ON THE EFFECTIVENESS OF PRIVATE FOOD STANDARDS

Eric Giraud-Héraud[1], Cristina Grazia[2], Abdelhakim Hammoudi[3]

1. Institut National de la Recherche Agronomique and Ecole Polytechnique, Paris, France, giraud@ivry.inra.fr
2. Agricultural Economics and Engineering Department, University of Bologna, Italy, c.grazia@unibo.it
3. Institut National de la Recherche Agronomique and ERMES/Université Paris II, France, hammoudi@ivry.inra.fr

c.grazia@unibo.it

THE ECONOMICS OF FOOD, FOOD CHOICE AND HEALTH
1st joint eaae/aaea seminar

2010

Selected Paper
prepared for presentation at the 1st Joint EAAE/AAEA Seminar

"The Economics of Food, Food Choice and Health"
Freising, Germany, September 15 – 17, 2010

On the effectiveness of private food standards

Eric Giraud-Héraud[1], Cristina Grazia[2], Abdelhakim Hammoudi[3]

Abstract

This paper provides an original theoretical framework to better understand the raise of private quality standards in agrifood chains. Reasons for the development and conditions for the effectiveness of private quality standards are identified, by investigating firms' strategic behaviour and, more precisely, both interactions among processing/retailing firms and upstream producers and the role of consumers' behaviour. Considering different levels of consumers risk perception, we show that the incentive for firms to develop a more stringent private standard may increase with the level of the regulated minimum quality standard. Moreover, setting a private standard may reduce the risk of consumer dissatisfaction while increasing the marketed quantity. Unexpected positive effects of a strengthening of the minimum quality standard may arise, in the sense that both market access for upstream producers and consumer surplus are improved.

Keywords:

Private quality standards, vertical relationships, risk perception.

JEL codes: L1, L15, Q13, Q18

[1] Institut National de la Recherche Agronomique and Ecole Polytechnique, Paris, France, giraud@ivry.inra.fr

[2] Agricultural Economics and Engineering Department, University of Bologna, Italy, c.grazia@unibo.it

[3] Institut National de la Recherche Agronomique and ERMES/Université Paris II, France, hammoudi@ivry.inra.fr

1 Introduction

Contemporary agrifood systems are increasingly pervaded by a plethora of *private (voluntary) food safety and quality standards* that operate alongside regulatory systems. The implementation of enhanced food safety and quality standards has been especially prominent among large food retailers, food manufacturers and food service operators (e.g. the Finest Brand by Tesco Stores PLC in the UK, and Filière Agriculture Raisonnée by Auchan and Filière Qualité by Carrefour in France), reflecting both their considerable market power and competitive strategies based around 'own' or private brands that tie a *firm's reputation* and performance to the quality supplied by its products. Indeed, a series of private food safety and quality standards has evolved, induced at various levels of the supply chain that are linked to co-brands and/or symbols that are directly communicated to consumers. A particular set of these private standards is that defined within the context of a buyer-supplier relationship (Valceschini and Saulais, 2005). Firms might be lead to select only the most effective producers or also to encourage their suppliers to upgrade upstream production conditions and comply with specific production requirements to ensure input's quality and safety. This input's normalization strategy often corresponds to more or less irreversible investments and procedures (supplier selection, contract setting, norm development, product certification, etc.). It also may influence the firms' decisions concerning quantity and price to adapt *in fine* to the evolution of demand and competitive environment.

A wide literature aims at explaining the development of private standards. The adoption of food safety/quality standards stems from both customer or regulation-driven external incentives and firm-driven internal incentives (Holleran and Bredahl, 1997; Lloyds, 1995; Seddon et al., 1993). First, the regulatory environment may provide an incentive for firms to adopt a particular food safety or quality assurance standard (Holleran et al. 1999). Namely, it is an accepted idea that firms will arguably have the greatest incentive to implement private standards where there are missing or inadequate public food safety and/or quality standards; here private standards act as a substitute for missing public institutions (Henson, 2006; Henson and Reardon, 2005). Another important force is the degree to which the customer requirements and regulations are enforced. Then, the main reason to argument the coexistence of private standards with highly demanding public regulation is given by the necessity for the firms to manage exposure to liability, limit exposure to potential regulatory

action and/or anticipate future regulatory developments (Lutz et al., 2000; Segerson, 1999)[4]. Moreover, trends in consumer demand have put greater focus on product quality. On the one hand, food scares in a number of industrialised countries have served to fuel consumer concerns and erode confidence in prevailing mechanisms of food safety control. On the other hand, consumers have increasingly focused on a broader array of food product and process attributes when assessing product quality, many of which are experience or credence characteristics. Finally, the structural and institutional changes of agricultural and food markets have to be taken into account: supply chains for agricultural and food products are extending beyond national and regional boundaries, concentration within food retailing is driving a shift towards buyer-driven supply chains that are extending internationally with global sourcing and the emergence of multinational retailers, food service operators and manufacturers and an increased emphasis is put on product quality attributes as a means to product differentiation. In addition to external incentives, *private incentives* drive firms to move beyond adopting approved practices that meet technical requirements towards adopting more exigent private standards: internal and transaction costs reduction (Bredahl and Zaibet, 1995, Henson, 2008; Holleran et al. 1999), improvement of reputation with the possibility to capture retail price premium (Fulponi, 2006).

Another set of contributions deals with the effects of standards in terms of reduced market access; the main argument is that the more the standard is constraining, the higher is the risk of firms' exclusion from the market. The compliance process represents a long-term decision and results in more or less high adaptation costs for firms (Henson and Heasman, 1998). Hence, it is shown for example, that the compliance with standards may pose a greater burden on small firms, due to the large investments needed (Henson and Caswell, 1999, Unnevehr and Jensen, 1999).

Nevertheless, deeper insight into why firms implement private standards and into their effects on market access as well as on consumer surplus requires a full investigation of firms' strategic behaviour and, more precisely, of both the role of consumer behaviour toward the risk and interactions among processing/retailing firms and upstream producers. Hence, given a public minimum quality standard (MQS), which regulates upstream production conditions, the firms' normalization strategy takes into account two main aspects: on the one hand, the

[4] For example, the 1990 Food Safety Act (FSA) significantly affected quality management practices in the UK food sector. The FSA requires firms to be proactive regarding the safety of food in their possession, assigning firms responsibility for both the safety of the supplies firms procure as well as the food they handle. The increased buyer/seller interaction forced firms to closely monitor suppliers because firms needed to verify and monitor the safety of supplier production processes, in addition to their own internal processes (Hobbs and Kerr, 1992).

opportunities to exploit on the final market (quantity/price strategy according to consumer behaviour) and on the other hand, the effort to be undertaken to facilitate the upgrading of upstream production conditions (suppliers' selection and definition of the intermediary price).

Given these premises, in this paper, we provide an original contribution by considering both (i) consumers' reaction to the level of risk[5], this latter being interpreted as the probability that the product does not meet consumer expectations about product quality and safety and (ii) the role of vertical relationship. Namely, we take into account the following assumptions.

On the demand side, following the seminal paper by Polinsky and Rogerson (1983), consumers are assumed to react to the perceived rather than to the actual level of risk. Hence, even if consumers receive more or less precise information about the risk, they may misperceive it; this has an important influence on firm's strategic behaviour (see also Yeung and Yee, 2002, McCarthy and Henson, 2005).

On the supply side, we consider a model of vertical relationship between a downstream processing/retailing firm and upstream producers. The downstream firm has a monopolist position towards the final market and a monopsonist position towards upstream suppliers. These latter are differentiated according to their equipment levels, which in turn determine the risk associated to their supply. The compliance with a public MQS or a private standard might lead producers to undertake investments in order to access to the intermediary market. Taking into account the vertical relationship makes it possible to show how the firms' strategic behaviour results from taking into account both the final market (quantity/final price strategy) and the upstream market (selection and remuneration of upstream producers).

In this context, the downstream firm faces a quality-quantity trade-off. That is, for a given level of quantity supplied on the final market, a reinforcement of the standard lowers the risk, while, for a given standard, an increase of quantity increases the risk. Hence, implementing a private standard may be necessary to avoid the risk-increasing effect of high volumes. Hence, we show that reinforcing the MQS by implementing a more severe private standard enables the firm to benefit from an improvement of consumer willingness to pay (especially when consumers tend to overestimate the risk) and increase the commercialized volumes. However,

[5] In this paper we use the term "risk" to specify the non-compliance of the processed product with respect to an expected quality. This terminology refers to the notion of "credence qualities" (Darby and Karni, 1973), which is important in the agrifood sector, especially when the product normalization concerns the aspects of certification of origin or food safety (see for example, Grunert, 2005 and Loureiro and Umberger, 2007).

also simply complying with a low-interventionist MQS may be optimal for the firm as it enables to commercialize great volumes without having to encourage any upgrading of supplier equipments.

More precisely, we demonstrate that the firms' normalization strategy depends both on the level of consumer risk perception and on the level of the public MQS. Namely, when consumers underestimate the risk, the firm simply complies with the MQS. When consumers overestimate the risk, but overestimation is relatively low, the firm has interest in reinforcing the MQS only when this latter is sufficiently severe. Finally, when consumers highly overestimate the risk, the firm reinforces the MQS regardless of its level. Hence, implementing a private standard enables the firm to benefit from an improvement of consumer willingness to pay and thus increase the marketed quantity. Furthermore, we show that the reinforcement of the MQS with a more stringent private standard reduces the risk while increasing the marketed quantity and consumer surplus. Moreover, the increase of quantity entails an improvement of upstream producer market access.

2 The model

We consider a vertical relationship between J heterogeneous upstream producers and a downstream processing and/or retailing firm, which is a monopoly in the final market and has monopsony in purchasing the input from producers. The firm is assumed to buy x units of input and convert them into y units of finished product, according to the fixed proportion production function $y = T(x)$, where we simply set $T(x) = x$. The downstream stage may concern processing, preserving, conditioning or packing operations. Upstream producers are differentiated according to their level of "equipment", represented by a one-dimensional parameter e, which is assumed to be uniformly distributed on the interval *[0,1]* according to the density function $f(e) \equiv 1$[6]. Upstream production characteristics are regulated by a public Minimum Quality Standard (MQS) e_0 which corresponds to the food safety standard in force in the market. Moreover, the compliance with the private food quality standard e_1 is requested for upstream producers to be selected by the processing firm and then access to the

[6] The equipment level can be interpreted as the value of the initial infrastructure of a producer (or as the cost associated with the equipment's introduction). The assumption of equipment continuity is a mathematical device for the sake of simplicity, which does not have any influence on the qualitative results of the model.

"intermediary market". The standard e_1 may either equal the public Minimum Quality Standard ($e_1 = e_0$) or being more demanding than the MQS ($e_1 > e_0$).

We consider that the compliance with the standard e_1, for a producer of type *e*, implies a fixed cost, which is assumed to take a linear form $Max\{0, e_1 - e\}$. Hence, the cost of compliance is given by $(e_1 - e)$ for a producer *e*, whose level of equipment is lower than the standard e_1 and zero otherwise.[7]

Endogenous risk

The risk is assumed to technically result from upstream production characteristics. The downstream firm is assumed not to influence the risk of product failure[8]. The risk associated with each producer, whose equipment level is e, is affected by the producer's level of equipment and is given by $\sigma(e)$; where $\sigma(.)$ is a decreasing function of e. For the sake of simplicity, we consider that $\sigma(e) = 1 - e$. Then, we have $\sigma(0) = 1$ and $\sigma(1) = 0$. Hence, the risk is certain with a producer characterized by the minimum level of equipment and zero with a producer characterized by the maximum level of equipment. Since the firm has to deal with different suppliers, some producers are involved, whose inputs do not meet the "ideal situation" for consumers (zero risk). Hence, the heterogeneity of inputs may determine a risk for the processed product. Namely, each input contributes up to $\sigma(e) = 1 - e$ to the total risk.

Consumer's risk perception

The concept of risk includes all the risks associated with consumer choices and thus concerns not only the health (for example fat content) or safety (for example food poisoning) risks associated with the product, but also the chance that the product may not meet taste expectations, money is wasted, a poor meal is served to guest, etc. (Feng et al., 2010; McCarthy and Henson, 2005).

It is well recognized in the literature that consumers react to the *perceived* rather than to the actual level of risk. First, consumers are *imperfect problem solvers* who collect limited

[7] Hence, given the heterogeneity of upstream supply, this cost function allows to explicitly take into account the heterogeneity of the compliance costs. For an illustration of this heterogeneity in the empirical literature, see for example Kleinwechter and Grethe, 2006.

information upon which to base their choices (Henson and Traill, 1993). The consumer decision-making process is *imperfect*. The result of these imperfections is biases in the subjective probabilities generated by consumers for different risky outcomes. For example, several studies show a systematic primary bias in probability estimation with high risks tending to be underestimated and low risk overestimated (Feng et al. 2010; Verbeke et al., 2007; Sparks and Shepherd, 1994). The qualitative nature of individual risk factors is also important in probability estimation: perceived level of control, degree of voluntariness, immediacy of effects, levels of consumer dread, likelihood of unknown effects, availability of alternatives and reversibility of consequences. Second, the information set available to consumers is itself imperfect[9].

In this context of asymmetric information, consumers rely upon *external risk indicators* to indicate the level of quality and safety of products (Kornelis et al., 2007; McCarthy and Henson, 2005; Mitchell and McGoldrick, 1996; Henson and Traill, 1993; Mitchell and Greatorex, 1990). Hence, the main approach taken by consumers to reduce the perceived risk consists in enhancing the probability of product success through the use of "risk relievers", that is "a piece of information that increases the likelihood of product success". Hence, when credence attributes are concerned, consumers trust in extrinsic quality cues as for example brands, product information, price, the nature of food packaging, the nature of the food store and its ability to handle produce. Indeed, several contributions show consumers' willingness to pay for a quality/safety improvement, while this latter is not directly observable (Loureiro and Umberger, 2007; Grunert, 2005). It is worthy to notice that the level of perceived risk influences consumers' risk reduction strategies: consumers that perceive the highest level of risk also use both the largest number of risk relievers and use them more frequently[10]. Moreover, the more individuals are concerned about risk (the higher the perceived risk), the higher their willingness to pay for food safety improvements (Angulo and Gil, 2007; Brown et al., 2005).

---

[8] This assumption is crucial as it makes it possible to isolate the influence of the firm's strategic behaviour on the risk, regardless of the role that she may play from a technical point of view.

[9] As regards to food safety, for example, all food-borne risks factors fall into the experience categories (e.g. acute food risk factors, *salmonellosis* and other food poisonings) and credence ones (e.g. chronic food risk factors, such as nutritional imbalance in the diet, food additives or pesticide residues). Furthermore, food manufacturers and retailers are better informed about the nature of the products they sell than individual consumers.

[10] For example, McCarthy and Henson (2005) show that "sceptic consumers", who have the lowest level of confidence in their ability to select beef and were least interested in beef, are the group that used the most risk reduction strategies. This lack of perceived ability manifested itself in both the intensive and wider use of risk relievers. Similarly, Kornelis et al. (2007) show that the so-called "low-users" of food safety information, i.e. those who have a low perceived "health control" (that is they believe themselves to be personally powerless to influence their own health outcomes resulting from exposure to food safety hazards) indicate *the highest intended use for product label information.*

Given these premises, following Polinsky and Rogerson (1983), we consider that in the end market consumers are identical and may react to the *perceived* rather than to the actual level of risk (Mazzocchi et al., 2008; McCarthy and Henson, 2005). Given the risk of product failure σ, we denote by ξ, with $\xi \in [0,+\infty[$, consumer risk perception for each unit of the product that fails[11]. Notably, if $0 \leq \xi < 1$ consumers underestimate the risk, whilst if $\xi > 1$, consumers overestimate the risk. If $\xi = 1$ consumers correctly perceive the actual level of risk. Hence, the aggregate inverse demand for the product is given by:

$$p(x) = \alpha - \xi\sigma - x \tag{1}$$

The risk is supposed to be communicated to consumers either by the firm or by a third party (for example a third party certifier). However, we consider that the quality of this signal is not necessarily perfect and thus consumers do not necessarily perceive the risk at its actual level[12].

We pose the following assumption[13]: $J + \frac{\xi}{2} < \alpha < 2J + \xi$ (HP1). This specification of the demand function makes it possible to highlight two mechanisms: for a given quantity x, the higher the risk perception ξ, (i) the higher the expected risk $\xi\sigma$ and thus the lower consumer willingness to pay (WTP) and (ii) the stronger the increase of consumer WTP for a risk reduction.

The game

Given the MQS e_0, $e_0 \geq 0$, we consider the following game.

Stage I. The firm chooses the level of private standard $e_1 \geq e_0$.

Stage II. The firm decides the quantity *x* of inputs to purchase (stage III.1). The firm then chooses *N* upstream producers ($N \leq J$) and proposes an intermediary price ω in order to

[11] In Polinsky and Rogerson (1983), $\xi = (1-\lambda)l$, where the parameter λ is interpreted as a measure of the extent of consumers' risk misperception and *l* represents the monetary loss for each unit of the product that fails.Without loss of generality, we normalize the monetary loss *l* at 1 in order to isolate the solely effect of consumer risk perception.

[12] Indeed, consumers are indirectly informed about the risk reduction through brands or private labels, which are based on the definition of specific production conditions pertaining to quality and safety attributes of the inputs. Hence, either suppliers are selected according to the quality of their inputs or encouraged to upgrade their production practices: see for example the high-quality retailers' brands like « Engagement Qualité Carrefour » or the procedures developed in the meat sector by Sainsbury, Marks and Spencer or Tesco (Giraud-Héraud, Rouached, Soler, 2006; Bazoche, Giraud-Héraud, Soler, 2005; Fearne, 1998).

obtain the quantity x (stage III.2). The *N* producers accept or reject this offer and upgrade their equipment if necessary (stage III.3).

Stage III. The firm converts the obtained inputs into a finished product and sells it on the final market.

The game is solved using backward induction. Hence, we analyze the firm's quantity strategy, and the related effects on the other economic agents, namely upstream suppliers and consumers, given the standard $e_1 \geq e_0$. Turning to the second stage of the game, we examine the strategic decision of the firm whether to reinforce the MQS with a more stringent private standard or not. At this stage, we refer to the literature dealing with the influence of public regulation on the incentive for firms to implement private quality / safety standards (see for example, Henson, 2006; Henson and Reardon, 2005).

3 Private standard, procurement strategy and endogenous risk

Given the quantity x, we denote by $\tilde{e}(x)$ the threshold of equipment starting from which producers are selected by the firm. Given the uniform distribution of the *J* upstream producers, the total quantity supplied on the market is given by $J(1-\tilde{e}(x))$. At these conditions, the equalization of supply and demand on this market is such that $x = J(1-\tilde{e})$, with $x \leq J$. This makes it possible to obtain the expression (1) below, which identifies the position of the initially less-equipped (i.e. the more risky) supplier, as a function of the quantity x demanded by the downstream firm. Hence, the threshold $\tilde{e}$ is given by:

$$\tilde{e}(x) = 1 - \frac{x}{J} \tag{2}$$

3.1 Interdependencies relationship between private standard, market behaviour and risk

The Benchmark

In the Benchmark we simply have $e_1 = e_0 = 0$. No standard is in force. Since no selected producer has to upgrade his equipment to supply the intermediary market, producers are

[13] This assumption makes it possible to always have $p(x) > 0, \forall \xi \in [0, +\infty[$ and to represent all the possible firm's

uniformly distributed on the interval $[\tilde{e}(x),1]$ according to the density function $f(e)=\frac{1}{1-\tilde{e}(x)}$, with $\int_{\tilde{e}(x)}^{1} f(e)de=1$.

The Benchmark is thus characterized by the following quantity and risk:

$$\left|\begin{array}{l} y=x \\ \sigma_{\cdot}=\int_{\tilde{e}(x)}^{1}\sigma(e)f(e)de=\frac{y}{2J} \end{array}\right. \tag{3}$$

As it will be detailed below, the Benchmark risk given by (3) may change if at least one producer modifies his equipment level over the course of time.

In the Benchmark, the firm selects all the producers located between $\tilde{e}$ and 1 at a zero intermediary price. Hence, using (1)-(3), the optimal quantity and the threshold of equipment from which producers are selected by the firm are given by:

$$\left|\begin{array}{l} x^{*}=J[1-\underline{e}] \\ \tilde{e}(x^{*})=\underline{e} \end{array}\right. \tag{4}$$

Where:

$$\underline{e}=1-\frac{\alpha}{2J+\xi} \tag{5}$$

As shown by (4) and (5) the Benchmark quantity is a decreasing function of ξ: the higher the risk perception, the lower consumer WTP for a given quantity. Hence, a higher risk perception implies the incentive for the firm to reduce the marketed quantity and consequently the proportion of upstream producers involved.

We assume now that the firm sets a standard e_1. Let us denote by $J(1-e_1)$ the proportion of supply, which initially complies with the standard e_1 and $\hat{x}=J(1-e_1)$ the quantity demanded by the firm, whereby *all* the initially well-equipped producers are selected ($\tilde{e}=e_1$). Using (2), we verify that $\tilde{e}\geq e_1$ if and only if $x\leq\hat{x}$. The quantity choice of the firm thus determines the relative position of $\tilde{e}$ with respect to e_1.

strategies for every level of risk perception $\xi\in[0,+\infty[$.

The standard e_1 affects the risk of product failure depending on whether the firm's strategy has an influence on producers' equipments or not. The firm's quantity choice may result in the following two scenarios, according to whether it requires an upgrade of upstream production characteristics or not.

If the quantity selected by the firm is relatively low, that is $x \leq \hat{x}$ ($\tilde{e} \geq e_1$), the firm's quantity choice does not affect upstream production characteristics. Namely, if $x < \hat{x}$ ($\tilde{e} > e_1$), the firm only selects *some* of the initially well-equipped producers. Hence, no selected producer is required to upgrade his equipment to supply the intermediary market and producers are uniformly distributed on the interval $[\tilde{e},1]$ according to the density function $f(e)$.

If $x > \hat{x}$, the firm's quantity choice affects upstream production characteristics. Namely, the firm *also* involves some initially not well-equipped producers in order to obtain the quantity x ($\tilde{e} < e_1$). As a consequence, the producers, who are initially located between $\tilde{e}$ and e_1 have to upgrade their equipment in order to supply the intermediary market. The statistical distribution then changes.

We denote by $\bar{\sigma}(e_1,x)$ the risk for a given standard e_1 and a quantity *x*. The risk is then given by :

$$\bar{\sigma}(e_1,x) = \frac{1}{1-\tilde{e}(x)} \begin{cases} \int_{e_1}^{1} \sigma(e)f(e)de + \left[e_1 - \tilde{e}(x)\right]\sigma(e_1) & \text{if } \tilde{e}(x) \leq e_1 \\ \int_{\tilde{e}(x)}^{1} \sigma(e)f(e)de & \text{if } \tilde{e}(x) \geq e_1 \end{cases} \tag{6}$$

Using (2) and (6), we then obtain:

$$\bar{\sigma}(e_1,x) = \int_{\tilde{e}}^{1} \sigma(e)h(e)de = \begin{cases} \dfrac{x}{2J} & \text{if } x \leq \hat{x} \\ (1-e_1)[1-\dfrac{J}{2x}(1-e_1)] & \text{if } x > \hat{x} \end{cases} \tag{7}$$

The expression (7) shows the existence of a quantity/quality trade-off for the firm in the following sense: (i) for a given quantity *x*, the risk decreases in e_1, as long as the firm's strategy leads to an improvement of upstream supply characteristics, i.e. when $x > \hat{x}$; (ii) for a given e_1, the risk is an increasing function of quantity because an increase of quantity implicitly implies the involvement of a higher number (of more and more underequipped) producers.

Intermediary price

Since we consider that the downstream firm has a monopsonist position towards upstream producers, then she has complete negotiation power in the definition of the intermediary price ω. The firm thus sets the quantity x by anticipating the necessary price in order to obtain this quantity x (see Xia and Sexton, 2004, for the original modelling of this decision process).

First, we assume that the intermediary price is the same for all the producers, regardless of their initial level of equipment. Hence, the downstream firm does not have the possibility to discriminate between upstream producers. Note that this assumption is consistent with the fact that intermediate price is usually negotiated between the retailer and the Producers Organizations and/or the cooperatives and rarely between the processing and/or retailing firm and each of the upstream farmers.[14] Second, if the requested quantity is relatively low, the firm will only select producers whose equipment is better than the standard ($x \leq \hat{x}$); otherwise – and given that the production capacity of each producer is limited – the firm will be forced to also source from initially under-equipped producers ($x > \hat{x}$). This assumption is also consistent with the existence of an intermediary organization, which can select the producers who want to participate to the collective transaction.

Thus, if $x \leq \hat{x}$, the firm anticipates that all the selected producers enter the market without any cost and can obtain the quantity with a zero intermediary price. Conversely, when $x > \hat{x}$, the producers initially located between $\tilde{e}$ and e_1 have to invest in a better equipment. In particular, the producer located in $\tilde{e}$ is the last (less equipped) producer who upgrades his equipment by investing $e_1 - \tilde{e}$. Hence, he does not find it profitable to participate if the intermediary price is lower than $e_1 - \tilde{e}$. In order to obtain the optimal quantity of input, the downstream firm proposes a price so that the less-equipped producer can participate. Thus, using (2), the intermediary price $\omega(e_1, x)$ is given by:

$$\omega(e_1, x) = \begin{cases} 0 & \text{if } x \leq \hat{x} \\ \dfrac{x}{J} - (1 - e_1) & \text{if } x > \hat{x} \end{cases} \tag{8}$$

[14] It is noteworthy that individual contracts rarely exist in the agrifood sector (see for example, Royer, 1998, Kleinwechter and Grethe (2006) and Malorgio and Grazia (2008) for an analysis of the role of Producers Organizations in the implementation of EurepGap by fruit and vegetables farmers). We have voluntarily left out the explicit formalization of the intermediation assured by the Producers Organization, with which the downstream firm negotiates (as shown by empirical evidence). Indeed, taking into account this intermediary in the model would not change either the analysis or the qualitative results.

When, $x \leq \hat{x}$ whereas all the producers located within the interval $[e_1,1]$ would agree to enter the intermediary market, the firm exerts at the maximum level its monopsonist power by refusing the producers, whose equipment is lower than $\tilde{e}$.

When $x > \hat{x}$, the intermediary price $\omega(e_1,x)$ satisfies the *participation constraint* of the less-equipped producer. Hence, for a given quantity, the intermediary price is an increasing function of the standard. Moreover, the existence of a unique intermediary price generates a positive externality for the producers, whose equipment is lower than the standard, but higher than the lowest level of equipment $\tilde{e}$.

3.2 Optimal procurement and production process evolving

For a given level of risk perception ξ, the firm's expected profit $\pi(e_1,x)$, for a given standard e_1 and quantity x, is given by:

$$\pi(e_1,x) = [\, p(\bar{\sigma}(e_1,x),x) - \omega(e_1,x)]\, x \tag{9}$$

Where the risk $\bar{\sigma}(e_1,x)$ is given by (6), the final price $p(\bar{\sigma}(e_1,x),x)$ is obtained by substituting (6) into (1) and the intermediary price is given by (8). For a given standard, the quantity choice affects the expected profit in two ways: (i) the lower the quantity, the lower the intermediary price; (ii) the lower the quantity, the higher the final price. The second effect is due to direct "rarity effect" and to an indirect risk-reducing effect of a decrease of quantity. The risk perception affects the extent of the indirect effect. Using (9), we then maximize the expected profit $\pi(e_1,x)$ with respect to the quantity x, given e_1; for any level of risk perception and given e_1, there exist two levels of equipment, $\underline{e}(\xi)$, given by (5), and $\bar{e}(\xi)$, both increasing in ξ, such that the optimal quantity $x^*(e_1)$ chosen by the firm is given by:

$$x^*(e_1) = \begin{cases} J[1-\underline{e}] & \text{if } e_1 \leq \underline{e}(\xi) \\ J[1-e_1] & \text{if } \underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi) \\ J\Psi(e_1) & \text{if } e_1 \geq \bar{e}(\xi) \end{cases} \tag{10}$$

Setting:

$$\Psi(e_1) = \frac{[\alpha + (1-e_1)(1-\xi)]}{2(J+1)} \tag{11}$$

We can verify that $\Psi(\bar{e}) = 1 - \bar{e}$ and thus the optimal quantity choice of the firm is continuous in e_1. The two levels of equipment, $\underline{e}(\xi)$ and $\bar{e}(\xi)$ identify the relative position of the optimal quantity with respect to $\hat{x}$.

Using (10) and (11), we obtain the consumer surplus $S(e_1, x^*(e_1))$ for a given standard e_1:

$$S(e_1, x^*(e_1)) = \begin{cases} \frac{J^2}{2}[1-\underline{e}]^2 & \text{if } e_1 \leq \underline{e}(\xi) \\ \frac{J^2}{2}(1-e_1)^2 & \text{if } \underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi) \\ \frac{J^2}{2}\Psi^2(e_1) & \text{if } e_1 \geq \bar{e}(\xi) \end{cases} \tag{12}$$

By comparing the optimal quantity $x^*(e_1)$ to the quantity $\hat{x}$, for any given level of standard, we highlight in Propositions 1 the influence of the standard e_1 on the firm's quantity choice.

Proposition 1

If $e_1 \leq \underline{e}(\xi)$, the firm selects only some of the initially well-equipped producers and quantity is constant in e_1.

If $\underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi)$, the firm selects all the initially well-equipped producers and quantity decreases in e_1.

If $e_1 > \bar{e}(\xi)$, the firm also involves some initially not well-equipped producers and quantity may increase in e_1.

Let us consider in Figure 1 the influence of level of standard on the firm's quantity strategy[15].

[15] The Figures illustrate the mechanisms behind each proposition.

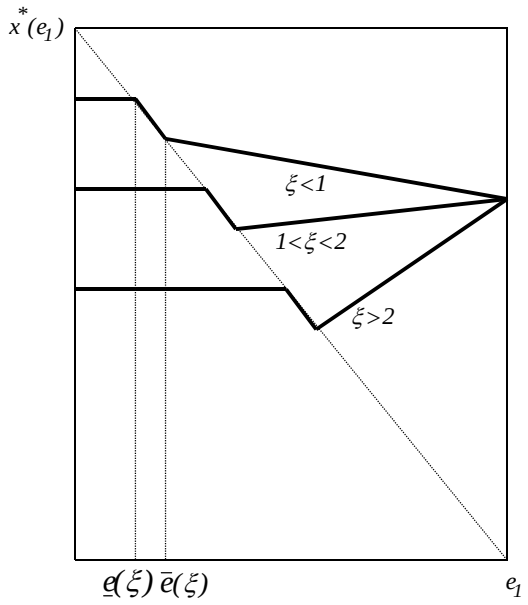

Figure 1 *- Effects of the standard on the firm's quantity choice, according to the level of risk perception*

If the standard is relatively low (lower than the threshold $\underline{e}(\xi)$), the firm's strategic behaviour is not constrained with respect to the Benchmark and the firm behaves as if no standard were in force. In the Benchmark, the whole available supply (*J*) is "candidate" to access the intermediary market. Introducing a standard rarefies the initially compliant supply. Nevertheless, as long as the standard remains lower than $\underline{e}(\xi)$ it does not constraint the firm's strategic choice: the firm chooses a relatively low quantity (with respect to the available supply) which does not require involving initially not well-equipped producers. In other words, the reinforcement of the standard rarefies the "eligible supply", but does not affect the firm's quantity strategy, as long as the standard is lower than $\underline{e}(\xi)$. As no equipment upgrading is needed for the selected producers to participate in the market, the intermediary price is fixed at zero.

If the standard is moderate ($\underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi)$), the firm selects *all* the initially well-equipped producers at a zero intermediary price. Thus, the firm chooses the whole initially compliant supply and continues to implement this strategy if the standard remains lower than $\bar{e}(\xi)$. In this context, quantity is reduced with respect to the Benchmark and decreases in e_1. Hence, when e_1 rises above the threshold $\underline{e}(\xi)$, the firm prefers to reduce the supplied quantity, regardless of the level of risk perception, and thus increase final price, rather than beginning to remunerate the equipments' upgrading of some initially not well-equipped producers in order to maintain the Benchmark quantity.

If the standard is highly constraining ($e_1 > \bar{e}(\xi)$) it constraints the firm's strategic choice by strongly reducing the eligible supply. In this context the firm's optimal quantity is higher than the eligible supply and thus the firm also involves some initially not well-equipped producers in order to implement her optimal quantity strategy and thus extends the quantity over the initially standard-compliant supply ($x > \hat{x}$).

In this context, the effect of a standard's reinforcement on firm's quantity choice depends on consumers' risk perception. Hence, for a given quantity *x*, a more exigent standard implies an increased unitary procurement cost (intermediary price) for the firm. The firm has thus interest in decreasing quantity if the standard is reinforced. However, for a given quantity *x*, a more exigent standard implies a reduced risk of product failure and thus an enhanced consumers' WTP. The firm has thus interest in increasing quantity if the standard is reinforced, in order to benefit from the improvement of consumers' WTP. Consumers' risk perception plays a crucial role in the following sense. While the risk perception does not affect the intermediary price-increasing effect of the standard's reinforcement, it influences consumers' reaction (in terms of WTP) to the risk-reducing effect of the standard's reinforcement. More specifically – for a given quantity – the higher is the risk perception the higher is the perceived risk-reduction (and the WTP improvement) due to the standard's reinforcement.

Hence, when risk perception is relatively low ($\xi < 1$), i.e. consumers underestimate the risk, the firm has interest in decreasing quantity in order to reinforce the risk-reducing effect of the standard's reinforcement and mitigate the intermediary price-increasing effect.

However, when risk perception is relatively high ($\xi > 1$), i.e. consumers overestimate the risk, the WTP improvement is more important than the increase of procurement costs, for a given quantity. Since the increase in the marginal benefit exceeds the increase in the marginal cost, the firm responds to a reinforcement of the standard with an increase of the supplied quantity, at a higher intermediary price.

In the context of the traditional literature on MQS, which aims at analyzing the effects of MQS on the firm's strategic behaviour (see for example Ronnen, 1991; Crampes and Hollander, 1995; Scarpa, 1998), the MQS is exogenously given[16]. In the following sections, we analyze the effects of firm's quantity choice on the risk, consumer surplus and market access of upstream producer, given the standard e_1.

Firm's strategic behaviour and effects on the risk and consumers' surplus

In this section, we illustrate the effect of firm's strategic behaviour on the risk and on consumers' surplus.

In the following Proposition, we illustrate the consequences of firm's quantity choice on the risk.

Proposition 2

If $e_1 \leq \underline{e}(\xi)$, *the risk is constant in* e_1.

If $\underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi)$, *the risk decreases in* e_1.

If $e_1 > \bar{e}(\xi)$, *the risk may increase in* e_1.

Let us consider in Figure 2 the influence of e_1 on the risk[17].

[16] Even if a few contributions consider the endogenous choice of the MQS (see for example, Ecchia and Lambertini, 1997), the choice of the criterion for determining the MQS is a very complex issue. Hence, there exist several criteria for the definition of a MQS, especially in the agricultural sector. In addition to the traditional criteria of maximization of social welfare, other criteria could represent the public authority's concerns, as for example the minimization of the risk, especially in the case of product's safety, or the minimization of upstream producers' exclusion. Following the main swathe of the economic literature on MQS, we thus examine the effects of the level of MQS on the firm's strategic behaviour, on the average quality provided on the market and on the surplus of the other economic agents, without specifying the criterion of choice of the MQS.

[17] The Figures illustrate the mechanisms behind each proposition; simulations have been made according to values of the parameters (J, α, ξ), which are consistent with (HP1).

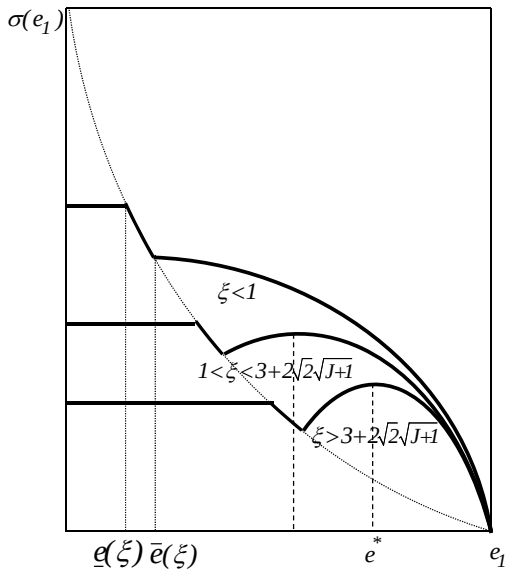

Figure 2 *- Effects of the standard on the risk of product failure according to the level of risk perception.*

If $e_1 \leq \underline{e}(\xi)$, the risk is not affected by the level of standard e_1. As no equipment upgrading is needed for the selected producers to participate in the market, in this context, the risk is not influenced by the level of standard e_1. Moreover, as quantity is constant in e_1, the risk is also constant in e_1. When $\underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi)$, the risk decreases in e_1 both through the decrease of quantity and the reinforcement of the standard e_1. Moreover, we show that, within this context, the final price increases, both through the rarity effect and the risk reduction.

If $e_1 > \bar{e}(\xi)$, the firm's strategic behaviour affects the *risk* in the following sense.

When risk perception is relatively low ($\xi < 1$), i.e. consumers underestimate the risk, the risk decreases as a result of both the standard's reinforcement and the decrease of quantity. Moreover, the decrease of quantity increases the final price both through a direct effect and an indirect effect on the risk, which reinforces the positive effect of the standard's reinforcement. The final price thus increases.

However, when risk perception is relatively high ($\xi > 1$), i.e. consumers overestimate the risk, the firm responds to a reinforcement of the standard with an increase of the supplied quantity (Proposition 1). As long as the risk-increasing effect of the raise of quantity dominates the risk-reducing effect of the standard's reinforcement, the risk of product failure increases in e_1. The risk has thus a local maximum on the interval $[\bar{e}(\xi),1]$. As a consequence, two levels

of e_1 may exist whereby the same risk arises, i.e. the same probability of product success may be achieved by implementing the higher of these two levels of standard (which corresponds to the highest level of quantity supplied on the market). Moreover, the firm's strategic behaviour affects the *final price* in the following sense. The increase of quantity reduces the final price both through a direct effect and an indirect effect on the risk, which contrasts the positive effect of the standard's reinforcement. The final price thus has an initially decreasing trait when the increase of quantity dominates the WTP-increasing effect of a standard's reinforcement and an increasing trait conversely.

As shown by Proposition 1, setting a standard $e_1 \leq \underline{e}(\xi)$ does not constraint the firm with respect to the Benchmark situation ($e_1 = e_0 = 0$) and the firm chooses $\tilde{e}(e_1, x^*(e_1)) = \underline{e}(\xi)$ as long as the standard remains lower than $\underline{e}(\xi)$. Whereas, introducing a standard $e_1 \in [\underline{e}(\xi),1]$ constraints the firm with respect to the Benchmark. Hence, following Propositions 1 and 2, we now analyze the effects of a standard $e_1 \in [\underline{e}(\xi),1]$ on consumers' surplus and on the risk, with respect to the Benchmark. As detailed in Proposition 1 when risk perception is relatively high ($\xi > 1$), i.e. consumers overestimate the risk, quantity increases in the standard e_1 and the risk has a local maximum, on the interval $[\bar{e}(\xi),1]$.

First, we show that, if $\xi > 2$ there exist a level of standard $\breve{e}_1(\xi)$, with $\bar{e}(\xi) < \breve{e}_1(\xi) < 1$ such that $x^*(e_1) > x^*(\underline{e}(\xi))$ (and $S(e_1) > S(\underline{e}(\xi))$) if and only if $e_1 > \breve{e}_1(\xi)$. Second, we show that if $\xi > 3 + 2\sqrt{2}\sqrt{J+1}$, there exist two levels of standard $e_1'(\xi)$ and $e_1''(\xi)$, with $\bar{e}(\xi) < \breve{e}_1(\xi) < e_1'(\xi) < e_1''(\xi) < 1$ such that $\bar{\sigma}(e_1) > \bar{\sigma}(\underline{e}(\xi))$ if and only if $e_1'(\xi) < e_1 < e_1''(\xi)$.

We thus distinguish the following three cases, which are summarized in Corollary 1 below.

When $\xi < 2$, introducing $e_1 \in [\underline{e}(\xi),1]$ always implies a risk reduction, with respect to the Benchmark, but also a lower consumers' surplus.

When $2 < \xi < 3 + 2\sqrt{2}\sqrt{J+1}$, it always implies a lower risk and moreover *may* imply a higher consumers' surplus, namely, when the standard is sufficiently strict ($e_1 > \breve{e}_1(\xi)$).

When $\xi > 3 + 2\sqrt{2}\sqrt{J+1}$, it may imply a higher surplus (namely if $e_1 > \breve{e}_1(\xi)$), but not necessarily a risk reduction, with respect to the Benchmark[18]. Hence, when $e_1'(\xi) < e_1 < e_1''(\xi)$, it implies a higher surplus, but also a higher risk, with respect to the Benchmark.

Corollary 1

With respect to the Benchmark, introducing a standard $e_1 \in [\underline{e}(\xi),1]$ *:*

- *If* $\xi < 2$ *, implies a lower risk, but also a lower surplus;*
- *If* $2 < \xi < 3 + 2\sqrt{2}\sqrt{J+1}$ *, implies a lower risk, and moreover may imply a higher surplus, provided that the standard is sufficiently strict;*
- *If* $\xi > 3 + 2\sqrt{2}\sqrt{J+1}$ *, it may imply a higher surplus, but not necessarily a lower risk.*

A reinforcement of the standard does not necessarily have either a surplus-improving effect or a risk-reducing effect.

More specifically, introducing e_1 such that $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$ always reduces risk, but also consumer surplus with respect to the Benchmark, regardless of the level of risk perception, as a consequence of the incentive for the firm to decrease quantity (see Propositions 1, 2).

If $e_1 > \bar{e}(\xi)$, and the risk perception is sufficiently low ($\xi < 1$), i.e. consumers underestimate the risk, a reinforcement of the standard reduces risk, but also consumers' surplus. Moreover, as shown by Corollary 1, introducing $e_1 \in [\underline{e}(\xi),1]$ always implies a risk reduction, with respect to the Benchmark, but a lower consumers' surplus.

When consumers overestimate the risk ($\xi > 1$), a reinforcement of the standard increases consumers' surplus (as a result of the increase of quantity); nevertheless, in this context, the risk does not necessarily decrease in the standard. Moreover, as shown by Corollary 1, introducing $e_1 \in [\underline{e}(\xi),1]$ may imply a higher surplus, but not necessarily a risk reduction, with respect to the Benchmark.

---

[18] The possible quality-reducing effect of a standard has been widely illustrated by the literature on MQS. See for example Scarpa (1998), who shows that if a MQS is introduced in a vertically differentiated market with three firms, then the maximum quality level, the average quality consumed as well as the profit levels of all firms decrease. In this spirit, Maxwell (1998) illustrates that a MQS may reduce firm incentives to innovate – when the innovating firm correctly anticipates that a regulator will raise the minimum standard once an innovation has been discovered – leading to a lower level of social welfare under regulation. Furthermore, the introduction of "innocuous" minimum quality standards, namely below the lowest quality level in a market, may reduce the incentive to invest in R&D by the quality-leading firm (Garella, 2006).

Firm's strategic behaviour and effects on upstream producers' exclusion

In this section, we highlight the effects of firm's strategic behaviour on upstream suppliers. For a given e_1, the firm's optimal quantity choice determines *de facto* the number of upstream producers selected. We denote by $\tilde{e}(e_1, x^*(e_1))$ the threshold equipment starting from which producers are selected by the firm, for a given e_1.

If $e_1 \leq \underline{e}(\xi)$, the firm selects only some of the initially well-equipped producers ($\tilde{e}(e_1, x^*(e_1)) = \underline{e}$) and the number of upstream producers selected is not affected by the level of standard.

If $\underline{e}(\xi) \leq e_1 \leq \bar{e}(\xi)$, the firm selects *all* the initially well-equipped producers at a zero intermediary price. In this context, as quantity decreases in e_1, the number of selected upstream producers also decreases, or equivalently producers' exclusion increases as the standard is reinforced.

If $e_1 > \bar{e}(\xi)$ and consumers underestimate the risk ($\xi < 1$) the firm has interest in decreasing quantity and thus the number of upstream producers, as the standard is reinforced. In this case, the reinforcement of the standard implies a detriment of upstream producers' market access.

However, when consumers overestimate the risk ($\xi > 1$), the firm has interest in increasing quantity when the standard is reinforced (Proposition 1). In this case, a reinforcement of e_1 improves market access. Moreover, since the intermediary price increases in e_1, an unexpected effect of a standard's reinforcement arises, whereby both the remuneration of upstream producers and the number of participating producers may increase if the standard is reinforced. Furthermore, when risk overestimation is sufficiently high ($\xi > 2$) and the standard sufficiently strict, introducing a standard $e_1 \in [\underline{e}(\xi), 1]$ may imply an improved market access for upstream producers, with respect to the Benchmark.

We thus show that producers' exclusion from the market does not only depend on the stringency of the quality standard (and thus, on the level of compliance costs), but also on the strategic behaviour of the downstream firm – in a context of vertical relationship – both

towards the upstream and the downstream market. In this sense, we depart from the accepted idea that the more stringent is a quality standard, the higher producers' exclusion from a particular market requiring the standard (Henson and Heasman, 1998; Henson and Caswell, 1999; Unnevehr and Jensen, 1999).

4 Firm's normalization strategy

In this section we detail at which conditions the firm has interest in reinforcing the MQS with a more stringent private standard.

Definition 1 below illustrates the set of firm's strategies.

Definition 1 *– A normalization strategy is denoted "MQS- adapting strategy" if* $e_1^*(e_0) = e_0$ *and "MQS-reinforcing strategy" if* $e_1^*(e_0) > e_0$.

As illustrated by the Definition 1, the firm may simply comply with the level of public MQS or be more demanding than the public authority by implementing a more stringent private standard. The firm's decision whether to reinforce the MQS is influenced both by the level of risk perception and by the level of MQS.

Let us now describe the firm's normalization strategy.

When $\xi \leq 1$, the firm simply adapts to the public MQS by choosing $e_1^*(e_0) = e_0$ regardless of the level of the MQS. However we can distinguish the following three cases, according to the stringency of the standard. If $e_0 \leq \underline{e}(\xi)$, the firm is *implicitly* more exigent than the MQS by selecting only some of the initially well-equipped upstream producers ($\tilde{e} > e_0$). If $\underline{e}(\xi) \leq e_0 \leq \bar{e}(\xi)$ the firm selects all the initially well equipped producers ($\tilde{e} = e_0$) without financing any upgrading of upstream production conditions. Finally, if $e_0 \geq \bar{e}(\xi)$, then the firm also involves some of the initially not well equipped producers, and finance their compliance process, but without being more exigent than the public MQS.

When $1 \le \xi \le 2$, the firm reinforces the public MQS by choosing $e_1^*(e_0) = 1 > e_0$, if and only if the MQS is sufficiently strict. Namely, we show that there exist a level of MQS $\hat{e}_0(\xi)$ such that $\pi(1) \ge \pi(e_0)$ (and the firm explicitly reinforces the public MQS by choosing $e_1^*(e_0) = 1 > e_0$) if and only if the MQS is sufficiently strict, namely if $e_0 \ge \hat{e}_0(\xi)$, with $\hat{e}_0(\xi)$ given by:

$$\hat{e}_0(\xi) = \begin{cases} 1 - \dfrac{2\alpha(\xi - 1)}{1 + \xi(2J + \xi)} & \text{if } 1 \le \xi \le U \\ 1 - \alpha\left[\dfrac{4(J+1) - \sqrt{8(J+1)(2-\xi)}}{4(J+1)(2J+\xi)}\right] & \text{if } U \le \xi \le 2 \end{cases} \tag{13}$$

Where $U = \sqrt{(J+1)(J+3)} - J$, with $1 < U < 2$. Using (13), we verify that $\hat{e}_0(\xi)$ is decreasing in ξ, with $\underline{e}(\xi) \le \hat{e}_0(\xi) \le 1$. Namely, we distinguish two cases: (1) if $1 \le \xi \le U$ then $\bar{e}(\xi) \le \hat{e}_0(\xi) \le 1$, (2) if $U \le \xi \le 2$ then $\underline{e}(\xi) \le \hat{e}_0(\xi) \le \bar{e}(\xi)$. Let us now illustrate these two cases.

- In the case $1 \le \xi \le U$, we have $\bar{e}(\xi) \le \hat{e}_0(\xi) \le 1$ and thus we distinguish the following cases. If $e_0 \le \underline{e}(\xi)$, the firm is implicitly more exigent than the MQS by selecting only some of the initially well-equipped upstream producers ($\tilde{e} > e_0$). If $\underline{e}(\xi) \le e_0 \le \bar{e}(\xi)$ the firm selects all the initially well equipped producers ($\tilde{e} = e_0$) without financing any upgrading of upstream production conditions. If $\bar{e}(\xi) \le e_0 \le \hat{e}_0(\xi)$, then the firm also involves some of the initially not well equipped producers, and finance their compliance process, but without being more demanding than the public MQS. Finally, if $e_0 \ge \hat{e}_0(\xi)$, the firm explicitly reinforces the public MQS by choosing $e_1^*(e_0) = 1 > e_0$.

- In the case $U \le \xi \le 2$, we have $\underline{e}(\xi) \le \hat{e}_0(\xi) \le \bar{e}(\xi)$. In this context, if $e_0 \le \underline{e}(\xi)$, the firm is implicitly more demanding than the MQS by selecting only some of the initially well-equipped upstream producers ($\tilde{e} > e_0$). If $\underline{e}(\xi) \le e_0 \le \hat{e}_0(\xi)$ the firm selects all the initially well equipped producers ($\tilde{e} = e_0$) without financing any upgrading of upstream production conditions. If $e_0 \ge \hat{e}_0(\xi)$, the firm explicitly reinforces the public MQS by choosing $e_1^*(e_0) = 1 > e_0$.

When $\xi \geq 2$, the firm always reinforces the public MQS by choosing $e_1^*(e_0) = 1 > e_0$.

The following Proposition 3 summarizes these cases.

Proposition 3

When $\xi \leq 1$, the firm always chooses $e_1^*(e_0) = e_0$;

When $1 \leq \xi \leq 2$, there exist a level of standard $\hat{e}_0(\xi)$, such that the firm chooses $e_1^*(e_0) = 1 > e_0$ if and only if $e_0 \geq \hat{e}_0(\xi)$ and $e_1^*(e_0) = e_0$ otherwise.

When $\xi \geq 2$, the firm always chooses $e_1^*(e_0) = 1 > e_0$.

Proposition 3 shows that on the one hand, if $\xi \leq 1$, i.e. consumers underestimate the risk, the firm has never interest in reinforcing the MQS. On the other hand, if $\xi \geq 2$, i.e. risk overestimation is sufficiently high, the firm has always interest in reinforcing the MQS, by anticipating that a zero-risk will imply the maximal consumers' WTP, for any given quantity. In other words, the same "ideal" situation occurs as if consumers perceive zero risk. Hence, the firm reinforces the MQS in order to increase quantity.

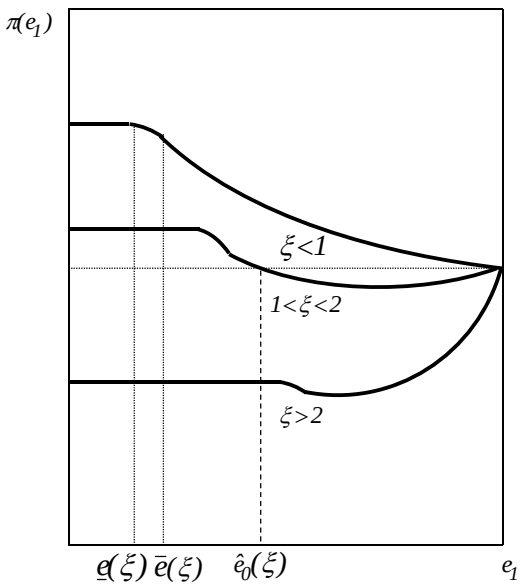

Figure 3 *- firms' normalization strategy according to the level of risk perception*

If $1 \leq \xi \leq 2$, i.e. consumers overestimate the risk, but risk overestimation is relatively low, the firm has interest in implementing a more stringent private standard only when the MQS is sufficiently strict. In this context, If no MQS were in force, the firm would simply select

some of the initially well-equipped producers at a zero intermediary price. When the MQS rises above $\hat{e}_0(\xi)$, the firm reinforces it with a most demanding private standard. Highly constrained in her procurement strategy by the introduction of the MQS, the firm implements the risk-minimizing private standard in order to increase quantity.

Hence, we show that it is not necessarily when the MQS is relatively weak that the firm has interest in implementing a private standard, more demanding than the MQS. In this sense, we depart from the established idea that private standards generally act as a substitute for missing or inadequate public regulation (Henson, 2006; Henson and Reardon, 2005).

The following Proposition 4 illustrates the effects of the private standard on risk, quantity, market access of upstream producers, consumers' surplus.

Proposition 4

When the firm reinforces the MQS with a more stringent private standard, risk is reduced and quantity is increased, with respect of simply complying with the MQS, and both upstream producers' market access and consumers' surplus are improved.

At the conditions such that the firm implements a more stringent private standard, *quantity (and surplus) increase and risk is reduced*, with respect to simply complying with the public MQS. Hence, consumers are better off, both in terms of quantity and risk of product failure. Moreover, market access of upstream producers is improved, since the quantity improvement implicitly leads to an increase in the number of upstream producers involved. Departing from the accepted idea that a reinforcement of the standard increases the risk of producers' exclusion from the market, we show that, when the downstream firm has interest in remunerating the upstream producers' adaptation effort, market access may be improved through a reinforcement of the standard[19].

[19] In this context, we consider that the cost for the firm to implement a private standard, more stringent than the MQS, is represented by the intermediary price that the firm pays to upstream producers to support the compliance process of the initially not well-equipped ones. Hence, the level of intermediary price the firm has to pay to support the upstream producer adaptation to the standard is anticipated by the firm in her decision whether to simply select upstream initially well-equipped

5 Final remarks

Our paper provides an original contribution as we explicitly consider how both public and private policies are affected by consumers' information about the average quality provided on the market.

We have studied the incentive for the firm to develop private standards, more constraining that the minimum quality standard set by the public authority, in a context where product's attributes are signalled to consumers (either by the firm or by third parties) through a communication based on the product's average quality. We have shown that when consumer risk perception is sufficiently high, and even if the MQS is relatively severe, the firm has interest in developing a more constraining private standard, in order to benefit from the improvement of willingness to pay and thus increase the supplied quantity.

Empirical evidence shows an increasing use of global business to business (B2B) standards, which are not communicated directly to consumers, in procurement from suppliers and as a governance tool in the food system. In general, investments in quality or quality control mechanisms are seen as a way to build consumer trust and increase the value of a firm's reputation, once signalled to consumers. But why do firms exceed the legal MQS, when quality signals are not transmitted to consumers, such as use of EurepGap, or GFSI standards? Some reasons may be put forward. At first, providing consumers with products that meet consistent quality and safety standards that go beyond the minimum requirements builds reputation, the key asset for current and future earnings flows (Fulponi, 2006). Secondly, major processors and retailers implement private standards as instruments for the coordination of supply chains by standardizing product requirements over suppliers (Henson and Reardon, 2005). This becomes of greater importance as supply chains become more global and cut across differing regulatory, economic and regulatory environments. Private standards may thus be implemented in order to reduce the transaction costs and risks associated with procurement. Thirdly, firms may be prompted to develop private standards in order to limit exposure to potential regulatory action and/or anticipate future regulatory developments (Lutz et al., 2000) and manage exposure to liability. Our analysis could thus be extended by considering that the public authority jointly uses ex-ante regulation (MQS) and ex-post liability rules. The existence of an expected sanction associated with product's failure and the consequently risk of market share erosion in the long term is thus likely to incentive

producers or support an upgrading of upstream supply characteristics. Here, we do not consider other costs associated to the processing stage or to the certification and quality control procedures concerning the development of the brand.

firms to implement private standards, even if they are not signalled to consumers (Fulponi, 2006, Henson, 2006).

Moreover, in this paper we explicitly takes into account the dimension of vertical relationships, by considering that the MQS is applied to the upstream firms, whereas the downstream firm maintains the strategic flexibility to choose both quantity and quality, given that the upstream supply complies with the MQS. Hence, empirical evidence shows that MQS often concern intermediate products[20]. In a context where the risk arises both from the upstream production conditions and from the strategic behaviour of the downstream firm, the MQS may have different effects whether it is applied to the upstream suppliers or to the downstream firm. This extends our analysis in the larger debate about the optimal public policy between "obligation of means" and "obligation of results". In the latter case, the MQS is applied to the downstream firm, which is thus constrained in the quality-quantity choice by a level of average quality fixed by the public authority. The question raised is thus whether the firm has interest in developing a private standard and which are the effects of the different policy instruments on social welfare.

References

Angulo, A. M., Gil, J. M. (2007). Risk perception and consumer willingness to pay for certified beef in Spain. *Food Quality and Preference*, 18: 1106-1117.

Antle, J.M. (1999). Benefits and Costs of food safety regulation. Food Policy, 24: 605-623

Besanko, D., Donnenfeld, S., White, L.J. (1987). Monopoly and Quality Distortion: Effects and Remedies. The Quarterly Journal of Economics, 102(4): 743-768

Beverland, M. (2007). Can cooperatives brand? Exploring the interplay between cooperative structure and sustained brand marketing success. Food Policy 32: 480-495

Boom, A. (1995). Asymmetric International Minimum Quality Standards and Vertical Differentiation. *The Journal of Industrial Economics*, 43(1): 101-119

Brown, J., Cranfield, J. A. L., Henson, S. (2005). Relating consumer willingness to pay for food safety to risk tolerance: an experimental approach. *Canadian Journal of Agricultural Economics* 53: 249-263.

Caswell, J. A., Kleinschmit, J. K. (1997). Using Benefit-Cost Criteria for Settling Federalism Disputes: An Application to Food Safety Regulation. American Journal of Agricultural Economics, 79: 24-38

Copeland, M. T. (1923). The Relation of Consumers' Buying Habits to Marketing Methods. Harvard Business Review, 1: 282-289

[20] To the best of our knowledge, the existing literature of minimum quality standards does not take into account the dimension of vertical relationships and almost uniquely deals with MQS concerning final products markets: obligation for a car producer to install airbags, safety standards for pharmaceutical products (Boom, 1995), service quality in the market of local cable television subscription (Besanko et al., 1987) or licensing standards for medical services (Leland, 1979).

Costa-Font, J., Mossialos, E. (2007). Are perceptions of “risks” and “benefits” of genetically modified food (in) dependent? Food Quality and Preference, 18: 173-182

Crampes, C., Hollander, A. (1995). Duopoly and Quality standards. European Economic Review, 39: 71-82

Darby, M. R., Karni, E. (1973). Free Competition and the Optimal Amount of Fraud. Journal of Law and Economics, 16: 67-88

Deighton, J. (1992). The consumption of performance. Journal of Consumer Research, 19: 362-372

Delgado-Ballester, E., Munuera-Alemán, J. L. (2000). Brand Trust in the context of consumer loyalty. European Journal of Wine Marketing, 35 (11/12): 1238-1258

Ecchia, G., Lambertini, L. (1997). Minimum Quality Standards and Collusion. The Journal of Industrial Economics, XLV(1): 101-113

Feng, T., Keller, L. R., Wang, L., Wang, Y. (2010). Product quality risk perceptions and decisions: contaminated pet food and lead-painted toys. *Risk Analysis,* no. doi: 10.1111/j.1539-6924.2010.01459.x.

Fearne, A. (1998). The evolution of partnerships in the meat supply chain: Insights from the beef industry. Supply Chain Management, 3: 214-231

Fulponi, L. (2006). Private voluntary standards in the food system: The perspective of major food retailers in OECD countries. Food Policy, 31: 1-13

Garella, P. G. (2006). “Innocuous Minimum Quality Standards. Economic Letters, 92: 368-374.

Grazia, C. (2006). Il sistema delle denominazioni di origine nel settore vitivinicolo: meccanismi di regolazione dell’offerta e analisi delle scelte strategiche delle imprese. PhD Dissertation, University of Bologna.

Grenn, R., Zúńiga, M.R., Seabra Pinto, A. (2006). Imprese del vino: un sistema in continua evoluzione. In Cesaretti et al. (eds), Il Mercato del Vino. Tendenze strutturali e strategie dei concorrenti. Franco Angeli, 74-112

Grunert, K. G. (2005). Food quality and safety: consumer perception and demand. European Review of Agricultural Economics, 32 (3): 369-391

Henson, S. (2006). The role of public and private standards in regulating international food markets. Paper prepared for IATRC Summer Symposium “Food Regulation and Trade: Institutional Framework, concepts of analysis and empirical evidence”.

Henson, S., Caswell, J. (1999). Food safety regulation: an overview of contemporary issues. Food Policy, 24: 589-603

Henson, S., Heasman, M. (1998). Food safety regulation and the firm: understanding the compliance process. Food Policy, 23(1): 9-23

Henson, S., Reardon, T. (2005). Private agri-food standards: Implications for food policy and the agri-food system. Food Policy, 30: 241-253

Henson, S., Traill, B. (1993). The demand for food safety. Market imperfections and the role of government. *Food Policy*, 18 (2): 152-162.

Keller, K. L. (1993). Conceptualizing, measuring and managing customer-based brand equity. Journal of Marketing, 57(1): 1-22

Kornelis, M., De Jonge, J., Frewer, L., Dagevos, H. (2007). Consumer selection of food-safety information sources. *Risk Analysis,* 27 (2): 327-335.

Krishnan, H. S. (1996). Characteristics of memory associations: a consumer-based brand equity perspective. International Journal of Research in Marketing, 13 (4)- 389-405

Leland, H.E. (1979). Quacks, Lemons, and Licensing: A Theory of Minimum Quality Standards. The Journal of Political Economy, 87(6): 1328-1346

Lobb, A. E., Mazzocchi, M., Traill, W. B. (2007). Modelling risk perception and trust in food safety information within the theory of planned behaviour. Food Quality and Preference, 18: 384-395

Loureiro, M.L., Umberger, W.J. (2007). A choice experiment model for beef: What US consumer responses tell us about relative preferences for food safety, country-of-origin labelling and traceability. Food Policy, 32: 496-514

Lutz, S., Lyon, T.P., Maxwell, J.W. (2000). Quality Leadership When Regulatory Standards Are Forthcoming. The Journal of Industrial Economics, 48(3): 331-348

Maurer, O., Drescher, K. (1996). Industrial Standards as Driving Forces of Corporate Innovation and Internationalization. In Galizzi, G., Venturini, L. (eds), Economics of Innovation: The Case of Food Industry. Physica-Verlag, 221-237

Maxwell, J.W. (1998). Minimum Quality Standards as a barrier to innovation. Economic Letters, 58: 355-360

McCarthy, M., Henson, S. (2005). Perceived Risk and risk reduction strategies in the choice of beef by Irish consumers. Food Quality and Preference, 16: 435-445

Mitchell, V-W., Greatorex, M. (1990). Consumer Perceived Risk in the UK Food Market. British Food Journal, 92 (2): 16-22

Mitchell, V-W., McGoldrick, P.J. (1996). Consumers' risk reduction strategies: A review and synthesis. The International Review of Retail, Distribution and Consumer Research, 6 (1): 1-33

Mora, P. (2006). Key factors of success in today's wine sector. International Journal of Wine Marketing, 18(2): 139-149

O'Brien, T.M., Diaz Rodriguez, A. (2004). Improving the competitiveness and market access for agricultural exports through the development and application of food safety and quality standards. The example of Peruvian asparagus. A Report by the Agricultural Health and Food Safety Program of the Inter-American Institute for Cooperation on Agriculture (IICA), http://www.bountybay.com/Peru-case-english.pdf

Polinsky, A.M., Rogerson, W.P. (1983). Products Liability, Consumers Misperceptions and Market Power. The Bell Journal of Economics, 14(2): 581-589

Pomarici, E., Boccia, F. (2006). La filiera del vino in Italia: struttura e competitività. In Cesaretti et al. (eds), Il Mercato del Vino. Tendenze strutturali e strategie dei concorrenti. Franco Angeli, 142-189

Ponssard, J-P., Sevy, D., Tanguy, H. (2005). Économie de l'entreprise. Les Éditions de l'École Polytechnique, 19-71

Ronnen, U. (1991). Minimum Quality Standards, Fixed Costs, and Competition. The Rand Journal of Economics, 22(4): 490-504

Scarpa, C. (1998). Minimum Quality Standards with more than two firms. International Journal of Industrial Organization, 16: 665-676

Sparks, P., Shepherd, R. (1994). Public perceptions of food-related hazards: individual and social dimensions. *Food Quality and Preference*, 5: 185-194.

Theng Lau, G., Han Lee, S. (2000). Consumers' Trust in a Brand and the Link to Brand Loyalty. Journal of Market Focused Management, 4: 341-370

Unnevehr, L.J., Jensen, H.H. (1999). The economic implications of using HACCP as a food safety regulatory standard. Food Policy, 24: 625-635

Verbeke, W., Frewer, L. J., Scholderer, J., De Brabander, H. F. (2007). Why consumers behave as they do with respect to food safety and risk information. *Analytica Chimica Acta*, 586: 2-7.

Viscusi, W.K. (2006). Regulation of Health, Safety and Environmental Risks. Discussion Paper No.544, Harvard Law School. Cambridge, MA 02138

Xia, T., Sexton, R.J. (2004). The Competitive Implications of the Top-of-the-Market and related Contract-Pricing Clauses. American Journal of Agricultural Economics, 86(1): 124-138

Yeung, R.M.V., Yee, W.M.S. (2002). Multi-dimensional analysis of consumer-perceived risk in chicken meat. Nutrition and Food Science, 32(6): 219-22.

Appendix

We first determine the risk $\bar{\sigma}(e_1,\tilde{e})$ as a function of the threshold equipment $\tilde{e}$, given the standard e_1.

If $x \le \hat{x}$ ($\tilde{e} \ge e_1$), then producers are uniformly distributed on the interval $[\tilde{e},1]$ according to the density function $f(e) = \frac{1}{1-\tilde{e}}$, with $\int_{\tilde{e}}^{1} f(e)de = 1$. Then, the risk $\bar{\sigma}(e_1,\tilde{e})$ is given by:

$$\bar{\sigma}(e_1,\tilde{e}) = \int_{\tilde{e}}^{1} \sigma(e) f(e) de = \frac{1-\tilde{e}}{2} \tag{A1}$$

If $x > \hat{x}$ ($\tilde{e} < e_1$), then producers are distributed on the interval $[\tilde{e},1]$ according to the density function $f'(e)$, given by (4) with $\int_{\tilde{e}}^{1} f'(e)de = 1$. Then, the risk $\bar{\sigma}(e_1,\tilde{e})$ is given by:

$$\bar{\sigma}(e_1,\tilde{e}) = \int_{\tilde{e}}^{1} \sigma(e) f'(e) de = \frac{1}{2(1-\tilde{e})}(1-e_1)(1+e_1-2\tilde{e}) \tag{A2}$$

We denote by $h(e)$ the statistical distribution of producers' equipments, where $h(e) = f(e)$ if $x \le \hat{x}$ and $h(e) = f'(e)$ if $x > \hat{x}$.

By substituting ($\tilde{e} = 1 - \frac{x}{J}$) in (A1) and (A2), we then obtain the risk $\bar{\sigma}(e_1,x)$ as a function of the quantity x:

$$\bar{\sigma}(e_1,x) = \int_{\tilde{e}}^{1} \sigma(e) h(e) de = \begin{cases} \frac{x}{2J} & \text{if } x \le \hat{x} \\ (1-e_1)[1-\frac{J}{2x}(1-e_1)] & \text{if } x > \hat{x} \end{cases} \tag{A3}$$

By using (A3) we verify that for a given level of standard e_1, the risk $\bar{\sigma}(e_1,x)$ is an increasing function of the quantity x.

Firm's quantity strategy

By substituting (1), (5) and (6) into (7), we determine the firm's expected profit $\pi(e_1,x)$ as a function of the level of standard e_1 and the quantity x:

$$\pi(e_1,x) = \begin{cases} -\frac{2J+\xi}{2J}x^2 + \alpha x & \text{if } x \le \hat{x} \\ -\frac{J+1}{J}x^2 + [\alpha + (1-e_1)(1-\xi)]x + \frac{J}{2}(1-e_1)^2\xi & \text{if } x \ge \hat{x} \end{cases} \tag{A4}$$

We verify that the function $\pi(e_1,x)$ is continuous in $\hat{x}$ and has two local maxima. Using (A4), we determine the quantity chosen by the firm as a function of the standard e_1.

If $x \le \hat{x}$, the optimal quantity x' chosen by the firm is given by:

$$x' = \frac{\alpha J}{2J + \xi} \tag{A5}$$

Using (A5) we verify ex-post that $x' \le \hat{x}$ if and only if $e_1 \le 1 - \frac{\alpha}{2J + \xi}$.

If $x \ge \hat{x}$, the optimal quantity $x''(e_1)$ chosen by the firm is given by:

$$x''(e_1) = \frac{J[\alpha + (1 - e_1)(1 - \xi)]}{2(J + 1)} \tag{A6}$$

We pose:

$$\Psi(e_1) = \frac{[\alpha + (1 - e_1)(1 - \xi)]}{2(J + 1)} \tag{A7}$$

Using (A6) we verify ex-post that $x''(e_1) \ge \hat{x}$ if and only if $e_1 \ge 1 - \frac{\alpha}{(2J + 1) + \xi}$.

Si $1 - \frac{\alpha}{2J + \xi} \le e_1 \le 1 - \frac{\alpha}{(2J + 1) + \xi}$ we have $x' \ge \hat{x}$ and $x''(e_1) \le \hat{x}$ and the optimal quantity is given by $\hat{x}$.

Using (A5) and (A6)-(A7), the optimal quantity $x^*(e_1)$ is given by:

$$x^*(e_1) = \begin{cases} J[1 - \underline{e}] & \text{if } e_1 \le \underline{e}(\xi) \\ J[1 - e_1] & \text{if } \underline{e}(\xi) \le e_1 \le \overline{e}(\xi) \\ J\Psi(e_1) & \text{if } e_1 \ge \overline{e}(\xi) \end{cases} \tag{A8}$$

With $\underline{e}(\xi)$ and $\overline{e}(\xi)$ ($\overline{e}(\xi) > \underline{e}(\xi)$), increasing functions of ξ respectively given by:

$$\left| \begin{array}{l} \underline{e}(\xi) = 1 - \dfrac{\alpha}{2J + \xi} \\ \\ \overline{e}(\xi) = 1 - \dfrac{\alpha}{(2J + 1) + \xi} \end{array} \right. \tag{A9}$$

By using (2) and (A9) we determine $\tilde{e}(e_1, x^*(e_1))$:

$$\tilde{e}(e_1, x^*(e_1)) = \begin{cases} \underline{e} & \text{if } e_1 \le \underline{e}(\xi) \\ e_1 & \text{if } \underline{e}(\xi) \le e_1 \le \overline{e}(\xi) \\ 1 - \Psi(e_1) & \text{if } e_1 \ge \overline{e}(\xi) \end{cases} \tag{A10}$$

By using (A3)-(A8) we determine the risk $\overline{\sigma}(e_1, x^*(e_1))$:

$$\overline{\sigma}(e_1, x^*(e_1)) = \begin{cases} \frac{1}{2}[1 - \underline{e}] & \text{if } e_1 \le \underline{e}(\xi) \\ \frac{1}{2}(1 - e_1) & \text{if } \underline{e}(\xi) \le e_1 \le \overline{e}(\xi) \\ (1 - e_1)[1 - \frac{1}{2\Psi(e_1)}(1 - e_1)] & \text{if } e_1 \ge \overline{e}(\xi) \end{cases} \tag{A11}$$

By using (6), we determine the intermediary price $\omega(e_1, x^*(e_1))$:

$$\omega(e_1, x^*(e_1)) = \begin{cases} 0 & \text{if } e_1 \le \bar{e}(\xi) \\ \Psi(e_1) - (1 - e_1) & \text{if } e_1 \ge \bar{e}(\xi) \end{cases} \tag{A12}$$

Proof of Proposition 1

By using (A7)-(A9) and (A11), we easily verify that:

When $e_1 \le \underline{e}(\xi)$, then the optimal quantity $x^*(e_1)$ is a *constant* function of the standard e_1.

When $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$, then optimal quantity $x^*(e_1)$ is a *decreasing* function of the standard e_1.

When $e_1 \ge \bar{e}(\xi)$, then we have:

- If $\xi < 1$, the optimal quantity $x^*(e_1)$ is a decreasing functions of e_1.
- If $\xi > 1$, the optimal quantity $x^*(e_1)$ is an increasing function of e_1.

Proof of Proposition 2

By using (A7)-(A9) and (A11), we easily verify that:

When $e_1 \le \underline{e}(\xi)$, then the risk $\bar{\sigma}(e_1, x^*(e_1))$ is a *constant* function of the standard e_1.

When $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$, then the risk $\bar{\sigma}(e_1, x^*(e_1))$ is a *decreasing* function of the standard e_1.

When $e_1 \ge \bar{e}(\xi)$, then we have:

- If $\xi \le 1$, the risk $\bar{\sigma}(e_1, x^*(e_1))$ is a decreasing functions of e_1.
- If $\xi > 1$, the risk $\bar{\sigma}(e_1, x^*(e_1))$ has a local maximum given by:

$$e_1^*(\xi) = 1 - \alpha\left[\frac{(J+\xi) - \sqrt{(J+1)(J+\xi)}}{(J+\xi)(\xi-1)}\right] \tag{A13}$$

Proof of Corollary 1

1) Quantity $x^*(e_1)$ and surplus $S(e_1)$.

By using (A7)-(A9), we easily verify that:

When $e_1 \le \underline{e}(\xi)$, then the optimal quantity $x^*(e_1)$ is a *constant* function of the standard e_1.

When $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$, then the optimal quantity $x^*(e_1)$ is a *decreasing* function of the standard e_1.

When $e_1 \ge \bar{e}(\xi)$, then:

- If $\xi < 1$, the optimal quantity $x^*(e_1)$ is decreasing in e_1 (then $x^*(e_1) < x^*(\underline{e}(\xi)), \forall e_1 \in [\underline{e}(\xi), 1]$);
- If $1 < \xi < 2$, the optimal quantity $x^*(e_1)$ is increasing in e_1 and $x^*(e_1) < x^*(\underline{e}(\xi)), \forall e_1 \in [\underline{e}(\xi), 1]$;
- If $\xi > 2$, the optimal quantity $x^*(e_1)$ is increasing in e_1 and there exist a level of standard $\breve{e}_1(\xi)$, with $\bar{e}(\xi) < \breve{e}_1(\xi) < 1$ such that $x^*(e_1) > x^*(\underline{e}(\xi))$ if and only if $e_1 > \breve{e}_1(\xi)$, where $\breve{e}_1(\xi)$ is given by:

$$\bar{e}_1(\xi) = 1 - \frac{\alpha(\xi - 2)}{(2J + \xi)(\xi - 1)} \tag{A14}$$

2) Risk $\bar{\sigma}(e_1, x^*(e_1)) = \bar{\sigma}(e_1)$

By using (A7)-(A9) and (A11), we easily verify that:

When $e_1 \le \underline{e}(\xi)$, then the risk $\bar{\sigma}(e_1)$ is a *constant* function of the standard e_1.

When $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$, then the risk $\bar{\sigma}(e_1)$ is a *decreasing* function of the standard e_1.

When $e_1 \ge \bar{e}(\xi)$, then:

- If $\xi \le 1$, the risk $\bar{\sigma}(e_1)$ is decreasing in e_1 (then $\bar{\sigma}(e_1) < \bar{\sigma}(\underline{e}(\xi)), \forall e_1 \in [\underline{e}(\xi), 1]$);
- If $1 < \xi < 3 + 2\sqrt{2}\sqrt{J+1}$, the risk $\bar{\sigma}(e_1)$ has a local maximum on the interval $[\bar{e}(\xi), 1]$, which is given by (A13) and $\bar{\sigma}(e_1) < \bar{\sigma}(\underline{e}(\xi)), \forall e_1 \in [\underline{e}(\xi), 1]$;
- If $\xi > 3 + 2\sqrt{2}\sqrt{J+1}$, the risk $\bar{\sigma}(e_1)$ has a local maximum on the interval $[\bar{e}(\xi), 1]$, which is given by (A13) and there exist two levels of standard $e_1'(\xi)$ and $e_1''(\xi)$, with $\bar{e}(\xi) < e_1'(\xi) < e_1''(\xi) < 1$ such that $\bar{\sigma}(e_1) > \bar{\sigma}(\underline{e}(\xi))$ if and only if $e_1'(\xi) < e_1 < e_1''(\xi)$, where $e_1'(\xi)$ and $e_1''(\xi)$ are given by:

$$\begin{cases} e_1'(\xi) = 1 - \dfrac{\alpha[4J + 3\xi - 1 + \sqrt{1 - 8J + \xi^2 - 6\xi}\,]}{4(2J + \xi)(J + \xi)} \\ e_1''(\xi) = 1 - \dfrac{\alpha[4J + 3\xi - 1 - \sqrt{1 - 8J + \xi^2 - 6\xi}\,]}{4(2J + \xi)(J + \xi)} \end{cases} \tag{A15}$$

3) Final price $p(e_1, x^*(e_1)) = p(e_1)$.

By using (A7)-(A9), (A11) and (3), we easily verify that the final price is given by:

$$p(e_1, x^*(e_1)) = p(e_1) = \begin{cases} \dfrac{\alpha}{2} & \text{if } e_1 \le \underline{e}(\xi) \\ \alpha - \dfrac{1}{2}(1 - e_1)(2J + \xi) & \text{if } \underline{e}(\xi) \le e_1 \le \bar{e}(\xi) \\ \alpha - \dfrac{1}{2\Psi(e_1)}(1 - e_1)\xi[2\Psi(e_1) - (1 - e_1)] - J\Psi(e_1) & \text{if } e_1 \ge \bar{e}(\xi) \end{cases} \tag{A16}$$

By using (A16), we verify that:

When $e_1 \le \underline{e}(\xi)$, then the price $p(e_1)$ is a *constant* function of the standard e_1.

When $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$, then the price $p(e_1)$ is an increasing function of the standard e_1.

When $e_1 \ge \bar{e}(\xi)$, then:

- If $\xi < 1$, the price $p(e_1)$ is an increasing function of e_1 (then $p(e_1) > p(\underline{e}(\xi)), \forall e_1 \in [\underline{e}(\xi), 1]$);
- If $1 < \xi < 3 + 2\sqrt{2}$, the price $p(e_1)$ has a local minimum on the interval $[\bar{e}(\xi), 1]$, which is given by:

$$\underline{e}_1(\xi) = 1 - \frac{\alpha}{\xi - 1} + \frac{\alpha\sqrt{2\xi}(J + 1)}{(\xi - 1)\sqrt{\xi(J + 2)(2J + \xi) - J}} \tag{A17}$$

and $p(e_1) > p(\underline{e}(\xi)), \forall e_1 \in [\underline{e}(\xi), 1]$;

- If $\xi > 3 + 2\sqrt{2}$, the price $p(e_1)$ has a local minimum on the interval $[\bar{e}(\xi), 1]$, which is given by (A17) and there exist two levels of standard $e_1^a(\xi)$ and $e_1^b(\xi)$, with $\bar{e}(\xi) < e_1^a(\xi) < e_1^b(\xi) < 1$ such that $p(e_1) < p(\underline{e}(\xi))$ if and only if $e_1^a(\xi) < e_1 < e_1^b(\xi)$, where $e_1^a(\xi)$ and $e_1^b(\xi)$ are given by:

$$\left|\begin{array}{l} e_1{}^a(\xi)=1-\dfrac{\alpha[J(1+\xi)+3\xi-1+(J+1)\sqrt{1+\xi^2-6\xi}\,]}{2[\xi(J+2)(2J+\xi)-J]} \\ e_1{}^b(\xi)=1-\dfrac{\alpha[J(1+\xi)+3\xi-1-(J+1)\sqrt{1+\xi^2-6\xi}\,]}{2[\xi(J+2)(2J+\xi)-J]} \end{array}\right. \tag{A18}$$

We also verify that $p(1) > p(\bar{e}(\xi)) > p(\underline{e}(\xi))$.

By using (A14), (A15), (A18) we verify that $\bar{e}(\xi) < \breve{e}_1(\xi) < e_1{}^a(\xi) < e_1{}'(\xi) < e_1{}''(\xi) < e_1{}^b(\xi) < 1$; given that $1 < U < 2 < 3+2\sqrt{2} < 3+2\sqrt{2}\sqrt{J+1}$, then the following cases arise:

Level of ξ	***Quantity/Surplus***	***Risk***	***Final price***
$\xi < 1$	Decreasing on $[\bar{e}(\xi),1]$ and $x^*(e_1) < x^*(\underline{e}(\xi))$ $S(e_1) < S(\underline{e}(\xi))$	Decreasing on $[\bar{e}(\xi),1]$ and $\bar{\sigma}(e_1) < \bar{\sigma}(\underline{e}(\xi)$	Increasing on $[\bar{e}(\xi),1]$ and $p(e_1) > p(\underline{e}(\xi)$
$1 < \xi < 2$	Increasing on $[\bar{e}(\xi),1]$ and $x^*(e_1) < x^*(\underline{e}(\xi))$ $S(e_1) < S(\underline{e}(\xi))$	Local max on $[\bar{e}(\xi),1]$ and $\bar{\sigma}(e_1) < \bar{\sigma}(\underline{e}(\xi)$	Local min on $[\bar{e}(\xi),1]$ and $p(e_1) > p(\underline{e}(\xi)$
$2 < \xi < 3+2\sqrt{2}$	Increasing on $[\bar{e}(\xi),1]$ and $x^*(e_1) > x^*(\underline{e}(\xi))$ if $e_1 > \breve{e}_1(\xi)$; $S(e_1) > S(\underline{e}(\xi))$ if $e_1 > \breve{e}_1(\xi)$		
$3+2\sqrt{2} < \xi < 3+2\sqrt{2}\sqrt{J+1}$			Local min on $[\bar{e}(\xi),1]$ and $p(e_1) < p(\underline{e}(\xi))$ if $e_1{}^a(\xi) < e_1 < e_1{}^b(\xi)$
$\xi > 3+2\sqrt{2}\sqrt{J+1}$		Local max on $[\bar{e}(\xi),1]$ and $\bar{\sigma}(e_1) > \bar{\sigma}(\underline{e}(\xi))$ if $e_1{}'(\xi) < e_1 < e_1{}''(\xi)$	

Firm's normalization strategy.

Using (A4), (A7), (A8) we determine the firm's expected profit $\pi(e_1)$ as a function of e_1.

$$\pi(e_1)=\begin{cases} \dfrac{\alpha^2 J}{2(2J+\xi)} & \text{if } e_1 \le \underline{e}(\xi) \\ -\dfrac{J}{2}(2J+\xi)(1-e_1)^2+\alpha J(1-e_1) & \text{if } \underline{e}(\xi) \le e_1 \le \bar{e}(\xi) \\ \dfrac{J[\alpha+(1-e_1)(1-\xi)]^2}{4(J+1)}+\dfrac{J}{2}(1-e_1)^2\xi & \text{if } e_1 \ge \bar{e}(\xi) \end{cases} \tag{A19}$$

Proof of Proposition 3

By using (A14), we verify the following.

When $e_1 \le \underline{e}(\xi)$ the profit $\pi(e_1)$ is a constant function of e_1.

When $\underline{e}(\xi) \le e_1 \le \bar{e}(\xi)$ the profit $\pi(e_1)$ is a decreasing function of e_1.

When $e_1 \geq \bar{e}(\xi)$ then on the interval $[\bar{e}(\xi),1]$:

(i) If $\xi > 1$, the profit $\pi(e_1)$ has a local minimum given by:

$$e_1'(\xi) = 1 - \frac{\alpha(\xi - 1)}{(\xi - 1)^2 + 2\xi(J+1)} \tag{A20}$$

(ii) If $\xi < 1$, the profit $\pi(e_1)$ is a decreasing function of e_1.

By using (A9) and (A14) we obtain $\pi(1) = \dfrac{\alpha^2 J}{4(J+1)}$ and we verify the following cases:

- If $\xi \leq 1$ then $\forall e_0 \in [0,1]$, $\pi(1) \leq \pi(e_0)$.
- If $1 \leq \xi \leq 2$ then:
  - If $1 \leq \xi \leq U : \pi(1) \geq \pi(e_0)$ if and only if $e_0 \geq \hat{e}_0(\xi)$, with $\hat{e}_0(\xi)$ given by:

$$\hat{e}_0(\xi) = 1 - \frac{2\alpha(\xi - 1)}{(\xi - 1)^2 + 2\xi(J+1)} \tag{A21}$$

Using (A9) and (A21), we verify that $\hat{e}_0(\xi)$ is a decreasing function of ξ, with $\hat{e}_0(1) = 1$, $\hat{e}_0(U) = \bar{e}(U)$ and $\bar{e}(\xi) \leq \hat{e}_0(\xi) \leq 1 \Leftrightarrow 1 \leq \xi \leq U$, where $U = \sqrt{(J+1)(J+3)} - J$, $1 < U < 2$.

  - If $U \leq \xi \leq 2 : \pi(1) \geq \pi(e_0)$ if and only if $e_0 \geq \hat{e}_0(\xi)$, with $\hat{e}_0(\xi)$ given by:

$$\hat{e}_0(\xi) = 1 - \alpha\left[\frac{2(J+1) - \sqrt{2(J+1)(2-\xi)}}{2(J+1)(2J+\xi)}\right] \tag{A22}$$

Using (A9) and (A22), we verify that $\hat{e}_0(\xi)$ is a decreasing function of ξ, with $\hat{e}_0(U) = \bar{e}(U)$, $\hat{e}_0(2) = \underline{e}(2)$ and $\underline{e}(\xi) \leq \hat{e}_0(\xi) \leq \bar{e}(\xi) \Leftrightarrow U \leq \xi \leq 2$.

- If $\xi \geq 2$ then $\forall e_0 \in [0,1]$, $\pi(1) \geq \pi(e_0)$.

We thus identify the following strategies, according to the level of risk perception and the level of public standard:

Level of ξ	Level of public standard	Firm's normalization strategy (stage I), $e_1^*(e_0) \geq e_0$	Firm's quantity strategy (stage II)
$0 \leq \xi \leq 1$	$e_0 \leq \underline{e}(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} > e_0\ (x < \hat{x})$
	$\underline{e}(\xi) \leq e_0 \leq \bar{e}(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} = e_0\ (x = \hat{x})$
	$e_0 \geq \bar{e}(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} < e_0\ (x > \hat{x})$
$1 \leq \xi \leq U$	$e_0 \leq \underline{e}(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} > e_0\ (x < \hat{x})$
	$\underline{e}(\xi) \leq e_0 \leq \bar{e}(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} = e_0\ (x = \hat{x})$
	$\bar{e}(\xi) \leq e_0 \leq \hat{e}_0(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} < e_0\ (x > \hat{x})$
	$\hat{e}_0(\xi) \leq e_0 \leq 1$	$e_1^*(e_0) = 1 > e_0$	$\tilde{e} < e_0\ (x > \hat{x})$
$U \leq \xi \leq 2$	$e_0 \leq \underline{e}(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} > e_0\ (x < \hat{x})$
	$\underline{e}(\xi) \leq e_0 \leq \hat{e}_0(\xi)$	$e_1^*(e_0) = e_0$	$\tilde{e} = e_0\ (x = \hat{x})$

	$\hat{e}_0(\xi) \le e_0 \le 1$	$e_1^*(e_0) = 1 > e_0$	$\tilde{e} < e_0\ (x > \hat{x})$
$\xi \ge 2$	$e_0 \in [0,1]$	$e_1^*(e_0) = 1 > e_0$	$\tilde{e} < e_0\ (x > \hat{x})$

Proof of Proposition 4

Using (A7) and (A8) and following Proposition 4, we verify that:

- If $\xi \ge 2$, $x^*(1) > x^*(e_0)$, $\forall e_0 \in [0,1]$.
- If $1 \le \xi \le 2$, $x^*(\bar{e}(\xi)) \le x^*(1) \le x^*(\underline{e}(\xi))$, $x^*(1) \ge x^*(e_0) \Leftrightarrow e_0 \ge 1 - \frac{\alpha}{2(J+1)} = \hat{e}_0(2) = \underline{e}(2)$, namely:
  - If $1 \le \xi \le U$: as the firm chooses $e_1^* = 1 \Leftrightarrow e_0 \ge \hat{e}_0(\xi)$, with $\bar{e}(\xi) \le \hat{e}_0(\xi) \le 1$ and $x^*(e_1)$ is increasing in e_1 on the interval $[\bar{e}(\xi),1]$; then we have $x^*(1) > x^*(\hat{e}_0(\xi))$.
  - If $U \le \xi \le 2$: as the firm chooses $e_1^* = 1 \Leftrightarrow e_0 \ge \hat{e}_0(\xi)$, with $\hat{e}_0(\xi) > \hat{e}_0(2)$, $\forall$ $1 \le \xi \le 2$ and $x^*(e_1)$ is increasing in e_1 on the interval $[\bar{e}(\xi),1]$; then we have $x^*(1) > x^*(\hat{e}_0(\xi))$.

By using (10) and (A10), we easily verify that:

- If $\xi \ge 2$, $S(1) > S(e_0)$ and $\tilde{e}(1) < \tilde{e}(e_0)$ $\forall e_0 \in [0,1]$.
- If $1 \le \xi \le 2$, then:
  - If $1 \le \xi \le U$: $S(1) > S(\hat{e}_0(\xi))$ and $\tilde{e}(1) < \tilde{e}(\hat{e}_0(\xi))$.
  - If $U \le \xi \le 2$: $S(1) > S(\hat{e}_0(\xi))$ and $\tilde{e}(1) < \tilde{e}(\hat{e}_0(\xi))$.