PRODUCT SAFETY PROVISION AND CONSUMERS' INFORMATION

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Summary : Economic mechanisms related to the provision of product safety are explored, with particular attention paid to the structure of consumers' information. The case of perfect information, of *experience* goods (for which consumers detect product safety after consumption) and of *credence* goods (where consumer cannot link a disease to a particular product consumed in the past) are explored. Imperfect competition is assumed in the supply sector. In the case of both perfect information and *experience* goods, market equilibrium is characterized by a less-than-socially optimal provision of safety, when the safety effort is costly. With *credence* goods, imperfect information leads to the absence of safety effort and to a market closure. Different types of public regulation aiming at increasing consumer protection and circumventing market failures are explored. Particular attention is paid to minimum safety standards, labels and liability enforcement. The relative efficiency of these instruments depends on the information structure. In the cases of perfect information and *experience* goods, a minimum safety standard can be an efficient instrument. Regulation is necessary but not sufficient to avoid market failure in the case of credence goods.

Keywords: Economics of product safety; imperfect information; quality standards; liability.

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I. INTRODUCTION

Product safety has become a major policy issue in most developed countries. This is the case for example in the food sector, where safety has become an increasing concern over the recent years, mainly because of highly-publicized outbreaks of food-borne diseases (*E. Coli*, *Salmonella* in the US and Japan) and worries about transmission to humans of animal diseases (the "mad cow" crisis in Europe). Risks are also less and less tolerated with pharmaceutical products, an issue made very sensitive in countries such as France and Canada because of sales of HIV contaminated drugs in the

80s. Consumers are also more demanding as to safety of buildings (asbestos), cars, and a variety of products, particularly those designed for children.

Economic growth, industrialization and increased international trade have put on the shelves many new products, requiring a better mastering of product safety. As incomes rise, consumers are more prepared to pay for a regulatory regime that provides higher standards and minimizes risks. As a result, demands for more regulation have gained momentum across developed countries in recent years. Governments have responded by setting stricter regulations and by expanding the role of agencies enforcing existing regulations.[1] Government regulation is not the only approach deserving consideration, with measures ranging from voluntary practice, codes of good conduct, private standards, labeling and economic incentives. Indeed, regulations such as quality standards are often costly. Many economists have argued for careful assessment of the usefulness, costs and benefits of regulations on product safety (Arrow *et al*, 1996). In particular, it is well admitted that regulations involving large compliance costs should be restricted to cases where market-based mechanisms lead to an insufficient provision of product safety.

Empirical evidence shows that markets do not always provide the adequate level of safety, and that there may be a role for government intervention (Viscusi *et al*, 1995). Economic theory has identified several reasons why the provision of safety may not be socially optimal with unregulated markets (OECD, 1999). If consumers are not fully informed about product characteristics, they may consume a dangerous product, or take a level of risk they were not willing to take, or pay a price that does not reflect the risk associated to the good in question. Imperfect competition may also interfere. Safety can be seen as a particular attribute of quality.[2] When both quantity (or price) and quality are decision variables for the firm, it has been shown that a monopolistic supplier may select a socially undesirable level of quality, in addition to limiting the quantity on offer (Spence, 1975). More generally, in a situation of imperfect competition there are few reasons why producers setting both levels of quality and quantity simultaneously would supply socially optimum quality. This is particularly true in the presence of fixed costs and other types of entry barriers (Krouse, 1990).

Few studies have explored the consequences of the information structure on market equilibria and on the resulting provision of product quality, let alone product safety. A widely used framework is the one developed by Shapiro (1983), where firms build a reputation over time (Falvey 1989; Grossman and Shapiro 1988). While it is appropriate to the case of experience goods, it does not shed much light on the working of markets when consumers remain unaware of the product quality even after a long period after consumption, a problem observed in many instances (cancer-inducing residues in food, BSE, asbestos, etc.). Moreover, even fewer papers have addressed the issue of public regulation for different information structures, while the efficiency of policy instruments differ according to the degree of information of consumers. For example, long delays between consumption and safety detection may require specific forms of public intervention, since they make it difficult to rely on reputation-building mechanisms.

In this paper, we build on the literature on safety revelation and safety effort (Daughety and Reinganum, respectively 1995 and 1997). We explore the economic mechanisms affecting product safety when consumers face different information structure. Economic literature suggests that regulation on product safety cannot be considered independently of the competition structure (Daughety and Reinganum, 1997). Many normative results on safety regulation depend on the combined effect of information and competition (Donnenfeld *et al*, 1985). In order to take into account the interactions between imperfect competition and consumers' information, we use an extremely simplified framework. Indeed, the economics of information revelation becomes rapidly mathematically intractable when models become sophisticated. Our purpose is to explore stylized economic mechanisms, rather than dealing with real-life situations.

We consider a monopolistic market with a large number of consumers (we assess the consequences of more competition in the last section). We characterize market equilibria for different structures of information. We first consider the case where consumers are informed in the sense that they are able, although possibly with some cost, to acquire information about the safety of the product prior to purchase. This case corresponds to *search* goods. Second, the case where consumers are imperfectly informed on product safety prior to purchase, but where they find out right after consumption whether the product was safe or not. This characterizes *experience* goods (Nelson, 1970). Third, the case where consumers do not detect that a particular product was dangerous after consumption, namely if they are unable to link a long-term disease to a particular product consumed. This characterizes *credence* goods (Darby and Karni, 1973).

In section II, we discuss market mechanisms and their ability to guarantee that products are safe. Under perfect information on product safety, we show that the seller selects a safety level which does not always correspond to the socially optimal level, depending on the cost of the safety effort. With experience goods, the seller selects a lower safety effort than under perfect information. Quality signaling does not always emerge spontaneously from market equilibrium, and consumers may remain unaware of the safety of the products on the market. With credence goods, imperfect information may lead to the absence of effort to supply safe products. In Section III, we investigate possible regulations that could help solving some market inefficiencies. We focus on labeling, liability and minimum safety standard. Particular attention is paid to market-based regulations and we explore the effects of investment in reputation, when reputation is obtained from providing a safe product. We show that a minimum safety standard (MSS) helps correct an insufficient safety effort in both the cases of search and experience goods. Regulations such as labeling, liability enforcement or MSS are necessary to allow trade under credence goods. However, when the safety effort is costly, a label or a

MSS cannot always prevent market closure. Section IV revisits the assumptions of the model in order to assess the sensitivity of the results. Section V concludes.

II. ECONOMIC MECHANISMS AND INFORMATION

In order to illustrate possible effects of the information structure on product safety provision, we consider a very stylized framework with a single seller. We assume that trade takes place over two periods. A common discount factor $\delta \geq 0$ is used for valuing the second period gains relative to the first period ones. The marginal cost of production c is constant, regardless of the safety of the product. We consider that a product is either harmful or harmless, and that a higher level of safety effort made by the seller increases the probability of it being harmless. The seller supplies either harmless products with a probability λ, or harmful products with a probability $(1-\lambda)$. For the sake of simplicity, we assume that the safety effort is also represented by λ, so that there is an exact correspondence between the level of safety effort and the probability to get safe products. Risks are only eliminated for a maximum level of effort, i.e. $\lambda=1$. By selecting a level of effort λ, the seller incurs a fixed cost equal to $f\lambda^2/2$ in the first period. We assume that investment in safety effort is a sunk cost, and that the resulting safety level is constant over both periods. Note that this framework involves both a moral hazard effect and an adverse selection effect when consumers are imperfectly informed. Indeed, the level of safety depends on the seller's effort, which refers to moral hazard. However, when $\lambda<1$, the seller cannot totally control the final safety of the product, which refers to adverse selection.

Consumers purchase either one or zero unit of the good. Acquiring harmful products results in a zero utility for consumers. That is, if consumers are aware that the product is harmful, the demand is zero. Consumers differ in their willingness to pay for those goods that are safe. Heterogeneous willingness to pay are represented by a parameter $\theta \in [0,1]$ uniformly distributed over the population of consumers. Without loss of generality, the mass of consumers is normalized at unity (see Mussa and Rosen, 1978).

We consider three cases, according to the information that consumers possess. In the first case, that we call "perfect information", the consumer knows the level of safety of the product in the beginning of the first period. In the case of "experience goods", the consumer does not have this information in the beginning of the first period, but only at the end of the first period (i.e. after purchase). He/she however uses this information for his/her purchase decision in the second period. Finally, in the case of "credence goods", the consumer does not have the information on product safety in any of the two periods. In all cases, we assume that the consumer knows the marginal cost, and that he/she observes the price before buying one unit of the good. As a result he/she can infer the cost of a possible quality signal by the firm, given that we will assume that these signal are conveyed by the first period price (see section II).

In the first period, if a consumer detects that the good is harmful prior to purchase, he/she does not acquire any product, resulting in a zero utility. The consumer will acquire a good in the second period only if he/she acquired a harmless product in the first period. In other cases, we assume that there is no consumption in the second period. This departs from the framework proposed by Shapiro (1983), where quality may vary between periods, and where consumers pick another seller when they are not satisfied with the first period supplier.

Perfect Information.

Under perfect information, we assume that consumers detect product safety before purchase so that they do not acquire harmful products. We assume that consumers' willingness to pay is θq_h for a harmless product and zero for a harmful product. The seller selects a safety effort λ at the beginning of the first period, taking into account expected profit. The selected λ can thus be solved by backward induction, as a case of subgame perfect equilibrium.

With a probability λ, the seller offers safe products. With a probability $1-\lambda$ the (harmful) product faces no demand. Since consumers differ in their willingness to pay for harmless products, not all consumers will acquire the product at a given price p. The one consumer with an indirect utility equal to $\theta q_h - p = 0$ is indifferent between buying and not buying one unit of good, implying that he/she can be represented by his/her taste parameter $\theta_0 = p/q_h$. As the distribution of preferences is uniform, the demand for safe products is therefore $D(p,q_h) = 1 - p/q_h$ (see Mussa and Rosen, 1978; Recall that the maximum value of θ is one, given our assumptions on the distribution of preferences and that the number of consumers above θ_0 equals the quantity demanded). The seller's intertemporal profit is then $\Pi = \lambda(1+\delta)(p-c)(1-p/q_h) - f\lambda^2/2$.

Solving the profit maximization program by backward induction leads to an equilibrium price $p_a = (q_h + c)/2$ for both periods. Substituting p_a in the expression of the seller's intertemporal profit leads to the expected profit Π_a

$$\Pi_a = \lambda \frac{(1+\delta)(q_h - c)^2}{4q_h} - f\frac{\lambda^2}{2}. \quad (1)$$

By maximizing Π_a in the first stage, the seller selects a safety effort λ_a

$$\lambda_a = Min[1, \frac{(1+\delta)(q_h - c)^2}{4q_h f}]. \quad (2)$$

The consumers' expected surplus is SC_a given by (3) and the overall welfare is $W_a=\Pi_a+SC_a$.

$$SC_a = (1+\delta)\lambda \int_{\theta_0}^{1} (\theta q_h - p_a) d\theta = \frac{\lambda(1+\delta)(q_h-c)^2}{8q_h} \quad \text{with } \theta_0 = p_a/q_h=(q_h+c)/(2q_h). \qquad (3)$$

When the fixed cost f is low, i.e. $f < (1+\delta)(q_h - c)^2 / 4q_h$, the seller selects the maximum effort, i.e. λ_a=1, and only offers safe products. However, the effort decreases when f increases (surpluses are given in appendix A). When $f \geq (1+\delta)(q_h - c)^2 / 4q_h$, the effort level is λ_a<1. In that case, harmful products may be supplied even though, under perfect information, consumers are able to detect them and avoid them. Note that, spontaneously, the market is not always covered because of the low willingness to pay for the (harmless) products of those consumers characterized with a low θ. Consumers with a preference θ located between 0 and $\theta_0=p_a/q_h=(q_h+c)/(2q_h)$ do not buy the product because of the price set by the profit maximizing seller, while they would do so if they could access cheaper products.

Define the socially optimal product safety as the effort level that maximizes welfare. In the situation of perfect information, there is no welfare loss due to the consumption of unsafe product (recall that these products are detected and rejected by consumers). However, the safety effort is costly for the seller. Extra costs can only be passed to consumers through product price in a limited extent, given that a higher price results in a smaller number of consumers. Even under perfect information, the safety effort that emerges from market equilibrium is not necessarily socially optimal in the sense that it maximizes the seller's profit rather than overall welfare.[3] The maximum welfare would be reached if the seller were to set the competitive price c. In that case the sellers' profit would be $-f\lambda^2/2$ (i.e. negative), and the consumer surplus would be SC_m.

$$SC_m = (1+\delta)\lambda \int_{\theta m}^{1} (\theta q_h - c) d\theta = \frac{\lambda(1+\delta)(q_h-c)^2}{2q_h} \text{,with } \theta_m = c/q_h. \qquad (4)$$

The optimal level of safety can be defined as the one that maximizes the social welfare SC_m-$f\lambda^2/2$. The expression of the socially optimal safety effort is given by (5).

$$\lambda_m = Min[1, \frac{(1+\delta)(q_h-c)^2}{2q_h f}]. \qquad (5)$$

We can draw two conclusions from the previous results characterizing market equilibrium under perfect information

Proposition 1. By comparing (2) and (5), one can see that the effort selected by the monopolistic seller is not always the socially optimal level. For low costs of the safety effort, the seller selects the maximal effort. This is also the socially optimal safety level for these particular values of f, even though the monopoly pricing strategy results in a collective welfare loss. When the effort is costlier, the seller selects an effort systematically below the socially optimal level.[4]

Implementing the socially optimal safety level together with a (socially optimal) competitive price would result in a loss for the seller. This suggests that public intervention seeking to implement a first best equilibrium would require subsidizing the seller, for example through public funding of the fixed costs of the safety effort. [5]

The problems raised by a lower-than-optimal safety effort are worsened by imperfect information, since consumers no longer have the means to detect and avoid harmful products. In the following sections we address this question. Because it raises different regulatory issues, we make a distinction between *experience* and *credence* goods.

Experience goods

We assume that the seller knows whether a given product is harmful or not in the beginning of the first period. Consumers, however, only observe product safety at the end of the first period. Recall that we assumed that there was no cost due to the consumption of harmful product in the first period.[6] We assume that parameters c and f are common knowledge. That is, consumers are able to anticipate the seller's program. If a consumer expects a safety level λ (in the absence of signal by the seller), his/her willingness to pay for the product is $\theta \lambda q_h$ in the first period. In the second period, he/she uses his/her first period experience and repeats his/her purchase only if the product was harmless in the first period.

Under these assumptions, prices are determined at the beginning of the first period as a perfect Bayesian equilibrium of the subgame that starts after the safety effort was chosen. We assume that a seller of harmless products can signal that its products are safe by a low introductory price. This stylized behavior encompasses a larger range of possible investments in reputation ("discount" prices, introductory special offers, publicity investments, etc.). In the first period, the seller may choose between two pricing strategies, a price-separating strategy and a pooling strategy, in order to influence consumers' expectations on product safety. Under the price separating strategy, the price provides a reliable information on the safety of the product, while, under the price pooling strategy, the price does not reveal the safety of the product in the first period.

First, consider the case of a *separating* equilibrium. The seller signals that its products are safe by a low introductory price that affects consumers' expectation on the safety of the products available on the market. An equilibrium is said to be separating if the seller of safe products selects a price p_S that it could not select if its product was dangerous, since this would result in a negative intertemporal profit. Clearly, the highest possible signaling price is $p_e = c - \varepsilon$ (with ε close to zero). Because this price is lower than the marginal cost c, it sends a signal to consumers that the seller is not a fly-by night supplying harmful products. The signal is credible since a fly-by night seller would make a negative intertemporal profit if it chose to signal itself as selling safe products (there would be no demand for its product in the second period). The seller of safe products in the first period can select a second-period price equal to the price under perfect information, i.e. $p_a=(q_h+c)/2$. Before choosing a safety effort, the seller therefore knows that its overall average expected profit is Π_e given by (6). The expected consumers' surplus is SC_e, given by (7).

$$\Pi_e = \lambda\left[\varepsilon\left(1-\frac{(c-\varepsilon)}{q_h}\right)+\delta\frac{(q-c)^2}{4q_h}\right]-f\frac{\lambda^2}{2}, \tag{6}$$

$$SC_e = \lambda\left[\int_{\theta_1}^{1}(\theta q_h - c+\varepsilon)d\theta + \delta\int_{\theta_0}^{1}(\theta q_h - p_a)d\theta\right] = \lambda\left[\frac{(q_h-c+\varepsilon)^2}{2q_h}+\frac{\delta(q_h-c)^2}{8q_h}\right], \tag{7}$$

with $\theta_1=(c-\varepsilon)/q_h$ and $\theta_0= p_a/q_h=(q_h+c)/(2q_h)$. With $\varepsilon=0$ for the sake of simplicity, profit maximization leads to a safety λ_e effort under separating equilibrium.

$$\lambda_e = Min[1,\frac{\delta(q_h-c)^2}{4q_h f}]. \tag{8}$$

In brief, in the separating equilibrium, in period 1 the seller sets a price below marginal cost in order to induce buyers with low reservation prices to purchase the good. A low quality producer would not find it profitable to make the investment because once the quality was revealed in period 2 after consumption, demand would fall to zero. Thus, the low price is an invitation to experience the good on the part of the high quality producer.

Consider now the case of a *pooling* equilibrium. The seller of safe products charges a first-period price that the seller with unsafe products could select. Consumers cannot rely on this signal to be sure that its products are safe. However, this can be a profitable strategy since, if the effort level is high enough, the probability that the consumers who purchased in the first period will repeat their purchase is high. A high effort and no signal can save signaling costs while ensuring a high level of sales in the second period. However, if the consumers' maximum willingness to pay in the first period λq_h is lower than the marginal cost c, no trade occurs in the first period. As no consumer experiences the product, there is no trade in the second period either. When the effort is high enough to avoid market closure, demand can be found by using the threshold consumer with an indirect utility equal to $\theta\lambda q_h-p=0$, who is indifferent between buying and not buying one unit of good. This particular consumer is characterized by a taste parameter $\theta_1=p/(\lambda q_h)$. As the distribution of preferences parameter $\theta\in[0,1]$ is uniform, demand is $1-p/(\lambda q_h)$. The first-period price is then $p_p=(\lambda q_h+c)/2$.

Note that, as a result of the pooling equilibrium, safe as well as dangerous products can be sold in the first period. Under the pooling equilibrium, the seller's expected profit is Π_P given by (9) and the expected consumers' surplus is SC_P given by (10), with $\theta_1 = p_p/\lambda q_h = (\lambda q_h + c)/(2\lambda q_h)$ and $\theta_0 = p_a/q_h = (q_h + c)/(2q_h)$.

$$\Pi_P = \frac{(\lambda q_h - c)^2}{4\lambda q_h} + \lambda\delta\frac{(q_h - c)^2}{4q_h} - f\frac{\lambda^2}{2} \text{ if } \lambda \geq c/q_h, \tag{9}$$

$$SC_P = \int_{\theta_1}^{1}(\theta\lambda q_h - p_p)d\theta + \lambda\delta\int_{\theta_0}^{1}(\theta q_h - p_a)d\theta = \frac{(\lambda q_h - c)^2}{8\lambda q_h} + \frac{\lambda\delta(q_h - c)^2}{8q_h} \text{ if } \lambda \geq c/q_h. \tag{10}$$

We now turn to *the choice of one or the other* strategy by the seller and to the resulting equilibrium (separating or pooling) in the case of experience goods. In order to eliminate the out-of-equilibria strategies, the Mailath *et al* (1993) refinement criterion is used. That is, the pooling equilibrium is selected when this situation results in a higher profit than the best separating equilibrium that the seller can access. The outcome depends on the cost *f*. It is easy to verify that $\Pi_P > \Pi_e$ when λ is large enough to avoid market closure. It implies that the seller prefers the pooling equilibrium to the separating equilibrium as soon as consumers are willing to buy a product in the first period (i.e., $\lambda_P \geq c/q_h$). However, if consumers do not buy under a pooling equilibrium (i.e., $\lambda_P < c/q_h$), the seller is bound to select the separating equilibrium in spite of the negative price distortion. Characterization of market equilibria with experience goods can be summarized as follows:

<u>Proposition 2</u>. i/ When $f < \delta(q_h - c)^2/2c$, corresponding to $\lambda_P \geq c/q_h$, the pooling equilibrium is selected and consumers are willing to buy the product. The safety effort is either equal to 1 or to $\lambda_P = \delta(q_h - c)^2/2q_h f$, depending on the value of *f* [7]. Even though the seller does not signal the safety of its product, possible sales in the second period provide sufficient incentives for making a significant safety effort. This result is explained by the existence of repeat purchases that incites the seller to propose safe products, revealed in the second period.

ii/ When $\delta(q_h - c)^2/2c < f$, corresponding to $\lambda_P < c/q_h$, the separating equilibrium is selected. The price is therefore $p_e = c - \varepsilon$ and the safety effort is $\lambda_e = \delta(q_h - c)^2/4q_h f$.

Note that when the monopolist selects an effort lower than one (for $f > \delta(q_h - c)^2/2q_h$), this effort is systematically lower than the socially optimal level λ_m. Moreover, both the safety effort and the welfare are lower than under perfect information.

Credence goods

We now consider the case of *credence* goods. Because buyers are unable to detect the effective level of safety and effort, credence goods are a somewhat particular case of experience goods, where the lag between purchase/consumption and quality detection tends towards infinity. Caswell and Modjuszka (1994) show that, in practice, many goods fall into the "credence" category. This is particularly the case when hazard appears in the long run and when the exact source of the disease cannot be determined.

Proposition 3. In the case of credence goods, the seller is unable to signal its level of effort or the safety of its product since consumers draw no lesson from past experience. The seller has no incentive to make an effort which would not be considered as credible by consumers, and selects $\lambda=0$.

This is expected by (rational) consumers who anticipate that the probability of getting a safe product is zero. Under our assumptions, no trade takes place. Even though complete market breakdown is a stylized case, it suggests that unregulated markets lead to market failures in the case of credence goods.

In brief

One may conclude from the previous sections characterizing market equilibria under various information structures that there are some possible market inefficiencies in the absence of regulation. The previous results based on a very stylized model suggest that:

- When the cost of the safety effort *f* is large, the safety effort is systematically lower than the socially optimal level (under perfect information as well as with experience goods).
- Despite experience by consumers, imperfect information is likely to lead to a lower safety effort than under perfect information.
- With experience goods, the seller chooses not to signal the safety of its product. Nevertheless, the prospect of sales in the second period is an incentive for providing a significant safety effort while, with credence goods, market forces result in an absence of effort and a market failure.

III. OPTIMAL REGULATION

Governments can use several policy instruments to protect consumers and alleviate market inefficiencies. We focus on minimum safety standards (MSS), labeling and liability enforcement. We try to assess how such instruments can circumvent two kinds of market inefficiencies described in the previous section: non-revelation of safety and insufficient safety effort. Note that in the following sections, we assume that the regulator selects the instrument(s) before the seller chooses the level of safety effort.

Minimum safety standard (MSS)

We consider an equipment standard that constrains the level of effort (Marino, 1998). We assume that the MSS is imposed to the seller and that consumers are aware of its existence. We characterize the regulator's choice for three types of information structure.

Under *perfect information*, consumers identify the seller of safe products. We saw in section II that unregulated market leads to a less than socially optimal safety effort when $f \geq (1+\delta)(q_h - c)^2 / 4q_h$. In this case, the regulator should impose a safety effort λ_s that maximizes welfare W_a.

$$\lambda_S = Min[1, \frac{3(1+\delta)(q_h - c)^2}{8q_h f}]. \qquad (11)$$

Because this level is always sustainable by the seller (see detailed expressions in appendix A), a MSS is an efficient instrument for correcting the effort level. However, this instrument does not lead to a first best equilibrium since it does not correct market distortions caused by the monopolistic price setting.

With *experience goods*, market forces provide an insufficient safety effort when f is large (see section II). A MSS may correct this less-than-optimal effort. However, because it makes it useless to signal safety, a MSS results in a shift from a separating to a pooling equilibrium. Since the signal results in a negative price distortion that reduces the deadweight loss caused by the market power of the seller, the overall effect of a MSS on welfare is ambiguous.[8]

With *credence goods*, a MSS leads to dramatic changes in the information structure. Without a MSS, the lack of verification on the safety effort leads to market closure (see section 2). With a MSS, consumers are informed on the seller's effort λ (which is equal to the MSS). Given their willingness to pay $\theta \lambda q_h$, and the uniform distribution of $\theta \in [0,1]$, demand is $1-p/(\lambda q_h)$ in each period. The selected price is then $(\lambda q_h + c)/2$ for both periods. In this case the expected seller's profit is

$$\Pi_M = \frac{(1+\delta)(\lambda q_h - c)^2}{4\lambda q_h} - f\frac{\lambda^2}{2} \text{ if } \lambda \geq c / q_h. \qquad (12)$$

The consumers' expected surplus is

$$SC_M = \frac{(1+\delta)(\lambda q_h - c)^2}{8\lambda q_h} \text{ if } \lambda \geq c / q_h. \qquad (13)$$

The welfare is $W_M = \Pi_M + SC_M$. For low values of f, the seller will select an effort $\lambda = 1$. For f large, a high level of effort is too costly to generate a positive profit, while a lower safety effort results in a negative indirect consumers' utility and in the absence of demand. Even though consumers know λ, the value $(\lambda q_h - c)$ may still be negative. That is, for large values of *f*, a MSS does not necessarily make trade possible with credence goods (see appendix B).

Characterization of market equilibria with a MSS can be summarized as follows:

- A MSS can be a useful tool for correcting a sub-optimal level of safety under both perfect and imperfect information.
- With experience goods, a MSS leads to shifting from a separating to a pooling equilibrium. This results in a higher safety effort, but may increase the welfare losses due to the pricing strategy of the monopolistic seller.
- With credence goods, a MSS is a necessary and efficient tool when the cost of the safety effort is low. However, for large values of *f* a MSS does not make it possible to avoid market closure.

Labeling

When human health is at stake, public intervention often favors command-and-control instruments such as MSS. However, such instruments are sometimes costly and do not always pass cost-benefit analysis (Arrow *et al*, 1996). In some cases, instruments relying on consumers' information are preferable. When risk is deemed to be small and/or non lethal, giving consumers the choice between different levels of risk at different prices may be economically efficient (Beales *et al*, 1981).

A label is obviously useless in the case of *perfect information*. In the case of *experience goods*, consumers can infer the safety effort from the pricing strategy of the seller. A label may make the negative price distortion unnecessary. However, in our case, this negative distortion has a positive effect on welfare and a label will not improve welfare compared to reputation-building strategies. Under our simplifying assumptions, a label is therefore only useful for *credence goods*. However, labeling credence goods requires certification by a third party whose ability to investigate safety exceeds that of an individual consumer (e.g. verification of the production process, see section II). For the sake of simplicity, we assume that the public regulator is able to provide a credible information on the safety effort λ to consumers. In this case, the expected seller's profit is similar to Π_M given in (12) and the consumer's surplus is similar to SC_M given in (13). As it is the case with a MSS, the label brings information to the consumer but does not always make it possible to avoid market closure if *f* is large.[9]

In brief, a label is potentially a useful instrument for reducing market inefficiencies in the case of credence goods, provided that the regulator or a third party mandated by consumers has the ability to verify the safety effort. This may require specific means for monitoring the production process. Note however that we assumed here that the public regulator incurs no cost in providing the information on safety effort. This is only true in particular cases (for example, when the government imposes firms to disclose the result of quality testing procedures that already existed, such as in the case of *listeria* detection in food in the EU). In some other cases, this information may involve large costs (e.g. the EU policy of detecting genetically modified material in food). These should be accounted for in the overall assessment of the various policies.

Liability

In some countries such as the United States, *ex post* liability is a major incentive for ensuring product safety. Because of the potential outcome of tort law, firms often set up standards that exceed those required for passing government approval process. In other countries, such as France, Spain or Italy, economic sanctions are very limited in case of product safety problems, and the risk of penal sanctions for managers do not provide as much incentive for firms to adopt higher standards. *Ex post* litigation may be an efficient instrument for ensuring product safety (Viscusi *et al*, 1995). Here, we focus on the punitive damage for misrepresentation (Daughety and Reinganum, 1997). We assume that consumers know the existence of the punitive damage, which would be paid by the seller to the buyer at the end of the second period.

Under *perfect information*, liability enforcement is irrelevant since consumers are aware of the characteristics of the products by assumption, and dangerous products are not purchased. Enforcement of liability policy in the case of *credence* goods runs into the lack of conclusive evidence that a particular disease results from a well-identified source. If the regulator verifies the production process, punitive damage for misrepresentation with a credence good has effects similar to those of a MSS (the punitive damage is similar to a fine for non compliance with the MSS, and the economic mechanism is the same as the one described in the previous section).

In the case of *experience* goods, the regulator may implement a punitive damage so that it prevents the seller from selecting the pooling equilibrium with harmful products. The punitive damage P must therefore be larger than the profit under pooling equilibrium without any effort [Π_0 given in endnote 7], i.e. $\Pi_0 - P < 0$. When P>Π_0, liability enforcement may be a policy instrument that dominates the MSS in terms of welfare. Indeed, it makes it possible to benefit from the safety revelation mechanism, while avoiding possible prohibitive compliance and enforcement cost of the MSS.

However, it is noteworthy that liability laws are likely to work for the limited cases of experience goods in the main. This is important in practical terms because emphasis is often given to this avenue by policy makers. The frontier between experience and credence goods is not clearcut, and the longer the delay between consumption and apparition of the damage, the more the good falls in the credence category. When delays are long, liability is hardly a useful policy instrument because of the discounted fines and because of the difficulty of enforcement of such policies (the seller may have ran out of business or merged with another firm, and responsibilities may be hard to identify). Note also that there we ignored transaction costs. They can be very large (costs of litigation). and should be accounted for in the comparison of the various policy instruments.

The combination of liability enforcement and MSS may show some form of social optimality. The setting of an appropriate MSS could result in a socially optimal level of effort λ_s given by (11). Simultaneously, liability enforcement deters the sale of harmful products. This policy mix therefore leads to a market equilibrium which is similar to the one under perfect information, even in the presence of experience goods.

IV. RETURN TO THE MAIN ASSUMPTIONS

In order to focus on the main economic mechanisms and to keep the mathematical aspects as simple as possible, we used a very stylized framework that relies on a number of assumptions. Some of them may seem very restrictive and we need to address the sensitivity of the results to changes in these assumptions.

We assumed that there was only one seller. One may provide hints on how the above results are affected by different competition structures. Consider the case of oligopolistic competition.[10]. Where there are two sellers, Bertrand or Cournot competition leads to a decrease in the sellers' profit. Competition results in a lower price and an increase in overall welfare, but smaller profits lead to a reduction in the safety effort compared to the monopoly situation. The overall effect on welfare is therefore ambiguous. Under *perfect information*, one can show that the welfare enhancement effect of increased competition outweighs the negative effect on the safety effort, and that the overall welfare increases. With *experience goods*, competition between sellers provides extra-incentives to signal safety in order attract consumers (Daughety and Reinganum, 1997). It is possible to show that this effect leads to an increase in welfare, in spite of the reduction of the safety effort, compared to the monopoly situation. With *credence* goods, there is a market closure regardless the number of sellers. The mechanisms illustrated in the monopoly case are not significantly affected when competition increases in the supply sector.

Regarding the relative efficiency of policy instruments, a duopolistic supply sector also leads to changes in the previous results. Even though the economic mechanism remains unaltered, a MSS is more likely to result in negative profits when competition increases. In order to be an efficient instrument, a MSS is more likely to require a subsidy from the regulator. In the case of experience goods, because increased competition makes it more likely to lead to safety revelation, instruments such as liability are less useful than in the monopoly case.

We assumed that by selecting a level of effort λ, the seller incurred a convex cost equal to $f\lambda^2/2$, and that investment in safety effort was a sunk cost. Since the cost parameter plays an important role in the results, one may wonder how the results change with the cost function. Take the case of perfect information (other results can be developed along similar lines). When the cost function is concave in λ, e.g. the cost is $f\lambda^\alpha/2$ with $0<\alpha<1$, the profit function, $\lambda(1+\delta)(q_h-c)^2/4q_h - f\lambda^\alpha/2$, is then convex. The seller increases the effort as long as the profit is positive, leading to λ =1 (when the profit is negative λ =0). This does not fundamentally alter the results of section II, but restricts the interest of the separating equilibria and therefore makes the signal less likely to occur. The case where the investment cost in quality does not depend on λ, i.e. the investment is a fixed sunk cost, the producer faces a discrete choice when selecting the effort, but the mechanisms illustrated in section II remain valid.

We also assumed that the producers signaled their quality by a low introductory price. In reality, suppliers of premium products often signal their higher quality by setting a higher price than the one normally set for regular goods. However, the negative price distortion in the first period represents in a very simple way the main economic idea behind the concept of signaling, that is that high quality firms must inform consumers about their products in a way that producers of low quality products have no incentive to imitate. A positive price distortion (compared to the price under perfect information) would be possible with experience goods if there were a demand for low quality goods, which is not the case here, since consumers avoid unsafe products by assumption. If there were a positive demand for low quality products, Bagwell and Riordan (1991) demonstrate that a seller of high quality products could be incited to reduce its sales (increase price) to signal its high-quality. This entails a high-quality seller selecting a specific strategy that a low-quality seller cannot afford. A signal through positive price distortion would be possible. With a positive distortion, the seller would still arbitrate between a pooling and separating strategy in the case of experience goods. The results in section III are not fundamentally altered, even though the positive price distortion would make separating equilibria more likely.

V. CONCLUSION

Using a very stylized framework, we illustrated various mechanisms by which the structure of consumers' information may influence the provision of product safety. Because the effect of imperfect information and imperfect competition are intermingled, we considered the case of a monopolistic supplier. We characterized market equilibria in the presence of full information, of experience goods and credence goods. We showed that the various policy instruments have different effects on the safety of the products supplied on the market and on the overall welfare, depending on the information structure. For example, a minimum safety standard can be an efficient policy instrument and lead to a higher collective welfare than the one on an unregulated market when consumers detect unsafe products prior to consumption. When they find out about production safety after consumption, the prospect of future sales provides incentives for firms to supply safe products. However, market mechanisms can be usefully complemented by a minimum safety standard or a liability policy when the spontaneous provision of safety is less than socially optimal because of the high cost of the safety effort.

The particular case where consumers do not detect the safety of the product even after consumption (or where they only do so after a very long period) is a challenge for regulators. Because of the absence of verification of their claims in the medium run, sellers have no incentive to implement (costly) signals in order to inform consumers of the harmlessness of their products. Suppliers of unsafe products can therefore imitate them. Market forces may lead to a less-than-optimal provision of safety, and possibly in the absence of trade à la Akerlof (1970). In such cases, a minimum safety standard or a label is necessary for making trade possible. This label must however be backed by certification from a third party able to monitor the effort level. When effort safety is very costly, though, market closure may persist.

Restrictive assumptions limit the scope of this paper. These are, for example, the assumption of monopolistic supply, the presence of only two levels of safety, and the assumption that consumers who purchase unsafe product leave the market in the second period. However, this framework made it possible to infer some stylized economic mechanisms which may remain valid in more realistic situations.

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APPENDIX A

Perfect Information. When $f < \frac{(1+\delta)(q_h - c)^2}{4q_h}$, the seller selects the maximum effort, λ_a=1, and only offers safe products. The seller's profit and the consumers' surplus are, respectively, $\Pi_A = \frac{(1+\delta)(q_h - c)^2}{4q_h} - \frac{f}{2}$, and $SC_A = \lambda_a \int_{\theta_0}^{1} (\theta q_h - p_a) d\theta = \frac{(1+\delta)(q_h - c)^2}{8q_h}$ with $\theta_0 = p_a/q_h = (q_h + c)/(2q_h)$. When $f \geq \frac{(1+\delta)(q_h - c)^2}{4q_h}$, the seller selects the effort, $\lambda_a = \frac{(1+\delta)(q_h - c)^2}{4q_h f}$. The seller's profit and the consumers' surplus are, respectively, $\Pi_B = \frac{(1+\delta)^2 (q_h - c)^4}{32 q_h^2 f}$, and $SC_B = \lambda_a \int_{\theta_0}^{1} (\theta q_h - p_a) d\theta = \frac{(1+\delta)^2 (q_h - c)^4}{32 q_h^2 f}$ with $\theta_0 = p_a/q_h = (q_h + c)/(2 q_h)$.

Experience goods. When $f < \delta (q_h - c)^2 / 2q_h$, the seller selects an effort equal to 1 without signaling the products' safety in the first period (i.e., pooling equilibrium). In this case the welfare is equal to W_A. When $\delta (q_h - c)^2 / 2q_h < f < \delta (q_h - c)^2 / 2c$, the seller makes an effort, $\lambda_P = \delta (q_h - c)^2 / 2q_h f$, again a pooling equilibrium. The seller's profit is $\Pi_C = \frac{\left(\delta (q_h - c)^2 - 2fc\right)^2}{8 f \delta (q_h - c)^2}$, and the consumers' surplus is:

$$SC_C = \int_{\theta_1}^{1} (\theta \lambda q_h - p_p) d\theta + \delta \int_{\theta_0}^{1} (\theta \lambda q_h - p_a) d\theta = \frac{\left(\delta q_h (q_h - c)^2 - 2c q_h f\right)^2 + \delta^3 (q_h - c)^6}{(16 q_h^2 f \delta)(q_h - c)^2},$$

with $\theta_1 = (\lambda q_h + c)/(2 \lambda q_h)$ and $\theta_0 = p_a/q_h = (q_h + c)/(2q_h)$.

When $f \geq \frac{\delta(q_h - c)^2}{2c}$, the separating equilibrium is selected and the seller makes the effort, $\lambda_e = \frac{\delta(q_h - c)^2}{4q_h f}$. The seller's profit and the consumers' surplus are, respectively,

$$\Pi_D = \frac{\delta^2(q_h - c)^4}{32q_h^2 f}, \text{ and } SC_D = \lambda_e \left[\int_{\theta_1}^{1} (\theta q_h - c)d\theta + \int_{\theta_0}^{1} (\theta q_h - p_a)d\theta \right] = \frac{\delta(q_h - c)^4}{8q_h^2 f} + \frac{\delta^2(q_h - c)^4}{32q_h^2 f},$$

with $\theta_1 = c/q_h$ and $\theta_0 = p_a/q_h = (q_h + c)/(2q_h)$.

MSS standard under perfect information. When $\frac{(1+\delta)(q_h - c)^2}{4q_h} < f < \frac{3(1+\delta)(q_h - c)^2}{8q_h}$, the standard level is λ_S=1, and the seller's profit and the consumers' surplus are, respectively, Π_A and SC_A. The seller's profit is always positive. When $f \geq \frac{3(1+\delta)(q_h - c)^2}{8q_h}$, the standard level is λ_S<1. The welfare is $W_S = \frac{9(1+\delta)^2(q_h - c)^4}{128q_h^2 f}$ with a positive seller's profit.

APPENDIX B

One can infer the MSS level under credence goods by analyzing the first order derivative $dW_M / d\lambda = \left[3(1+\delta)(\lambda^2 q_h^2 - c^2) - 8f\lambda^3 q_h\right]/(8\lambda^2 q_h)$. For the low values of f or for q_h sufficiently large, $dW_M / d\lambda > 0$ for $\lambda \in [c/q_h, 1]$. It implies that the seller will select an effort λ equal to one. In this case the welfare is equal to W_A given in appendix A. For large values of *f*, no effort is selected because the profit W_M is always lower than zero for $\lambda \in [c/q_h, 1]$. A large value of *f* prevents the regulator from setting a safety level equal to one. For $\lambda = 1$, the welfare, W_M, is negative as soon as $f > 3(1+\delta)(q_h - c)^2 / 4q_h$. This implies that the welfare is negative for $\lambda \in [c/q_h, 1]$.

Notes

[1] In the food sector, for example, Canada, France and the United Kingdom have recently established new agencies with a broad mandate for health, safety and inspection responsibilities. The United States has announced a new initiative to address the health risks of food consumption involving several federal agencies with related responsibilities and the authority of the USDA in this area has been recently enhanced. In the European Union, the Commission has issued a green paper aimed at triggering a wide debate on food policy and food law (see OECD, 1999).

[2] "Quality" usually refers to a vertical differentiation framework, while "variety" is more appropriate to horizontal differentiation. Safety can be seen as component of quality, defined as a multi-attribute concept, since, for a given price, all consumers would unambiguously choose safer products (Caswell and Modjuszka, 1994).

[3] Sub-optimality is here only caused by the departure from marginal cost pricing, and should not be confused with another source of sub-optimality, i.e. cases where harmful products are consumed.

[4] More precisely, if $f > (1+\delta)(q_h - c)^2 / 4q_h$, the seller selects an effort $\lambda_a<1$ systematically lower than the socially optimal level: $\lambda_a=\lambda_m/2$ if $\lambda_m<1$. If $f < (1+\delta)(q_h - c)^2 / 4q_h$ the effort selected is $\lambda_a=1$.

[5] Another solution would be to remove monopoly power, for example by restoring competition in the sector. There is however a trade-off since extra competition has a negative effect on economies of scale. In addition, competition may result in less safety effort. For example, one could easily demonstrate that, under Bertrand or perfect competition, there would be an absence of effort leading to a market breakdown.

[6] One may consider the case where consumption of harmful products results in a desutility *M*. Here, we assume that the damage is $M=0$ in order to make the algebra simpler, but the assumption that $M>0$ does not alter fundamentally the economic mechanism that we want to illustrate.

[7] The value of λ_P is given by the equality $\Pi_P = \Pi_0$, where Π_0 is the profit in the absence of effort. Without any effort, there would be no sale in the second period. The seller may however make a profit in the first period. Mimicking the price selected by a seller setting an effort λ would lead to a profit $\Pi_0 = (\lambda q_h - c)^2 / 4\lambda q_h$ for a seller making no effort. Consumers are willing to buy the product at the price p_p, if $\lambda_P \geq c / q_h$. As consumers are aware of costs *c* and *f*, they are able to deduce that $\Pi_P \geq \Pi_0$ when they observe the posted price p_p. If $\Pi_P \geq \Pi_0$ and $\lambda_P \geq c / q_h$, the seller posts a price $p_p=(\lambda q_h+c)/2$ and selects a strictly positive safety effort $\lambda_P = Min[1, \frac{\delta(q_h - c)^2}{2q_h f}]$. It is possible to check that $d\Pi_P / d\lambda > 0$ when $\lambda = \lambda_P$ so that λ_P is selected in order to respect the incentive constraint $\Pi_P \geq \Pi_0$. Note that $\lambda_P=1$ when $f < \delta(q_h - c)^2 / 2q_h$. Conversely, if $\lambda_P < c / q_h$, there is no possibility of trade with a pooling equilibrium because consumers refuse to buy the product. In this case the separating equilibrium is selected.

[8] A possibility for maintaining the negative price distortion could lie in imposing a MSS without informing consumers about it. In this case, the negative distortion would be necessary to signal safety for large values of *f*. If such a policy were empirically implementable, it might lead to both a larger effort and a lower monopoly rent than in the absence of regulation.

[9] The seller maximizes Π_M, and the demonstration that this results in a negative profit for large values of *f* is similar to the one given in appendix B.

[10] Analyses in the case of perfect competition would be better handled by different modeling approaches. Indeed, because of our assumption of a constant marginal cost *c*, perfect competition provides little incentive for selecting strictly positive safety efforts, due to the absence of positive profit, regardless of the information structure.