The Minimum Safety Standard, Consumers' Information, and Competition

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Abstract

This paper explores the effects of a standard influencing care choice. Firm(s) may increase the probability of offering safe products by incurring a cost. Under duopoly, they compete either in prices or in quantities. Under perfect information about safety for consumers, the selected standard that corrects a safety underinvestment is always compatible with competition. Safety overinvestment only emerges under competition in quantities and relatively low values of the cost. Under imperfect information about safety for consumers, the standard leads to a monopoly situation. However, for relatively large values of the cost, a standard cannot impede the market failure coming from the lack of information.

Keywords: information, market structure, safety, standard.

JEL: L1, L5

1. Introduction

Guaranteeing products' safety to consumers is challenging for many industries offering products such as aircrafts, cars, bridges, machine tools, food, and drugs (…). The uncertainty arises as a result of practical matters such as a producer's inability to strictly control all of the inputs or processes that determine the safety of a manufactured product. Lack of care in design or manufacture of goods often results in failures of these goods. Monitoring the entire supply chain is obviously costly; ineffectual monitoring or half measures can lead to flaws in quality/safety controls.

The economics literature posits that regulations involving large compliance costs should be restricted to cases in which market-based mechanisms lead to an insufficient provision of product safety (see, for instance, Viscusi *et al.*, 1995). It is generally recognized that it is rarely possible or economically feasible to achieve zero risk with respect to safety, even if such a conclusion is not always publicly accepted.[1] Empirical evidence shows that markets do not always provide an adequate level of safety. Risk assessment requires scientific knowledge or/and complex tests, unaffordable for consumers and even sometimes for firms or professionals, particularly for long-term risks.[2] For instance, after a 14-year ban due to health risks, the US Food and Drug Administration (FDA) recently approved revamped silicone breast implants because of compelling scientific evidence (Rundle and Mathews, 2006).

In such a context, regulatory interventions and agencies such as the US Food and Drug Administration (FDA) or the US National Highway Traffic Safety Administration (…) have strong economic support, despite risks of inefficiency and bureaucracy. In particular, approval process, standards, auditing, inspection and certification, and prosecutions and sanctions on

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[1] The US National Highway Traffic Safety Administration set up federal safety standards with which "the public is protected against unreasonable risk of crashes occurring as a result of the design, construction, or performance of motor vehicles and is also protected against unreasonable risk of death or injury in the event crashes do occur" (see the Department of Transport, 2006, p. 1). "Unreasonable" risk does not mean zero risk.

[2] Safety may be divided into experience and credence characteristics. With an experience characteristic (Nelson, 1970), a consumer discovers quality only after consuming it, and with a credence characteristic (Darby and Karni, 1973) a consumer never discovers the quality of the good (or does so only in the very long term, such as in the case of some long-term diseases or a better life expectancy). Because buyers have difficulty detecting both the effective level of safety and efforts by firms, credence goods are a somewhat particular case of experience goods, whereby the lag between purchase/consumption and quality detection tends toward infinity. In practice, many goods fall into the "credence" category.

fraudulent firms help maintain consumers' trust. In 2005, the US federal regulatory agencies for social and safety regulations spent $37.2 billion (Dudley and Warren, 2006), in order to reduce both damages and probabilities of exposure to risks (such as the ones given in table 1, p. 124, in Viscusi, 1996).

Despite private and regulatory efforts, some dangerous products may be offered willy-nilly on the market, as the two following examples suggest. First, some scientific studies recently linked use of Merck & Co.'s painkiller Vioxx with increased risks of heart attacks and strokes among patients. This case underlined difficulties to fully eliminate risky products. A drug safety specialist mentioned that "new medicines should only go on the market once they are proven to be safe" (see Capell and Carey, 2005, p. 23). The US government has responded by reinforcing both FDA's approval process and safety standards for sending strong signals to doctors and patients.

Second, safety sometimes varies significantly among cars. For instance, *Status Report* (2003, p. 5) provides side impact crash tests and frontal offset crash tests for 12 small SUVs.[3] On a 4-point scale with 4 meaning good and 1 meaning poor, the averages for side impact crash tests and frontal offset crash tests are respectively 1.83 and 3.33 (standard deviations are respectively 1.19 and 0.77). Moreover, the correlation between these two tests is almost insignificant (-0.03), which means that informed consumers may be embarrassed for using these two tests in their purchase decisions.[4] Even if there are many sources of information about car safety, such as *Consumer Reports* (2006) or the free *Safercar* website (Safercar, 2006), safety awareness and risk perception are heterogeneous among consumers, since the 12 SUVs tested by *Status Report* (2003) had positive market shares in the US.

The previous examples raise the issues of both consumers' information and an "acceptable" level of safety. This paper examines firms' strategies and regulatory decisions when safety is at stake under different configurations of information. We seek to answer the question: How does a safety standard influence market mechanisms?

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[3] Sometimes, information revealed to consumers is sufficient for eliminating dangerous products. For instance, sales of the Chevrolet Corvair Monza (1966) were hit by well-known activist Ralph Nader's book *Unsafe at Any Speed* (1966). One chapter of this book claimed that this car was dangerously unstable and responsible for thousands of rollover accidents in the US.

[4] Robertson (1996, p. 31) showed that in addition to federal standards, "increments in reduced death rates, attributable to additional improved vehicle crashworthiness, occurred during the period of publicized crash tests."

This paper considers two competing sellers who may increase the probability of offering safe products by incurring a cost. In order to check robustness, both Bertrand and Cournot competitions are considered when producers face consumers.

Perfect and imperfect contexts of information for consumers are assumed for simplicity. The available information about safety depends on consumers' search and trust, independent consumers' groups, publications such as *Consumer Reports*, firms' advertising, guarantees, labelling, and regulation and/or liability systems.[5] As it is impossible to detail all previous strategies, only two polar information contexts are studied without focusing on information revelation/acquisition.[6] The perfect information case represents a situation in which a perfect certification process completes the safety standard, so that no dangerous products hit the shelves. Under imperfect information, only the safety standard is used because of unreliable or expensive certification processes, which means that dangerous products can be sold despite the standard and efforts for reducing risks.[7]

The minimum safety standard (MSS) consists of determining a minimum level of care (influencing the safety probability) with which all sellers should comply in offering their products. The MSS is selected by a regulator seeking to maximize welfare defined by the sum of the sellers' profits and consumers' surplus. An MSS may also influence firms' exit because of relatively large costs of safety improvement.

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[5] Because certification/signaling processes differ in precision and cost, there are various situations of imperfect information in which consumers have more or less precise information about safety supplied by firms. The new technologies for detecting products quality/safety lead to different levels of precision. Firn (2004) notes that, for food safety, detection may be very precise, with technologies based on genetic code of food, which is costly to enforce. The endogenous certification choice will be detailed at the end of this paper.

[6] Scientific information may also be very difficult to deliver to consumers in a credible manner. In the United States, the FDA broadcasted warnings for pregnant women in 2004 to avoid consumption of long-lived, predatory fish, such as tuna, shark, and swordfish. Because of a high level of methylmercury, these fish are considered dangerous to a developing fetus and to children. According to RealMercuryFacts (2006), the US recommendation resulted in confusion; consumers had difficulty recalling species with a high content of mercury. An alternative choice would consist in not informing consumers and reinforcing the existing standards for fish, namely, reducing acceptable levels of mercury for fish sold in the market.

[7] In our framework, MSS concerns care choices across the supply chain, while certification mainly concerns detection of product failure before consumer purchase. For instance, after the bovine spongiform encephalopathy (BSE) outbreaks (or "Mad Cow" disease) in the nineties in Europe, a first regulatory option consisted of animal flour prohibition for feeding animals. The second option consisted of the previous option combined with a systematic use of *prionics* to test animals in slaughterhouses, aimed at the complete eradication of BSE before beef consumption. Compared to our model, the first option corresponds to an MSS limiting risks without a complete withdrawal of tainted products (i.e., imperfect information), while the second option corresponds to an MSS with perfect certification (i.e., perfect information).

This paper shows that the determination of market structure as part of safety regulation depends on the available information about safety. Under perfect information about safety for consumers, the selected MSS increases the probability of offering safety and maintains competition. The MSS is compatible with competition since safety is recognized by consumers, which guarantees sufficient profits for covering the safety cost. Under Bertrand competition, the MSS always corrects a safety underinvestment by firms. Under Cournot competition, the MSS corrects a safety underinvestment by firms for a relatively large cost of safety improvement. However, for a relatively low cost of safety improvement, the MSS is ineffective, since there is a safety overinvestment by firms compared to the socially optimal level. In other words, firms select a higher effort than the one that would maximize welfare.

Under imperfect information about safety for consumers, it is socially optimal (under Bertrand and Cournot competitions) to impose a standard that, except for a few cases, leads to a monopoly situation. The monopoly situation guarantees profits necessary to cover the cost for complying with the MSS. However, when the cost of safety improvement is very large, the MSS is useless in impeding the absence of trade à la Akerlof (1970) because of a large probability to get dangerous products.

The results of this paper differ from the enormous literature about regulation of product safety. Polinsky and Rogerson (1983), Chan and Marino (1994), Daughety and Reinganum (1995), Marino (1995a,b and 1998) and Marette *et al.* (2000) focused on products' safety, whereby sellers try to limit the probability of harm and the consequence of a product's defects. Product defects can be (perfectly or not) thwarted by a complex combination of ex ante safety standards and/or ex post liability (the negligence rule is a combination of both instruments). Conversely, in this paper we focus only on the ex ante safety standard under various contexts of information. We show that the different types of market structure (duopoly or monopoly) linked to the MSS choice crucially depend on the available information.[8]

The results of this study also make important contributions to the vast literature on the minimum quality standard (MQS). The term MSS is preferred in this paper to the "classical" notion of MQS that applies to cases in which the lowest acceptable quality is controlled without

[8] We also show that the overinvestment in safety under Cournot competition is not linked to the issue of the "judgment proof," meaning that an injurer is unable to pay some portion of the losses to victims under strict liability. Beard (1990) showed that, considering a strict liability rule, potentially insolvent injurers might over-invest in safety prevention.

any uncertainty by firms or regulators. First, the literature on MQS points toward a difference between Bertrand and Cournot competition under perfect information (see Valletti, 2000, and Jinji and Toshimitsu, 2004). In particular, the MQS is not used under Cournot competition since it reduces welfare. Our paper differs from the previous results since the MQS is used under both Bertrand and Cournot competition for improving the safety effort. However, for a relatively low cost of safety improvement under Cournot competiton, the MSS is ineffective (but never welfare decreasing), since there is a safety overinvestment by all firms.

Second, unlike the present paper, the existing literature on the MQS is based upon models considering only one context of information. A large part of this literature considers a context of perfect information about quality for consumers, as, for instance, in Ronnen (1991), Crampes and Hollander (1995), Ecchia and Lambertini (1997), Scarpa (1998), Lutz *et al.* (2000), Valletti (2000), Garella (2006) and Jinji and Toshimitsu (2004). Some other papers focus on the standard in a context of imperfect information for consumers, as in Leland (1979), Garella and Petrakis (2006), and Lapan and Moschini (2006). Conversely, our paper compares the standard under perfect and imperfect information, which leads to the determination of different market structures (duopoly or monopoly). Maintaining competition is important under perfect information (as demonstrated by Ronnen, 1991), but reducing the number of firms under imperfect information allows to mitigate the market failure.[9] In this paper, a frontier regarding the link between competition and regulation is delineated based on the consumer's information.

The paper is organized as follows. The next section introduces the stylized model. Following that, both market equilibrium and regulatory choice are successively detailed under perfect information and imperfect information for consumers. The two last sections present some extensions and conclusions.

2. The Model

In this stylized framework, trade occurs in a single period, with two firms able to produce the good. The ability to offer safe products is determined by a combination of firms' effort and randomness. Firm i=1,2 offers either safe products or dangerous products. The firm's ability to

[9] This result does not depend on the timing of quality/safety decision as in Constantatos and Perrakis (1998).

reduce risks and offer safe products is dependent on the firm's care choice but is also to some degree uncertain.

For simplicity, we let the firm's effort be equivalent to the probability of a safe product emerging. (Making the probability a function of the effort just adds a degree of complication that is unnecessary for the point being made in this paper.) With a probability $0 \le \lambda_i \le 1$, firm *i* only offers safe products and with a probability $(1-\lambda_i)$ firm *i* only offers dangerous products. We assume that the care choice, namely, the effort to increase the probability of offering safe products, implies a cost equal to $f\lambda_i^2/2$ with $f \ge 0$.[10] For simplicity, the marginal cost is zero whatever the safety.

Consumers are risk neutral and want to purchase only one unit of the good, and no consumer would *knowingly* purchase a dangerous product.[11] For a safe product, consumers have a willingness to pay equal to θs. They differ in their willingness to pay for the safety level *s*, which is described by the uniformly distributed parameter $\theta \in [0,1]$ (see Mussa and Rosen, 1978, and Shaked and Sutton, 1983). The consumption of harmful products results in some disutility equal to $-\theta d$. A consumer has an expected willingness to pay equal to $Max\{\theta[\mu s-(1-\mu)d],0\}$, where μ is the probability of purchasing safe products. The mass of those consumers is normalized at 1.

A consumer who buys one unit of the product at a price of *p* has an indirect utility equal to $Max\{\theta[\mu s-(1-\mu)d],0\}-p$. For a probability, $\mu \ge d/(d+s)$ (equivalent to an expected safety $\mu s-(1-\mu)d>0$), consumers are ready to buy the product. The consumer indifferent between buying a product at price *p* and buying nothing is identified by the preference parameter $\overline{\theta}=p/[\mu s-(1-\mu)d]$ (such that $\theta[\mu s-(1-\mu)d]-p=0$), leading to an overall demand $x(\mu,p)=(1-\overline{\theta})$ and an inverse demand equal to $p(\mu,x)=[\mu s-(1-\mu)d\ ](1-x)$. For a given price *p*, the consumer surplus is

$$cs(\mu,p)=\int_{\overline{\theta}}^{1}(\theta[\mu s-(1-\mu)d\ ]-p)d\theta=\left(\mu s-(1-\mu)d-p\right)^2\Big/2[\mu s-(1-\mu)d].$$

For a probability $\mu < d/(d+s)$ (equivalent to an expected safety $\mu s-(1-\mu)d<0$),

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[10] Safety mainly relies on sunk costs spending, such as R&D experiments and/or high-skill workers, such as engineers, designers, or lawyers.

[11] Our assumption of risk neutrality makes our demand and welfare conclusions more conservative: if buyers are risk averse, the desire for and the benefits from MSS increase.

consumers do not buy the product and their surplus is zero.[12] The probability μ depends on sellers' efforts λ_i and available information.

Two contexts of information for consumers are considered for simplicity. First, we study a situation of perfect information about safety, in which dangerous products are perfectly detected before consumers' purchases. Then, we examine situations of imperfect information in which consumers (*a*) only have information about the average safety effort selected by the two firms (namely, a common reputation for safety effort) or (*b*) have no information about any effort.

The timing of this game is divided into three stages. In period 1, the regulator chooses whether or not to impose an MSS, $\lambda^s \geq 0$. The regulator influences the effort for reducing the probability of having dangerous products. The minimum level of effort, λ^s, is known by all firms and consumers. The mandatory MSS is selected by a regulator searching to maximize welfare defined by the sum of the firms' profits and consumers' surplus. For simplicity, the regulatory/inspection cost of the effort is zero (the regulatory cost will be discussed later) and the regulator has perfect information about the selected levels of effort, λ_i, selected in period 2 with $\lambda_i \geq \lambda^s$ and *i*=1,2. We assume that no MSS is imposed ($\lambda^s = 0$) if private choices by firms without regulation are superior or equal to the level of effort maximizing the welfare.

In period 2, firms choose the level of effort $\lambda^s \leq \lambda_i \leq 1$ equal to the probability of offering safe products. Each firm complies with the regulation ($\lambda_i \geq \lambda^s$) and incurs the cost, $f\lambda_i^2/2$. Once this cost is sunk, the safety level (*s* or –*d*) is determined at the beginning of period 3, and firms compete for business. In period 3, firms compete either in prices (Bertrand competition) or in quantities (Cournot competition). Each firm has the possibility of exiting the market by selecting no effort in period 2 and no price/quantity in period 3. In this case, there is no sale for this firm and there is a reduction in the number of competitors. This game is solved by backward

[12] Results are robust with the demand given by Polinsky and Rogerson (1983) in equations (1) and (2) of their paper. For an aggregate inverse demand without dangerous products given by $p = \alpha - \beta q$ and a per unit damage *d*, the inverse demand under imperfect information (only studied by Polinsky and Rogerson) would be $p = \alpha - \beta q - (1-\lambda)d$, where $(1-\lambda)$ is the probability of getting dangerous products. Under perfect information, the demand would be $p = \alpha - \beta q$ for safe products, and $p = \alpha - \beta q - d$ for dangerous products if $\alpha > d$ or zero if $\alpha < d$.

induction (i.e., subgame Nash equilibrium) under each information context. We now turn to the case under perfect information for consumers

3. The Minimum Safety Standard under Perfect Information for Consumers

In period 1, the MSS defining the effort (equal to the probability of getting safe products) is determined by taking into account the effort/exit decision in period 2 and the prices/quantities decisions in period 3. Recall that in period 3, the safety level is already determined for each firm and the cost is fixed.

As the game is solved by backward induction, period 3 is now detailed. As consumers are perfectly informed about safety, any firm with dangerous products is driven out of the market in period 3. If both firms offer dangerous products ($\mu = 0$) there is no sale since no buyer purchases these goods under perfect information. Profit and consumers' surplus are zero.

Consumers only purchase safe products ($\mu = 1$). If only one firm offers safe products, this firm maximizes its gross profit (i.e., profits net of the cost $f\lambda^2/2$) given by $px(1, p)$ (respectively, $p(1, x)x$) with $x(\mu, p)$ and $p(\mu, x)$ detailed in the previous section. The maximization of gross profit with respect to *p* (respectively, *x*) leads to an equilibrium price $p_1 = s/2$ and to an equilibrium quantity $x_1 = 1/2$. By using $cs(\mu, p)$ defined in the previous section, the equilibrium gross profit and the consumer's surplus are, respectively,

$$\begin{cases} \pi_1 = s/4 \\ cs_1 = cs(1, p_1) = s/8 \end{cases}. \tag{1}$$

If safe products are offered by the two producers, the type of competition matters. Under Bertrand competition, the equilibrium price is $p_2^B = 0$. The equilibrium gross profit and the consumer's surplus are, respectively,

$$\begin{cases} \pi_2^B = 0 \\ cs_2^B = cs(1, p_2^B) = s/2 \end{cases}. \tag{2}$$

Under Cournot competition, both firms' gross profits are $p(1, x_i + x_j)x_i$ and $p(1, x_i + x_j)x_j$. The maximization of these profits leads at the equilibrium to quantities $x_i^C = x_j^C = 1/3$ and to price $p_2^C = s/3$. The equilibrium gross profit for both firms and the consumer's surplus are, respectively,

$$\begin{cases} \pi_2^C = s/9 \\ cs_2^C = cs(1, p_2^C) = 2s/9 \end{cases}. \tag{3}$$

In period 2, the efforts (equal to the probability of getting safe products) are determined by taking into account the decisions in period 3. Effort influences the cost $f\lambda_i^2/2$ and determines the safety level. The situation with two firms in period 2 is presented before the situation with one firm in period 2.

Without any exit, two firms make some efforts. With a probability $\lambda_i\lambda_j$ (respectively, $(1-\lambda_i)(1-\lambda_j)$) both firms offer safe (respectively, dangerous) products, leading to a profit π_2^r with *r*=*B*,*C* for the Bertrand, Cournot competition (respectively, zero profits). With probabilities $\lambda_i(1-\lambda_j)$ or $(1-\lambda_i)\lambda_j$, one firm offers safe products leading to a profit π_1 and the other one offers dangerous products, leading to no sales and zero gross profits. When two firms select an effort level in period 2, the expected profits for firms *i* and *j* are thus

$$\begin{cases} \Pi_i^r(\lambda_i, \lambda_j) = \lambda_i\lambda_j\pi_2^r + \lambda_i(1-\lambda_j)\pi_1 - f\lambda_i^2/2 \\ \Pi_j^r(\lambda_j, \lambda_i) = \lambda_j\lambda_i\pi_2^r + \lambda_j(1-\lambda_i)\pi_1 - f\lambda_j^2/2 \end{cases}. \tag{4}$$

By using cs_2^r with *r*=*B*,*C* for the Bertrand, Cournot competition and cs_1 defined above in (1), the expected consumers' surplus is $CS^r(\lambda_i, \lambda_j) = [\lambda_i(1-\lambda_j) + (1-\lambda_i)\lambda_j]cs_1 + \lambda_i\lambda_j cs_2^r$. By using equations given by (4), the expected welfare is

$$W^r(\lambda_i, \lambda_j) = \Pi_i^r(\lambda_i, \lambda_j) + \Pi_i^r(\lambda_j, \lambda_i) + CS^r(\lambda_i, \lambda_j)\,. \tag{5}$$

If one seller exits the market in period 2, the other firm offers safe products with a probability λ and dangerous products with a probability (1-λ). In this case, the expected profits for the single firm offering products is

$$\Pi^1(\lambda) = \lambda\pi_1 - f\lambda^2/2. \qquad (6)$$

By using equations (1), the expected consumers' surplus is $CS^1(\lambda) = \lambda cs_1$. The expected welfare under monopoly is then

$$W^1(\lambda) = \Pi^1(\lambda) + CS^1(\lambda). \qquad (7)$$

Before detailing the precise results under Bertrand and Cournot competition, we sketch the regulator's choices.

3.1. Regulator's Choices

In period 1, the MSS defining the effort (equal to the probability of getting safe products) is determined by taking into account the effort/exit decision in period 2 and the prices/quantities decisions in period 3. A regulator may impose an MSS, λ^s, for influencing the level of effort λ_i selected in period 2 by both firms, since $\lambda_i \geq \lambda^s$. The regulator maximizes welfare by taking into account the firms' profits and the consumers' surplus. Three configurations are taken into account by the regulator, namely, the absence of MSS, an MSS under duopoly, or an MSS leading to a monopoly when only one seller can afford the MSS.

Absence of MSS

Under the absence of MSS, both firms maximize their profits subject to the constraint $0 \leq \lambda_i \leq 1$ in period 2. The maximization of firms' profits given by equations (4) leads to the first-order conditions $\partial\Pi_i^r(\hat{\lambda}^r, \hat{\lambda}^r)/\partial\lambda_i = 0$ and $\partial\Pi_j^r(\hat{\lambda}^r, \hat{\lambda}^r)/\partial\lambda_j = 0$ (or $\partial\Pi_i^r(1,1)/\partial\lambda_i > 0$ and

$\partial\Pi_j^r(1,1)/\partial\lambda_j > 0$) with *r*=*B*,*C* for the Bertrand, Cournot competition.[13] Solving the first-order conditions subject to the constraint $0 \le \lambda_i \le 1$ leads to

$$\hat{\lambda}^r = Min\left[\frac{\pi_1}{f - \pi_2^r + \pi_1}, 1\right]. \tag{8}$$

MSS without exit in period 2

An MSS is compatible with a duopoly in period 2 if the firm's profits defined by (4) are positive (namely, $\Pi_i^r(\lambda^s, \lambda^s) \ge 0$). This is the case if $\lambda^s \le \underline{\lambda}^r$, with

$$\underline{\lambda}^r = Min\left[\frac{\pi_1}{f/2 - \pi_2^r + \pi_1}, 1\right], \tag{9}$$

with *r*=*B*,*C* for the Bertrand, Cournot competition, and such that $\Pi_i^r(\lambda^s, \lambda^s) = 0$.

For keeping duopoly in stage 2, the regulator maximizes welfare under the constraints $\lambda^s \le \underline{\lambda}^r$. The maximization of welfare $W_d(\lambda_i, \lambda_j)$ given by (5) with $\lambda_i = \lambda_j = \lambda^s \le 1$ is such that $dW^r\left(\overline{\lambda}^{s,r}, \overline{\lambda}^{s,r}\right)/d\lambda^s = 0$ or $dW^r(1,1)/d\lambda^s > 0$, which leads to the following choice:

$$\overline{\lambda}^{s,r} = Min\left[\frac{\pi_1 + cs_1}{f + 2(\pi_1 + cs_1) - 2\pi_2^r - cs_2^r}, 1\right]. \tag{10}$$

The MSS is the socially optimal level $\overline{\lambda}^{s,r}$ that is compatible with a duopoly situation if the constraint $\overline{\lambda}^{s,r} \le \underline{\lambda}^r$ is satisfied with $\underline{\lambda}^r$ defined by (9). Conversely, for $\overline{\lambda}^{s,r} > \underline{\lambda}^r$, the socially optimal level cannot be imposed without leading to a monopoly situation. For maintaining a duopoly, the regulator imposes an MSS equal to $\underline{\lambda}^r$. The MSS is imposed if $Min\left[\overline{\lambda}^{s,r}, \underline{\lambda}^r\right]$

[13] Second-order conditions are satisfied with $\partial^2\Pi_i^r()/\partial\lambda_i^2 = -f < 0$ and $\partial^2\Pi_j^r()/\partial\lambda_j^2 = -f < 0$.

exceeds the firm's private choices, $\hat{\lambda}^r$ (recall from section 2 that an MSS is selected only if it is larger than private choices).

It is easy to show that effort levels given by (8), (9), and (10) decrease with the cost parameter *f*, since the cost negatively influences the profits and/or the welfare. The ranking of values given by (8), (9), and (10) depends on the competition in period (3), namely, the values of π_2^r and cs_2^r with *r=B,C*.

MSS leading to seller's exit in stage 2

A high MSS may lead to a monopoly situation in period 2. An MSS λ^s is not compatible with a duopoly if $\Pi_i^r(\lambda^s,\lambda^s)<0$, which is equivalent to $\lambda^s>\underline{\lambda}^r$ with $\underline{\lambda}^r$ defined by (9). In this case, only a monopoly is compatible with such a level of effort. As the cost for improving the probability is sunk in period 3, only one firm is able to cover the sunk cost, which leads to a monopoly price. If the two firms offered products with $\lambda^s>\underline{\lambda}^r$, the competition in stage 3 would lead to negative profit (due to the sunk cost). Thus, one firm exits the market in stage 2 and only the situation of a single firm offering products (and the other one selecting no price and no effort) can be a subgame perfect equilibrium. By selecting an MSS, the regulator also integrates the possibility of driving out one firm from the market with the resulting distortions.

The regulator maximizes this welfare given by (7) under the constraint $\underline{\lambda}^r<\lambda^s\leq 1$, leading to a monopoly situation. The maximization of welfare given by (7) is such that $dW^1\left(\overline{\overline{\lambda}}^{s,1}\right)/d\lambda^s=0$ or $dW^1(1)/d\lambda^s>0$, which leads to

$$\overline{\overline{\lambda}}^{s,1}=Min\left[\frac{\pi_1+cs_1}{f},1\right]=Min\left[\frac{3s}{8f},1\right]. \quad (11)$$

The MSS $\overline{\overline{\lambda}}^{s,1}$ is compatible with a monopoly situation if the constraint $\overline{\overline{\lambda}}^{s,1}>\underline{\lambda}^r$ is satisfied with $\underline{\lambda}^r$ defined by (9). Conversely, for $\overline{\overline{\lambda}}^{s,1}<\underline{\lambda}^r$, the MSS would lead to a duopoly situation. For maintaining a monopoly, the regulator imposes an MSS equal to $\underline{\lambda}^r+\varepsilon$, with $\varepsilon>0$. The MSS is imposed if $d\Pi^1\left(Max\left[\overline{\overline{\lambda}}^{s,1},\underline{\lambda}^r+\varepsilon\right]\right)/d\lambda_i<0$, which means that the MSS exceeds the firm's private choice defined by $d\Pi^1(\lambda_1)/d\lambda=0$ or $d\Pi^1(1)/d\lambda>0$ with Π^1 given by (6) and $\lambda_1=Min\left[s/4f,1\right]$.

The regulator compares the welfare under the three previous configurations for determining its choice in period 1. Based on the possible MSS defined above, the equilibrium welfares are compared for determining the best policy. The optimal choice for determining the MSS is now presented under both Bertrand and Cournot competition. This allows us to underline the difference between the firms' choices (based on profit maximization) and the socially optimal choice (based on welfare maximization).

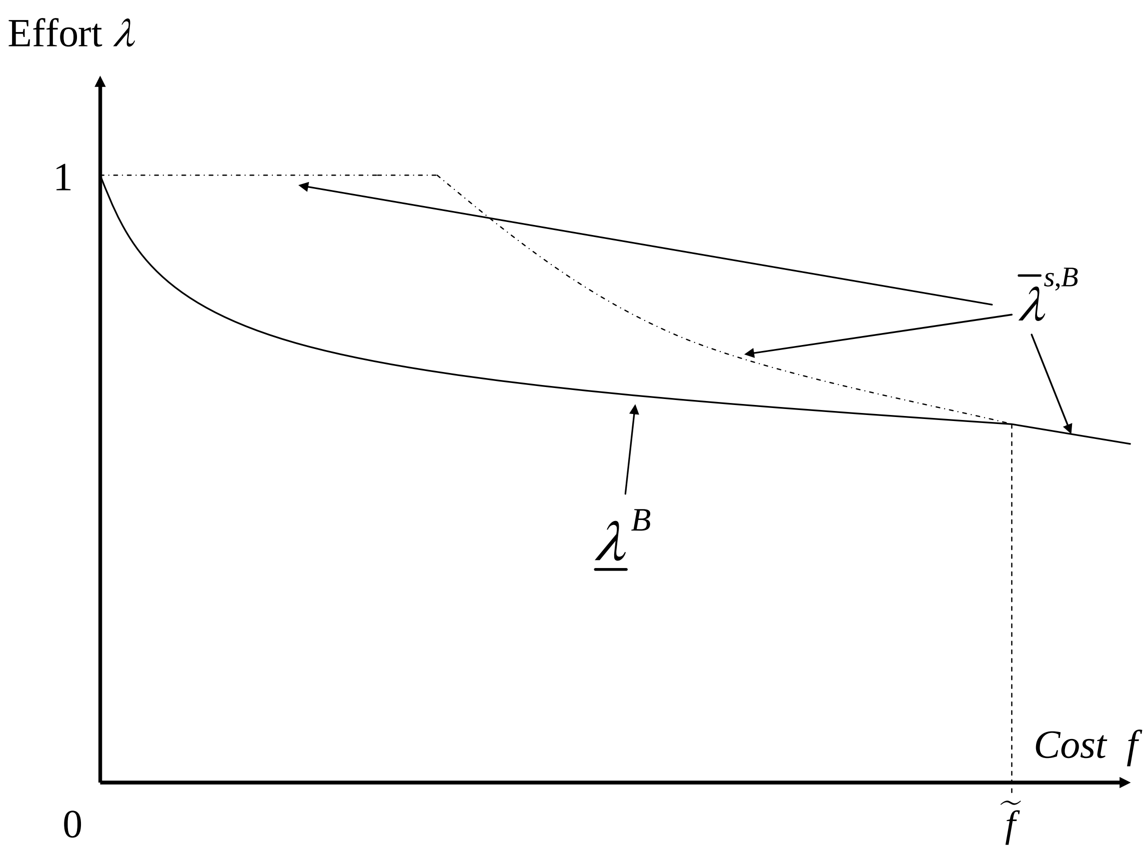
3.2. Bertrand Competition

If both firms offer safe products under Bertrand competition, profits and consumers' surplus are given by (2). By using (9) and (10) with *r=B* for the Bertrand competition, the optimal choice for determining the MSS is presented in proposition 1 (see the appendix for the proof and the detailed values).

Proposition 1. *Under Bertrand competition and perfect information, the regulatory choice is an MSS equal to* $Min\left[\underline{\lambda}^B,\overline{\lambda}^{s,B}\right]<1$ *leading to a duopoly in period 2. The MSS improves the welfare and both firms comply with it.*

Proposition 1 means that it is always optimal to select an MSS for $f>0$. The MSS imposes a higher effort to both firms by preserving competition in period 2. Figure 1 is useful for illustrating the regulatory choice of proposition 1 by using the notations defined in this proposition. The cost parameter, *f*, is located along the horizontal axis, and the effort level, λ, is located along the vertical axis. The value of *f* influences the regulator's optimal strategy. The plain curve is the selected MSS. The dash curve is the socially optimal level (that cannot be selected for preserving the competition). The level preserving competition, $\underline{\lambda}^B$, is only represented by the plain curve when it is the MSS, namely, for $f<\tilde{f}$.

Figure 1. The MSS under Bertrand Competition



The MSS is strictly lower than 1 for f >0. An effort equal to 1 would lead to gross profits π_2^B equal to zero and to the impossibility of firms covering the cost $f/2$. With the MSS represented by the plain curve, the regulator preserves the competition in period 2, since the monopoly situation coming from $\lambda^s > \underline{\lambda}^B$ is socially dominated. The monopoly is dominated since it implies (*a*) price distortions, and (*b*) a probability λ of having safe products while the duopoly in period 2 combines probabilities of having at least one firm with safe products (equal to $\lambda^2 + 2\lambda(1-\lambda)$).

Both firms comply with the level of effort defined by the MSS that is larger than the private choice of effort $\hat{\lambda}^B$. When firms incur sunk costs $f\lambda^2/2$ not passed on to consumers in the price in period 3, competition causes producers to set safety levels further removed from the socially optimal level in order to limit declines in profits. The MSS is useful for improving product safety in a competitive context. Consumers benefit from this safety improvement compared with the absence of MSS.

The MSS decreases with *f*. Even a relatively small MSS under duopoly coming from a relatively large cost *f* is selected, since dangerous products are detected and withdrawn before consumers can purchase them. The regulator increases the effort that leads to the presence of both firms entailing the largest surplus, cs_2^B, but zero gross profit , $\pi_2^B = 0$, incompatible with the coverage of cost $f\lambda^2/2$. For relatively low values of *f*, the duopoly is not viable with the socially optimal safety $\overline{\lambda}^{s,B}$ that is relatively large (dashed curve in figure 1). In this case, the regulator selects the level, $\underline{\lambda}^B$, such that the profits are equal to zero, namely, $\Pi_i(\lambda_1^s, \lambda_1^s) = 0$. The MSS aims at keeping a competitive structure and increasing the level of effort. For relatively large values of the cost parameter, $f > \tilde{f}$, the selected MSS $\overline{\lambda}^{s,B}$ is compatible with two firms on the market.

3.3. Cournot Competition

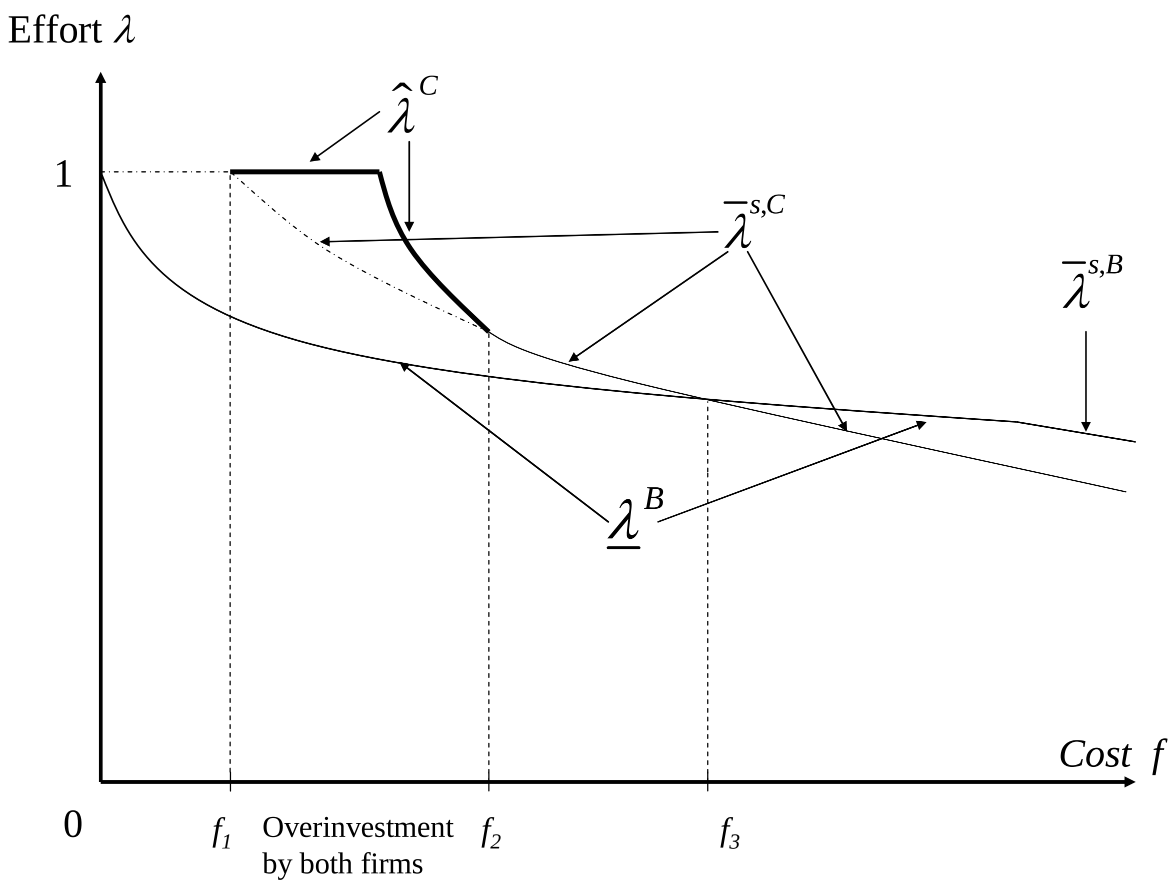
If both firms offer safe products under Cournot competition, profits and consumers' surplus are given by (3). By using (8) and (10) with r=C for the Cournot competition, the optimal choice for determining the MSS is presented in proposition 2 (see the appendix for the proof and the detailed values).

Proposition 2. *Under Cournot competition and perfect information, the regulatory choice is as follows:*

- *(i)* *If $f \le f_1$, the absence of MSS, since the MSS would be equal to the private firms' choice (equal to 1).*
- *(ii)* *If $f_1 < f \le f_2$, the absence of MSS, since the socially optimal level $\overline{\lambda}^{s,C} < 1$ is lower than the private choice $\hat{\lambda}^C$.*
- *(iii)* *If $f > f_2$, the MSS $\overline{\lambda}^{s,C} < 1$ leading to a duopoly in period 2. The MSS improves the welfare and both firms comply with it.*

Proposition 2 means that it is optimal to impose an MSS only for $f \geq f_2$. The MSS imposes a higher effort on both firms by preserving competition in period 2. Figure 2 is useful for illustrating the regulatory choice of proposition 2 by using the notations defined in this proposition (with the MSS, $Min\left[\underline{\lambda}^B, \overline{\lambda}^{s,B}\right]$, under Bertrand competition also represented with a plain curve allowing further comparison). The plain curve is the selected MSS, $\overline{\lambda}^{s,C}$. The dash curve is the socially optimal level that is not selected, because the value $\overline{\lambda}^{s,C}$ is lower than or equal to the private choice, $\hat{\lambda}^C$. The bold curve is the private choice $\hat{\lambda}^C$ selected by firms when this one is strictly larger than the socially optimal effort.

Figure 2. The MSS under Bertrand and Cournot Competition



For $f < f_1$, both socially optimal effort and private choice by both firms are equal to one, so that an MSS is useless. This is possible since both firms have positive gross profits (π_2^C >0) with safe products. For relatively low values of *f* (namely, $f_1 < f \leq f_2$), the MSS is ineffective in correcting the firms' efforts. There is a safety overinvestment. As firms get positive profits when both of them offer safe products ($\pi_2^C > 0$), they have an incentive to select a relatively large level of effort, $\hat{\lambda}^C$, when the cost parameter *f* is relatively low. From the regulator's point of view, the cost $f\lambda^2/2$ is incurred twice with two firms, so that the socially optimal level of effort is capped compared to private choices. This explains why $\overline{\lambda}^{s,C}$ is lower than $\hat{\lambda}^C$ for $f_1 < f \leq f_2$. The MSS is not selected for $f \leq f_2$, since it is ineffective in correcting the private choice.

When the cost parameter *f* is relatively large, the regulator searches to increase the firms' effort that leads to the selection of an MSS, $\overline{\lambda}^{s,C}$. The selected MSS $\overline{\lambda}^{s,C}$ is compatible with two firms on the market in period 2 since $\overline{\lambda}^{s,C} < \underline{\lambda}^C$. In this case, the private effort $\hat{\lambda}^C$ is lower than $\overline{\lambda}^{s,C}$, since the cost $f\lambda^2/2$ becomes very large for firms. The MSS equal to the socially optimal safety is useful for increasing the welfare under Cournot competition. These results differ from those of Valetti (2000) (in a different context) showing that the MQS unambiguously reduces total welfare under Cournot competition.

The comparison between Bertrand and Cournot competitions is interesting, since competition is maintained with an MSS whatever the competitive intensity (namely, Bertrand or Cournot). Even if curves under Cournot and Bertrand in figure 2 are relatively similar, the regulator should pay attention to the differences. The socially optimal level $\overline{\lambda}^{s,B}$ under Bertand competition is higher than the one $\overline{\lambda}^{s,C}$ under Cournot competition, since the welfare with the two firms offering safe products is higher under Bertrand competition ($cs_2^B = s/2$) than under Cournot competition ($cs_2^C + 2\pi_2^C = 4s/9$). In other words, for a same level of effort the ratio between the welfare and the cost $f\lambda^2/2$ is higher under Bertrand than under Cournot competition. This explains why the MSS is larger under Bertrand than Cournot when *f* is relatively large (namely, for $f > f_3 = 5s/18$ in figure 2).

However, recall that gross profits under Bertrand competition are zero ($\pi_2^B = 0$) and lower than the gross profits under Cournot competition ($\pi_2^C > 0$). Even if the regulator seeks to increase the effort toward one when *f* is relatively low, the gross profit for both sellers is too low compared to the cost coverage under Bertrand competition. In this case, the regulator caps the MSS with an imposed effort, $\underline{\lambda}^B$. Conversely, the positive gross profits ($\pi_2^C > 0$) under Cournot competition allow firms to bear the cost coming from the imposition of a level $\overline{\lambda}^{s,C}$. This explains why the MSS is larger under Cournot competition than under Bertrand competition for relatively medium values of *f* (namely, for $f_2 < f < f_3$).

Figure 2 shows that, despite some differences between Bertrand and Cournot competitions, the MSS is useful for improving the welfare in a context of perfect information. As awareness or knowledge about safety may vary a lot among consumers, the consequences of safety uncertainty under other information contexts are briefly examined.

4. The Minimum Safety Standard under Imperfect Information for Consumers

For simplicity, we briefly examine two situations of imperfect information in which consumers (*a*) only have information about the average safety effort selected by the two firms (namely, a common reputation for safety effort) or (*b*) have no information about any effort. As the MSS, $\lambda^s \geq 0$, is known by all firms and consumers, it may influence the expected level of safety that affects consumers' willingness to pay.[14] The MSS can be used for modifying efforts without a complete withdrawal of dangerous products because of unreliable or expensive certification.

4.1. Information about Average Safety Effort

This situation of knowledge about average safety efforts corresponds to the situation in which an

[14] Leland (1979) and Garella and Petrakis (2006) also consider a situation in which an MQS informs consumers. One extension could be to consider an MSS $\lambda^s + \varepsilon$ that imperfectly informs consumers with a disturbance ε generated by a random process. The social benefits of imposing an MSS in proposition 3 would be diminished by considering an MSS that imperfectly signals quality to consumers.

industry has a common reputation about safety without any possibility of individual signals (see Tirole, 1996, and Carriquiry and Babcock, 2004). The entire industry can lose consumers' trust as a result of actions of one participant. In other words, consumers are somewhat informed but not perfectly informed about individual safety efforts.[15] We consider a situation in which only the average effort selected by the industry is known. In this context, a firm with dangerous products is not eliminated in period 3 because of the absence of precise information. The expected level of effort is the average effort for the industry equal to $\overline{\mu} = (\lambda_i + \lambda_j)/2$ under duopoly and λ under monopoly.[16] The situation with two firms in period 3 is presented before the situation with one firm in period 3.

The expected level of safety under duopoly and common reputation is $\overline{s} = \overline{\mu} s - (1 - \overline{\mu})d$, with an average effort (and probability) $\overline{\mu} = (\lambda_i + \lambda_j)/2$ of getting safe products. For a probability $\overline{\mu} = (\lambda_i + \lambda_j)/2 < d/(d+s)$ (equivalent to an expected safety $\overline{s} < 0$), no purchase occurred and the welfare is zero.

For a probability $\overline{\mu} \geq d/(d+s)$ (equivalent to an expected safety $\overline{s} > 0$), consumers are ready to buy products. As safety is not detected before purchasing, no firm leaves the market at period 3. We restrict our attention to the Cournot competition. By using notations from section 2, the inverse demand is equal to $p\left(\overline{\mu}, x\right) = \left[\overline{\mu} s - (1 - \overline{\mu})d\right](1 - x)$ if $\overline{\mu} \geq d/(d+s)$. Under Cournot competition, both firms' gross profits are $p(\overline{\mu}, x_i + x_j)x_i$ and $p(\overline{\mu}, x_i + x_j)x_j$. The

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[15] Because of limited knowledge and/or media coverage, consumers often perceive common reputation as safety. For instance, *Status Report* (2006) revealed frontal crash testing for types of vehicles (minivans, SUVs, etc.) without detailing each type of vehicle. With the 1995 models, the ratings for most vehicles were far from good, while with for the 2005 vehicles, 80 percent of vehicles earned good ratings in frontal crash tests. This means that the average safety increased during the last decade. The common reputation also leads to self-regulation by professions (Andrews, 2002). As Spector (2006, p. D2) mentions, "Federal regulations don't require side air bags in passenger vehicles, but more auto makers are installing them under a voluntary 2003 industry-wide agreement to improve side-impact safety in SUVs and pickup trucks. The accord means virtually all cars, SUVs, and pickups will have head-protection side air bags by 2010."

[16] An alternative case would be to consider that consumers know all individual levels of effort (equal to the probability of offering safe products) λ_i and λ_j. In this case, the expected safety would be $\lambda_i s - (1 - \lambda_i)d$ and $\lambda_j s - (1 - \lambda_j)d$. Firms could differentiate their choices λ_i and λ_j for differentiating the expected safety. In this case, results would be close to the ones presented by Ronnen (1991), Valletti (2000), and Jinji and Toshimitsu (2004). Under asymmetric information about this level of effort, the possibility for each firm to signal its level of effort (equal to the probability of offering safe products) would be similar to ones presented by Daughety and Reinganum (1997).

maximization of these profits leads to equilibrium individual quantity $1/3$ and to a price $\overline{p}_2^C = \left[\overline{\mu}s - (1-\overline{\mu})d\right]/3$. The equilibrium gross profit for both firms and the equilibrium consumer's surplus are, respectively, $\overline{\pi}_2^C = \left[\overline{\mu}s - (1-\overline{\mu})d\right]/9$ and $\overline{cs}_2^C = cs(\overline{\mu}, \overline{p}_2^C) = 2\left[\overline{\mu}s - (1-\overline{\mu})d\right]/9$. When two firms select effort levels λ_i and λ_j in period 2, the expected level of effort is $\overline{\mu} = (\lambda_i + \lambda_j)/2$ and the expected profits for firms *i* and *j* are thus:

$$\begin{cases} \overline{\Pi}_i(\lambda_i,\lambda_j) = \overline{\pi}_2^C - f\lambda_i^2/2 = \left[(\lambda_i+\lambda_j)s - (2-\lambda_i-\lambda_j)d\right]/18 - f\lambda_i^2/2 \\ \overline{\Pi}_j(\lambda_j,\lambda_i) = \overline{\pi}_2^C - f\lambda_i^2/2 = \left[(\lambda_i+\lambda_j)s - (2-\lambda_i-\lambda_j)d\right]/18 - f\lambda_i^2/2 \end{cases}. \tag{12}$$

In particular, an MSS of λ^s is compatible with two firms in period 2 if the firm's profits defined by (12) are positive (namely, $\overline{\Pi}_i(\lambda^s,\lambda^s) \geq 0$). The expected welfare is

$$\overline{W}(\lambda_i,\lambda_j) = \overline{\Pi}_i(\lambda_i,\lambda_j) + \overline{\Pi}_i(\lambda_j,\lambda_i) + \overline{cs}_2^C. \tag{13}$$

If one seller exits the market in period 2 because of profits $\overline{\Pi}_i(\lambda_i,\lambda_j) < 0$, the other firm offers safe products with a probability λ and dangerous products with a probability (1-λ). As there is a monopoly in period 3, the common reputation is equal to the individual reputation regarding the effort λ. For an effort λ known by consumers, the expected level of safety under common reputation is $\overline{\overline{s}} = \lambda s - (1-\lambda)d$. For a probability $\lambda \geq d/(d+s)$ (equivalent to positive expected safety), consumers are ready to buy products. The firm's gross profit is $p(\lambda, x)x$. The maximization of these profits leads to equilibrium individual quantity $1/2$ and to a price $\overline{p}_1 = \left[\lambda s - (1-\lambda)d\right]/2$. The equilibrium gross profit for both firms and the equilibrium consumer's surplus are, respectively, $\overline{\pi}_1 = \left[\overline{\mu}s - (1-\overline{\mu})d\right]/4$ and $\overline{cs}_1 = cs(\lambda, \overline{p}_1) = \left[\lambda s - (1-\lambda)d\right]/8$. In this case, the expected profit is

$$\overline{\Pi}^{1}(\lambda) = \left[\lambda s - (1-\lambda)d\right]/4 - f\lambda^{2}/2\,. \qquad (14)$$

The expected welfare is

$$\overline{W}^{1}(\lambda) = \overline{\Pi}^{1}(\lambda) + \overline{cs}_{1}\,. \qquad (15)$$

As in the previous section, three configurations are taken into account by the regulator, namely, an MSS with no exit in period 2, an MSS leading to exit in period 2, and the absence of an MSS. The equilibrium welfare with and without MSS are compared for determining the best policy. Proposition 3 describes the regulator's choice (see the appendix for the proof and the detailed values).

Proposition 3. *Under Cournot competition and information about the average safety effort, the regulatory choice is as follows:*

(i) *If* $f \leq f_4$*, the absence of MSS, since it is equal to the private firms' choices (equal to 1) under duopoly.*

(ii) *If* $f_4 < f \leq f_5$*, an MSS equal to 1 under duopoly. The MSS improves the welfare and both sellers comply with it.*

(iii) *If* $f_5 < f \leq f_6$*, an MSS equal to* $Min\left[\overleftarrow{\lambda}^{1}, \underleftarrow{\lambda}^{1}\right]$*, leading to a monopoly situation. The MSS improves the welfare and the monopolist complies with it.*

(iv) *If* $f > f_6$*, the absence of MSS and the absence of trade. The MSS is useless for mitigating the market failure.*

When f is very low, firms voluntarily adopt a level of effort equal to one under Cournot competition. The common reputation does not impede a large effort since the cost $f\lambda^2/2$ is very low. If f is relatively low ($f \leq f_5$), both firms may incur the cost linked to the MSS under Cournot competition. Conversely, the monopoly is better than the duopoly for relatively large values of the cost parameter *f*. The reason is that the cost $f\lambda^2/2$ is incurred once under monopoly and profits under duopoly are too low because of the absence of precise information that limits consumers' willingness to pay. Compared to proposition 2, the absence of precise information requires an MSS that leads to a monopoly situation when *f* is relatively large. The standard reinforces the concentration for relatively large values of *f* since only a monopoly is viable for covering the cost that allows consumers' to purchase.[17] When the cost parameter *f* is very large, the MSS would be too low to allow trade and consumers would refuse to purchase goods with a negative expected safety $\overset{=}{s}$ (with a probability lower than the value $d/(d+s)$). The MSS is ineffective for mitigating the effects of imperfect information.

4.2. No Information about Safety

We now consider the extreme case, in which consumers have no information about safety (or effort). By the absence of precise information coming from certification, the regulator only certifies the effort for limiting risk. Without regulation, the probability of offering safety is zero for both sellers because of the absence of any incentives to improve safety. By imposing a minimum probability, the MSS provides a credible signal and information to consumers about the probability of getting safe products. In this case the MSS is essential for $f > 0$. Compared to proposition 3 under Cournot competition, only point (*i*) changes under the absence of information with the necessity to have an MSS equal to one imposed on the duopoly. The other points (*ii*), (*ii*), and (*iii*) are still the same.

4.3. Bertrand Competition

Eventually, under Bertrand competition, only the MSS under monopoly is viable whatever the value of *f* under the different contexts of imperfect information previously mentioned (common

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[17] The MSS under perfect information is $\overline{\lambda}^{s,C} = 27s/(22s+72f) < 1$ with two firms complying with it if $f > f_2$ (see proposition 2). This level with two firms under perfect information is lower than the MSS under imperfect information equal to $Min\left[\overset{\leftrightarrow}{\lambda}^{1}, \underset{\leftrightarrow}{\lambda}^{1}\right]$ with a monopolist complying with it if $f_5 < f \leq f_6$. Note that the welfare under perfect information with two firms is larger than the welfare under imperfect information with a monopoly for $f_5 < f \leq f_6$ or with the absence of trade for $f > f_6$.

reputation and absence of information). Duopoly is not viable for covering a cost $f\lambda^2/2$ greater than zero when firms cannot be distinguished by their individual level of safety or effort. The absence of consumers' recognition regarding safety differentiation would lead to a price equal to zero under duopoly. Monopoly emerges when the cost is greater than zero. In this case, by using and rewriting one part of proposition 3, the regulatory choice is point (*iii*) if $0 < f < f_6$ and point (*iv*) if $f > f_6$, since the monopoly allocation does not depend on the type of competition. The MSS under Bertrand competition reinforces the concentration for any value of the cost parameter $f > 0$.

5. Extensions

In order to focus on the main economic mechanisms and to keep the mathematical aspects as simple as possible, our analytical framework was admittedly simple. In order to fit different problems coming from various contexts, some extensions could be integrated into the model presented here.

(1) For simplicity, we assumed a regulatory/inspection cost equal to zero, even if imposing an MSS is obviously costly to monitor. The product's approval process is generally very costly for both agencies and firms. Without audit or inspection, the regulator will rarely have as accurate information as the firm with respect to the effort for getting safety. Depending on the cost of firms' inspection, the regulator has to determine the number of inspections, the penalty for absence of compliance, and the way to finance such a policy (see Marette and Crespi, 2005). Clearly, the social benefits of imposing an MSS in proposition 1 would be diminished by taking into account the cost of regulation. For relatively large values of regulatory cost, the absence of MSS may become optimal.

(2) The choice regarding the private/public certification influencing the context of information for consumers could also be endogenous. The difference between these two contexts of information represents a difference of certification intensity, where the auditing, inspection and certification, differ and are obviously costly. For instance, in a context of no initial information for consumers, a product certification process guaranteeing that no dangerous products will hit the shelves is equivalent to a situation of perfect information described in section 3. By abstracting from the certification cost and by using notations of propositions 2 and

3 (under Cournot competition), the social choice regarding public certification would be the following. For $f \leq f_5$, an MSS equal to one is sufficient from the social of view and the product certification is useless. For $f > f_5$, the product certification is socially useful for completing the MSS defined in point (*iii*) of proposition 3 (since $f_5 > f_2$). The welfare under perfect information with two firms is larger than the welfare under imperfect information with a monopoly for $f_5 < f \leq f_6$ or with the absence of trade for $f > f_6$.

Obviously, the cost of certification will diminish its advantages. Consider for instance that each firm incurs a certification fixed cost *C* guaranteeing that no dangerous products will hit the shelves.[18] The ability to incur this cost *C* would challenge the possibility to impose an MSS. Using equation (4), the profit under duopoly with certification would be rewritten as $\Pi_i^r(\lambda_i, \lambda_j) - C$. The positive firms' incentive to certify would be given by the condition $\Pi_i^r(\lambda_i, \lambda_j) - C \geq \overline{\Pi}_i(\lambda_i, \lambda_j)$, where the profit $\overline{\Pi}_i(\lambda_i, \lambda_j)$ under imperfect information is given by (12). In this context, the maximum value of an MSS compatible with a duopoly (namely, $\Pi_i^r(\lambda^s, \lambda^s) - C \geq 0$) previously given by $\underline{\lambda}^r$ in (9) would decrease with *C*. It means that the MSS would be capped by the cost of certification for relatively medium values of *C*. The regulator may also finance one part of the certification cost, since consumers who are taxpayers also benefit from certification. If *C* was very large, the certification would not be socially profitable and proposition 3 would apply. Alternatively, a sanction/liability system (not studied in this paper) that would perfectly reimburse consumers injured by dangerous products would also be equivalent to the case of perfect information studied in section 3.

(3) In section 4, we abstracted from safety signaling (via prices, guarantees, brand investment) and reputation in a context of repeat purchases under imperfect information. One strand of the asymmetric information literature concerns the sellers' ability to signal safety via prices, advertising, or guarantees or via the liability/regulation (see Daughety and Reinganum, 1997). Safety signalling was omitted from the present model for at least three reasons. First, the constraints required to prove the existence of separating/pooling equilibria (under monopoly and

[18] The certification could be credible for a proportion of consumers only, with the other portion of consumers paying no attention to certification (see Garella and Perrakis, 2006). In this case, the private/social benefit of certifying would diminish with an increase in the number of consumers paying no attention to the certification. See also Mason and Sterbenz (1994) for imperfect product certification.

duopoly) would make it very difficult, if not impossible, to consider the choices of exit/entry by firms (see for instance Marette *et al.*, 2000, for a safety signalling under monopoly only). Second, rational expectations about safety require consumers to know all parameters (common knowledge) in signalling models, a requirement very unlikely to be met in the presence of contexts in which safety also involves scientific expertise and/or complex experiments. Third, inclusion of signaling would require either repeat purchases (e.g., Milgrom and Roberts, 1986) or significantly restrictive assumptions on marginal cost (e.g., Bagwell and Riordan, 1991), mainly in a monopolistic context.[19] However, as noted in note 2 of this paper, repeat purchases may lead to no new information for consumers since safety of a good could be revealed in the very long term, which ruins the possibility of signals or reputation.[20]

(4) Throughout the model, we assumed that the regulator was acting in the public's best interest. One stumbling block for such regulatory "fairness" is the efficiency of the public regulatory authority itself. Public agencies may be doomed to failure (*i*) if their mandate is not clearly defined, (*ii*) if they suffer from excessive bureaucracy, or (*iii*) if the industrial lobby's influence creates lax regulation. A regulator may sometimes choose more than the necessary amount of regulation with very large MSSs, depending on the incumbent's influences upon the agency. Kim (1997) underscores how regulation is suboptimal when an incumbent behaves strategically against the government (the regulator, as a follower, deters entry by newcomers, protecting the incumbent's oligopoly situation), an aspect we do not consider here. The standard can be a potential barrier to innovation (Maxwell, 1998, and Garella, 2006) or to entry (Lutz, 2000). Lutz *et al.* (2000) showed that if the high-quality firm can commit to a quality level before regulations are promulgated, it induces the regulator to weaken standards, and welfare falls. Further, the absence of restriction in the number of firms leading to a duopoly (in propositions 1 and 2) needs to be mitigated with respect to the government's ability to collect information regarding parameters such as firms' fixed costs and market demand.

[19] Milgrom and Roberts showed that conspicuous spending is essential for signaling high quality in a monopolistic context, whereas Bagwell and Riordan demonstrated that a monopolist would resort to positive price distortions (relative to the price prevailing under perfect information) to signal high quality. Along such lines, the present model could be extended by allowing part of the cost to consist of conspicuous spending and signaling with two competing firms.

[20] Under perfect information, results under repeat purchases can be replicated from equation (4) with a new profit function $\lambda_i \lambda_j \pi_2^r (1+\delta+...+\delta^n) + \lambda_i (1-\lambda_j) \pi_1 (1+\delta+...+\delta^n) - f \lambda_i^2 / 2$, where safety effort results in a constant safety level over *n* periods and where $\delta < 1$ is a discount factor used for valuing the subsequent period gains relative to the previous period gains.

(5) Government regulation is not the only approach deserving consideration, with measures ranging from voluntary practice, codes of good conduct, “private” MSS, and market incentives as reputation mechanisms or quality/safety signaling. One extension that is of interest concerns that of a voluntary standard/certification system in which each firm decides whether or not to comply with it. Self-regulation by professions fixing MSS could also be studied (see Andrews, 2002).

(6) We could expand the number of firms in our market or introduce multi-product firms. In particular, the results with three firms competing would be very close to the results of propositions 1 and 2. The regulator would calibrate the MSS to allow the presence of the three firms on the market under perfect information. The results of proposition 3 hold for contexts of imperfect information. The assumption of homogeneous producers may be considered unrealistic. However, allowing for heterogeneous producers would significantly lengthen the paper and would divert attention into numerous modelling details.

6. Conclusion

Using a very stylized framework, various mechanisms were illustrated by which the structure of consumers’ information and producers’ competition may influence the provision of product safety. Because the effect of consumers’ information and regulatory policy are intermingled, different contexts of information were considered. This stylized framework made it possible to infer some stylized economic mechanisms that are valid in various realistic situations.

By focusing on safety, the paper led to new results. Results are not trivial when the information structure for consumers varies. The results are novel by directly considering the probability of getting safety under different consumers’ information contexts, the MSS, and the exit/entry considerations. The MSS under perfect information about safety is compatible with competition, which is not the case under imperfect information. Clearly, the MSS under imperfect information entails competition restriction.

This simple model suggests that it is especially imperative for governments to examine not only the types of regulations imposed upon an industry but also both information context and competitive structure (including the firms’ profitability influencing the exit/entry). These results mean that a regulator should also focus on both consumers' information and competitive structures, and not only on risk assessment, when an MSS is imposed.

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Appendix

<u>Proof of proposition 1.</u>

The different levels of efforts (8), (9), (10) and the corresponding equilibrium welfare are detailed with *r=B* for the Bertrand competition and by using equation (2). By using (5) and (8), the private choice by firms $\hat{\lambda}^B = s/(s+4f) < 1$ leads to the equilibrium welfare

$$W^B\left(\hat{\lambda}^B, \hat{\lambda}^B\right) = \frac{s^2}{2(s+4f)}. \tag{A1}$$

By using (5) and (9), the value $\underline{\lambda}^B = s/(2f+s) < 1$ (for which profits are zero) leads to the equilibrium welfare

$$W^B(\underline{\lambda}^B, \underline{\lambda}^B) = \frac{s^2(s+f)}{2\left[s+2f\right]^2}. \tag{A2}$$

As $\underline{\lambda}^B < 1$, an MSS equal to one can never be implemented. By using (5) and (10), the socially optimal level $\overline{\lambda}^{s,B} = 3s/(8f + 2s) < 1$ leads to the equilibrium welfare

$$W^B\left(\overline{\lambda}^{s,B}, \overline{\lambda}^{s,B}\right) = \frac{9s^2}{16\left[s + 4f\right]}. \tag{A3}$$

The socially optimal level $\overline{\lambda}^{s,B}$ is compatible with a duopoly situation, if the constraint $\overline{\lambda}^{s,B} \leq \underline{\lambda}^B$ is satisfied, which is equivalent to $f \geq \widetilde{f} = s/2$.

When one firm exits the market in period 2 with an effort $\lambda > \underline{\lambda}^B$, the MSS is $\overline{\overline{\lambda}}^{s,1}$ given by (11). If $f < \widehat{f} = 3s/8$, the MSS is $\overline{\overline{\lambda}}^{s,1}$ =1, which leads to the equilibrium welfare

$$W^1(1) = 3s/8 - f/2. \tag{A4}$$

If $f > \widehat{f} = 3s/8$, the MSS is $\overline{\overline{\lambda}}^{s,1} = 3s/(8f)$, which leads to the equilibrium welfare

$$W^1\left(\frac{3s}{8f}\right) = \frac{9s^2}{128f}. \tag{A5}$$

We now turn to the welfare comparison. First, both strict inequalities

$W^B\left(\overline{\lambda}^{s,B}, \overline{\lambda}^{s,B}\right) - W^B\left(\hat{\lambda}^B, \hat{\lambda}^B\right) = \dfrac{s^2}{16\left[s + 4f\right]} > 0$ and

$W^B(\underline{\lambda}^B, \underline{\lambda}^B) - W^B\left(\hat{\lambda}^B, \hat{\lambda}^B\right) = \dfrac{fs^3}{2\left[s + 2f\right]^2 (s + 4f)} > 0$ mean that the choice of a private effort $\hat{\lambda}^B$ is dominated by the social choices $\overline{\lambda}^{s,B}$ or $\underline{\lambda}^B$. No firm has an incentive to select an effort $Min\left[\underline{\lambda}^B, \overline{\lambda}^{s,B}\right] + \varepsilon$ in period 2.

For $f < \widehat{f}$, an MSS $\underline{\lambda}^B$ with two firms in period 2 improves the welfare compared to an exit situation in period 2 with $\overline{\overline{\lambda}}^{s,1}$=1 since $W^B(\underline{\lambda}^B,\underline{\lambda}^B)-W^1(1)=\frac{1}{8}\left(\frac{4s^2(f+s)}{[s+2f]^2}+4f-3s\right)>0$. In particular, this last inequality is *29s/784>0* for $f=\widehat{f}$.

For $\widehat{f}<f<\widetilde{f}$, an MSS $\underline{\lambda}^B$ with two firms in period 2 improves the welfare compared to a monopoly situation with $\overline{\overline{\lambda}}^{s,1}$<1, since $W^B(\underline{\lambda}^B,\underline{\lambda}^B)-W^1(3s/8f)=\frac{s^2}{128}\left(\frac{64(f+s)}{[s+2f]^2}-\frac{9}{f}\right)>0$. In particular, this last inequality is *3s/64>0* for $f=\widetilde{f}$.

For $f>\widetilde{f}$, an MSS $\overline{\lambda}^{s,B}$ with two firms in period 2 improves the welfare compared to a monopoly situation with $\overline{\overline{\lambda}}^{s,1}$<1, since $W^B\left(\overline{\lambda}^{s,B},\overline{\lambda}^{s,B}\right)-W^1(3s/8f)=\frac{9(4f-s)s^2}{128f[s+4f]}>0$ for $f\geq\widetilde{f}=s/2$.

QED.

<u>Proof of proposition 2.</u>

The different levels of efforts (8), (9), (10) and the corresponding equilibrium welfare are detailed with *r=C* for the Cournot competition and by using equation (3). By using (5) and (8), the private choice by firms $\hat{\lambda}^C=9s/(5s+36f)<1$ (namely, for $f>f_1=s/9$) leads to the equilibrium welfare

$$W^C\left(\hat{\lambda}^C,\hat{\lambda}^C\right)=\frac{9s^2(s+18f)}{[5s+36f]^2}. \tag{A6}$$

By using (5) and (10), the socially optimal effort $\overline{\lambda}^{s,C}=27s/(22s+72f)<1$ leads to the equilibrium welfare

$$W^C\left(\overline{\lambda}^{s,C},\overline{\lambda}^{s,C}\right)=\frac{81s^2}{176s+576f}. \tag{A7}$$

The private choice by firms is equal to one for $f < f_1 = s/9$ and the socially optimal effort is one for $f < 5s/72$. By using (5), an effort equal to one leads to the equilibrium welfare

$$W^C(1,1) = 4s/9 - f \ . \qquad \text{(A8)}$$

The private choice $\hat{\lambda}^C$ is greater (respectively lower) than the socially optimal choice $\overline{\lambda}^{s,C}$ for $f_1 < f < f_2 = 7s/36$ (respectively for $f > f_2 = 7s/36$). When $\hat{\lambda}^C$ is greater than the socially optimal choice, $\overline{\lambda}^{s,C}$, the MSS is ineffective.

The values $\hat{\lambda}^C$ and $\overline{\lambda}^{s,C}$ are compatible with two firms in period 2 since these values are lower than the value $\underline{\lambda}^C = Min[9s/(5s+18f),1]$ for which the presence of both firms at period 2 is viable. One firm could exit the market in period 2 with an effort $\lambda > \underline{\lambda}^B$. The MSS would be $\overline{\overline{\lambda}}^{s,1}$ given by (11) and the equilibrium welfare would be given by (A4) or by (A5).

We now turn to the welfare comparison.

(*i*) For $f < f_1$, both private and socially optimal effort are equal ($\hat{\lambda}^C = \overline{\lambda}^{s,C} =1$), so that no MSS is necessary. This level of effort with 2 firms at period 2 is better than an exit situation with one firm selecting $\overline{\overline{\lambda}}^{s,1}=1$, since $W^C(1,1) - W^1(1) = 5s/72 - f/2 > 0$ for $f < f_1 = s/9$. In particular, this last expression is equal to *s/72>0* for $f = f_1$.

(*ii*) For $f_1 < f < f_2 = 7s/36$, the private level of effort by firms $\hat{\lambda}^C$ is higher than the socially optimal level $\overline{\lambda}^{s,C}$. No MSS can correct this level, $\hat{\lambda}^C$. The private choice $\hat{\lambda}^C$ by firms under duopoly leads to a higher welfare than the welfare with a monopoly situation since $W^C(\hat{\lambda}^C,\hat{\lambda}^C) - W^1(1) = \dfrac{9s^2(s+18f)}{[5s+36f]^2} + \dfrac{1}{8}(4f-3s) > 0$. In particular, this last inequality is *s/288>0* for $f = f_2$.

(*iii*) For $f > f_2$, the private level of effort by firms $\hat{\lambda}^C$ is lower than the socially optimal level $\overline{\lambda}^{s,C}$. For $f_2 < f < \hat{f}$, an MSS $\overline{\lambda}^{s,C}$ improves the welfare compared to a monopoly situation with $\overline{\overline{\lambda}}^{s,1}$=1, since $W^B(\overline{\lambda}^{s,C},\overline{\lambda}^{s,C}) - W^1(1) = \frac{f}{2} + \frac{3s(5s-72f)}{176s+576f} > 0$. In particular, this last inequality is *15s/784>0* for $f = \hat{f}$. For $f > \hat{f}$, an MSS $\overline{\lambda}^{s,C}$ improves the welfare compared to a monopoly situation with $\overline{\overline{\lambda}}^{s,1}$<1, since

$W^B(\overline{\lambda}^{s,C},\overline{\lambda}^{s,C}) - W^1(3s/8f) = \frac{9(36f-11s)s^2}{128f[11s+36f]} > 0$ for $f \geq \tilde{f} = s/2$.

QED.

<u>Proof of proposition 3.</u>

Under duopoly in period 2, the maximization of profits given by (12) leads to the private choice $\vec{\lambda}^{2,C} = Min[(s+d)/(18f),1]$. The private choice is $\vec{\lambda}^{2,C} = (s+d)/(18f)$ if $f > f_4 = (s+d)/18$ and 1 if $f < f_4 = (s+d)/18$. With an MSS, the maximization of the expected welfare under duopoly given by (13) and equal to $\overline{W}(\lambda^s,\lambda^s) = 4[\lambda^s s + (1-\lambda^s)d]/9 - f(\lambda^s)^2$ leads to a socially optimal choice $\underline{\underline{\lambda}}^C = Min[2(s+d)/(9f),1]$. The socially optimal choice is $\underline{\underline{\lambda}}^C = 2(s+d)/(9f)$ if $f > f_5 = 2(s+d)/9$ and 1 if $f < f_5 = 2(s+d)/9$. If $f < f_5 = 2(s+d)/9$, this socially optimal level is always compatible with the duopoly situation, since $\overline{\Pi}_i(1,1) = 0$. This leads to an equilibrium welfare

$$\overline{W}(1,1) = 4s/9 - f. \tag{A9}$$

If $f > f_5 = 2(s+d)/9$, the socially optimal choice $\underline{\underline{\lambda}}^C = 2(s+d)/(9f)$ is not compatible with a duopoly situation since $\overline{\Pi}_i(\underline{\underline{\lambda}}^C,\underline{\underline{\lambda}}^C) = -d/9$. In this case, the regulator may select a level of effort $\underset{\rightarrow}{\lambda}^C$ such that $\overline{\Pi}_i(\underset{\rightarrow}{\lambda}^C,\underset{\rightarrow}{\lambda}^C) = 0$. For $f_5 < f < \hat{f} = (d+s)^2/(18d)$, the higher root of the equality $\overline{\Pi}_i(\underrightarrow{\lambda}^C, \underrightarrow{\lambda}^C) = 0$ leads to $\underrightarrow{\lambda}^C = \dfrac{d + s + \sqrt{(d+s)^2 - 18df}}{9f}$ (with $\underrightarrow{\lambda}^C$ larger than the private choice $\overrightarrow{\lambda}^{2,C}$) and an equilibrium welfare

$$\overline{W}(\underrightarrow{\lambda}^C, \underrightarrow{\lambda}^C) = \frac{2(s+d)^2 - 18df + 2(d+s)\sqrt{(s+d)^2 - 18df}}{81f}. \tag{A10}$$

For $f > \hat{f} = (d+s)^2/(18d)$, the expression $(d+s)^2 - 18df$ under the square root in (A10) is lower than zero, which means that $\overline{\Pi}_i(\lambda, \lambda) < 0$ for any $0 \le \lambda < 1$. There is no effort compatible with a duopoly situation and some positive purchases by consumers with $\overline{\mu} = (\lambda_i + \lambda_j)/2 \ge d/(d+s)$.

Under monopoly in period 2, the maximization of profit given by (14) leads to the private choice $\tilde{\lambda}^1 = Min[(s+d)/(4f), 1]$. The private choice is $\tilde{\lambda}^1 = (s+d)/(4f)$ if $f > \tilde{f} = (s+d)/4$ and 1 if $f < \tilde{f} = (s+d)/4$. In particular, with $\tilde{\lambda}^1 = (s+d)/(4f)$, the profit is $\overline{\Pi}^1(\tilde{\lambda}^1) < 0$ for $f > f_6 = (d+s)^2/(8d)$. With an MSS, the maximization of the expected welfare under duopoly given by (15) leads to a socially optimal choice $\overleftrightarrow{\lambda}^1 = Min\left[3(s+d)/(8f), 1\right]$. The socially optimal choice is $\overleftrightarrow{\lambda}^1 = 3(s+d)/(8f)$ if $f > \overrightarrow{f} = 3(s+d)/8$ and 1 if $f < \overrightarrow{f} = 3(s+d)/8$. If $f < \overrightarrow{f} = 3(s+d)/8$, this socially optimal level is always compatible with the monopoly situation, since $\overline{\Pi}^1(1) > 0$. This leads to an equilibrium welfare

$$\overline{W}^1(1) = 3s/8 - f/2. \tag{A11}$$

If $\overrightarrow{f} < f < \underrightarrow{f} = 3(s+d)^2/(32d)$, the socially optimal choice $\overrightarrow{\lambda}^1 = 3(s+d)/(8f)$ is compatible with a monopoly situation since $\overline{\Pi}^1(\overleftrightarrow{\lambda}^1) = \left[3(s-d)^2 - 32\,fd\right]/(128\,f) > 0$. In this case, the equilibrium welfare is

$$\overline{W}^1\left(\overleftrightarrow{\lambda}^1\right) = \frac{3\left[3(s-d)^2 - 16\,fd\right]}{128\,f}. \qquad \text{(A12)}$$

If $f > \underrightarrow{f} = 3(s+d)^2/(32d)$, the socially optimal choice $\overleftrightarrow{\lambda}^1 = 3(s+d)/(8\,f)$ is not compatible with a monopoly situation since $\overline{\Pi}^1(\overleftrightarrow{\lambda}^1) < 0$. The regulator may select a level of effort $\underleftrightarrow{\lambda}^1$ such that $\overline{\Pi}^1(\underleftrightarrow{\lambda}^1) = 0$. For $\underrightarrow{f} < f < f_6 = (d+s)^2/(8d)$, the higher root of the last equality leads to $\underleftrightarrow{\lambda}^1 = \dfrac{d+s+\sqrt{(d+s)^2 - 8df}}{4\,f}$ and an equilibrium welfare

$$\overline{W}^1(\underleftrightarrow{\lambda}^1) = \frac{(s+d)^2 - 4df + (d+s)\sqrt{(s+d)^2 - 8df}}{32\,f}. \qquad \text{(A13)}$$

For $f > f_6 = (d+s)^2/(8d)$, the expression $(s+d)^2 - 8df$ under the square root in (A13) is lower than zero, which means that $\overline{\Pi}^1(\lambda) < 0$ for any $0 \le \lambda < 1$. There is no effort compatible with a monopoly situation and allowing the trade between the producer and the consumers (for $\lambda \ge d/(d+s)$). For $f > f_6 = (d+s)^2/(8d)$, there is no exchange under monopoly.

We now turn to the welfare comparisons leading to proposition 3.

(*i*) If $f < f_4 = (s+d)/18$, the private choice by both firms $\overrightarrow{\lambda}^{2,C}$ and the socially optimal effort $\underline{\underline{\lambda}}^C$ are equal to one, so that an MSS is not necessary. The duopoly situation leads to a higher welfare than a monopoly situation since $\overline{W}(1,1) > \overline{W}^1(1)$.

(*ii*) If $f_4 < f < f_5 = 2(s+d)/9$, the private choice by both firms $\overrightarrow{\lambda}^{2,C}$ is lower than the socially optimal effort $\underline{\underline{\lambda}}^C$ (equal to one), so that an MSS equal to one is necessary. The duopoly situation leads to a higher welfare than a monopoly situation since $\overline{W}(1,1) > \overline{W}^1(1)$. The welfare under duopoly $\overline{W}(1,1)$ is higher than the welfare $\overline{W}^1(1)$ under monopoly if $f < \hat{f}_4 = 5s/36$. The welfare under duopoly $\overline{W}(1,1)$ is lower than the welfare $\overline{W}^1(1)$ under a monopoly if $f > \hat{f}_4 = 5s/36$, but no MSS may lead to the monopoly situation for $\hat{f}_4 < f < f_5$. The MSS improves the welfare under duopoly but this MSS is ineffective to lead to a monopoly situation that would be better from a welfare point of view.

(*iii*) If $f_5 < f < f_6$, an MSS equal to $Min\left[\overleftrightarrow{\lambda}^1, \underleftrightarrow{\lambda}^1\right]$ is selected and leads to a monopoly situation. If $f_5 < f < \hat{f} = (d+s)^2/(18d)$, the effort $\underrightarrow{\lambda}^C$ is the level that would maximize the welfare under a viable duopoly with $\overline{\Pi}_i(\underrightarrow{\lambda}^C, \underrightarrow{\lambda}^C) = 0$. However, the welfare $\overline{W}(\underrightarrow{\lambda}^C, \underrightarrow{\lambda}^C)$ with a level of effort $\underrightarrow{\lambda}^C$ under duopoly is strictly lower than the welfare $\overline{W}^1(1)$ under monopoly. An MSS equal to one is essential for reducing the number of firms and leading to a monopoly.

For $f > \hat{f}$, the duopoly situation is not viable anymore since $\overline{\Pi}_i(\lambda, \lambda) < 0$ for any $0 \le \lambda < 1$. If $\hat{f} < f < \underrightarrow{f} = 3(s+d)^2/(32d)$, an MSS $\overleftrightarrow{\lambda}^1 = Min\left[3(s+d)/(8f), 1\right]$ is useful for improving the level of effort selected by the monopolist. If $\underrightarrow{f} < f < f_6 = (d+s)^2/(8d)$, the MSS $\underleftrightarrow{\lambda}^1 = \dfrac{d+s+\sqrt{(d+s)^2 - 8df}}{4f}$ improves the level of effort selected by the monopolist since the welfare $\overline{W}^1(\underleftrightarrow{\lambda}^1)$ is greater than zero.

(*iv*) If $f > f_6 = (d+s)^2/(8d)$, the monopoly situation is not viable anymore since $\overline{\Pi}^1(\lambda) < 0$ for any $0 \le \lambda < 1$. There is no exchange and there is a market closure.

QED.