dynamic environments. In particular, our analysis contributes to better understand whether product experimentation hinders or facilitates firms cooperation, and how this relationships interplays with consumer loss aversion.

We have argued that, in repeated games, consumer loss aversion has important implications on the way firms selling experience goods use marketing instruments, such as tests, product demonstrations, free-trial and return policies, to achieve cooperative market outcomes, at the consumers' expense. One key element to understand how these instruments are used strategically to soften competition and foster market power, is determined by the regulatory regime in place. Specifically, depending on whether experimentation is forbidden, mandated or allowed but not imposed (*laissez-faire*), it turns out that the degree of consumer loss aversion has ambiguous effects on the profits that firms can achieve through implicit collusion, on the stability of these agreements, and even on consumer surplus.

We have shown that the regulatory regime that favors the most the emergence of collusive agreements is one in which firms are forced to allow consumers to experiment products before purchase. However, as we noted, this regime is not necessarily the one that maximizes joint profits, which highlights a novel trade off between stability and profitability of collusive agreements in markets for experience goods. Specifically, the regime that maximizes cooperative profits is the one in which experimentation is forbidden when consumers are not too loss averse. By contrast, when they are sufficiently loss averse, firm profits are higher when comparative experimentation is viable. As a result, collusive agreements should be more likely to involve experimentation in markets in which, other things being equal, the informative benefits of experimentation are considerably important for consumers.

The overall impact on consumer welfare is ambiguous too, which suggests that while in static environments a *laissez-faire* approach can only harm consumers, in a dynamic environment the opposite may happen insofar as leaving firms free to choose whether allowing perspective customers to test or not their products before purchase, hinders cartel stability and avoids full surplus extraction, which would occur when collusion is sustained without the help of experimentation. Notably, the optimality of *laissez-faire* falls apart when firms use punishment codes harsher than Nash reversion. If that is the case, the optimal policy requires either mandatory experimentation or it should forbid it.

A Appendix

Proof of Lemma 1. The proof of this result hinges on a straightforward revealed preferences argument. Testing products cannot harm consumers because by doing so they are able to pick the best option, including no purchase at all if this is optimal ex post. Suppose that firms allow the consumer to test their products. If the consumer decides to test neither product, he buys the one with lowest price (say firm i's product) and his expected utility is

$$u^{N,N}(p_i) = \int_{p_i}^{1} (\theta_i - p_i)\, dF(\theta_i) + \alpha \int_{0}^{p_i} (\theta_i - p_i)\, dF(\theta_i).$$

If the consumer test only one product (say firm i's product), his expected utility is

$$u^{T,N}(p_i, p_j) = \max \left\{ \int_{p_i}^{1} (\theta_i - p_i)\, dF(\theta_i) ; \int_{p_j}^{1} (\theta_j - p_j)\, dF(\theta_j) + \alpha \int_{0}^{p_j} (\theta_j - p_j)\, dF(\theta_j) \right\}.$$

Finally, testing both products yields the following expected utility

$$u^{T,T}(p_i, p_j) = \max \left\{ \int_{p_i}^{1} (\theta_i - p_i)\, dF(\theta_i) ; \int_{p_j}^{1} (\theta_j - p_j)\, dF(\theta_j) \right\}.$$

It is immediate to see that

$$u^{T,T}(p_i, p_j) \geq u^{T,N}(p_i, p_j) \geq u^{N,N}(p_i),$$

so that expected utility is maximized when the consumer tests both products. ∎

Proof of Proposition 1. When experimentation is not viable, products are perceived as perfect substitutes. Hence, the equilibrium price follows immediately from a standard Bertrand logic. ∎

Proof of Proposition 2. Suppose that both firms allow experimentation. The consumer patronizes firm i if and only if:

$$u(\theta_i, p_i) \geq 0 \quad \Leftrightarrow \quad \theta_i \geq p_i \quad i = 1, 2$$

and

$$u(\theta_i, p_i) \geq u(\theta_j, p_j) \quad \Leftrightarrow \quad \theta_i - \theta_j \geq p_i - p_j, \quad i, j = 1, 2.$$

Firm i's expected profit is

$$\pi_i^{T,T}(p_i, p_j) = p_i \times \int_{p_i}^{1} (\theta_i + p_j - p_i)\, d\theta_i, \quad i, j = 1, 2,$$

whose maximization yields the following first-order condition

$$2p_j - 4p_i + 3p_i^2 - 4p_i p_j + 1 = 0.$$

Hence, firm i's best reply is

$$p_i^T(p_j) \equiv \frac{2}{3}(1+p_j) - \frac{1}{3}\sqrt{2p_j + 4p_j^2 + 1} \quad i,j = 1,2.$$

Imposing symmetry, the equilibrium price becomes $p^{T,T} \equiv \sqrt{2} - 1$. ■

Proof of Proposition 3. Suppose that only one firm (say i) allows experimentation. The consumer patronizes that firm if and only if

$$u(\theta_i, p_i) \geq 0, \quad i = 1,2,$$

and

$$u(\theta_i, p_i) \geq u(p_j) \quad \Leftrightarrow \quad \theta_i - p_i \geq \int_{p_j}^{1} (\theta_j - p_j)\, d\theta_j + \alpha \int_0^{p_j} (\theta_j - p_j)\, d\theta_j, \quad i,j = 1,2,$$

which implies

$$\theta_i - p_i \geq \frac{1}{2} - p_j - \frac{(\alpha-1)\, p_j^2}{2} \quad \Leftrightarrow \quad \theta_i \geq \frac{1}{2} + p_i - p_j - \frac{(\alpha-1)\, p_j^2}{2}, \quad i,j = 1,2.$$

Hence, firm i's expected profit is

$$\pi_i^{T,N}(p_i, p_j) = p_i \times \left(p_j - p_i + \frac{1}{2} + \frac{(\alpha-1)\, p_j^2}{2}\right).$$

Maximizing with respect to p_i we have the following first-order condition

$$2p_j - 4p_i + 1 - p_j^2 + \alpha p_j^2 = 0,$$

which yields firm i's best reply is

$$p_i^{T,N}(p_j) \equiv \frac{2p_j + p_j^2(\alpha-1) + 1}{4}. \tag{16}$$

Applying the same logic, firm j's expected profit is

$$\pi_j^{N,T}(p_j, p_i) = p_j \times \left(p_i - p_j + \frac{1}{2} - \frac{(\alpha-1)\, p_j^2}{2}\right).$$

Maximizing with respect to p_i we have the following first-order condition

$$4p_j - 2p_i - 1 - 3p_j^2 + 3\alpha p_j^2 = 0,$$

which yields firm j's best reply is

$$p_j^{N,T}(p_i) \equiv \frac{\sqrt{3\alpha + 6p_i(\alpha - 1) + 1} - 2}{3(\alpha - 1)}. \tag{17}$$

Substituting (17) into (16), and vice-versa, we have the following equilibrium prices

$$p^{T,N} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha - 2} - 13}{25(\alpha - 1)},$$

$$p^{N,T} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha - 2} - 13}{5(\alpha - 1)} - 2.$$

Simple comparison between these expressions implies that $p^{T,N} \geq p^{N,T}$. ■

Proof of Lemma 2. Using the results obtained before, it can be easily verified that

$$\pi^{T,T} = 3 - 2\sqrt{2},$$

and

$$\pi^{N,T} = \frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha - 2})(\sqrt{3}\sqrt{5\alpha - 2} - 3)}{250(\alpha - 1)^2}.$$

Comparing these expressions, it turns out that $\pi^{T,T} \geq \pi^{N,T}$ if and only if

$$250(\alpha - 1)^2(3 - 2\sqrt{2}) \geq (30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha - 2})(\sqrt{3}\sqrt{5\alpha - 2} - 3),$$

It can be checked that this inequality is satisfied for any $\alpha \geq \alpha^* \approx 3.1$. ■

Proof of Proposition 4. Consider first a candidate equilibrium in which neither firm allows experimentation. In this case, products are viewed as perfect substitutes. Hence, Bertrand competition leads to a zero-profit outcome. However, both the firms have an incentive to deviate from this candidate equilibrium by allowing experimentation and charge a price (slightly) larger than marginal cost. Indeed, using $p^{T,N}$ and $p^{N,T}$ obtained before, it is easy to show that

$$\pi^{N,T} = \frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha - 2})(\sqrt{3}\sqrt{5\alpha - 2} - 3)}{250(\alpha - 1)^2} \geq 0 \quad \forall \alpha \geq 1.$$

Hence, there cannot exist a SPNE in which experimentation is not allowed.

Next, consider a candidate equilibrium in which both firms allow experimentation. As seen in the text, in this candidate equilibrium each firm obtains an expected profit equal to $\pi^{T,T} = 3 - 2\sqrt{2}$. We now check that firms have no incentive to deviate in the first period by choosing a different experimentation policy — i.e., $\pi^{T,T} > \pi^{N,T}$. By Lemma 2, this inequality is always satisfied for $\alpha > \alpha^*$.

Hence, suppose that $\alpha \leq \alpha^*$. In this region of parameters there does not exist a symmetric Nash equilibrium in pure strategies: each firm has an incentive to deviate by impeding experimentation, if the rival allows it. Therefore, consider a symmetric equilibrium in which each firm randomizes in the first stage by allowing experimentation with probability β. Such an equilibrium exist if and only if the solution with respect to β of the following equation

$$\beta \times \pi^{T,T} + (1-\beta)\, \pi^{T,N} = \beta \times \pi^{N,T},$$

is such that $\beta \in (0,1]$ for $\alpha \leq \alpha^*$.

Using the expressions for $\pi^{T,T}$, $\pi^{T,N}$ and $\pi^{N,T}$ obtained before, it follows that

$$\beta\,(\alpha) = \frac{(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)^2}{5\left[19\alpha\sqrt{3}\sqrt{5\alpha-2}+250\sqrt{2}-\alpha((500\sqrt{2}-641)+355\alpha-250\sqrt{2}\alpha)\right]-71\sqrt{3}\sqrt{5\alpha-2}-1502}.$$

As shown in Figure 3, it is easy to verify that this expression is increasing in α for every $\alpha \in [1, \alpha^*)$. ■

Proof of Proposition 5. In the regime with forbidden tests, collusion is sustainable if and only if

$$\frac{\pi^c_{FT}}{1-\delta} \geq \pi^d_{FT},$$

which implies immediately $\delta \geq \delta_{FT} \equiv \frac{1}{2}$. ■

Proof of Proposition 6. In the regime with mandatory tests, collusion is sustainable if and only if

$$\frac{\pi^c_{MT}}{1-\delta} \geq \pi^d_{MT} + \frac{\delta}{1-\delta}\pi^*_{MT},$$

where

$$\pi^d_{MT} = p^d_{MT} \times \int_{p^d_{MT}}^{1} \left(\theta_i - p^d_{MT} + p^c_{MT}\right) d\theta_i.$$

Substituting p^d_{MT} and p^c_{MT} in the profit function π^d_{MT}, we have $\pi^d_{MT} \approx 0.21136$. Hence, deviating from the collusive agreement is unprofitable if and only if $\delta \geq \delta_{MT} \approx 0.47532$. ■

Proof of Lemma 3. Suppose that firms collude through experimentation. What is the best deviation from this candidate equilibrium? As we have seen in the text, firms could change experimentation policy in the first stage of the game, with an expected profit equal to $\pi^{N,T}$, or announce the expected experimentation policy, but then deviate at the pricing-setting stage and gain an expected profit equal to π^d_{MT}. The best deviation requires no experimentation if and only if $\pi^{N,T} \geq \pi^{d}_{MT}$ — i.e.,

$$\frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2}-3)}{250\,(\alpha-1)^2} \geq \frac{\sqrt{3}}{243} + \left[\frac{2}{81} + \frac{7\sqrt{3}}{243}\right]\sqrt{2\sqrt{3}+7} - \frac{1}{27}.$$

This inequality is satisfied for $\alpha \leq \widehat{\alpha} \approx 1.67$. Instead, if $\alpha > \widehat{\alpha}$, the best deviation consists in keeping the expected experimentation policy and then undercutting the collusive price. ■

Proof of Proposition 7. Under *laissez-faire*, if firms cooperate through experimentation, collusion is sustainable if and only if

$$\frac{\pi^{c}_{MT}}{1-\delta} \geq \pi^{d}_{LF} + \frac{\delta}{1-\delta}\pi^{*}.$$

The stage game may feature an equilibrium in mixed strategies. In that case, the expected profit during the punishment phase is

$$\pi^{*} = \beta\,(\alpha) \times \pi^{N,T}.$$

Substituting $\beta\,(\alpha)$ and $\pi^{N,T}$ into π^{*}, we have

$$\pi^{*} = \frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^2(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left[\alpha^2(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right](\alpha-1)^2}.$$

The stability of a collusive agreement is therefore affected by the degree of consumer loss aversion. Specifically, for $\alpha \leq \widehat{\alpha}$, the critical discount factor is

$$\delta^{T}_{LF}\,(\alpha) = \frac{\frac{(30\alpha-24-2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2}-3)}{250(\alpha-1)^2} - \frac{\sqrt{3}}{9}}{\frac{(30\alpha-24-2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2}-3)}{250(\alpha-1)^2} - \frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^2(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left(\alpha^2(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right)(\alpha-1)^2}}.$$

Instead, for $\alpha > \widehat{\alpha}$, the critical discount factor is

$$\delta^{T}_{LF}\,(\alpha) = \frac{0.21136 - \frac{\sqrt{3}}{9}}{0.21136 - \frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^2(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left[\alpha^2(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right](\alpha-1)^2}}.$$

Finally, for $\alpha > \alpha^{*}$, the punishment phase is characterized by a Nash Equilibrium in pure strategies, in which firms allow experimentation and charge $p^{*} = \sqrt{2} - 1$. Hence, the critical discount factor coincides with that in a regime with mandatory experimentation.

Deviation profits are clearly decreasing in α in the interval between 1 and $\widehat{\alpha}$. Specifically, the partial derivative is

$$\frac{\partial \pi^{N,T}}{\partial \alpha} = \frac{\frac{9}{2}\sqrt{3}-12\alpha\sqrt{3}+\frac{15}{2}\alpha^2\sqrt{3}-\frac{39}{5}\sqrt{5\alpha-2}+15\alpha\sqrt{5\alpha-2}+\sqrt{3}\sqrt{15\alpha-6}-\alpha\sqrt{3}\sqrt{15\alpha-6}+\frac{3}{5}\sqrt{5\alpha-2}\sqrt{15\alpha-6}-3\alpha\sqrt{5\alpha-2}\sqrt{15\alpha-6}}{25(\alpha-1)^3\left(\sqrt{5\alpha-2}\right)},$$

which is negative for any $\alpha > 1$. This makes collusion easier to sustain. Next, in order to show that $\delta^{T}_{LF}\,(\alpha) \in [\delta^{T}_{MT}, 1)$, it is sufficient to verify that the expected profit when firms mix in the first-stage is always larger than the profit they obtain when playing pure strategies — i.e.,

$$\frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^2(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left[\alpha^2(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right](\alpha-1)^2} > 3-2\sqrt{2},$$

which always holds for $\alpha < \alpha^*$. ■

Proof of Lemma 4. Suppose that firms cooperate without experimentation. As discussed in the text, a deviator can either change experimentation policy in the first stage of the game, with an expected profit equal to $\pi^{T,N}$, or announce the expected experimentation policy, but then undercut the rival at the price-setting stage, gaining an expected profit equal to π^d_{FT}. It can be shown that $\pi^d_{FT} \geq \pi^{T,N}$ if and only if

$$\frac{\sqrt{\alpha}-1}{\alpha-1} \geq \frac{(5\alpha-20+3\,(5\alpha-2)+2\sqrt{3}\sqrt{5\alpha-2})(10\alpha-13+\sqrt{3}\sqrt{5\alpha-2})}{1250\,(\alpha-1)^2},$$

which is satisfied if and only if $\alpha \leq \widetilde{\alpha} \approx 19.39$. ■

Proof of Proposition 8. Under *laissez-faire*, if firms cooperate without experimentation, collusion is sustainable if and only if

$$\frac{\pi^c_{FT}}{1-\delta} \geq \pi^d_{LF} + \frac{\delta}{1-\delta}\pi^*.$$

Consider first $\alpha \leq \alpha^*$. In this region of parameters, firms play mixed strategies in the stage game. Hence, the critical discount factor is

$$\delta^N_{LF}\left(\alpha\right) = \frac{1}{2-\frac{2(\alpha-1)\left(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3\right)\left(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2}\right)^2\left(3-\sqrt{3}\sqrt{5\alpha-2}\right)}{375\left(\sqrt{\alpha}-1\right)(\alpha-1)^2\left(\alpha^2\left(1775-1250\sqrt{2}\right)+5\alpha\left(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641\right)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right)}}.$$

Consider now $\alpha \in (\alpha^*, \widetilde{\alpha}]$. In this case, in the punishment phase firms allow experimentation with certainty. Hence, the critical discount factor is

$$\delta^N_{LF}\left(\alpha\right) = \frac{1}{2-\frac{2(\alpha-1)(3-2\sqrt{2})}{\sqrt{\alpha}-1}},$$

which is always positive and lower than 1 for $\alpha \leq \alpha^N \equiv 3.66$.

Finally, it can be shown that $\pi^c_{FT} \geq \pi^{T,N}$ for $\alpha \geq \alpha^N$. Hence, for $\alpha \geq \widetilde{\alpha}$ collusion is not viable without experimentation under *laissez-faire*. ■

Proof of Lemma 5. Assuming that collusion is always enforceable, colluding firms choose the experimentation policy which maximizes their joint profit. Specifically, collusive profit is higher with rather than without experimentation if and only if

$$\pi^c_{MT} \geq \pi^c_{FT} \quad \Leftrightarrow \quad \alpha \geq \overline{\alpha} \approx 2.55. \qquad ■$$

Proof of Lemma 6. Notice that $\delta_{LF}^{T}(\alpha)$ and $\delta_{LF}^{N}(\alpha)$ are respectively decreasing and increasing in α, with

$$\delta_{LF}^{T}(\alpha) < \delta_{LF}^{N}(\alpha) \quad \Leftrightarrow \quad \alpha > \underline{\alpha} \approx 1.31,$$

where $\widehat{\alpha} > \underline{\alpha}$. Hence, under *laissez faire*, comparative experimentation facilitates joint profit maximization if and only if $\alpha > \underline{\alpha}$. ■

Proof of Proposition 9. Suppose first that $\alpha \in [1, \underline{\alpha}]$. In this region of parameter $\delta_{LF}^{N}(\alpha) < \delta_{LF}^{T}(\alpha)$ (see Lemma **6).** This implies that collusion is easier to sustain without (rather than with) experimentation. Moreover, $\pi_{FT}^{c} > \pi_{MT}^{c}$ as shown in Lemma **5**. Hence,for $\alpha \in [1, \underline{\alpha}]$ and $\delta \geq \delta_{LF}^{N}(\alpha)$, joint-profit maximization does not require experimentation.

Next, suppose that $\alpha \in (\underline{\alpha}, \overline{\alpha})$. As shown in Lemma **5,** in this case it is still the case that $\pi_{FT}^{c} > \pi_{MT}^{c}$. However, in this range of parameters, experimentation facilitates collusion — i.e., $\delta_{LF}^{T}(\alpha) < \delta_{LF}^{N}(\alpha)$ by Lemma **6**. Hence, for $\alpha \in (\underline{\alpha}, \overline{\alpha})$ and $\delta \geq \delta_{LF}^{N}(\alpha)$, joint profit is maximized without experimentation. By contrast, if $\alpha \in (\underline{\alpha}, \overline{\alpha})$ and $\delta \in \left[\delta_{LF}^{T}(\alpha), \delta_{LF}^{N}(\alpha)\right)$, collusion is optimally enforced via comparative experimentation.

Finally, suppose that $\alpha \geq \overline{\alpha}$. In this case, $\pi_{FT}^{c} \leq \pi_{MT}^{c}$ as shown in Lemma **5.** Moreover, $\delta_{LF}^{T}(\alpha) < \delta_{LF}^{N}(\alpha)$ by Lemma **6**. Hence, for $\alpha \geq \overline{\alpha}$ and $\delta \geq \delta_{LF}^{T}(\alpha)$, firms collude through experimentation. ■

Consumer welfare. When tests are forbidden, the consumer's utility from purchasing firm i's product at price p_i is:

$$u(p_i) \equiv \int_{p_i}^{1} (\theta_i - p_i)\, d\theta_i + \alpha \int_{0}^{p_i} (\theta_i - p_i)\, d\theta_i, \quad i = 1, 2.$$

Hence, when $\delta < \frac{1}{2}$ collusion is not viable and the equilibrium price is $p^* = 0$ yielding

$$u(p_i = 0) \equiv \mathbb{E}[\theta] = \frac{1}{2}.$$

By contrast, if collusion is sustainable — i.e., $\delta \geq \frac{1}{2}$ — firms fully extract all the consumer surplus.

By contrast, when tests are mandatory, the consumer can realize the matching values of both products before purchase. Hence, evaluated at $p_i = p_j = p^*$ his expected utility is

$$u(p^*, p^*) \equiv \int_{p^*}^{1} [\theta_i - p^*]\, \theta_i d\theta_i + \int_{p^*}^{1} [\theta_j - p^*]\, \theta_j d\theta_j = \frac{2}{3} - \frac{2}{3}(2 - \sqrt{2}) \approx 0.27614$$

Instead, if collusion is sustainable — i.e., $\delta \geq \delta_{MT}$ — firms charge $p_{MT}^{c} = \frac{1}{3}\sqrt{3}$. Substituting p_{MT}^{c} into the consumer's utility function we have

$$u(p_{MT}^{c}, p_{MT}^{c}) \equiv \int_{p_{MT}^{c}}^{1} [\theta_i - p_{MT}^{c}]\, \theta_i d\theta_i + \int_{p_{MT}^{c}}^{1} [\theta_j - p_{MT}^{c}]\, \theta_j d\theta_j = \frac{2}{3} - \frac{8}{27}\sqrt{3} \approx 0.153\,47.$$

Proof of Proposition 10. Suppose first that $\delta < \frac{1}{2}$. In this case, collusion is not viable when tests are forbidden. Clearly, the consumer's expected utility is higher when tests are forbidden than with mandatory experimentation. Instead, under *laissez-faire*, the stage game may either feature a pure strategy equilibrium in which both firms allow experimentation with certainty ($\alpha > \alpha^*$), or an equilibrium in mix strategies ($\alpha \leq \alpha^*$). In the former case, the consumer's expected utility is clearly the same as in the regime with mandatory test. Instead, when $\alpha \leq \alpha^*$, it is equal to

$$\begin{aligned} u_{LF}(\alpha) &= \beta(\alpha)^2 \left(\tfrac{2}{3} - \tfrac{2}{3}(2-\sqrt{2})\right) + \frac{1}{2}(1-\beta(\alpha))^2 + \\ &\quad +2\beta(\alpha)(1-\beta(\alpha)) \left[\begin{array}{c} \left[\frac{4(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)}{25\alpha-25} + \frac{\alpha-1}{2}\left(\frac{5(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)}{25\alpha-25} - 2\right)^2 - \frac{5}{2}\right] \times \\ \left[\frac{10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13}{5(\alpha-1)} + \frac{\alpha-1}{2}\left(\frac{5(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)}{25\alpha-25} - 2\right)^2 - \frac{5}{2}\right] + \\ + \frac{200\alpha^2-415\alpha+16\sqrt{3}\sqrt{5\alpha-2}-6\sqrt{3}(5\alpha-2)^{\frac{3}{2}}+20\sqrt{3}\alpha\sqrt{5\alpha-2}+161}{1250(\alpha-1)^2}. \end{array} \right]. \end{aligned}$$

It can be shown that $u_{LF}(\alpha)$ is weakly increasing in α, reaches its maximum for any $\alpha \geq \alpha^*$ (see Figure 9) and is always lower than $\frac{1}{2}$. Hence, the policy that maximizes consumer surplus is the one that forbids tests regardless of α.

Next, suppose that $\delta \geq \frac{1}{2}$. In this case, firms collude and fully extract the consumer surplus if experimentation is forbidden. Under *laissez-faire*, colluding without experimentation is an optimal strategy if $\alpha \in [1, \overline{\alpha})$ and $\delta \geq \delta^N_{LF}(\alpha)$. This means that, in the region of parameters under consideration, firms are still able to fully extract the consumer surplus. Conversely, forcing firms to allow the consumer to test their products yields a strictly positive surplus to the latter. As a result, the optimal policy is to force product experimentation.

We will show now that a *laissez-faire* approach is optimal otherwise. As shown in Lemma 6, $\delta^N_{LF}(\alpha) < \delta^T_{LF}(\alpha)$ if and only if $\alpha < \underline{\alpha}$. Moreover, using the expression for the discount factor, we have $\delta^N_{LF}(\alpha) > \frac{1}{2}$ for any α. When firms collude via experimentation the consumer's surplus is lower than in *laissez-faire* when collusion is not sustainable (see Figure 9). Hence, *laissez-faire* is the optimal policy if $\delta < \delta^N_{LF}(\alpha)$ and $\alpha < \underline{\alpha}$, because it prevents collusion.

Now, suppose that $\alpha \geq \underline{\alpha}$ and firms collude via experimentation. If $\delta \in \left[\delta^T_{LF}(\alpha), \delta^N_{LF}(\alpha)\right)$ the consumer's surplus coincides with that under mandatory experimentation. Instead, if $\delta < \delta^T_{LF}(\alpha)$ collusion is not enforceable and the consumer's surplus is always strictly positive. Moreover, the critical discount factor under *laissez-faire* is never lower than with mandatory test, as shown in Proposition 7.

Finally, notice that

$$\delta^T_{LF} > \frac{1}{2} \quad \Leftrightarrow \quad \alpha < \alpha^{**} \approx 2.65.$$

Hence, for $\alpha < \alpha^*$ colluding under *laissez-faire* is more difficult to sustain compared to the regime in which experimentation is forbidden. This implies that if $\delta < \delta^T_{LF}(\alpha)$, the *laissez-faire* regime is optimal. ■

Proof of Proposition 11. Consider the penal code described by properties $(i)-(iii)$ in the text.

The proof will proceed by showing that, under *laissez-faire*, all the self-enforceability conditions are slack at $\delta = \frac{1}{2}$ for every $\alpha \geq 1$, which implies that collusion via experimentation is sustainable for some $\delta < \frac{1}{2}$ regardless of α.

Hence, we need to check that: (a) no firm has an incentive to deviate from the collusive path; (b) no firm has an incentive to deviate from the punishment code.

As we have shown in the text, if a cheating firm deviates during the price-setting stage of the game, it earns $\pi_d^{T,T} \approx 0.21136$. Conversely, if a cheating firm, say firm 1, deviates in the first-stage of the game, the rival charges a price $p = 0$, as mandated by the penal code. Hence, firm 1 will manage to sell its product if and only if

$$\theta_2 \leq \frac{1}{2} - p_1 - \frac{(\alpha - 1)\, p_1^2}{2} \rightarrow \theta_2 \leq \frac{1}{2} - p_1 - \frac{(\alpha - 1)\, p_1^2}{2}.$$

This implies the following maximization problem

$$\max_{p_1} p_1 \times \left(\frac{1}{2} - p_1 - \frac{(\alpha - 1)\, p_1^2}{2} \right),$$

which yields the first-order condition

$$\frac{\partial \pi^{N,T}}{\partial p_1} = \left(-\frac{1}{2} \right) \left(4p_1 - 3p_1^2 + 3\alpha p_1^2 - 1 \right) = 0$$

Therefore the optimal deviation price is

$$p_1 = \frac{\sqrt{3\alpha + 1} - 2}{3\,(\alpha - 1)},$$

which implies the following expected profit

$$\pi^{N,T} = \frac{\left(6\alpha - 2\sqrt{3\alpha + 1} - 2\right)\left(\sqrt{3\alpha + 1} - 2\right)}{54\,(\alpha - 1)^2}.$$

It is easy to check that $\pi_d^{T,T} \geq \pi^{N,T}$ for any $\alpha \geq 1$. Consequently, we can rule out first-stage deviations because they are less profitable than price deviations. As a consequence, there are no profitable deviations from the equilibrium path if and only if

$$\frac{\pi^{T,T}}{1 - \delta} \geq \pi_d^{T,T} + \frac{\delta^2}{1 - \delta} \pi^{T,T} \quad \Leftrightarrow \quad \delta \geq \underline{\delta} \approx 0.098259 \tag{18}$$

Next, we show the condition under which firms have no incentive to deviate from the punishment phase. Consider first the defecting firm. In this subgame, the unique profitable deviation strategy consists in allowing product experimentation and charging a price $p > 0$. Indeed, if both firms do not allow product experimentation, the two brands are perceived as perfect substitutes. Hence, if one firm charges a price $p = 0$, any price $p > 0$ entails zero profits. Therefore, focus on a deviation such that the deviating firm, say firm 1, allows experimentation and charges a positive price. Clearly, firm 1 manages to sell its product if and only if

$$\frac{1}{2} \leq \theta_1 - p_1 \quad \Rightarrow \quad \theta_1 \geq \frac{1}{2} + p_1.$$

This implies the following maximization problem

$$\max_{p_1 \geq 0} p_1 \left(\frac{1}{2} - p_1 \right),$$

whose first-order condition is

$$-\frac{1}{2} (4p_1 - 1) = 0 \quad \Rightarrow \quad p_1 = \frac{1}{4}.$$

Firm 1's expected profit is $\pi^{T,N} = 0.0625$. Hence, the deviator is willing to comply with the punishment code if and only if

$$\frac{\delta}{1-\delta} \pi^{T,T} \geq \pi^{T,N} + \frac{\delta^2}{1-\delta} \pi^{T,T} \quad \Leftrightarrow \quad \delta \geq \widehat{\delta} \approx 0.32476. \tag{19}$$

Hence, if (19) holds, (18) holds too.

Finally, we show that the punishment is credible — i.e., the punisher has no incentive to charge a price different than $p = 0$ after a first-stage deviation. If a firm, say firm 1, deviates in the first-stage in period τ, firm 2 (the punisher) has incentive to charge $p = 0$ within the deviation period if and only if

$$\frac{\delta}{1-\delta} \pi^{T,T} \geq \widetilde{\pi}^{N,T} + \frac{\delta^3}{1-\delta} \pi^{T,T}, \tag{20}$$

where $\widetilde{\pi}^{N,T}$ is the profit deriving from a deviation from the punishment code. Specifically, given the price $p_1 = \frac{1}{4}$ charged by the cheating firm, the punisher (firm 2) will manage to sell its product if and only if

$$\theta_1 - \frac{1}{4} \leq \mathbb{E}[\theta] - p_2 - \frac{(\alpha - 1) p_2^2}{2}.$$

Hence, firm 1's expected profit is

$$\widetilde{\pi}^{N,T} \equiv p_2 \times \left(\frac{1}{4} - p_2 + \frac{1}{2} - \frac{(\alpha - 1) p_2^2}{2} \right),$$

whose maximization yields the following first-order condition

$$\frac{3}{2}p_2^2 - 2p_2 - \frac{3}{2}\alpha p_2^2 + \frac{3}{4} = 0,$$

which implies

$$p_2 = \frac{\sqrt{2}\sqrt{9\alpha - 1} - 4}{6\left(\alpha - 1\right)},$$

and a profit

$$\widetilde{\pi}^{N,T} = \frac{2\left(18\alpha - 2\sqrt{2}\sqrt{9\alpha - 1} - 10\right)\left(\sqrt{2}\sqrt{9\alpha - 1} - 4\right)}{\left(72\alpha - 72\right)\left(6\alpha - 6\right)}. \tag{21}$$

Substituting (21) into (20), the deviation is unprofitable if and only if

$$\delta \geq \overline{\delta}\left(\alpha\right) \equiv \sqrt{\frac{\sqrt{3}}{72\left(\alpha - 1\right)^2}\left(\sqrt{2}\sqrt{9\alpha - 1} - 4\right)\left(18\alpha - 2\sqrt{2}\sqrt{9\alpha - 1} - 10\right) + \frac{1}{4}} - \frac{1}{2},$$

which is decreasing in α and lower than $\frac{1}{2}$ for every $\alpha \geq 1$. Hence, (20) also holds for some $\delta < \frac{1}{2}$. This concludes the proof. ■

References

[1] Abreu, D. (1986). "Extremal Equilibria of Oligopolistic Supergames". *Journal of Economic Theory*, 39(1), pp. 191-225.

[2] Abreu, D. (1988). "On the Theory of Infinitely Repeated Games with Discounting". *Econometrica*, 56(2), pp. 383-396.

[3] Anderson, S. P. and R. Renault (2006), "Advertising Content". *American Economic Review,* 96(1), pp. 93-113.

[4] Anderson, S. P. and R. Renault (2009), "Comparative advertising: disclosing horizontal match information". *RAND Journal of Economics,* 40(3), pp. 558-581.

[5] Boleslavsky, R., C. S. Cotton and H. Gurnani (2016), "Demonstrations and Price Competition in New Product Release". *Management Science,* forthcoming.

[6] Celik, L. (2014), "Information Unraveling Revisited: Disclosure of Horizontal Attributes". *Journal of Industrial Economics,* 62(1), pp. 113-136.

[7] Chang, M. (1991), "The Effects of Product Differentiation on Collusive Pricing". *International Journal of Industrial Organization*, 9(3), pp. 453-469.

[8] Che, Y. (1996), "Customer Return Policies for Experience Goods". *Journal of Industrial Economics*, 44(1), pp. 17-24.

[9] Colombo, S. (2013), "Product Differentiation and Collusion Sustainability When Collusion is Costly". *Marketing Science*, 32(4), pp. 669-674.

[10] Davis, S., E. Gerstner and M. Hagerty (1995), "Money Back Guarantees in Retailing: Matching Products to Consumer Tastes". *Journal of Retailing*, 71(1), pp. 7-22.

[11] Deneckere, R. (1983), "Duopoly Supergames with Product Differentiation". *Economics Letters*, 11(1-2), pp. 37-42.

[12] Deneckere, R. (1984), "Corrigendum". *Economics Letters*, 15(3-4), pp. 385-387.

[13] Fishman, M. J. and K. M. Hagerty (2003), "Mandatory Versus Voluntary Disclosure in Markets with Informed and Uninformed Customers". *Journal of Law, Economics & Organization*, 19(1), pp. 45-63.

[14] Friedman, J. (1971), "A Non-cooperative Equilibrium for Supergames". *Review of Economic Studies*, 38(1), pp. 1-12.

[15] Grossman, S. and O. D. Hart (1980), "Disclosure Law and Takeover Bids". *Journal of Finance*, 35(2), pp. 323-334.

[16] Grossman, S. (1981), "The Informational Role of Warranties and Private Disclosure about Product Quality". *Journal of Law & Economics*, 24(3), pp. 461-483.

[17] Grubb, M. D. (2015), "Selling to Loss Averse Consumers: A Survey". Mimeo BC.

[18] Gupta, B. and G. Venkatu (2002). "Tacit Collusion in a Spatial Model with Delivered Pricing". *Journal of Economics*, 76(1), pp. 49-64.

[19] Hahn, S. (2005), "Allowing a Pre-Purchase Product Trial in Duopoly". *Economics Letters*, 87(2), pp. 175-179.

[20] Heidhues, P. and B. Kőszegi (2008), "Competition and Price Variation When Consumers Are Loss Averse". *American Economic Review,* 98(4), pp. 1245-1268.

[21] Heiman, A., B. McWilliams, E. Z. Shen and D. Zilberman (2001), "Test Drives: Learning, Sorting, and Buying". *Working Paper* (No. 20114).

[22] Heiman, A., B. McWilliams and D. Zilberman (2001), "Learning and Forgetting: Modeling Optimal Product Sampling Over Time". *Management Science,* 47(4), pp. 532-546.

[23] Heiman, A. and E. Muller (1996), "Using Demonstration to Increase New Product Acceptance: Controlling Demonstration Time". *Journal of Marketing Research,* 33(4), pp. 422-430.

[24] Ivanov, M. (2013), "Information Revelation in Competitive Markets". *Economic Theory*, 52(1), pp. 337-365.

[25] Janssen, M. C. W. and S. Roy (2015), "Competition, Disclosure and Signalling". *Economic Journal,* 125, pp. 86-114.

[26] Janssen, M. C. W. and M. Teteryatnikova (2016), "Horizontal Product Differentiation: Disclosure and Competition". Forthcoming in *Journal of Industrial Economics.*

[27] Johnson, J. P. and D. P. Myatt (2006), "On the Simple Economics of Advertising, Marketing, and Product Design". *American Economic Review,* 96(3), pp. 756-784.

[28] Jovanovic, B. (1982), "Truthful Disclosure of Information". *Bell Journal of Economics*, 13(1), pp. 36-44.

[29] Kahneman, D., J. L. Knetsch and R. H. Thaler (1991), "Anomalies: the Endowment Effect, Loss Aversion and Status Quo Bias". *Journal of Economic Perspectives,* 5(1), pp. 193-206.

[30] Kahneman, D. and A. Tversky (1979), "Prospect Theory: an Analysis of Decision Under Risk". *Econometrica,* 47(2), pp. 263-291.

[31] Kahneman, D. and A. Tversky (1991), "Loss Aversion in Riskless Choice: A Reference-Dependent Model". *Quarterly Journal of Economics,* 106(4), pp. 1039-1061.

[32] Karle, H. and M. Peitz (2014), "Competition Under Consumer Loss Aversion". *RAND Journal of Economics,* 45(1), pp. 1-31.

[33] Koessler, F. and R. Renault (2012), "When Does a Firm Disclose Product Information?". *RAND Journal of Economics,* 43(4), pp. 630-649.

[34] Kőszegi, B. and M. Rabin (2006), "A Model of Reference-Dependent Preferences". *Quarterly Journal of Economics,* 121(4), pp. 1133-1165.

[35] Kőszegi, B. and M. Rabin (2007), "Reference-Dependent Risk Attitudes". *American Economic Review,* 97(4), pp. 1047-1073.

[36] Lambertini, L. and D. Sasaki (1999), "Optimal Punishments in Linear Duopoly Supergames with Product Differentiation". *Journal of Economics*, 69(2), pp. 173-188.

[37] Levin, D., J. Peck and L. Ye (2009), "Quality Disclosure and Competition". *Journal of Industrial Economics*, 57(1), pp. 167-196.

[38] Mailath, G., V. Nocke and L. White (2004), "When the Punishment Must Fit the Crime: Remarks on the Failure of Simple Penal Codes in Extensive-Form Games". *CEPR Discussion Paper* (No. 4793).

[39] Matsumura, T. and N. Matsushima (2005), "Cartel Stability in a Delivered Pricing Oligopoly". *Journal of Economics*, 86(3), pp. 259-292.

[40] Miklós-Thal, J. (2008), "Delivered Pricing and the Impact of Spatial Differentiation on Cartel Stability". *International Journal of Industrial Organization*, 26(6), pp. 1365-1380.

[41] Østerdal, L. P. (2003), "A Note on the Stability of Collusion in Differentiated Oligopolies". *Research in Economics*, 57(1), pp. 53-64.

[42] Piccolo, S., P. Tedeschi, and G. Ursino (2016), "Deceptive Advertising with Rational Buyers". Forthcoming in *Management Science.*

[43] Piccolo, S., P. Tedeschi, and G. Ursino (2015), "How Limiting Deceptive Practices Harms Consumers." *RAND Journal of Economics*, 46(3), pp. 611-624.

[44] Piccolo, S. and J. Miklós-Thal (2012), "Colluding Through Suppliers". *RAND Journal of Economics*, 43(3), pp. 492-513.

[45] Roberts, J. H. and G. L. Urban (1988), "Modeling Multiattribute Utility, Risk, and Belief Dynamics for New Consumer Durable Brand Choice". *Management Science*, 34(2), pp. 167-185.

[46] Rhodes, A., and C. M. Wilson (2015): "False Advertising and Consumer Protection Policy". Mimeo.

[47] Rosato, A. (2016), "Selling Substitute Goods to Loss-Averse Consumers: Limited Availability, Bargains, and Rip-offs". *RAND Journal of Economics*, 47(3), pp. 709-733.

[48] Ross, T. W. (1992), "Cartel Stability and Product Differentiation". *International Journal of Industrial Organization*, 10(1), pp. 1-13.

[49] Rothschild, R. (1992), "On the Sustainability of Collusion in Differentiated Duopolies". *Economics Letters*, 40(1), pp. 33-37.

[50] Shulman, J. D., A. T. Coughlan, and R. C. Savaskan (2011), "Managing Consumer Returns in a Competitive Environment" *Management Science*, 57(2), pp. 347-362.

[51] Sun, M. (2011), "Disclosing Multiple Product Attributes". *Journal of Economics & Management Strategies,* 20(1), pp. 195-224.

[52] Thomadsen, R. and K. Rhee (2007), "Costly Collusion in Differentiated Industries". *Marketing Science*, 26(5), pp. 660-665.

[53] Tyagi, R. K. (1999), "On the Relationship between Product Substitutability and Tacit Collusion". *Managerial and Decision Economics*, 20(6), pp. 293-298.

[54] Viscusi, W. K. (1978), "A Note on "Lemons" Markets with Quality Certification". *Bell Journal of Economics*, 9(1), pp. 277-279.

[55] Wernefelt, B. (1989). "Tacit Collusion in Differentiated Cournot Games". *Economics Letters*, 29(4), pp. 303-306.

[56] Zhou, J. (2011). "Reference Dependence and Market Competition". *Journal of Economics & Management Strategy*, 20(4), pp. 1073-1097.

1 Introduction

People often refrain from consuming experience goods because they are afraid of buying products not worth their price. The fear of making a bad purchase is particularly strong for loss averse consumers — i.e., individuals that prefer avoiding losses to making gains (e.g., Kahneman, Knetsch and Thaler, 1991, Kahneman and Tversky, 1979 and 1991). A recent and growing literature has started to study the implications of loss aversion both for consumer and firm behavior (see, e.g., Köszegi and Rabin, 2006 and 2007, Heidues and Köszegi, 2008, Karle and Peitz, 2014, Rosato, 2016, and Zhou, 2011, among others). But, these models mostly focus on static environments, while little is known on how firms react to consumer loss aversion in dynamic environments (Grubb, 2015). To contribute filling this hole, in this paper we analyze how consumer loss aversion affects the strategic use of product experimentation in a repeated game where firms selling products with uncertain (but ex post verifiable) characteristics compete to attract loss averse consumers.

Tests, product demonstrations, free-trial policies, return policies and any other marketing initiative that allows consumers to learn product characteristics and resolve valuation uncertainty before purchase, are usually seen as 'customer friendly' practices because they reduce (or even eliminate) the risk of bad purchases (e.g., Roberts and Urban, 1988). In the real world, consumers can often test many high-tech products — e.g., software, smartphones, tablets, laptops, printers, video-games, consoles and all their components, etc. (e.g., Heiman and Muller, 1996, Heiman, McWilliams and Zilberman, 2001, and Hahn, 2005). Similarly, in the car industry, many dealers regularly avail free drive-tests to their customers (e.g., Heiman *et al.*, 2001 and Roberts and Urban, 1988). Food and wine tasting initiatives are further notable examples (e.g., Hahn., 2005).

Yet, even if consumers are typically not charged for testing products before purchase, the information they are able to collect through these services might have hidden costs. The reason is simple: besides allowing people to better ground their choices, experimentation also creates (vertical) product differentiation by changing consumers' relative taste between products that, *behind the veil of ignorance*, appear as close (or even perfect) substitutes. Clearly, this softens competition and allows firms to charge non-competitive prices in equilibrium, whereby expropriating the informative benefits of experimentation (e.g., Hahn, 2005). Hence, regulatory rules that force experimentation may not necessarily benefit consumers, at least from a static standpoint.

To what extent this logic carries over to a dynamic environment in which firms interact repeatedly over time? Does experimentation facilitate or hinder collusion? How these incentives are affected by consumer loss aversion? To address these issues we study a simple (infinitely) repeated game in which two firms supplying experience goods compete to attract loss averse consumers that are (ex ante) uncertain about the fit between the characteristics of the products on sale and their needs (in brief, quality). To resolve this uncertainty, before the price-setting stage, firms can commit to allow consumers to freely test their products prior to sales (experimentation). When both firms do so (comparative experimentation) consumers can make purchasing decisions based not only on price differences, but also on the relative fit between product characteristics and their needs (in other words, on their relative taste). Within this framework, we investigate how consumer loss aversion influences firms' incentive to use experimentation as a collusive device, and analyze the resulting effects on consumer welfare.

Loss aversion has interesting effects already in the static environment. We show that, for low degrees of loss aversion, the stage game features a unique symmetric equilibrium in which firms randomly choose their experimentation policy. By contrast, for high degrees of loss aversion, the game features a unique symmetric equilibrium in which firms allow experimentation with certainty. The intuition is straightforward. When consumers are sufficiently loss averse, a firm has no incentive to deviate from a candidate equilibrium with comparative experimentation because consumers require a substantial price discount to buy a product with unknown characteristics. Hence, a deviation to a non experimentation policy must be followed by a considerable price discount in order to attract customers. By contrast, if the degree of loss aversion is not too high, the same deviation becomes profitable because the deviating firm can successfully exploit monopoly power *vis-à-vis* customers, who after having tested the rival's product, find it not appealing. As explained before, consumers are always harmed by comparative experimentation in the stage game (see, Hahn, 2005, for a result in this spirit).

The existence of a mixed strategy equilibrium provides a novel managerial insight: it partly explains why firms producing similar products may adopt different experimentation policies. Notably, in contrast to some of their competitors, Apple, Samsung and Microsoft usually allow potential customers to test their new devices in dedicated showrooms (Boleslavsky *et al.*, 2016). Similarly, in the car and the software industries not all companies allow customers to test their products.

The picture becomes considerably more complex when considering the repeated game. The analysis shows that, depending on the regulatory regime in place — i.e., whether experimentation is forbidden, mandated or allowed but not imposed (*laissez-faire*) — the degree of consumer loss aversion has ambiguous effects both on the profits that firms can achieve through implicit collusion, and on the stability of these agreements.

Concerning stability, we derive the following results. First, we show that implicit collusion is easier to sustain when experimentation is mandated relative to the regime in which it is forbidden. The reason is that deviating in the regime with mandatory tests is (other things being equal) less profitable than in the regime in which tests are forbidden. Indeed, while in the latter case a deviating firm is able to obtain the monopoly profit (due to a standard undercutting logic), in the former it earns less than the monopoly profit due to product differentiation — i.e., it is harder to attract consumers that value relatively more the rival's product. Second, other things being equal, we show that collusion is easier to sustain when experimentation is mandated relative to the *laissez-faire* regime. The reason is again straightforward: under *laissez-faire*, firms can deviate not only by undercutting the collusive price, but also by changing experimentation policy, which (by revealed preferences) secures a higher deviation profit. Third, when comparing the *laissez-faire* regime with that in which experimentation is forbidden we show that, ceteris paribus, collusion is easier to sustain under *laissez-faire* if and only if consumers are sufficiently loss averse (the opposite result holds otherwise).

Therefore, the regulatory regime that maximizes the scope for firms' cooperation is the one in which tests are compulsory. However, this regime is not necessarily the one that also maximizes firms' joint profit. Specifically, the analysis highlights a trade off between stability and profitability of collusion. We show that the regime that maximizes firms' joint profit from cooperation is the one in which experimentation is forbidden when consumers are not too loss averse. By contrast, when consumers are sufficiently loss averse, joint profit is higher when comparative experimentation is viable. This shows that implicit collusion is more likely to involve experimentation when consumers are particularly loss averse — i.e., when other things being equal, the benefits of experimentation are considerably important for them. By contrast, cooperation does not require experimentation when consumers are not too loss averse. Hence, our analysis suggests that tests, product demonstrations, free-trial policies etc., might be interpreted as a signal of price fixing in markets where consumers are particularly loss averse and product characteristics are difficult to ascertain before consumption — e.g., high-tech products, electronic devices, organic food, dietary supplements, etc. Overall, firms' equilibrium profits from collusion are (weakly) decreasing with the degree of consumer loss aversion.

Finally, as a normative exercise we study the effects of experimentation on consumer surplus. We show that the optimal policy for an Antitrust Authority, whose objective is to maximize consumer welfare, depends in an ambiguous manner on the model parameters. Forcing experimentation is harmful to consumers when firms are unable to collude regardless of the regulatory regime in place — i.e., for sufficiently low discount factors. The reason is simple, (vertical) product differentiation, as induced by comparative experimentation, conveys monopolistic power to firms, which charge prices above marginal costs in equilibrium. Hence, when firms are expected to play the static outcome of the game, the best policy from the consumers' point of view is to forbid experimentation so as to intensify competition and implement the Bertrand outcome. By contrast, when collusion is sustainable with a ban on experimentation, the optimal policy cannot forbid tests because, otherwise, firms would fully extract the surplus of the uninformed consumers.

In this case, forcing experimentation is an optimal policy when the consumer is not too loss averse and the discount factor is large enough. Conversely, a *laissez-faire* approach is optimal as long as firms collude through experimentation.

All our results are derived under the hypothesis that, in every regulatory regime, collusion is sustained by Nash reversion during the punishment phase. In an extension we show that when firms can punish deviations with harsher and more complex penal codes, *laissez-faire* is actually the regime that maximizes stability of collusive agreements, so it is never optimal for consumers. As a result, whenever experimentation maximizes consumer surplus, it must be mandated.

The rest of the paper is structured as follows. Section 2 relates our contribution to the existing literature. Section 3 sets up the baseline model. In Section 4 we report some preliminary results that will be useful for the equilibrium analysis both in the stage game and in its infinitely repeated version. In Section 5 we characterize the equilibrium of the model. For each regulatory regime we determine the critical discount factor above which firms are able to enforce joint profit maximization, and then analyze how product experimentation affects both stability and profitability of collusion. Finally, in Section 6, we study how the expected consumer surplus is affected by comparative experimentation. Section 7 extends the analysis to harsher punishments. Section 8 concludes. All proofs are in the appendix.

2 Related literature

Our paper contributes and is related to several strands of literature.

Loss-aversion and oligopolistic markets. Many recent papers analyze the effects of loss aversion on firm conduct in oligopolistic markets — see, e.g., Heidues and Köszegi (2008), Karle and Peitz (2014) and Zhou (2011) among others. This literature highlights the implications of loss aversion on strategic aspects such as firms' advertising and pricing behavior, and shares with us the idea that loss averse consumers must be either offered price discounts when they buy products with uncertain characteristics, or they need to be persuaded about the quality of the products they purchase through informative and/or persuasive advertising. Yet, all these models focus on static environment and little is known on the link between loss aversion and collusion (see, e.g., Grubb, 2015, for a survey). We complement this bulk of work precisely by studying how loss aversion affects firms ability to collude and the implications on their experimentation strategies.

Collusion and product differentiation. By studying how experimentation affects firms' ability to sustain implicit collusion, our paper is also related to the traditional IO literature dealing with price fixing under product differentiation. Starting with Deneckere (1983, 1984) and Wernefelt (1989), many models have shown that product differentiation helps firms to enforce implicit collusion.[1] These models do not consider loss aversion and usually take the degree of product differentiation as given, while in our model firms choose whether or not differentiate their products by means of experimentation. In contrast to these models, product differentiation has ambiguous effects in our environment. Specifically, it helps collusion only when comparing the regime with mandatory experimentation with that in which tests are forbidden. But, the opposite result obtains when considering the *laissez-faire* regime — i.e., the case in which firms are free to choose experimentation policy at any point in time. In this case, experimentation hinders collusion when consumers are sufficiently loss averse, and the opposite holds otherwise.

Gupta and Venkatu (2002) and Matsumura and Matsushima (2005) also obtain ambiguous results in a context of delivered pricing policies where collusion is sustained by Nash reversion.[2] Thomadsen and Rhee (2007) and Colombo (2013), instead, show that a negative relationship between firms' ability to collude and product differentiation obtains when firms need to invest sufficiently large resources in monitoring and coordination activities to enforce collusion.

Information disclosure and advertising. Our analysis also adds to the theoretical and policy debate on quality disclosure. There are many papers that deal with this issue. The main question they address is whether firms have an incentive to disclose information about product quality and how this information affects consumer welfare. It turns out that an important aspect of the problem is whether products are vertically or horizontally differentiated.

When products are vertically differentiated the unraveling result establishes that firms selling products of quality above the average will truthfully disclose the quality of their products to consumers. Hence, also firms below the average will disclose their quality, so that all private information is revealed in equilibrium through voluntary disclosure — see, e.g., Viscusi (1978), Grossman (1981), Grossman and Hart (1980), Jovanovic (1982), and Fishman and Hagerty (2003). By contrast, the unraveling logic might fail when frictions, such as disclosure costs, consumer cognitive costs etc., are taken into consideration — see, e.g., Grossman and Hart (1980), Jovanovic (1982), and Fishman and Hagerty (2003). In these cases a pooling equilibrium can emerge — i.e., quality is not disclosed and the market might break down. Recently, Janssen and Roy (2015) have shown that nondisclosure can also be explained by a combination of market competition and the availability of signaling as an alternative means (to disclosure) of communicating private information.

[1] See, for example, Chang (1991), Lambertini and Sasaki (1999), Østerdal (2003), Ross (1992), Rothschild (1992) and Tyagi (1999) among many others.

[2] In the same framework, Miklós-Thal (2008) came to an opposite conclusion with optimal punishment.

With horizontal differentiation the unraveling result might fail even without frictions — see, e.g., Anderson and Renault (2006, 2009), Celik (2014), Ivanov (2013), Janssen and Teteryatnikova (2016) Johnson and Myatt (2006), Koessler and Renault (2012) and Sun (2011).

Although these models share with us the idea that quality disclosure might have important effects on competition by changing consumers' perception of competing product brands, they only take a static perspective. The only exception is Levin *et al.* (2009). As we do, they also set up a repeated game in which two cartel members must decide how much information to disclose about product quality. They show that cartels tend to be more transparent than competitive industries since (on equilibrium path) colluding firms can afford more easily the fixed cost of disclosure. By contrast, in our model, experimentation has ambiguous effects on consumer welfare, which depend (among other things) on the regulatory regime in place. Overall, all these models are silent on the impact of consumer loss aversion. One important difference between our set-up and this stream of literature is that firms are uninformed about the quality of their products in our model: in this sense, experimentation can be viewed as a form of informative advertising, even though in such a framework disclosure cannot not be driven by an unraveling logic, but rather by dynamic considerations.

Return policies. Finally, there exists a literature in marketing and IO studying the cost and benefits of return policies and money back guarantees. These instruments can be obviously seen as a specific forms of experimentation. In these models customers purchase items with incomplete information that is later resolved via postpurchase inspection. Return policies reduce customer risk, which allows retailers to raise prices, but a customer will return an item if the price exceeds her ex post valuation, which will reduce demand. Che (1996) and Shulman *et al.* (2009) show that retail information about product fit (i.e., tests, product demonstrations etc.) can serve the same role as postpurchase inspection (see, also, Davis *et al.*, 1995, for an application to money back guarantees). As a result, customers may have a higher willingness to pay in the absence of product information than with additional information. Again, all these models are static, do not consider consumer loss aversion and neglect the effect of return policies on collusion.

3 The model

Players. Consider an infinitely repeated game in which two firms ($i = 1, 2$) compete by setting prices. For simplicity, and with no loss of insights, assume that in every period ($\tau = 1, 2, .., +\infty$) there is only one (representative) consumer willing to purchase at most one unit of product. Consumers exit the market after consumption and are uncertain about how well the goods on sale satisfy their needs: each consumer only knows that, in period τ, consuming firm i's product yields utility θ_i^τ, which distributes on the support $[0,1]$ with cdf $F(\theta_i^\tau)$. For brevity, we will sometimes refer to θ_i^τ as to quality.

Following the literature — e.g., Köszegi and Rabin (2006) and Heidhues and Köszegi (2008) — we assume that consumers are loss averse. Hence, *behind the veil of ignorance* — i.e., when buying a product of unknown characteristics — the preferences of a consumer who purchases firm i's product at price p_i^τ are described by the following gain-loss utility

$$u^N(p_i^\tau) \equiv \underbrace{\int_{p_i^\tau}^1 (\theta_i^\tau - p_i^\tau)\, dF(\theta_i^\tau)}_{\text{Expected gain from purchase}} + \alpha \underbrace{\int_0^{p_i^\tau} (\theta_i^\tau - p_i^\tau)\, dF(\theta_i^\tau)}_{\text{Expected loss from purchase}}, \quad i = 1,2 \quad \tau = 1,2,..,+\infty. \tag{1}$$

The first integral in the left-hand-side of (1) reflects the gain in product satisfaction that occurs when quality exceeds the price — i.e., $\theta_i^\tau \geq p_i^\tau$. By contrast, the second integral in the left-hand-side of (1) reflects the expected loss that occurs when quality is not worth the price — i.e., $\theta_i^\tau < p_i^\tau$. Essentially, since consumers are ex ante uncertain about product quality, but learn it after consumption, their willingness to pay is determined by the comparison between the gain and the loss they expect to experience after purchase. The parameter $\alpha \geq 1$ represents the degree of loss aversion: the higher α, the more loss averse consumers are. For simplicity, we assume that α is time invariant, so that it is the same for all consumers.

Nevertheless, firms can allow consumers to test their products before purchase, which drastically changes consumers' expected utility. For simplicity, we posit that, once consumers test a product, valuation uncertainty resolves completely. That is, when allowed to test (experiment) a product (say firm i's product), consumers learn its quality. Hence, the expected utility that a consumer obtains when he tests a product i is

$$u^T(p_i^\tau) \equiv \int_0^1 \max\{0, \theta_i^\tau - p_i^\tau\}\, dF(\theta_i^\tau), \quad i = 1,2 \quad \tau = 1,2,..,+\infty.$$

Without loss of generality, we normalize consumers' outside option to zero, and assume that when indifferent between accepting and refusing an offer, consumers break the tie by choosing the former option.

Regulatory environment. To better highlight the policy implications of the model, we consider three alternative regulatory regimes: the first in which experimentation is banned; the second in which experimentation is mandated; the third in which firms face no restrictions on the use they make of experimentation (*laissez-faire*). Hence, under *laissez-faire* firms can potentially change experimentation policy at any period of the game or, to foster cooperation, they might adopt different policies in the collusive and the punishment phases (as we will see below).

Timing. In each period $\tau \geq 1$ the stage game is as follows:

T $=$ **1** Firms decide simultaneously, and publicly, whether to allow experimentation (provided that it is legal).

T $=$ **2** Firms simultaneously post prices.

T $=$ **3** Consumers observe prices and experimentation choices, and decide whether to test or not products (if legal). Then, they decide whether to buy or not, and which firm to patronize.

This sequential timing applies to environments in which prices are relatively more flexible than experimentation policies (see e.g., Boleslavsky *et al.*, 2016). In practice, planning product experimentation usually require time and effort, while prices can quickly and easily adjust in response to own and rivals' testing policies.

Assumptions. Firms are long lived and maximize the discounted sum of future profits over an infinite horizon, using the common discount factor $\delta \in (0, 1)$. There is perfect monitoring: any price deviation is detected in the next stage of the game following the one in which it occurred. Notice that our model is a repeated extensive-form (rather than normal-form) game since experimentation choices are observed before the price-setting stage. Hence, punishments of first-stage deviations might begin within the deviation period, which implies that the details of the punishment code can affect the price that the deviating firm can charge in the second stage. We discuss more in detail the punishment code as we go along the analysis. The equilibrium concept is Subgame Perfect Nash Equilibrium (SPNE).

To simplify exposition we also impose the following additional assumptions.

A1 Tests are costless both for the firms and the consumers.

Assumption **A1** allows us to focus exclusively on the strategic aspects of experimentation. Introducing fixed costs of experimentation would not alter qualitatively our conclusions.

A2 Qualities are drawn from independent uniform distributions — i.e., $F(\theta_i^\tau) = \theta_i^\tau$ for $i = 1, 2$ and $\tau = 0, 1, .., +\infty$.

Assumption **A2** allows us to obtain tractable closed-form solutions.

A3 Firms are uninformed about how well their products fit consumers' needs — i.e., at any stage $\tau \geq 1$, they do not know how well their goods satisfy the consumers' needs.

This assumption reflects the idea that, often in real life, 'quality' is a subjective assessment that each consumer makes of the characteristics of a product once it has experienced it. Formally, **A3** rules out signaling issues: firms cannot signal quality since they do not know it. The strategic aspects of signaling through advertising and/or prices has been largely addressed in the literature (see, e.g., Piccolo *et al.*, 2015 and 2016 for a competitive model and Rhodes and Whilson, 2016, for the monopoly case)

A4 Firms' technologies feature constant returns to scale. Marginal costs are normalized to zero.

4 Preliminaries

To begin with, we first establish some useful properties of consumer and firm behavior in the stage game.

Lemma 1 *Consumers always test products when they are entitled to do so.*

The intuition is straightforward. For given prices, consumers cannot be harmed by testing products: tests are costless and allow consumers to avoid buying products not worth their price. Hence, we can focus (without loss of generality) on equilibria in which consumers always test products when they are entitled to do so.

Next, for given experimentation policies, we derive the equilibrium prices of the corresponding price-setting subgame.

Proposition 1 *If both firms impede experimentation, the price-setting subgame has a unique Nash equilibrium in which the price is equal to the marginal cost — i.e.,* $p^{N,N} = 0$.

When experimentation is forbidden by both firms, the consumer perceives the two goods as perfect substitutes. Hence, a standard undercutting logic leads to the Bertrand outcome.

By contrast, when both firms allow experimentation, the consumer patronizes firm i if and only if his participation constraint is satisfied — i.e.,

$$u(\theta_i, p_i) \geq 0 \quad \Leftrightarrow \quad \theta_i \geq p_i \quad i = 1, 2,$$

and the product offered by firm i is preferred to the rival's one — i.e.,

$$u(\theta_i, p_i) \geq u(\theta_j, p_j) \quad \Leftrightarrow \quad \theta_i - \theta_j \geq p_i - p_j, \quad i, j = 1, 2.$$

Firm i's expected profit is:

$$\pi_i^{T,T}(p_i, p_j) = p_i \times \underbrace{\int_{p_i}^{1} (\theta_i + p_j - p_i)\, d\theta_i}_{\Pr[\theta_i - \theta_j \geq p_i - p_j] \cap \Pr[\theta_i \geq p_i]}, \quad i, j = 1, 2,$$

whose maximization yields the following upward-sloping best-reply function

$$p_i^T(p_j) \equiv \frac{2}{3}(1 + p_j) - \frac{1}{3}\sqrt{2p_j + 4p_j^2 + 1} \quad i, j = 1, 2.$$

Therefore:

Proposition 2 *If both firms allow experimentation, the price-setting subgame has a unique Nash equilibrium in which both firms charge* $p^{T,T} \equiv \sqrt{2} - 1 > 0$.

When both products can be tested, the equilibrium price does not depend on α since quality is revealed before purchase — i.e., uncertainty about product characteristics is resolved before purchase. The equilibrium price is larger than marginal cost because comparative experimentation generates (vertical) product differentiation. Hence, each firm can extract some surplus from the consumer when he likes relatively more its product.

Finally, when only one firm (say firm i) allows experimentation, the consumer patronizes that firm if and only if

$$u(\theta_i, p_i) \geq 0, \quad i = 1, 2,$$

and

$$u(\theta_i, p_i) \geq u(p_j) \quad \Leftrightarrow \quad \theta_i \geq \underline{\theta}(p_i, p_j) \equiv \frac{1}{2} + p_i - p_j - \frac{(\alpha - 1)\, p_j^2}{2}, \quad i, j = 1, 2.$$

Hence, firm i's expected profit is

$$\pi_i^{T,N}(p_i, p_j) = p_i \times \underbrace{\left(p_j - p_i + \frac{1}{2} + \frac{(\alpha - 1)\, p_j^2}{2}\right)}_{\Pr[\theta_i \geq \underline{\theta}(p_i, p_j)]}, \tag{2}$$

whose maximization yields an upward-sloping best-reply function

$$p_i^{T,N}(p_j) \equiv \frac{2p_j + p_j^2(\alpha - 1) + 1}{4}. \tag{3}$$

By the same token, it can be readily shown that firm j's expected profit is

$$\pi_j^{N,T}(p_j, p_i) \equiv p_j \times \underbrace{\left(p_i - p_j + \frac{1}{2} - \frac{(\alpha - 1)p_j^2}{2}\right)}_{\Pr[\theta_i \leq \underline{\theta}(p_i, p_j)]}, \tag{4}$$

whose maximization yields the following upward-sloping best-reply function

$$p_j^{N,T}(p_i) \equiv \frac{\sqrt{3\alpha + 6p_j(\alpha - 1) + 1} - 2}{3(\alpha - 1)}. \tag{5}$$

Taken together, conditions (3) and (5) imply the following result.

Proposition 3 *If only firm i allows experimentation, the price-setting subgame has a unique Nash equilibrium in which*

$$p_i = p^{T,N} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha - 2} - 13}{25(\alpha - 1)} \geq p_j = p^{N,T} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha - 2} - 13}{5(\alpha - 1)} - 2. \tag{6}$$

The firm that allows experimentation charges a higher price in equilibrium because, by testing the product before purchase, the consumer does not bear the risk of a bad purchase. Figure 1 shows that both prices are decreasing in α.

The reason why the price charged by the firm that does not allow experimentation is also decreasing in α is fairly intuitive: the more loss averse the consumer is, the higher is the price discount that firms must offer in order to induce the consumer to purchase a product of uncertain quality. Since prices are strategic complements, this explains why the price of the firm that allows experimentation is decreasing in α too.

5 Equilibrium analysis

5.1 Static outcome

We now characterize the equilibrium of the stage game, which determines the punishment profit under Nash reversion. A first obvious observation is that there cannot exist an equilibrium in pure

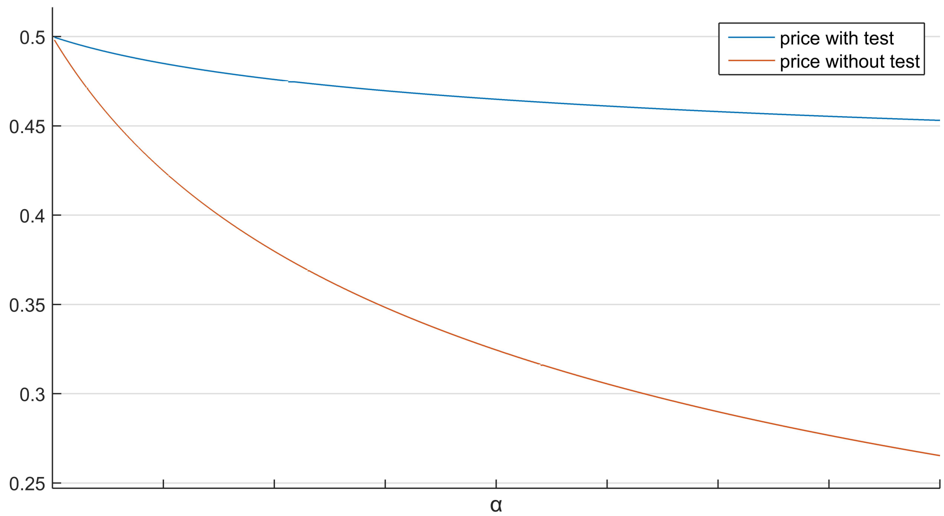


Figure 1: Equilibrium prices with asymmetric testing strategies

strategies without experimentation. Indeed, if the consumer cannot test products before purchase, he perceive the two brands as perfect substitutes and Bertrand competition leads firms to price at marginal cost. As a consequence, a firm has an incentive to deviate by allowing experimentation and charge a price (slightly) larger than marginal cost. This is profitable because the probability of making a sale is always larger than zero for the deviating firm, and when this occurs it makes positive profits.

Consider now the candidate equilibrium in which both firms allow experimentation. In the previous section, we have already characterized the price emerging in this scenario. Substituting $p^{T,T}$ into the profit function we have

$$\pi^{T,T} \equiv 3 - 2\sqrt{2}.$$

In order to check that this is an equilibrium, $\pi^{T,T}$ has to be compared with the profit that a firm obtains by deviating to no experimentation in the first stage. Substituting the prices obtained in (6) into the profit function (4), we have

$$\pi^{N,T} \equiv \frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha - 2})(\sqrt{3}\sqrt{5\alpha - 2} - 3)}{250\,(\alpha - 1)^2}. \tag{7}$$

It can be shown that $\pi^{N,T}$ is decreasing in α: the deviating firm must offer a higher discount as the consumer becomes more loss averse in order to induce him to buy a product with unknown characteristics. We can thus establish the following:

Lemma 2 *There exists a threshold* $\alpha^* > 1$ *such that* $\pi^{T,T} \geq \pi^{N,T}$ *if and only if* $\alpha \geq \alpha^*$.

Hence, the stage game features a pure strategy SPNE with comparative experimentation as long as the consumer is sufficiently loss averse. In this region of parameters, a deviation from the equilibrium candidate in the first stage must be followed by a considerable price discount in the second stage to attract the consumer. By contrast, if the degree of loss aversion is not too high, the deviation is profitable because it is sufficient to allow the consumer to test only one product in order to create enough differentiation between the two brands. In this case, the deviating firm can exploit monopoly power in the sates of nature where the consumer finds the rival's product unappealing.

What happens when α is sufficiently low? Clearly, there are no symmetric equilibria in pure strategies because an equilibrium in which both firms impede experimentation cannot exist either (as explained before). Hence, in this region of parameters, the game may feature a symmetric equilibrium in which firms randomize in the first stage. Suppose this is true, the rule according to which they allow experimentation is determined by the following indifference condition

$$\beta\pi^{T,T} + (1-\beta)\,\pi^{T,N} = \beta\pi^{N,T}, \tag{8}$$

where $\beta \in (0,1)$ is the probability according to which firms allow experimentation.

Using the results of the previous section, is easy to check that the profit a firm obtains when it allows experimentation, while the rival does not, is

$$\pi^{T,N} \equiv \frac{(5\alpha - 20 + 3\,(5\alpha-2) + 2\sqrt{3}\sqrt{5\alpha-2})(10\alpha - 13 + \sqrt{3}\sqrt{5\alpha-2})}{1250\,(\alpha-1)^2}. \tag{9}$$

As shown in Figure 2 below, this profit is always decreasing in α. The more loss averse the consumer is, the lower the price offered by the firm that impedes experimentation will be. Since prices are strategic complements, this results in lower equilibrium prices and profits for both both firms.

Let $\beta(\alpha)$ be the solution of (8). We can state the following result.

Proposition 4 *For* $\alpha \geq \alpha^*$, *the stage game has a unique symmetric pure strategy SPNE in which both firms allow experimentation. By contrast, for* $\alpha < \alpha^*$ *the stage game features a unique symmetric SPNE in which firms play mix strategies in the first stage: each firm allows experimentation with probability* $\beta(\alpha) \in (0,1)$, *such that* $\beta'(\alpha) > 0$ *and* $\beta(\alpha^*) = 1$.

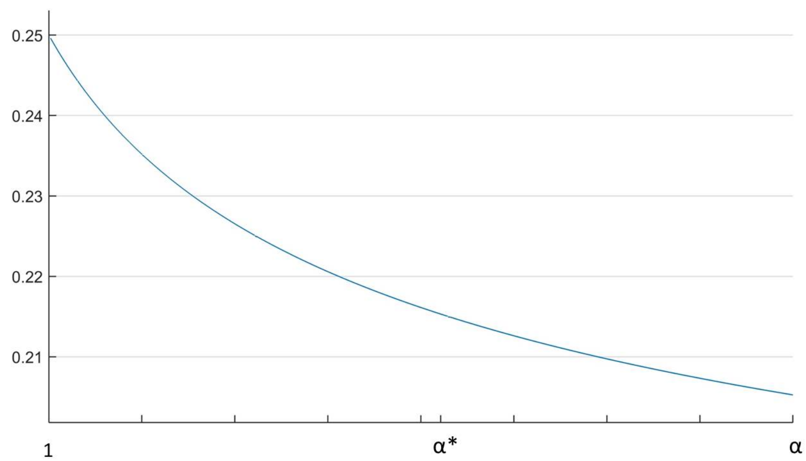


Figure 2: Firm i's profit when it is the only one to allow the test

The reason why the probability of allowing experimentation is increasing in the degree of consumer's loss aversion is straightforward. Large values of α imply that, when purchasing a product with unknown characteristics, the consumer values relatively more the expected loss than the expected gain. Hence, other things being equal, a larger α implies a lower willingness to pay for products of uncertain characteristics. This reduces equilibrium prices when only one firm allows experimentation, reduces profits, and therefore it increases the probability with which firms allow experimentation in equilibrium. Figure 3 below illustrates the relationship between $\beta(\alpha)$ and α.

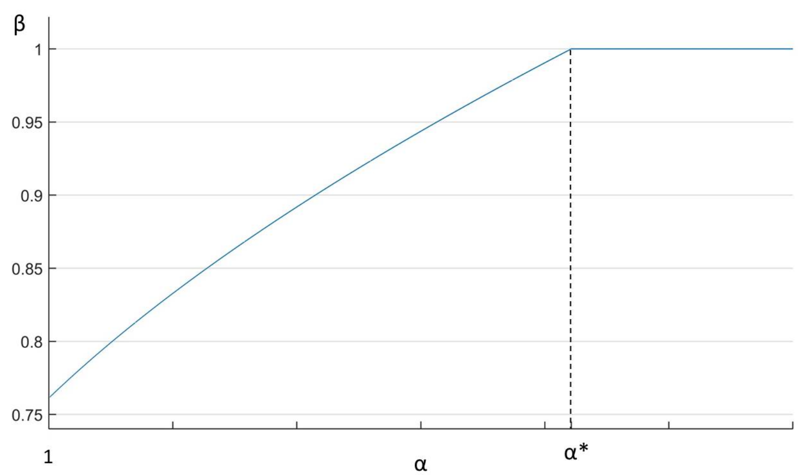


Figure 3: Relationship between $\beta(\alpha)$ and α

It is immediate to see that $\beta(\alpha) = 1$ for $\alpha \geq \alpha^* \approx 3.1$, whereas $\beta(\alpha) \in (0,1)$ for $\alpha < \alpha^*$.

Figure 4 below, instead, plots the equilibrium (expected) profit of the stage game — i.e., $\pi(\alpha) \equiv \beta(\alpha)\pi^{T,T} + (1-\beta(\alpha))\pi^{T,N}$.

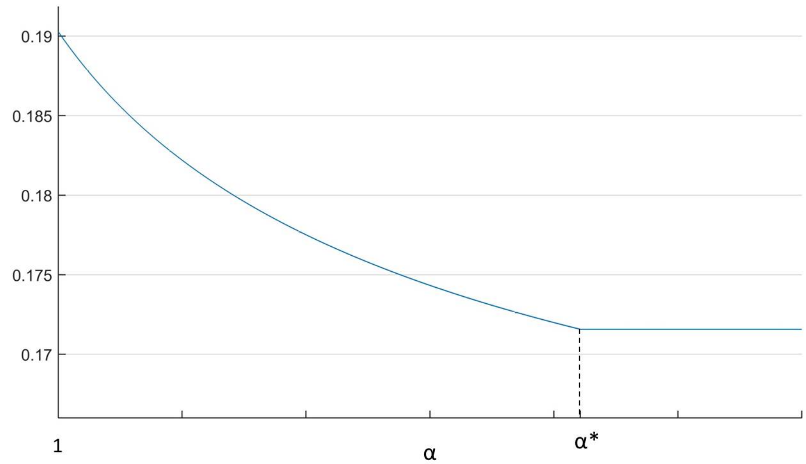


Figure 4: Profit function of the stage game

As intuition suggests, firms' equilibrium profit is weakly decreasing in α: competition is more intense when the consumer is relatively more loss averse because he needs to be offered a lower price in order to be willing to buy a product of unknown quality. Since firms randomize over the experimentation choice, also the expected (equilibrium) profit must fall as α grows large.

5.2 Repeated game

We can now turn to analyze firms' joint profit maximization behavior in the repeated game. In so doing, we restrict attention to symmetric and stationary strategies such that, depending on the regulatory regime in place, in each period firms decide whether or not allowing the consumer to test their products and quote a price that maximizes their joint profit. We assume that co-operation is sustained through 'Nash reversion'. Specifically, if a firm announces an unexpected experimentation policy, or undercuts the collusive price, both firms revert to play 'competitively' in every subgame following the deviation. Note that, since the stage game is sequential — i.e., firms observe each other experimentation policy before setting prices — a firm that deviates to an unexpected experimentation policy in period τ triggers an earlier reaction by inducing the rival to price competitively already in period τ at the price-setting stage.

5.2.1 Collusion with forbidden experimentation

As explained before, when experimentation is forbidden consumers perceive the two products as perfect substitutes. Hence, we can state the following intuitive result.

Proposition 5 *When experimentation is forbidden, joint profit maximization is sustainable if and only if* $\delta \geq \delta_{FT} \equiv \frac{1}{2}$.

On equilibrium path, firms charge a price that fully extracts the consumer's surplus — i.e.,

$$u^N(p^c) = \int_{p^c}^{1} (\theta_i - p^c)\, d\theta_i + \alpha \int_{0}^{p^c} (\theta_i - p^c)\, d\theta_i = 0,$$

yielding a price

$$p_{FT}^c \equiv \frac{\sqrt{\alpha} - 1}{\alpha - 1}. \tag{10}$$

Each firm's expected profit is

$$\pi_{FT}^c \equiv \frac{\sqrt{\alpha} - 1}{2(\alpha - 1)}. \tag{11}$$

As intuition suggests, the collusive price and profit are both decreasing in α.

5.2.2 Collusion under mandatory experimentation

Consider now the regime with mandatory experimentation — i.e., the regime in which firms are forced by an Authority to allow consumers to test their products before purchase. For any symmetric price p charged by both firms, the consumer makes a purchase if and only if

$$\max\{\theta_1, \theta_2\} \geq p.$$

Hence, the joint-profit maximization problem is

$$\max_{p \in [0,1]} p \times \Pr[\max\{\theta_1, \theta_2\} \geq p] \equiv \max_{p \in [0,1]} p \times \left(\int_p^1 \theta_1 d\theta_1 + \int_p^1 \theta_2 d\theta_2 \right).$$

Figure 5 below shows how the probability of selling one of the two products (which can be interpreted as a downward-sloping market demand curve) reacts to a change in the collusive price.

Essentially, if the collusive price is equal to zero — i.e., the lower bound of the support of the random variables θ_1 and θ_2 — the market demand is equal to 1, otherwise it is decreasing in the collusive price.

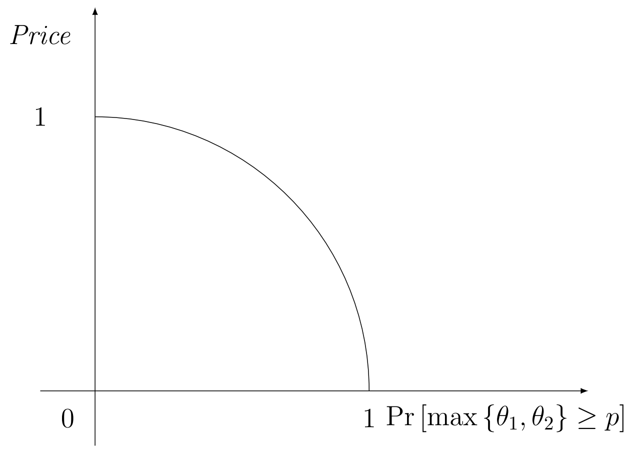


Figure 5: Demand function with mandatory tests

The price that maximizes firms' joint-profit is

$$p^c_{MT} \equiv \frac{\sqrt{3}}{3} \in (0, 1). \tag{12}$$

Hence, in the collusive phase each firm's expected profit is

$$\pi^c_{MT} \equiv \frac{\sqrt{3}}{9}.$$

Exactly as in a standard monopoly problem, when experimentation is mandatory, joint profit maximization requires firms to restrict quantity and choose a price high enough to induce the consumer not to buy in some (but not all) states of nature. By contrast, firms will never charge more than 1, as this would imply market breakdown.

Next, consider a deviation. Clearly, with mandatory tests, firms can only deviate at the pricing-setting stage. Suppose that firm i deviates by charging a price different than p^c_{MT}. The optimal deviation (say p^d_{MT}) solves

$$\max_{p\in[0,1]} p \times \underbrace{\int_p^1 \left(\theta_i - p + p^c_{MT}\right) d\theta_i}_{\Pr\left[\theta_i - \theta_j > p - p^c_{MT}\right] \cap \Pr\left[\theta_i > p\right]}, \tag{13}$$

whose first-order condition immediately yields

$$p^d_{MT} \equiv \frac{2\left(1 + p^c_{MT}\right) - p^c_{MT}\sqrt{7 + 2\sqrt{3}}}{3}. \tag{14}$$

Substituting p^d_{MT} and p^c_{MT} in equation (13), it can be shown that

$$\pi^d_{MT} \equiv p^d_{MT} \times \int_{p^d_{MT}}^{1} \left(\theta_i - p^d_{MT} + p^c_{MT}\right) d\theta_i > \pi^c_{MT}.$$

Finally, consider the punishment phase. With mandatory experimentation, following a deviation, Nash reversion implies that firms play the equilibrium of the stage game in which both allow experimentation for the rest of the game. Accordingly, they charge $p^{T,T}$ and earn $\pi^{T,T}$ during punishment.

Summing up, with mandatory experimentation, joint profit maximization is sustainable if and only if the following inequality holds

$$\frac{\pi^c_{MT}}{1-\delta} \geq \pi^d_{MT} + \frac{\delta}{1-\delta}\pi^{T,T}. \tag{15}$$

We can state the following result.

Proposition 6 *When experimentation is mandatory, joint profit maximization is sustainable if and only if $\delta \geq \delta_{MT}$, with $\delta_{MT} < \frac{1}{2}$ being the solution of (15).*

Note that joint profit maximization is easier to sustain when experimentation is mandated relative to the regime in which it is forbidden. Although deviations are punished more harshly when experimentation is forbidden (a punishment effect), deviating in the regime with mandatory tests is (other things being equal) less profitable than in the regime in which tests are forbidden (a deviation effect). This is because while in the latter regime the deviating firm is able to obtain the monopoly profit (due to a standard undercutting logic), in the former regime the deviating firm earns less than the monopoly profit because products are differentiated. The deviation effect outweighs the punishment effect.

5.2.3 Collusion under *laissez-faire*

Finally, suppose that firms face no restrictions on whether they should allow or impede tests. Do firms enforce joint-profit maximization with or without comparative experimentation? The answer to this question is not obvious. The reason is that, in this case the punishment phase might be different than in the two previous regimes. Indeed, when consumers are not too loss averse, firms play mixed strategies during punishment. Hence, a priori, it is not clear whether firms prefer to collude with or without experimentation.

Colluding via experimentation. Consider first the case in which collusion is enforced via comparative experimentation. On equilibrium path, firms allow consumers to test their products and, if a deviation occurs, they revert to the equilibrium of the stage game characterized in Proposition 4.

In this case, both firms charge a price equal to p^c_{MT} on equilibrium path, and each obtains π^c_{MT}. Yet, there are two types of deviations that a firm can envision with *laissez-faire*. First, a firm could deviate by changing experimentation policy, and then charge the equilibrium price of the subsequent price-setting stage (see, i.e., Section 4). Second, a firm can announce the expected experimentation policy, but deviate subsequently at the price-setting stage. Hence, the deviation profit is

$$\pi^d_{LF} \equiv \max\left\{\pi^d_{MT}, \pi^{N,T}\right\},$$

which leads to the following result.

Lemma 3 *There exists a threshold $\widehat{\alpha} > 1$ such that $\pi^d_{LF} = \pi^{N,T}$ if $\alpha \leq \widehat{\alpha}$, and $\pi^d_{LF} = \pi^d_{MT}$ otherwise.*

The intuition is straightforward. If consumers are sufficiently loss averse, they are (relatively) more willing to pay for products that can be tested before purchase. Hence, a deviating firm must allow experimentation, otherwise it would have to offer a considerable price discount in order to convince people to purchase a product of unknown quality — i.e., a product that cannot be tested prior to sale.

Summing up, cooperation is enforced via experimentation if and only if

$$\frac{\pi^c_{MT}}{1-\delta} \geq \pi^d_{LF} + \frac{\delta}{1-\delta}\pi\left(\alpha\right).$$

Notice that, compared with the regime in which tests are mandatory, the degree of consumer loss aversion impacts the stability of a collusive agreement under *laissez-faire*. The reason is that, in the regime under consideration, firms play mixed strategies during the punishment phase when $\alpha < \alpha^*$.

Proposition 7 *Under laissez-faire, joint-profit maximization is sustainable with experimentation if and only if $\delta \geq \delta^T_{LF}\left(\alpha\right)$, with $\delta^T_{LF}\left(\alpha\right) \in [\delta^T_{MT}, 1)$ being decreasing in α.*

While collusive profits do vary with α because there is no valuation uncertainty under comparative experimentation, deviation and punishment profits unambiguously fall as α grows large (as discussed before). Figure 6 below provides a graphical illustration of $\delta^T_{LF}\left(\alpha\right)$.

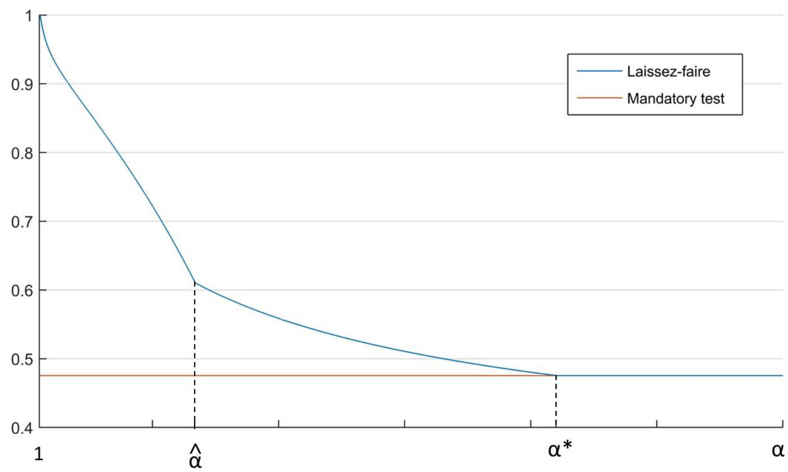


Figure 6: Critical discount factor when firms collude via comparative experimentation

Finally, collusion is easier to sustain when experimentation is mandatory relative to *laissez-faire* because: (i) under *laissez-faire*, firms can deviate not only by undercutting the collusive price, but also by changing experimentation policy; (ii) the punishment profit is higher under *laissez-faire* than under mandatory tests.

Colluding without experimentation. Consider now the case in which firms collude without experimentation. As seen before, the price that maximizes their joint profit is p^c_{FT}. So that, each firm sells with probability $\frac{1}{2}$ and earns π^c_{FT}. Off equilibrium path, there are again two feasible deviations. In defection, a firm can either change experimentation policy right away, by allowing experimentation, so to obtain $\pi^{T,N}$. Alternatively, it can stick to no experimentation and then undercut p^c_{FT} in the price-setting stage, which yields the monopoly profit $2\pi^c_{FT}$. Hence, the deviation profit is

$$\pi^d_{LF} \equiv \max\left\{2\pi^c_{FT}, \pi^{T,N}\right\},$$

which leads to the following result.

Lemma 4 *There exists a threshold* $\widetilde{\alpha} > 1$ *such that* $\pi^d_{LF} = 2\pi^c_{FT}$ *if* $\alpha \leq \widetilde{\alpha}$ *and* $\pi^d_{LF} = \pi^{T,N}$ *otherwise.*

As already explained before, the larger the degree of loss aversion, the higher the valuation that consumers assign to a product that cannot be tested. Hence, it is optimal to deviate by allowing experimentation when α is sufficiently large.

Summing up, under *laissez-faire*, cooperation is enforced without experimentation if and only if

$$\frac{\pi^c_{FT}}{1-\delta} \geq \pi^d_{LF} + \frac{\delta}{1-\delta}\pi(\alpha).$$

We can state the following result.

Proposition 8 *Under laissez-faire, there exists a threshold* $\alpha^N \in (\alpha^*, \widetilde{\alpha})$ *such that joint-profit maximization is sustainable without experimentation if and only if* $\delta \geq \delta^N_{LF}(\alpha)$ *and* $\alpha \leq \alpha^N$*, with* $\delta^N_{LF}(\alpha) \in (\delta^T_{MT}, 1]$ *being increasing in* α*.*

Differently than before, without experimentation it is relatively harder to collude when consumers are more loss averse (see Figure 7 below).

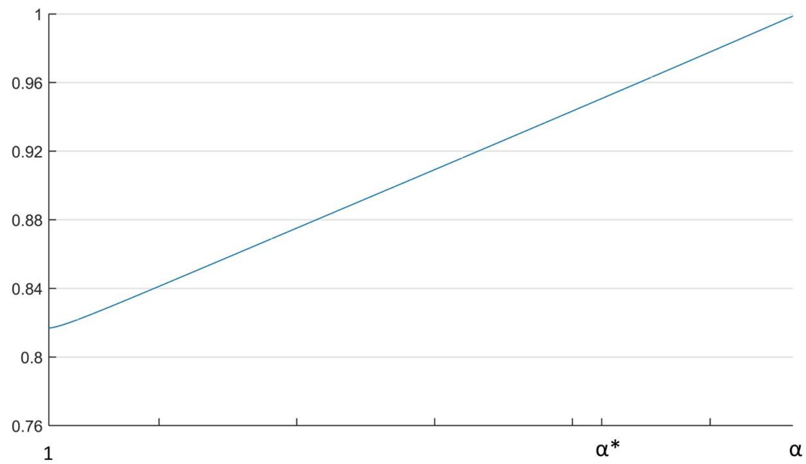


Figure 7: Critical discount factor when firms collude without experimentation

Indeed, although deviation and punishment profits drop when α increases, the prevailing effect is on the equilibrium profit: when α grows large, firms that do not allow experimentation must lower considerably the price they charge since consumers require a higher premium to buy products of uncertain quality. Figure 7 below shows how the critical discount factor $\delta^N_{LF}(\cdot)$ varies with α.

Optimal collusion. Building on the previous analysis, we can now characterize the optimal collusive scheme under *laissez-faire*. To this purpose, we first study how comparative experimentation affects firms' expected profit from cooperation, then we determine how it impacts stability — i.e., the critical discount factor above which collusion can be sustained.

Lemma 5 *There exists a threshold* $\overline{\alpha} > 1$ *such that* $\pi^c_{MT} \geq \pi^c_{FT}$ *if and only if* $\alpha \geq \overline{\alpha}$*.*

The intuition is straightforward. The more loss averse consumers are, the less firms can extract from them (even in collusion). Essentially, when consumers are not too loss averse, collusion without experimentation yields a higher profit to firms because the gain of preventing product differentiation more than compensates the cost of awarding discounts to consumers that purchase products of uncertain characteristics.

What about self-enforceability? In the next lemma we show that if consumers are sufficiently loss averse, collusion is not only relatively more profitable with experimentation, but it is also easier to sustain.

Lemma 6 *There exists a threshold $\underline{\alpha} \in (1, \overline{\alpha})$ such that, under laissez-faire, experimentation facilitates collusion if and only if $\alpha > \underline{\alpha}$ — i.e., $\delta_{LF}^{T}(\alpha) < \delta_{LF}^{N}(\alpha)$ if and only if $\alpha > \underline{\alpha}$.*

There are two effects pointing in the same direction. In addition to the fact that the difference between collusive profits with and without experimentation is increasing in the degree of consumer loss aversion, deviating from an equilibrium sustained via comparative experimentation is less profitable also because (other things being equal) a firm has a lower chance to attract relatively more loss averse consumers when its product cannot be tested before purchase.

Gathering Lemma (5) and Lemma (6) together, we can state the following.

Proposition 9 *Under laissez-faire, joint-profit maximization does not require experimentation if $\alpha \in [1, \overline{\alpha})$ and $\delta \geq \delta_{LF}^{N}(\alpha)$. Otherwise, when it is feasible, collusion requires experimentation.*

Figure 8 below represents graphically firms' optimal strategies conditional on the discount factor in the industry and the degree of consumer loss aversion.

This figure highlights the region of parameters in which experimentation is used as collusive device. Provided that the discount factor is not too small, colluding via comparative experimentation is both more profitable and easier to sustain for high degrees of loss aversion. By contrast, for intermediate values of loss aversion, sustaining collusion via experimentation is easier than without experimentation, but less profitable. Finally, for low values of loss aversion, colluding without experimentation is optimal. Of course, for low values of the discount factor, the outcome of the repeated game is the same as that of the stage game — i.e., cooperation is not feasible in every regulatory regime.

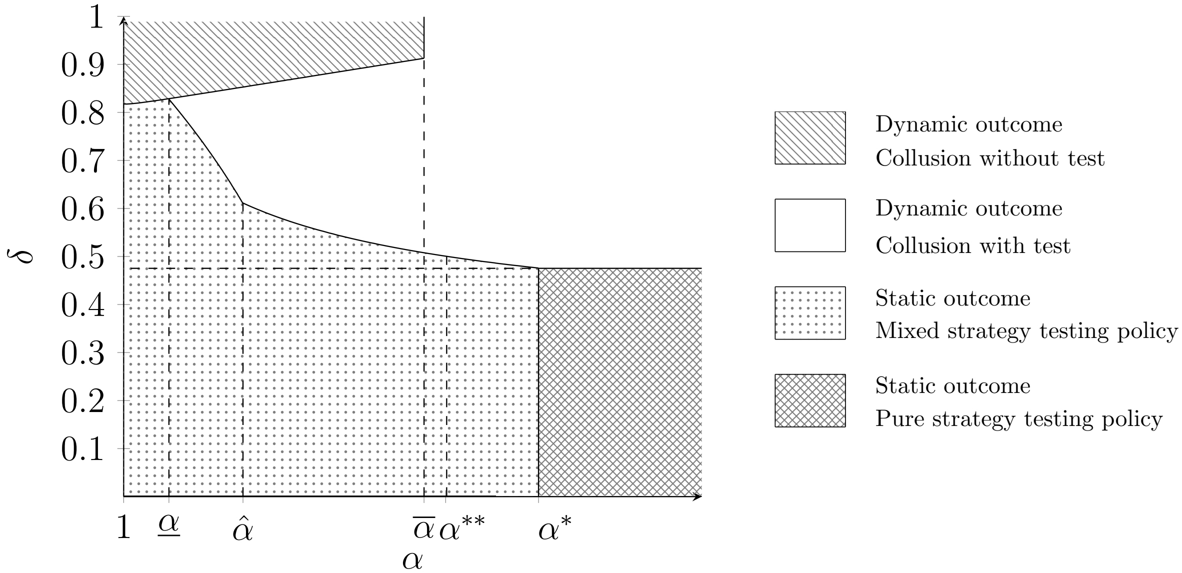


Figure 8: Optimal strategies under *laissez-faire* regime

6 Welfare implications

In this section we analyze the effects of comparative experimentation on consumers, and characterize the optimal policy for an Authority whose objective is to maximize consumer surplus.

Consider first the regime in which experimentation is forbidden. When collusion is not sustainable ($\delta < \frac{1}{2}$), firms price at marginal cost because products are perceived as perfect substitutes by the consumers. Hence, consumer welfare is simply equal to the expected quality (recall that we normalized marginal costs). Conversely, if collusion is sustainable, firms fully extract the consumer surplus. Hence, when tests are forbidden, consumer welfare is

$$u_{FT}(\delta) \equiv \begin{cases} 0 & \Leftrightarrow & \delta \geq \frac{1}{2} \\ \mathbb{E}[\theta] & \Leftrightarrow & \delta < \frac{1}{2} \end{cases}.$$

This proposition highlights an interesting trade off, which will be key for the rest of the analysis. By forbidding experimentation an Antitrust Authority maximizes consumer welfare if and only if collusion is not enforceable under this regime (since firms compete à la Bertrand). However, when collusion is viable, such a policy may actually deliver the worst possible outcome, because it enables firms to fully extract the consumer surplus.

Next, consider the regime in which experimentation is mandatory. In equilibrium, firms charge prices higher than marginal cost regardless of whether collusion can be sustained or not: comparative experimentation creates product differentiation, which relaxes competition and allows firms to exploit monopolistic power even in the static outcome. Recall that if both firms charge the same price, say p, the consumer surplus is

$$u^T(p) \equiv \int_p^1 (\theta_i - p)\,\theta_i d\theta_i + \int_p^1 (\theta_j - p)\,\theta_j d\theta_j.$$

Hence, when tests are mandatory, consumer welfare is

$$u_{MT}(\delta) \equiv \begin{cases} u^T(p^c_{MT}) = \frac{2}{3} - \frac{8}{27}\sqrt{3} > 0 & \Leftrightarrow \quad \delta \geq \delta_{MT} \\ u^T(p^{T,T}) = \frac{2}{3} - \frac{2}{3}(2-\sqrt{2}) > 0 & \Leftrightarrow \quad \delta < \delta_{MT} \end{cases},$$

where, as intuition suggests, collusion harms consumers — i.e., $u^T(p^c_{MT}) < u^T(p^{T,T})$.

There are two interesting points to highlight here. On the one hand, when collusion is not sustainable both with mandatory experimentation and in the regime where tests are forbidden, consumers are better off in the latter regime because experimentation relaxes price competition, while firms price competitively when it is banned. On the other hand, when collusion is feasible in both regimes, consumers prefer the regime with mandatory experimentation. The reason is simple: when products can be tested, consumers make more informed choices and, therefore, firms cannot fully extract their surplus as in the regime with forbidden tests — i.e., given prices, consumers purchase the product that better fits their taste.

Finally, consider the *laissez-faire* regime. This case is slightly more complex because firms can cooperate either through comparative experimentation or by preventing consumers to test products. In addition, when collusion is not sustainable, the stage game may either feature a pure strategy equilibrium in which both firms allow experimentation (if $\alpha < \alpha^*$), or an equilibrium in mixed strategies (if $\alpha \geq \alpha^*$), as shown in Proposition 4. When $\alpha < \alpha^*$ the consumer's surplus without collusion is the same as in the regime with mandatory test. By contrast, when $\alpha \geq \alpha^*$ consumer surplus must take into account firms' mixed strategies — i.e.,

$$u_{LF} = \beta(\alpha)^2 u^T(p^{T,T}) + (1-\beta(\alpha))^2 \mathbb{E}[\theta] +$$
$$+2\beta(\alpha)(1-\beta(\alpha)) \left[\int_{\underline{\theta}(p^{T,N},p^{N,T})}^1 \left(\theta - p^{T,N}\right) d\theta + \int_0^{\underline{\theta}\left(p^{T,N},p^{N,T}\right)} \left[\int_{p^{N,T}}^1 \left(\theta - p^{N,T}\right) d\theta + \alpha \int_0^{p^{N,T}} \left(\theta - p^{N,T}\right) d\theta \right] d\theta \right].$$

As illustrated in Figure 9 below, this expression (which is explicitly derived in the Appendix) is increasing in α. Again, more loss averse consumers pay lower prices to buy products of uncertain quality.

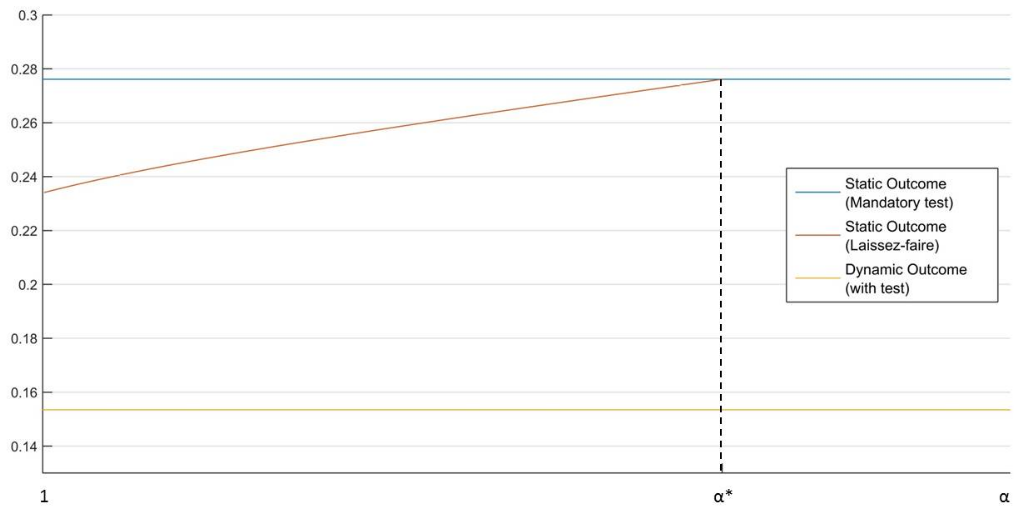


Figure 9: Expected consumer surplus if experimentations are not forbidden

Consider now the region of parameters in which firms collude. Consumer welfare depends on the optimal collusion rule, which may either require comparative experimentation or not depending on the degree of loss aversion α and the discount factor δ.

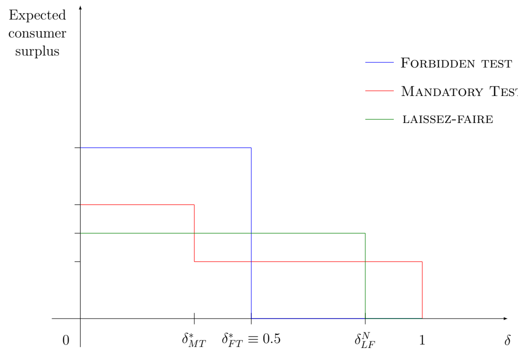
Suppose that $\alpha \in [1, \underline{\alpha}]$ and that $\delta \geq \delta_{LF}^{N}(\alpha)$. In this region of parameters joint profit maximization requires no experimentation as shown in Proposition 9. Hence, firms fully extract the consumer surplus.

Suppose now that $\alpha \in (\underline{\alpha}, \overline{\alpha})$. In this region of parameters firms maximize joint profits without experimentation. Hence, if $\delta \geq \delta_{LF}^{N}(\alpha)$, consumer surplus is still equal to zero. However, if collusion without experimentations is not enforceable — i.e., $\delta < \delta_{LF}^{N}(\alpha)$ — firms can still collude by allowing experimentation when $\delta \in \left[\delta_{LF}^{T}(\alpha), \delta_{LF}^{N}(\alpha)\right)$. In this case, consumer surplus is the same as in the case of mandatory experimentation.

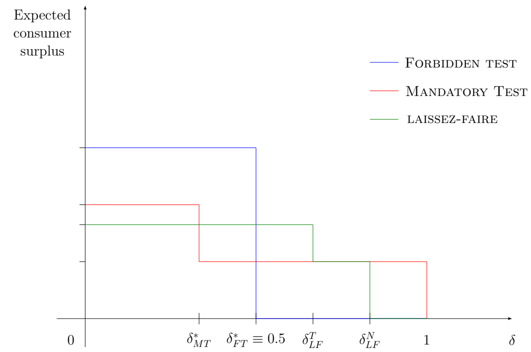
Finally, suppose that $\alpha \geq \overline{\alpha}$. In this region of parameters collusion is always enforced through experimentation because it yields higher profits and requires a lower discount factor to be self-enforceable. Hence, consumer surplus coincides with that obtained under mandatory experimentation.

What is the regulatory regime that maximizes consumers' well being? Figure 10 provides four illustrations of the consumer surplus for each parameter region of interest.[3]

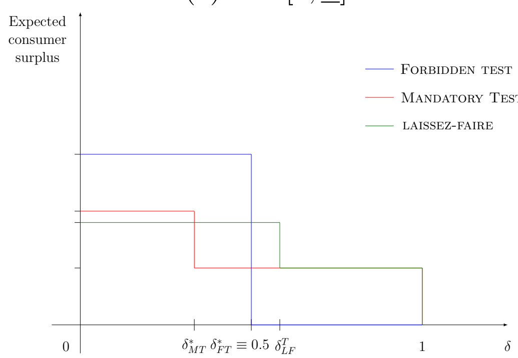
[3]We ruled out the interval of α, such that $\alpha \geq \alpha^*$. In fact, under *laissez-faire* firms have always incentive to allow the consumer to test their products. This means that this regime will coincide with that under mandatory experimentation.



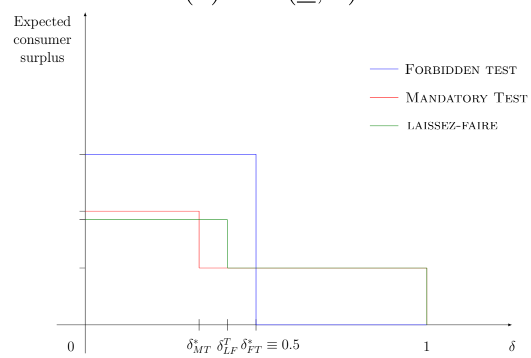
(a) $\alpha \in [1, \underline{\alpha}]$



(b) $\alpha \in (\underline{\alpha}, \overline{\alpha})$



(c) $\alpha \in [\overline{\alpha}, \alpha^{**}]$



(d) $\alpha \in (\alpha^{**}, \alpha^*)$

Figure 10: Expected consumer surplus

This leads to the following result.

Proposition 10 *For $\delta < \frac{1}{2}$ consumer surplus is maximized by a policy that forbids experimentation regardless of α. For $\delta \geq \frac{1}{2}$ comparative experimentation has a beneficial effect on consumer surplus. Specifically, for $\alpha \in [1, \overline{\alpha})$ and $\delta \geq \delta^N_{LF}(\alpha)$, the optimal policy is to force product experimentation. Otherwise, a laissez faire approach is optimal.*

Figure 11 below represents graphically the optimal policy as a function of α and δ.

Summing up, forcing experimentation is harmful to consumers when collusion is unviable regardless of the regulatory regime in place ($\delta < \frac{1}{2}$). Indeed, product differentiation, as induced by comparative experimentation, conveys monopolistic power to the firms who charge prices above marginal costs. Instead, a policy that forbids experimentation forces the Bertrand outcome.

By contrast, when firms are able to sustain collusion under the regulatory regime that forbids experimentation ($\delta \geq \frac{1}{2}$), the optimal policy must induce experimentation in equilibrium, otherwise firms would fully extract the consumer surplus. Interestingly, when consumers are not too loss

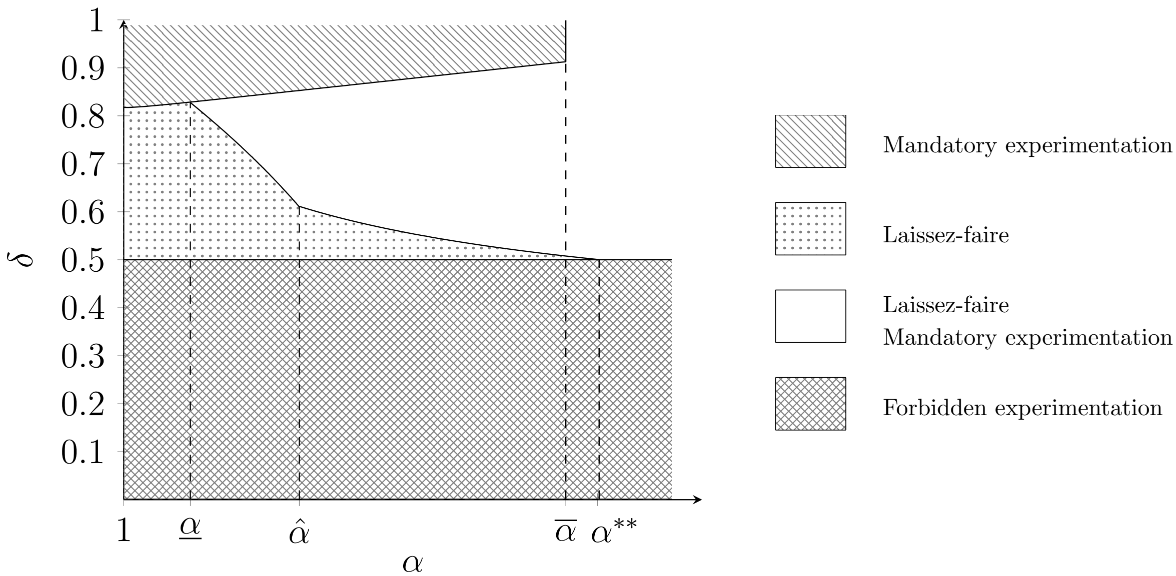


Figure 11: Optimal testing policy

averse ($\alpha < \overline{\alpha}$) and the discount factor is such that firms cooperate without experimentation in the *laissez-faire* regime ($\delta \geq \delta_{LF}^{N}(\alpha)$), the optimal policy must force experimentation. Conversely, if collusion is enforced via comparative experimentation, a *laissez-faire* approach is optimal because it hinders collusion and at the same time it avoids full surplus extraction. The dotted area of the graph represents the region of parameters in which *laissez-faire* is strictly better than any other regime: in this area it makes collusion unviable. By contrast, within the white area, firms collude via comparative experimentation under *laissez-faire*. Hence, the effect on consumer surplus coincides with that under mandatory experimentation — i.e., the two regimes yield the same consumer surplus and are thus both optimal.

7 Harsher punishment codes

In our model, Nash reversion is clearly an optimal punishment (i.e., the minmax) when consumers cannot test products before purchase. The same is not necessarily true under mandatory experimentation or *laissez-faire* since, in both these regimes, the stage game features an equilibrium in which firms make positive profits. In this section we show that, under *laissez-faire*, firms can use more complex punishment codes to sustain collusion via comparative experimentation in a wider range of discount factors relative to Nash reversion.

Before providing the result, it is important to notice that, unlike most of the existing models of tacit collusion, our model is a repeated extensive-form (rather than normal-form) game. Punishments of first-stage deviations begin within the deviation period, which implies that the details of the punishment code affect the price that the deviating firm can charge in the second stage. Unlike in repeated normal-form games where short-term deviation gains are independent of future play, the short-term deviation gain that can be achieved by means of a first-stage deviation thus depends on the exact nature of the punishment. Mailath, Nocke and White (2004) discuss the failure of simple penal codes (Abreu 1986, 1988) for repeated extensive-form games and show that it can be necessary to tailor the punishment to the nature of the deviation in order to sustain the desired equilibrium (see also Piccolo and Miklos-Thal, 2012).

To make our point in the simplest possible way, we consider the following penal code that firms use to sustain collusion via comparative experimentation:

(i) If a deviator unexpectedly does not allow experimentation in the first-stage of period τ, the rival (i.e., the punisher) prices at the marginal cost in the price-setting stage of the deviation period, while in period $\tau+1$ both firms do not allow experimentation and price at marginal cost. If both firms obey the punishment code, they go back to collusion for the rest of the game. If a deviation occurs at $\tau+1$ there is another round of punishment.

(ii) If a deviator does not allow experimentation in the first-stage of period τ and the punisher deviates by not charging a price equal to the marginal cost in the price-setting stage of period τ, then in periods $\tau+1$ and $\tau+2$ both firms do not allow experimentation and price at marginal cost. If both firms obey the punishment code, they go back to collusion for the rest of the game. Otherwise, there is another round of punishment.

(iii) If both firms allow experimentation but a price deviation occurs in the price-setting stage of period τ, then in period $\tau+1$ both firms do not allow experimentation and price at marginal cost. If both firms obey the punishment code, they go back to collusion for the rest of the game. Otherwise, there is another round of punishment.

This penal code has a very simple and intuitive structure. The main difference with the approach taken in repeated normal-form games is that the punisher can now deviate even at the price-setting stage of a period in which there has been a first-stage deviation. A penal code that does not hinge on Nash reversion needs to cope with this additional deviation from the punishment phase. Hence:

Proposition 11 *When firms use the penal code described by* $(i)-(iii)$*, they can sustain collusion with experimentation for some values of the discount factor (strictly) lower than* $\frac{1}{2}$*.*

This result has two interesting implications. First, the same logic can be applied to show that firms' ability to enforce collusion can also improve without experimentation when moving away from Nash reversion. Second, from a policy perspective, it implies that with punishment codes harsher than Nash reversion, a *laissez-faire* approach never improves consumer welfare relative to the other regimes. As explained before, under Nash reversion consumers prefer *laissez-faire* because (in this regime) punishment and deviation profits are (weakly) larger than in any other regime. Other things being equal, this clearly makes collusion more difficult to sustain. However, more complex punishment codes allow firms to actually play with the degree of flexibility offered by *laissez-faire* to reduce profits in the punishment phase, and make first-stage deviations less appealing by means of instantaneous price reactions harsher than simple Nash reversion. Clearly, this facilitates collusion and harms consumers.

8 Concluding remarks

The recent literature studying the link between consumer loss aversion and firm behavior has shown that surprising results on how companies price and market their products may emerge when behavioral aspects, such as loss minimization, are introduced in standard IO problems. In this article, we have contributed to this growing literature by highlighting novel aspects of the relationship between loss aversion and firm behavior in dynamic environments. In particular, our analysis contributes to better understand whether product experimentation hinders or facilitates firms cooperation, and how this relationships interplays with consumer loss aversion.

We have argued that, in repeated games, consumer loss aversion has important implications on the way firms selling experience goods use marketing instruments, such as tests, product demonstrations, free-trial and return policies, to achieve cooperative market outcomes, at the consumers' expense. One key element to understand how these instruments are used strategically to soften competition and foster market power, is determined by the regulatory regime in place. Specifically, depending on whether experimentation is forbidden, mandated or allowed but not imposed (*laissez-faire*), it turns out that the degree of consumer loss aversion has ambiguous effects on the profits that firms can achieve through implicit collusion, on the stability of these agreements, and even on consumer surplus.

We have shown that the regulatory regime that favors the most the emergence of collusive agreements is one in which firms are forced to allow consumers to experiment products before purchase. However, as we noted, this regime is not necessarily the one that maximizes joint profits, which highlights a novel trade off between stability and profitability of collusive agreements in markets for experience goods. Specifically, the regime that maximizes cooperative profits is the one in which experimentation is forbidden when consumers are not too loss averse. By contrast, when they are sufficiently loss averse, firm profits are higher when comparative experimentation is viable. As a result, collusive agreements should be more likely to involve experimentation in markets in which, other things being equal, the informative benefits of experimentation are considerably important for consumers.

The overall impact on consumer welfare is ambiguous too, which suggests that while in static environments a *laissez-faire* approach can only harm consumers, in a dynamic environment the opposite may happen insofar as leaving firms free to choose whether allowing perspective customers to test or not their products before purchase, hinders cartel stability and avoids full surplus extraction, which would occur when collusion is sustained without the help of experimentation. Notably, the optimality of *laissez-faire* falls apart when firms use punishment codes harsher than Nash reversion. If that is the case, the optimal policy requires either mandatory experimentation or it should forbid it.

A Appendix

Proof of Lemma 1. The proof of this result hinges on a straightforward revealed preferences argument. Testing products cannot harm consumers because by doing so they are able to pick the best option, including no purchase at all if this is optimal ex post. Suppose that firms allow the consumer to test their products. If the consumer decides to test neither product, he buys the one with lowest price (say firm i's product) and his expected utility is

$$u^{N,N}(p_i) = \int_{p_i}^{1} (\theta_i - p_i)\, dF(\theta_i) + \alpha \int_{0}^{p_i} (\theta_i - p_i)\, dF(\theta_i).$$

If the consumer test only one product (say firm i's product), his expected utility is

$$u^{T,N}(p_i, p_j) = \max \left\{ \int_{p_i}^{1} (\theta_i - p_i)\, dF(\theta_i);\, \int_{p_j}^{1} (\theta_j - p_j)\, dF(\theta_j) + \alpha \int_{0}^{p_j} (\theta_j - p_j)\, dF(\theta_j) \right\}.$$

Finally, testing both products yields the following expected utility

$$u^{T,T}(p_i, p_j) = \max \left\{ \int_{p_i}^{1} (\theta_i - p_i)\, dF(\theta_i);\, \int_{p_j}^{1} (\theta_j - p_j)\, dF(\theta_j) \right\}.$$

It is immediate to see that

$$u^{T,T}(p_i, p_j) \geq u^{T,N}(p_i, p_j) \geq u^{N,N}(p_i),$$

so that expected utility is maximized when the consumer tests both products. ■

Proof of Proposition 1. When experimentation is not viable, products are perceived as perfect substitutes. Hence, the equilibrium price follows immediately from a standard Bertrand logic. ■

Proof of Proposition 2. Suppose that both firms allow experimentation. The consumer patronizes firm i if and only if:

$$u(\theta_i, p_i) \geq 0 \quad \Leftrightarrow \quad \theta_i \geq p_i \quad i = 1, 2$$

and

$$u(\theta_i, p_i) \geq u(\theta_j, p_j) \quad \Leftrightarrow \quad \theta_i - \theta_j \geq p_i - p_j, \quad i, j = 1, 2.$$

Firm i's expected profit is

$$\pi_i^{T,T}(p_i, p_j) = p_i \times \int_{p_i}^{1} (\theta_i + p_j - p_i)\, d\theta_i, \quad i, j = 1, 2,$$

whose maximization yields the following first-order condition

$$2p_j - 4p_i + 3p_i^2 - 4p_i p_j + 1 = 0.$$

Hence, firm i's best reply is

$$p_i^T(p_j) \equiv \frac{2}{3}(1+p_j) - \frac{1}{3}\sqrt{2p_j + 4p_j^2 + 1} \quad i, j = 1, 2.$$

Imposing symmetry, the equilibrium price becomes $p^{T,T} \equiv \sqrt{2} - 1$. ■

Proof of Proposition 3. Suppose that only one firm (say i) allows experimentation. The consumer patronizes that firm if and only if

$$u(\theta_i, p_i) \geq 0, \quad i = 1, 2,$$

and

$$u(\theta_i, p_i) \geq u(p_j) \quad \Leftrightarrow \quad \theta_i - p_i \geq \int_{p_j}^{1} (\theta_j - p_j)\, d\theta_j + \alpha \int_0^{p_j} (\theta_j - p_j)\, d\theta_j, \quad i, j = 1, 2,$$

which implies

$$\theta_i - p_i \geq \frac{1}{2} - p_j - \frac{(\alpha-1)\, p_j^2}{2} \quad \Leftrightarrow \quad \theta_i \geq \frac{1}{2} + p_i - p_j - \frac{(\alpha-1)\, p_j^2}{2}, \quad i, j = 1, 2.$$

Hence, firm i's expected profit is

$$\pi_i^{T,N}(p_i, p_j) = p_i \times \left(p_j - p_i + \frac{1}{2} + \frac{(\alpha-1)\, p_j^2}{2}\right).$$

Maximizing with respect to p_i we have the following first-order condition

$$2p_j - 4p_i + 1 - p_j^2 + \alpha p_j^2 = 0,$$

which yields firm i's best reply is

$$p_i^{T,N}(p_j) \equiv \frac{2p_j + p_j^2(\alpha-1) + 1}{4}. \tag{16}$$

Applying the same logic, firm j's expected profit is

$$\pi_j^{N,T}(p_j, p_i) = p_j \times \left(p_i - p_j + \frac{1}{2} - \frac{(\alpha-1)\, p_j^2}{2}\right).$$

Maximizing with respect to p_i we have the following first-order condition

$$4p_j - 2p_i - 1 - 3p_j^2 + 3\alpha p_j^2 = 0,$$

which yields firm j's best reply is

$$p_j^{N,T}(p_i) \equiv \frac{\sqrt{3\alpha + 6p_i(\alpha-1)+1} - 2}{3(\alpha-1)}. \tag{17}$$

Substituting (17) into (16), and vice-versa, we have the following equilibrium prices

$$p^{T,N} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha-2} - 13}{25(\alpha-1)},$$

$$p^{N,T} \equiv \frac{10\alpha + \sqrt{3}\sqrt{5\alpha-2} - 13}{5(\alpha-1)} - 2.$$

Simple comparison between these expressions implies that $p^{T,N} \geq p^{N,T}$. ■

Proof of Lemma 2. Using the results obtained before, it can be easily verified that

$$\pi^{T,T} = 3 - 2\sqrt{2},$$

and

$$\pi^{N,T} = \frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2} - 3)}{250(\alpha-1)^2}.$$

Comparing these expressions, it turns out that $\pi^{T,T} \geq \pi^{N,T}$ if and only if

$$250(\alpha-1)^2(3-2\sqrt{2}) \geq (30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2} - 3),$$

It can be checked that this inequality is satisfied for any $\alpha \geq \alpha^* \approx 3.1$. ■

Proof of Proposition 4. Consider first a candidate equilibrium in which neither firm allows experimentation. In this case, products are viewed as perfect substitutes. Hence, Bertrand competition leads to a zero-profit outcome. However, both the firms have an incentive to deviate from this candidate equilibrium by allowing experimentation and charge a price (slightly) larger than marginal cost. Indeed, using $p^{T,N}$ and $p^{N,T}$ obtained before, it is easy to show that

$$\pi^{N,T} = \frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2} - 3)}{250(\alpha-1)^2} \geq 0 \quad \forall \alpha \geq 1.$$

Hence, there cannot exist a SPNE in which experimentation is not allowed.

Next, consider a candidate equilibrium in which both firms allow experimentation. As seen in the text, in this candidate equilibrium each firm obtains an expected profit equal to $\pi^{T,T} = 3 - 2\sqrt{2}$. We now check that firms have no incentive to deviate in the first period by choosing a different experimentation policy — i.e., $\pi^{T,T} > \pi^{N,T}$. By Lemma 2, this inequality is always satisfied for $\alpha > \alpha^*$.

Hence, suppose that $\alpha \leq \alpha^*$. In this region of parameters there does not exist a symmetric Nash equilibrium in pure strategies: each firm has an incentive to deviate by impeding experimentation, if the rival allows it. Therefore, consider a symmetric equilibrium in which each firm randomizes in the first stage by allowing experimentation with probability β. Such an equilibrium exist if and only if the solution with respect to β of the following equation

$$\beta \times \pi^{T,T} + (1-\beta)\,\pi^{T,N} = \beta \times \pi^{N,T},$$

is such that $\beta \in (0,1]$ for $\alpha \leq \alpha^*$.

Using the expressions for $\pi^{T,T}$, $\pi^{T,N}$ and $\pi^{N,T}$ obtained before, it follows that

$$\beta(\alpha) = \frac{(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)^2}{5\left[19\alpha\sqrt{3}\sqrt{5\alpha-2}+250\sqrt{2}-\alpha((500\sqrt{2}-641)+355\alpha-250\sqrt{2}\alpha)\right]-71\sqrt{3}\sqrt{5\alpha-2}-1502}.$$

As shown in Figure 3, it is easy to verify that this expression is increasing in α for every $\alpha \in [1, \alpha^*)$. ■

Proof of Proposition 5. In the regime with forbidden tests, collusion is sustainable if and only if

$$\frac{\pi^c_{FT}}{1-\delta} \geq \pi^d_{FT},$$

which implies immediately $\delta \geq \delta_{FT} \equiv \frac{1}{2}$. ■

Proof of Proposition 6. In the regime with mandatory tests, collusion is sustainable if and only if

$$\frac{\pi^c_{MT}}{1-\delta} \geq \pi^d_{MT} + \frac{\delta}{1-\delta}\pi^*_{MT},$$

where

$$\pi^d_{MT} = p^d_{MT} \times \int_{p^d_{MT}}^{1} \left(\theta_i - p^d_{MT} + p^c_{MT}\right) d\theta_i.$$

Substituting p^d_{MT} and p^c_{MT} in the profit function π^d_{MT}, we have $\pi^d_{MT} \approx 0.21136$. Hence, deviating from the collusive agreement is unprofitable if and only if $\delta \geq \delta_{MT} \approx 0.47532$. ■

Proof of Lemma 3. Suppose that firms collude through experimentation. What is the best deviation from this candidate equilibrium? As we have seen in the text, firms could change experimentation policy in the first stage of the game, with an expected profit equal to $\pi^{N,T}$, or announce the expected experimentation policy, but then deviate at the pricing-setting stage and gain an expected profit equal to π^d_{MT}. The best deviation requires no experimentation if and only if $\pi^{N,T} \geq \pi_{MT}^{d}$ — i.e.,

$$\frac{(30\alpha - 24 - 2\sqrt{3}\sqrt{5\alpha - 2})(\sqrt{3}\sqrt{5\alpha - 2} - 3)}{250\left(\alpha - 1\right)^{2}} \geq \frac{\sqrt{3}}{243} + \left[\frac{2}{81} + \frac{7\sqrt{3}}{243}\right]\sqrt{2\sqrt{3}+7} - \frac{1}{27}.$$

This inequality is satisfied for $\alpha \leq \widehat{\alpha} \approx 1.67$. Instead, if $\alpha > \widehat{\alpha}$, the best deviation consists in keeping the expected experimentation policy and then undercutting the collusive price. ■

Proof of Proposition 7. Under *laissez-faire*, if firms cooperate through experimentation, collusion is sustainable if and only if

$$\frac{\pi_{MT}^{c}}{1-\delta} \geq \pi_{LF}^{d} + \frac{\delta}{1-\delta}\pi^{*}.$$

The stage game may feature an equilibrium in mixed strategies. In that case, the expected profit during the punishment phase is

$$\pi^{*} = \beta\left(\alpha\right) \times \pi^{N,T}.$$

Substituting $\beta\left(\alpha\right)$ and $\pi^{N,T}$ into π^{*}, we have

$$\pi^{*} = \frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^{2}(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left[\alpha^{2}(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right](\alpha-1)^{2}}.$$

The stability of a collusive agreement is therefore affected by the degree of consumer loss aversion. Specifically, for $\alpha \leq \widehat{\alpha}$, the critical discount factor is

$$\delta_{LF}^{T}\left(\alpha\right) = \frac{\frac{(30\alpha-24-2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2}-3)}{250(\alpha-1)^{2}} - \frac{\sqrt{3}}{9}}{\frac{(30\alpha-24-2\sqrt{3}\sqrt{5\alpha-2})(\sqrt{3}\sqrt{5\alpha-2}-3)}{250(\alpha-1)^{2}} - \frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^{2}(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left(\alpha^{2}(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right)(\alpha-1)^{2}}}.$$

Instead, for $\alpha > \widehat{\alpha}$, the critical discount factor is

$$\delta_{LF}^{T}\left(\alpha\right) = \frac{0.21136 - \frac{\sqrt{3}}{9}}{0.21136 - \frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^{2}(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left[\alpha^{2}(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right](\alpha-1)^{2}}}.$$

Finally, for $\alpha > \alpha^{*}$, the punishment phase is characterized by a Nash Equilibrium in pure strategies, in which firms allow experimentation and charge $p^{*} = \sqrt{2} - 1$. Hence, the critical discount factor coincides with that in a regime with mandatory experimentation.

Deviation profits are clearly decreasing in α in the interval between 1 and $\widehat{\alpha}$. Specifically, the partial derivative is

$$\frac{\partial \pi^{N,T}}{\partial \alpha} = \frac{\frac{9}{2}\sqrt{3}-12\alpha\sqrt{3}+\frac{15}{2}\alpha^{2}\sqrt{3}-\frac{39}{5}\sqrt{5\alpha-2}+15\alpha\sqrt{5\alpha-2}+\sqrt{3}\sqrt{15\alpha-6}-\alpha\sqrt{3}\sqrt{15\alpha-6}+\frac{3}{5}\sqrt{5\alpha-2}\sqrt{15\alpha-6}-3\alpha\sqrt{5\alpha-2}\sqrt{15\alpha-6}}{25(\alpha-1)^{3}\left(\sqrt{5\alpha-2}\right)},$$

which is negative for any $\alpha > 1$. This makes collusion easier to sustain. Next, in order to show that $\delta_{LF}^{T}\left(\alpha\right) \in [\delta_{MT}^{T}, 1)$, it is sufficient to verify that the expected profit when firms mix in the first-stage is always larger than the profit they obtain when playing pure strategies — i.e.,

$$\frac{(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3)(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2})^2(3-\sqrt{3}\sqrt{5\alpha-2})}{375\left[\alpha^2(1775-1250\sqrt{2})+5\alpha(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right](\alpha-1)^2}>3-2\sqrt{2},$$

which always holds for $\alpha<\alpha^*$. ■

Proof of Lemma 4. Suppose that firms cooperate without experimentation. As discussed in the text, a deviator can either change experimentation policy in the first stage of the game, with an expected profit equal to $\pi^{T,N}$, or announce the expected experimentation policy, but then undercut the rival at the price-setting stage, gaining an expected profit equal to π^d_{FT}. It can be shown that $\pi^d_{FT}\geq\pi^{T,N}$ if and only if

$$\frac{\sqrt{\alpha}-1}{\alpha-1}\geq\frac{(5\alpha-20+3\left(5\alpha-2\right)+2\sqrt{3}\sqrt{5\alpha-2})(10\alpha-13+\sqrt{3}\sqrt{5\alpha-2})}{1250\left(\alpha-1\right)^2},$$

which is satisfied if and only if $\alpha\leq\widetilde{\alpha}\approx 19.39$. ■

Proof of Proposition 8. Under *laissez-faire*, if firms cooperate without experimentation, collusion is sustainable if and only if

$$\frac{\pi^c_{FT}}{1-\delta}\geq\pi^d_{LF}+\frac{\delta}{1-\delta}\pi^*.$$

Consider first $\alpha\leq\alpha^*$. In this region of parameters, firms play mixed strategies in the stage game. Hence, the critical discount factor is

$$\delta^N_{LF}\left(\alpha\right)=\frac{1}{2-\frac{2(\alpha-1)\left(15(\alpha-1)-\sqrt{3}\sqrt{5\alpha-2}+3\right)\left(10\alpha\sqrt{3}-13\sqrt{3}+3\sqrt{5\alpha-2}\right)^2\left(3-\sqrt{3}\sqrt{5\alpha-2}\right)}{375\left(\sqrt{\alpha}-1\right)(\alpha-1)^2\left(\alpha^2\left(1775-1250\sqrt{2}\right)+5\alpha\left(500\sqrt{2}-19\sqrt{3}\sqrt{5\alpha-2}-641\right)+71\sqrt{3}\sqrt{5\alpha-2}-1250\sqrt{2}+1502\right)}}.$$

Consider now $\alpha\in(\alpha^*,\widetilde{\alpha}]$. In this case, in the punishment phase firms allow experimentation with certainty. Hence, the critical discount factor is

$$\delta^N_{LF}\left(\alpha\right)=\frac{1}{2-\frac{2(\alpha-1)(3-2\sqrt{2})}{\sqrt{\alpha}-1}},$$

which is always positive and lower than 1 for $\alpha\leq\alpha^N\equiv 3.66$.

Finally, it can be shown that $\pi^c_{FT}\geq\pi^{T,N}$ for $\alpha\geq\alpha^N$. Hence, for $\alpha\geq\widetilde{\alpha}$ collusion is not viable without experimentation under *laissez-faire*. ■

Proof of Lemma 5. Assuming that collusion is always enforceable, colluding firms choose the experimentation policy which maximizes their joint profit. Specifically, collusive profit is higher with rather than without experimentation if and only if

$$\pi^c_{MT}\geq\pi^c_{FT}\quad\Leftrightarrow\quad\alpha\geq\overline{\alpha}\approx 2.55.\qquad\blacksquare$$

Proof of Lemma 6. Notice that $\delta^T_{LF}(\alpha)$ and $\delta^N_{LF}(\alpha)$ are respectively decreasing and increasing in α, with

$$\delta^T_{LF}(\alpha) < \delta^N_{LF}(\alpha) \quad \Leftrightarrow \quad \alpha > \underline{\alpha} \approx 1.31,$$

where $\widehat{\alpha} > \underline{\alpha}$. Hence, under *laissez faire*, comparative experimentation facilitates joint profit maximization if and only if $\alpha > \underline{\alpha}$. ■

Proof of Proposition 9. Suppose first that $\alpha \in [1, \underline{\alpha}]$. In this region of parameter $\delta^N_{LF}(\alpha) < \delta^T_{LF}(\alpha)$ (see Lemma **6).** This implies that collusion is easier to sustain without (rather than with) experimentation. Moreover, $\pi^c_{FT} > \pi^c_{MT}$ as shown in Lemma **5**. Hence,for $\alpha \in [1, \underline{\alpha}]$ and $\delta \geq \delta^N_{LF}(\alpha)$, joint-profit maximization does not require experimentation.

Next, suppose that $\alpha \in (\underline{\alpha}, \overline{\alpha})$. As shown in Lemma **5,** in this case it is still the case that $\pi^c_{FT} > \pi^c_{MT}$. However, in this range of parameters, experimentation facilitates collusion — i.e., $\delta^T_{LF}(\alpha) < \delta^N_{LF}(\alpha)$ by Lemma **6**. Hence, for $\alpha \in (\underline{\alpha}, \overline{\alpha})$ and $\delta \geq \delta^N_{LF}(\alpha)$, joint profit is maximized without experimentation. By contrast, if $\alpha \in (\underline{\alpha}, \overline{\alpha})$ and $\delta \in \left[\delta^T_{LF}(\alpha), \delta^N_{LF}(\alpha)\right)$, collusion is optimally enforced via comparative experimentation.

Finally, suppose that $\alpha \geq \overline{\alpha}$. In this case, $\pi^c_{FT} \leq \pi^c_{MT}$ as shown in Lemma **5.** Moreover, $\delta^T_{LF}(\alpha) < \delta^N_{LF}(\alpha)$ by Lemma **6**. Hence, for $\alpha \geq \overline{\alpha}$ and $\delta \geq \delta^T_{LF}(\alpha)$, firms collude through experimentation. ■

Consumer welfare. When tests are forbidden, the consumer's utility from purchasing firm i's product at price p_i is:

$$u(p_i) \equiv \int_{p_i}^{1} (\theta_i - p_i)\, d\theta_i + \alpha \int_{0}^{p_i} (\theta_i - p_i)\, d\theta_i, \quad i = 1, 2.$$

Hence, when $\delta < \frac{1}{2}$ collusion is not viable and the equilibrium price is $p^* = 0$ yielding

$$u(p_i = 0) \equiv \mathbb{E}[\theta] = \frac{1}{2}.$$

By contrast, if collusion is sustainable — i.e., $\delta \geq \frac{1}{2}$ — firms fully extract all the consumer surplus.

By contrast, when tests are mandatory, the consumer can realize the matching values of both products before purchase. Hence, evaluated at $p_i = p_j = p^*$ his expected utility is

$$u(p^*, p^*) \equiv \int_{p^*}^{1} [\theta_i - p^*]\, \theta_i d\theta_i + \int_{p^*}^{1} [\theta_j - p^*]\, \theta_j d\theta_j = \frac{2}{3} - \frac{2}{3}(2 - \sqrt{2}) \approx 0.27614$$

Instead, if collusion is sustainable — i.e., $\delta \geq \delta_{MT}$ — firms charge $p^c_{MT} = \frac{1}{3}\sqrt{3}$. Substituting p^c_{MT} into the consumer's utility function we have

$$u(p^c_{MT}, p^c_{MT}) \equiv \int_{p^c_{MT}}^{1} [\theta_i - p^c_{MT}]\, \theta_i d\theta_i + \int_{p^c_{MT}}^{1} [\theta_j - p^c_{MT}]\, \theta_j d\theta_j = \frac{2}{3} - \frac{8}{27}\sqrt{3} \approx 0.153\,47.$$

Proof of Proposition 10. Suppose first that $\delta < \frac{1}{2}$. In this case, collusion is not viable when tests are forbidden. Clearly, the consumer's expected utility is higher when tests are forbidden than with mandatory experimentation. Instead, under *laissez-faire*, the stage game may either feature a pure strategy equilibrium in which both firms allow experimentation with certainty ($\alpha > \alpha^*$), or an equilibrium in mix strategies ($\alpha \leq \alpha^*$). In the former case, the consumer's expected utility is clearly the same as in the regime with mandatory test. Instead, when $\alpha \leq \alpha^*$, it is equal to

$$\begin{aligned} u_{LF}(\alpha) &= \beta(\alpha)^2 \left(\tfrac{2}{3} - \tfrac{2}{3}(2-\sqrt{2})\right) + \frac{1}{2}(1-\beta(\alpha))^2 + \\ &\quad +2\beta(\alpha)(1-\beta(\alpha)) \left[\begin{array}{c} \left[\frac{4(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)}{25\alpha-25} + \frac{\alpha-1}{2}\left(\frac{5(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)}{25\alpha-25} - 2\right)^2 - \frac{5}{2}\right] \times \\ \left[\frac{10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13}{5(\alpha-1)} + \frac{\alpha-1}{2}\left(\frac{5(10\alpha+\sqrt{3}\sqrt{5\alpha-2}-13)}{25\alpha-25} - 2\right)^2 - \frac{5}{2}\right] + \\ + \frac{200\alpha^2-415\alpha+16\sqrt{3}\sqrt{5\alpha-2}-6\sqrt{3}(5\alpha-2)^{\frac{3}{2}}+20\sqrt{3}\alpha\sqrt{5\alpha-2}+161}{1250(\alpha-1)^2}. \end{array} \right]. \end{aligned}$$

It can be shown that $u_{LF}(\alpha)$ is weakly increasing in α, reaches its maximum for any $\alpha \geq \alpha^*$ (see Figure 9) and is always lower than $\frac{1}{2}$. Hence, the policy that maximizes consumer surplus is the one that forbids tests regardless of α.

Next, suppose that $\delta \geq \frac{1}{2}$. In this case, firms collude and fully extract the consumer surplus if experimentation is forbidden. Under *laissez-faire*, colluding without experimentation is an optimal strategy if $\alpha \in [1, \overline{\alpha})$ and $\delta \geq \delta_{LF}^{N}(\alpha)$. This means that, in the region of parameters under consideration, firms are still able to fully extract the consumer surplus. Conversely, forcing firms to allow the consumer to test their products yields a strictly positive surplus to the latter. As a result, the optimal policy is to force product experimentation.

We will show now that a *laissez-faire* approach is optimal otherwise. As shown in Lemma 6, $\delta_{LF}^{N}(\alpha) < \delta_{LF}^{T}(\alpha)$ if and only if $\alpha < \underline{\alpha}$. Moreover, using the expression for the discount factor, we have $\delta_{LF}^{N}(\alpha) > \frac{1}{2}$ for any α. When firms collude via experimentation the consumer's surplus is lower than in *laissez-faire* when collusion is not sustainable (see Figure 9). Hence, *laissez-faire* is the optimal policy if $\delta < \delta_{LF}^{N}(\alpha)$ and $\alpha < \underline{\alpha}$, because it prevents collusion.

Now, suppose that $\alpha \geq \underline{\alpha}$ and firms collude via experimentation. If $\delta \in \left[\delta_{LF}^{T}(\alpha), \delta_{LF}^{N}(\alpha)\right)$ the consumer's surplus coincides with that under mandatory experimentation. Instead, if $\delta < \delta_{LF}^{T}(\alpha)$ collusion is not enforceable and the consumer's surplus is always strictly positive. Moreover, the critical discount factor under *laissez-faire* is never lower than with mandatory test, as shown in Proposition 7.

Finally, notice that

$$\delta_{LF}^{T} > \frac{1}{2} \quad \Leftrightarrow \quad \alpha < \alpha^{**} \approx 2.65.$$

Hence, for $\alpha < \alpha^*$ colluding under *laissez-faire* is more difficult to sustain compared to the regime in which experimentation is forbidden. This implies that if $\delta < \delta_{LF}^{T}(\alpha)$, the *laissez-faire* regime is optimal. ■

Proof of Proposition 11. Consider the penal code described by properties $(i)-(iii)$ in the text.

The proof will proceed by showing that, under *laissez-faire*, all the self-enforceability conditions are slack at $\delta = \frac{1}{2}$ for every $\alpha \geq 1$, which implies that collusion via experimentation is sustainable for some $\delta < \frac{1}{2}$ regardless of α.

Hence, we need to check that: (a) no firm has an incentive to deviate from the collusive path; (b) no firm has an incentive to deviate from the punishment code.

As we have shown in the text, if a cheating firm deviates during the price-setting stage of the game, it earns $\pi_d^{T,T} \approx 0.21136$. Conversely, if a cheating firm, say firm 1, deviates in the first-stage of the game, the rival charges a price $p = 0$, as mandated by the penal code. Hence, firm 1 will manage to sell its product if and only if

$$\theta_2 \leq \frac{1}{2} - p_1 - \frac{(\alpha - 1)\, p_1^2}{2} \rightarrow \theta_2 \leq \frac{1}{2} - p_1 - \frac{(\alpha - 1)\, p_1^2}{2}.$$

This implies the following maximization problem

$$\max_{p_1} p_1 \times \left(\frac{1}{2} - p_1 - \frac{(\alpha - 1)\, p_1^2}{2} \right),$$

which yields the first-order condition

$$\frac{\partial \pi^{N,T}}{\partial p_1} = \left(-\frac{1}{2} \right) \left(4p_1 - 3p_1^2 + 3\alpha p_1^2 - 1 \right) = 0$$

Therefore the optimal deviation price is

$$p_1 = \frac{\sqrt{3\alpha + 1} - 2}{3\,(\alpha - 1)},$$

which implies the following expected profit

$$\pi^{N,T} = \frac{\left(6\alpha - 2\sqrt{3\alpha + 1} - 2\right)\left(\sqrt{3\alpha + 1} - 2\right)}{54\,(\alpha - 1)^2}.$$

It is easy to check that $\pi_d^{T,T} \geq \pi^{N,T}$ for any $\alpha \geq 1$. Consequently, we can rule out first-stage deviations because they are less profitable than price deviations. As a consequence, there are no profitable deviations from the equilibrium path if and only if

$$\frac{\pi^{T,T}}{1 - \delta} \geq \pi_d^{T,T} + \frac{\delta^2}{1 - \delta}\pi^{T,T} \quad \Leftrightarrow \quad \delta \geq \underline{\delta} \approx 0.098259 \tag{18}$$

Next, we show the condition under which firms have no incentive to deviate from the punishment phase. Consider first the defecting firm. In this subgame, the unique profitable deviation strategy consists in allowing product experimentation and charging a price $p > 0$. Indeed, if both firms do not allow product experimentation, the two brands are perceived as perfect substitutes. Hence, if one firm charges a price $p = 0$, any price $p > 0$ entails zero profits. Therefore, focus on a deviation such that the deviating firm, say firm 1, allows experimentation and charges a positive price. Clearly, firm 1 manages to sell its product if and only if

$$\frac{1}{2} \leq \theta_1 - p_1 \quad \Rightarrow \quad \theta_1 \geq \frac{1}{2} + p_1.$$

This implies the following maximization problem

$$\max_{p_1 \geq 0} p_1 \left(\frac{1}{2} - p_1 \right),$$

whose first-order condition is

$$-\frac{1}{2}(4p_1 - 1) = 0 \quad \Rightarrow \quad p_1 = \frac{1}{4}.$$

Firm 1's expected profit is $\pi^{T,N} = 0.0625$. Hence, the deviator is willing to comply with the punishment code if and only if

$$\frac{\delta}{1-\delta}\pi^{T,T} \geq \pi^{T,N} + \frac{\delta^2}{1-\delta}\pi^{T,T} \quad \Leftrightarrow \quad \delta \geq \widehat{\delta} \approx 0.32476. \tag{19}$$

Hence, if (19) holds, (18) holds too.

Finally, we show that the punishment is credible — i.e., the punisher has no incentive to charge a price different than $p = 0$ after a first-stage deviation. If a firm, say firm 1, deviates in the first-stage in period τ, firm 2 (the punisher) has incentive to charge $p = 0$ within the deviation period if and only if

$$\frac{\delta}{1-\delta}\pi^{T,T} \geq \widetilde{\pi}^{N,T} + \frac{\delta^3}{1-\delta}\pi^{T,T}, \tag{20}$$

where $\widetilde{\pi}^{N,T}$ is the profit deriving from a deviation from the punishment code. Specifically, given the price $p_1 = \frac{1}{4}$ charged by the cheating firm, the punisher (firm 2) will manage to sell its product if and only if

$$\theta_1 - \frac{1}{4} \leq \mathbb{E}[\theta] - p_2 - \frac{(\alpha - 1)p_2^2}{2}.$$

Hence, firm 1's expected profit is

$$\widetilde{\pi}^{N,T} \equiv p_2 \times \left(\frac{1}{4} - p_2 + \frac{1}{2} - \frac{(\alpha - 1)p_2^2}{2} \right),$$

whose maximization yields the following first-order condition

$$\frac{3}{2}p_2^2 - 2p_2 - \frac{3}{2}\alpha p_2^2 + \frac{3}{4} = 0,$$

which implies

$$p_2 = \frac{\sqrt{2}\sqrt{9\alpha - 1} - 4}{6\left(\alpha - 1\right)},$$

and a profit

$$\widetilde{\pi}^{N,T} = \frac{2\left(18\alpha - 2\sqrt{2}\sqrt{9\alpha - 1} - 10\right)\left(\sqrt{2}\sqrt{9\alpha - 1} - 4\right)}{\left(72\alpha - 72\right)\left(6\alpha - 6\right)}. \tag{21}$$

Substituting (21) into (20), the deviation is unprofitable if and only if

$$\delta \geq \overline{\delta}\left(\alpha\right) \equiv \sqrt{\frac{\sqrt{3}}{72\left(\alpha - 1\right)^2}\left(\sqrt{2}\sqrt{9\alpha - 1} - 4\right)\left(18\alpha - 2\sqrt{2}\sqrt{9\alpha - 1} - 10\right) + \frac{1}{4}} - \frac{1}{2},$$

which is decreasing in α and lower than $\frac{1}{2}$ for every $\alpha \geq 1$. Hence, (20) also holds for some $\delta < \frac{1}{2}$. This concludes the proof. ■

References

[1] Abreu, D. (1986). "Extremal Equilibria of Oligopolistic Supergames". *Journal of Economic Theory*, 39(1), pp. 191-225.

[2] Abreu, D. (1988). "On the Theory of Infinitely Repeated Games with Discounting". *Econometrica*, 56(2), pp. 383-396.

[3] Anderson, S. P. and R. Renault (2006), "Advertising Content". *American Economic Review,* 96(1), pp. 93-113.

[4] Anderson, S. P. and R. Renault (2009), "Comparative advertising: disclosing horizontal match information". *RAND Journal of Economics,* 40(3), pp. 558-581.

[5] Boleslavsky, R., C. S. Cotton and H. Gurnani (2016), "Demonstrations and Price Competition in New Product Release". *Management Science,* forthcoming.

[6] Celik, L. (2014), "Information Unraveling Revisited: Disclosure of Horizontal Attributes". *Journal of Industrial Economics,* 62(1), pp. 113-136.

[7] Chang, M. (1991), "The Effects of Product Differentiation on Collusive Pricing". *International Journal of Industrial Organization*, 9(3), pp. 453-469.

[8] Che, Y. (1996), "Customer Return Policies for Experience Goods". *Journal of Industrial Economics*, 44(1), pp. 17-24.

[9] Colombo, S. (2013), "Product Differentiation and Collusion Sustainability When Collusion is Costly". *Marketing Science*, 32(4), pp. 669-674.

[10] Davis, S., E. Gerstner and M. Hagerty (1995), "Money Back Guarantees in Retailing: Matching Products to Consumer Tastes". *Journal of Retailing*, 71(1), pp. 7-22.

[11] Deneckere, R. (1983), "Duopoly Supergames with Product Differentiation". *Economics Letters*, 11(1-2), pp. 37-42.

[12] Deneckere, R. (1984), "Corrigendum". *Economics Letters*, 15(3-4), pp. 385-387.

[13] Fishman, M. J. and K. M. Hagerty (2003), "Mandatory Versus Voluntary Disclosure in Markets with Informed and Uninformed Customers". *Journal of Law, Economics & Organization*, 19(1), pp. 45-63.

[14] Friedman, J. (1971), "A Non-cooperative Equilibrium for Supergames". *Review of Economic Studies*, 38(1), pp. 1-12.

[15] Grossman, S. and O. D. Hart (1980), "Disclosure Law and Takeover Bids". *Journal of Finance*, 35(2), pp. 323-334.

[16] Grossman, S. (1981), "The Informational Role of Warranties and Private Disclosure about Product Quality". *Journal of Law & Economics*, 24(3), pp. 461-483.

[17] Grubb, M. D. (2015), "Selling to Loss Averse Consumers: A Survey". Mimeo BC.

[18] Gupta, B. and G. Venkatu (2002). "Tacit Collusion in a Spatial Model with Delivered Pricing". *Journal of Economics*, 76(1), pp. 49-64.

[19] Hahn, S. (2005), "Allowing a Pre-Purchase Product Trial in Duopoly". *Economics Letters*, 87(2), pp. 175-179.

[20] Heidhues, P. and B. Kőszegi (2008), "Competition and Price Variation When Consumers Are Loss Averse". *American Economic Review,* 98(4), pp. 1245-1268.

[21] Heiman, A., B. McWilliams, E. Z. Shen and D. Zilberman (2001), "Test Drives: Learning, Sorting, and Buying". *Working Paper* (No. 20114).

[22] Heiman, A., B. McWilliams and D. Zilberman (2001), "Learning and Forgetting: Modeling Optimal Product Sampling Over Time". *Management Science,* 47(4), pp. 532-546.

[23] Heiman, A. and E. Muller (1996), "Using Demonstration to Increase New Product Acceptance: Controlling Demonstration Time". *Journal of Marketing Research,* 33(4), pp. 422-430.

[24] Ivanov, M. (2013), "Information Revelation in Competitive Markets". *Economic Theory*, 52(1), pp. 337-365.

[25] Janssen, M. C. W. and S. Roy (2015), "Competition, Disclosure and Signalling". *Economic Journal,* 125, pp. 86-114.

[26] Janssen, M. C. W. and M. Teteryatnikova (2016), "Horizontal Product Differentiation: Disclosure and Competition". Forthcoming in *Journal of Industrial Economics.*

[27] Johnson, J. P. and D. P. Myatt (2006), "On the Simple Economics of Advertising, Marketing, and Product Design". *American Economic Review,* 96(3), pp. 756-784.

[28] Jovanovic, B. (1982), "Truthful Disclosure of Information". *Bell Journal of Economics*, 13(1), pp. 36-44.

[29] Kahneman, D., J. L. Knetsch and R. H. Thaler (1991), "Anomalies: the Endowment Effect, Loss Aversion and Status Quo Bias". *Journal of Economic Perspectives,* 5(1), pp. 193-206.

[30] Kahneman, D. and A. Tversky (1979), "Prospect Theory: an Analysis of Decision Under Risk". *Econometrica,* 47(2), pp. 263-291.

[31] Kahneman, D. and A. Tversky (1991), "Loss Aversion in Riskless Choice: A Reference-Dependent Model". *Quarterly Journal of Economics,* 106(4), pp. 1039-1061.

[32] Karle, H. and M. Peitz (2014), "Competition Under Consumer Loss Aversion". *RAND Journal of Economics,* 45(1), pp. 1-31.

[33] Koessler, F. and R. Renault (2012), "When Does a Firm Disclose Product Information?". *RAND Journal of Economics,* 43(4), pp. 630-649.

[34] Kőszegi, B. and M. Rabin (2006), "A Model of Reference-Dependent Preferences". *Quarterly Journal of Economics,* 121(4), pp. 1133-1165.

[35] Kőszegi, B. and M. Rabin (2007), "Reference-Dependent Risk Attitudes". *American Economic Review,* 97(4), pp. 1047-1073.

[36] Lambertini, L. and D. Sasaki (1999), "Optimal Punishments in Linear Duopoly Supergames with Product Differentiation". *Journal of Economics*, 69(2), pp. 173-188.

[37] Levin, D., J. Peck and L. Ye (2009), "Quality Disclosure and Competition". *Journal of Industrial Economics*, 57(1), pp. 167-196.

[38] Mailath, G., V. Nocke and L. White (2004), "When the Punishment Must Fit the Crime: Remarks on the Failure of Simple Penal Codes in Extensive-Form Games". *CEPR Discussion Paper* (No. 4793).

[39] Matsumura, T. and N. Matsushima (2005), "Cartel Stability in a Delivered Pricing Oligopoly". *Journal of Economics*, 86(3), pp. 259-292.

[40] Miklós-Thal, J. (2008), "Delivered Pricing and the Impact of Spatial Differentiation on Cartel Stability". *International Journal of Industrial Organization*, 26(6), pp. 1365-1380.

[41] Østerdal, L. P. (2003), "A Note on the Stability of Collusion in Differentiated Oligopolies". *Research in Economics*, 57(1), pp. 53-64.

[42] Piccolo, S., P. Tedeschi, and G. Ursino (2016), "Deceptive Advertising with Rational Buyers". Forthcoming in *Management Science.*

[43] Piccolo, S., P. Tedeschi, and G. Ursino (2015), "How Limiting Deceptive Practices Harms Consumers." *RAND Journal of Economics*, 46(3), pp. 611-624.

[44] Piccolo, S. and J. Miklós-Thal (2012), "Colluding Through Suppliers". *RAND Journal of Economics*, 43(3), pp. 492-513.

[45] Roberts, J. H. and G. L. Urban (1988), "Modeling Multiattribute Utility, Risk, and Belief Dynamics for New Consumer Durable Brand Choice". *Management Science*, 34(2), pp. 167-185.

[46] Rhodes, A., and C. M. Wilson (2015): "False Advertising and Consumer Protection Policy". Mimeo.

[47] Rosato, A. (2016), "Selling Substitute Goods to Loss-Averse Consumers: Limited Availability, Bargains, and Rip-offs". *RAND Journal of Economics*, 47(3), pp. 709-733.

[48] Ross, T. W. (1992), "Cartel Stability and Product Differentiation". *International Journal of Industrial Organization*, 10(1), pp. 1-13.

[49] Rothschild, R. (1992), "On the Sustainability of Collusion in Differentiated Duopolies". *Economics Letters*, 40(1), pp. 33-37.

[50] Shulman, J. D., A. T. Coughlan, and R. C. Savaskan (2011), "Managing Consumer Returns in a Competitive Environment" *Management Science*, 57(2), pp. 347-362.

[51] Sun, M. (2011), "Disclosing Multiple Product Attributes". *Journal of Economics & Management Strategies,* 20(1), pp. 195-224.

[52] Thomadsen, R. and K. Rhee (2007), "Costly Collusion in Differentiated Industries". *Marketing Science*, 26(5), pp. 660-665.

[53] Tyagi, R. K. (1999), "On the Relationship between Product Substitutability and Tacit Collusion". *Managerial and Decision Economics*, 20(6), pp. 293-298.

[54] Viscusi, W. K. (1978), "A Note on "Lemons" Markets with Quality Certification". *Bell Journal of Economics*, 9(1), pp. 277-279.

[55] Wernefelt, B. (1989). "Tacit Collusion in Differentiated Cournot Games". *Economics Letters*, 29(4), pp. 303-306.

[56] Zhou, J. (2011). "Reference Dependence and Market Competition". *Journal of Economics & Management Strategy*, 20(4), pp. 1073-1097.