Better to Certify or to Advertise? The Role of Technological and Capacity Constraints

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Abstract

This paper explore the impacts of Protected Designation of Origin (PDO) certification on the costs and profits of firms, as well as consumers' and total welfare. Using a theoretical model of endogenous quality choice, we first explore the way producers can signal their quality either by certifying their product and opting for a PDO label or by investing in R&D and advertising to develop privately a common brand. Taking into account the technical requirements linked to PDO production, the certification cost as well as the possible capacity constraint producers could face given the geographical constraint of this label; we are able to characterize the various tradeoffs under which firms can opt for PDO or private certification. We then illustrate the theoretical findings by estimating the determinants of PDO label choice in the French Brie cheese industry, using a switching regression model to analyze producers' behavior. Results show that smaller firms are more likely to adopt a PDO certification; and that a one percent increase in the cost differential between the non-PDO and the PDO technology leads to a 0.3 percent increase in the probability of adopting PDO certification.

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JEL : D2, L13, L15, Q13

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1 Introduction

The European Commission (EC) has introduced in the last decades quality labels for mainly two reasons. First, the EC wanted to encourage the diversification of agricultural production and improve farmers'revenue and agricultural activity particularly in less favoured areas. The issue of farm revenues and activity became even more pressing with the reduction in price support that has been commited under the WTO. In this context, producers should particularly increase the level of quality of their products and promote it to counter the reduction in price support. Second, consumers increasingly value the quality and the geographical

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characteristics of agrofood proucts as stressed by the overview of Marette (2005).[1] In this perspective, the EC has defined three labels to guarantee proucts' quality and enhance its credibility for consumers: Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG). In this paper, we focus on PDO labels. Numerous agricultural and food products benefit from PDO regulation in the EU (wines, meat, olive oils, fruits and vegetables, etc.). Dairy products and particularly cheese are concerned. Thirteen European countries have adopted this regulation for cheese (see Babcock, 2003, for an overview).
This regulation certifies (i) that a given product originates in a defined region, place or country (that gives the name of the designation of origin), (ii) that "its quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent naturel and human factors, and (iii) that the production, processing and preparation of which take place in the defined geographical area."(Council Regulation (EEC) N°2081/92, article2, para.2). The PDO quality attributes thus concern not only raw materials and production but also the processing technology that has to be specific to the region. The PDO regulation induces technology constraints linked to a specific processing requirement and production area that have to be taken into account when dealing with PDO production issues. First, because of the geographical area definition, some producers are excluded and this tends to limit the production of this type of products. Moreover, the certification implies technological requirements that are most of the time not fulfilled above a production threshold (cf. Arnaud, Girand-Héraud and Mathurin). Second, when studying the impact of PDO labeling, it becomes therefore important to consider the underlying production technology. The cost of quality is modeled in the litterature as acting either on fixed cost or on the variable cost of production. When quality affects fixed cost, prices are not affected, the only effect is through the quality differentiation. If quality costs enter variable cost, increasing quality implies higher prices (cf. Crampes and Hollander, 1995). In both cases, duopoly firms always choose to offer distinct qualities at equilibrium (Motta, 1993 and Ronnen, 1991). The limitation of geographical area in this framework has not yet been investigated in our knowledge. This is however important in the case of PDO regulation because the restriction of the producing area could generate capacity constraint. This paper tries to capture the technological cost linked to PDO certification and the capacity constraints that firms may face.

Groups of producers may have several alternatives to signal the quality of their products. First they can certify their product using the EU regulation on PDO. The PDO regulation may be efficient to signal quality when some characteristics of a commodity can not be observable by consumers even before or after its purchase (cf. Shapiro, 1983 and Auriol and Schilizzi, 1999). The efficiency of public certification has been widely analyzed in the literature. Marette, Crespi and Schiavina (1999) have shown that cartels of high quality producers are welfare improving when the cost of PDO labeling is high and conversely, the society is worse-off when the cost of labeling is low. Zago and Pick (2002) have shown that a public regulation may be welfare detrimental in competitive markets when the quality difference is low and certification costs are high, because both consumers and the high quality producers benefit from the regulation but producers of the low quality good are worse-off. When the high quality producers have some market power, consumers are worse-off but

[1] Even though, some empirical studies on Protected Designation of Origin (PDO) show that the PDO label is less valued than the brand of the product (cf. Bonnet and Simioni, 2001 and Hassan and Monier-Dilhan 2002 for the case of the French camembert cheese)

the regulation favors producers. Auriol and Schilizzi (1999) pointed out the importance of certification cost for market structure and determined the conditions for which a public certification is better than a private quality provision. A high certification cost leads to a highly concentrated market for certification and if it is too high, the market for quality collapses. Yet none of these studies analyzes the particular case of the PDO regulation. An alternative way for producers could be to opt for a private common brand or to invest in R&D to enhance the quality of their product. If a group of producers opts for PDO certification, then it will incur extra variable cost because the production of the PDO quality will require more effort in terms of inputs and labor force mainly. It will also have to pay a cost for the certification of its product. On the other hand, if it opts for the second solution, it will have to invest in R&D or in a advertising campain. In this paper, we analyse the trade-off between these two options.

To better assess the technological differences between PDO and non PDO production, we first propose an analytical framework to analyse the trade-off faced by producers when choosing the way they signal the quality of their products. In this setting, producers have the choice to privately signal the level of quality through advertising/R&D, or to apply for a PDO certification. We show how the technology inherent to the PDO certification and the production capacity constraint they may incur affects the choice of signaling; and analyze the implications for producers, consumers as well as total welfare. We then use the theoretical results to empirically analyze the production of PDO Brie cheese in France, using a data set containing individual firm cost and production information. Using a switching regression model we are able to characterize the determinants of Brie producers' choice between PDO and non PDO Brie.

2 Theoretical analysis of the trade off between PDO certification and collective brand

We propose in this section an analytical framework to analyse the tradeoff faced by a group of producers between signaling their products through a PDO certification or through a common brand based on advertising or R&D. If it chooses to certify it will incur a variable cost for quality as well as a certification cost (as in Marette et Al, 1999). On the contrary, if it decides to develop a common brand, it will incur a fixed cost for quality. In this framework, the group of producers first choose not to signal their quality, or to signal their quality through PDO certification or through R&D/advertising. Then, if it chooses to signal its product, it sets the level of its quality and the quantity it will produce.

2.1 Public Certification

Following the empirical facts reported below, in the case of the French Brie cheese industry for instance, production of non PDO goods grew by 150 per cent during the last 20 years, while the production of high quality (PDO) goods did not exceed 10 million tons/year. We thus support the idea that PDO certification can also introduce capacity constraints. This would be the case if for instance firms are land constrained or technologically constrained by a given production process, which is supported by our cost estimations in the previous section. Certainly the reader can argue that producers of the high quality good are artificially constraining the market by setting a small quantity. However, we argue that the limitation in production could not only be the outcome of rent seeking producers that use the label to access high valuation consumers but that it could also be the consequence of actual restriction in production arising from a too costly or even impossible increase in production. We will analyse both cases, pointed out what the effect of a production capacity constraint will be. We assume that PDO producers face a higher variable cost and that this extra variable cost comes from the "PDO quality" and is due to the fact that PDO production enhances more hand producing techniques, more requirement on the inputs used and other specific technics.

We model the cost for producing the quality of the PDO good as variable cost, such that the cost function for the PDO good is given by $C(x_h, q_h) = c(s_h)q_h$ where s_h and q_h respectively denote the quality for the PDO good and the quantity produced. We assume a positive and increasing marginal cost, $c'(s_h) > 0$ and $c''(s_h) > 0$ for producing the PDO quality s_h. We can motivate this assumption by arguing that the production of the PDO quality requires manual techniques and specific ingredient requirements, as it is the case at least in the production of PDO Brie, that induce technological constraints and tend to increase marginal costs. This argument is similar in spirit to the one employed in Lehmann-Grube (1997) and the literature cited there, where producing a higher quality good implies higher costs. Given this, we assume as in Marette et al.(1999) that PDO certification costs to producers a fixed fee C.

We assume that the group of PDO producers behaves collectively as a single entity. In that sense, we consider that they collude inside a coalition to maximize profits and acts like a monopoly (similar to the approach followed by Marette et al., 1999 and Auriol and Schilizzi, 1999). We refer to this group as a cartel. Moreover, there is as set of competitive firms, co-existing with this cartel in the market, that only produce the low quality good. The cartel decides or not to go through the certification process. Then, it has the choice of producing a low quality (s_l) good or to certify its product knowing that it will incur both a variable cost to produce the PDO quality and a certification cost for the PDO certification. Without loss of generality, we assume that the competitive firms produce the low quality good at no cost. They are thus facing a price $p_l = 0$.

The consumer chooses between buying the standard quality good and the differentiatd PDO good. The preferences of consumers are represented by a Mussa-Rosen (1978) utility function. The utility of a consumer of type θ when he buys a unit of quality s at price p is given by $U(\theta, s) = \theta s - p$, where θ is the willingness to pay for quality and is distributed uniformly on the interval $[0, 1]$ as in Bagwell and Riordan (1991) so that the number of consumers is normalized to one and demand functions are linear in price and quality. Note that because the marginal cost for the low quality good is equal to zero, the market is fully covered and straightforward computations show that demand when only the low variety is produced by all players is equal to 1. When both varieties are produced, the inverse demands for the low quality good and for the PDO good, respectively denoted by $D_l(p_l, p_h)$ and $D_h(p_l, p_h)$, are determined as follows:

$$\begin{aligned} D_l(p_l, p_h) &= \frac{p_h - p_l}{s_h - s_l} - \frac{p_l}{s_l} = \frac{p_h}{s_h - s_l} \qquad (1a) \\ D_h(p_l, p_h) &= 1 - \frac{p_h - p_l}{s_h - s_l} = 1 - \frac{p_h}{s_h - s_l}. \end{aligned}$$

The cartel has to choose the level of the quality of the product knowing that it will face technological constraints that will be increasing with the level of the quality and knowing that he will face capacity constraints. Then we consider the case where it chooses the quantity produced and we analyse the equilibrium outcome with and without capacity constraint.

2.1.1 Benchmark case: quantity choice

We first present the benchmark case where the cartel is not restricted by a capacity constraint. We consider the following game. In the first period, the cartel decides whether to certify or not. If it decides not to certify then it produces the low quality good and continues to behave as perfectly competitive and produces the low quality good at a profit equal to zero. Note that by assumption, the producers of the low quality good behave competitively, and then the equilibrium price in the low quality sub-market is $p_l = 0$ as the marginal cost for the low quality is equal to zero. Therefore, if the cartel produces this low quality, its profit becomes equal to zero.
We assume that the level of the low quality is given. We can derive the inverse demand function of the certified good relative to this level and the level of the chosen quality for the certified product denoted respectively by $P_h(x_h, s_l, s_h)$ with:

$$P_h(x_h, s_l, s_h) = (s_h - s_l)(1 - x_h). \tag{2}$$

Then, its profit function if it produces the certified good is given by:

$$\begin{aligned} \pi_h(x_h, s_l, s_h, C) &= (P_h(x_h, s_l, s_h) - c(s_h))x_h - C \\ &= x_h(c(s_h) + (s_h - s_l)(1 - x_h)) - C \end{aligned} \tag{3}$$

with $\frac{\partial^2 \pi(.)}{\partial x_h^2} = -2(s_h - s_l) < 0$ as the certified quality is higher than the low quality by assumption.

Again, because the marginal cost for the low quality is equal to zero and because low quality producers behave as perfect competitive firms, the price for the low quality is equal to zero. We can thus derive the demand adressed to low quality firms as:

$$X_l(x_h) = 1 - x_h.$$

If the cartel chooses to certify, it chooses the quality level and given the quality level of the low quality good and of the certified good, it chooses the quantity he will produce. Then, the firms producing the low quality good produce the residual demanded quantity determined by the price charged by the cartel. The optimal production of the certified good is derived by maximising the cartel's profit with respect to x_h for a given level of quality s_h. Thus, we get the following last stage quantities:

$$\begin{aligned} x_h(s_l, s_h) &= \frac{1}{2}(1 - \frac{as_h^2}{s_h - s_l}) \\ x_l(s_l, s_h) &= \frac{1}{2}(1 + \frac{as_h^2}{s_h - s_l}). \end{aligned} \tag{4}$$

Note that when there is no cost for quality ($a = 0$), the market is halved between the low and the high quality good. However then there is a positive variable cost for quality ($a > 0$), the share of the certified good tends to decrease while the one of the low quality increases. The higher the quality, the larger this negative impact on PDO production. On the other hand, the higher the quality, the larger the differentiation is, which tends to reduce the effect on PDO production. The subgame equilibrium price for the certified good is given by:

$$p_h(s_l, s_h) = \frac{1}{2}(s_h - s_l + as_h^2).$$

This price is an increasing function of the certified good quality and a decreasing function of the low quality good. It reflects the fact that the price increases when the product is more vertically differentiated but also because a higher quality generates a higher variable cost which tends to increase the price. We now derive the unique optimal quality s_h^* when the cartel decides to certify its product by replacing the subgame quantity (4) into the profit function (6) and maximizing (3) with respect to s_h (cf. appendix 1).

$$s_h^* = \frac{1}{6a}(1 + 4as_l + \sqrt{1 - 4as_l + (4as_l)^2} \tag{5}$$

where $s_l < \frac{1}{4a}$. The certified quality exists only if the low quality is not to high relative to the cost of producing the certified good. Otherwise, the demand for the certified good is no more positive and the cartel will better not certify, wathever the cost for certification. This highlights the role of the certification technical constraints not only on the level of the chosen quality but also on the certification choice. The technical constraints could be too important compared to the willingness to pay for the consumers. We can show that the optimal certified quality is an increasing function of the low quality level ($\frac{\partial s_h}{\partial s_l} = \frac{1}{2+8as_l(4as_l-1)+(1-8as_l)\sqrt{1-4as_l+(4as_l)^2}} > 0$) and a decreasing function of the variable cost parameter ($\frac{\partial s_h}{\partial a} = \frac{2as_l-1-\sqrt{1-4as_l+(4as_l)^2}}{6a^2\sqrt{1-4as_l+(4as_l)^2}} < 0$).

From (5), we can derive the optimal demand for the certified good and for the low quality good:

$$\begin{aligned} x_h^*(s_l) &= \frac{1}{3}(2 - 4as_l - \sqrt{1 - 4as_l + (4as_l)^2} \\ x_l^*(s_l) &= \frac{1}{3}(2 + 4as_l + \sqrt{1 - 4as_l + (4as_l)^2}. \end{aligned} \tag{6}$$

where $s_l < \frac{1}{4a}$. The optimal price of the certified good is:

$$p_h^*(s_l) = \frac{1}{9a}[1 - as_l + 4a^2s_l^2 + (1 + 4as_l)\sqrt{1 - 4as_l + (4as_l)^2}]$$

Using (5) and (6), we get the maximum profit under certification as a function of the low quality level, the variable cost of quality and the certification fixed cost:

$$\pi_h^*(s_l, a, C) = \frac{1}{54a} - \frac{s_l}{27}(3 + 12as_l - 32a^2s_l^2) + \frac{1}{54a}[1 - 4as_l + (4as_l)^2]^{\frac{3}{2}} - C.$$

Lemma 1 *The cartel chooses to certify its product if:*

a) the low quality level is not too high compared to the variable cost of producing the high quality ($s_l < \frac{1}{4a}$)

b) and the certification cost is such that: $C \leq f(s_l, a) = \frac{1}{54a} - \frac{s_l}{27}(3 + 12as_l - 32a^2s_l^2) + \frac{1}{54a}[1 - 4as_l + (4as_l)^2]^{\frac{3}{2}}$.

Otherwise, the cartel do not certify and continue to produce the low quality good.

If the low quality level is equal to zero, then $\pi_h^*(s_l, a, C) = \frac{1}{27a} - C$.

We could also have consider the equilibrium outcome when the cartel chooses the price of the certified good rather than the quantity. In the first period, the cartel decide whether to certify or not. When it chooses to certify, it then chooses the quality and the price of the certified good. In this setting, we could also have supposed that the cartel restrict itself his quantity in order to increase the level of prices. However, in our framework, the cartel chooses the optimal level of price which leads to the optimal quantities he would have with a quota. Then, if the cartel is composed of a group of producers, the question is not to know the impact of implementing a quota for the cartel but rather how to reach this level of total quantity for the cartel. One option could be to give equal shares of the total production that can take the form of individual quotas as in Marette et al. (1995).

2.1.2 Production capacity constraint

We now analyse the impact of the capacity constraint the certification process may require. If the capacity constraint (Q) is not binding then we get the benchmark results presented above. In this section, we assume that the capacity constraint is restrictive and that the production of the cartel is thus limited to the level $Q \leq x_h^*(s_l)$, leading to a residual demand $(1-Q)$ for the low quality good producers. In this case, the cartel will choose the certified quality s_h^c such that it maximises its profit $\pi_h^c(s_l, s_h^c, C) = Qs_h^c(1-Q-as_h^c) + (Q-1)Qs_l - C$ when producing Q. The optimal quality becomes:

$$s_h^{c*} = \frac{1-Q}{2a}. \tag{7}$$

The more restrictive the capacity constraint is, the higher the optimal certified quality. As in the benchmark case, this optimal quality also depends on the marginal variable cost of quality, which tends on the other hand to limit the quality chosen. However, it does no more depend on the low quality level. As the production is limited, wathever the quality chosen by the cartel, the quantity produced by the low quality firms is unchanged, there is thus no strategic choice of quality with respect to the competitive firms' quality.

As shown in figure (1), the impact of the capacity constraint on the optimal quality level depends on the level of the low quality.[2] For a given binding capacity constraint Q and a range of relative low values of s_l, the introduction of the capacity constraint leads to a higher certified quality. However the difference between the certified quality with and without production restriction shrinks whith higher values of the low quality and for relatively higher values of s_l, the capacity constraint has a negative impact on the quality chosen with certification. Actually, When s_l increases, this tends to decrase the market share of the certified product. Then the cartel increases its quality to vertically differentiate its product and recover some market share. However if production is limited, the incentive of the cartel to increase its quality is reduced because it can not increase its production to increase its market share. When Q increases (case $Q' > Q$), the total cost for quality increases, which tends to decrease the level of the quality chosen. For a given level of s_l, this reduces the difference between the constrained certified quality and the non constrained one and the range of s_l such that the constraint generates an increase in the certified quality is reduced.

[2] We assume in figure 1 a the marginal cost of quality $a = \frac{1}{2}$. Then for the existence of an equilibrium with coexistence of both the certified and the low quality good on the market, the low quality has such that $s_l \leq \frac{1}{2}$.

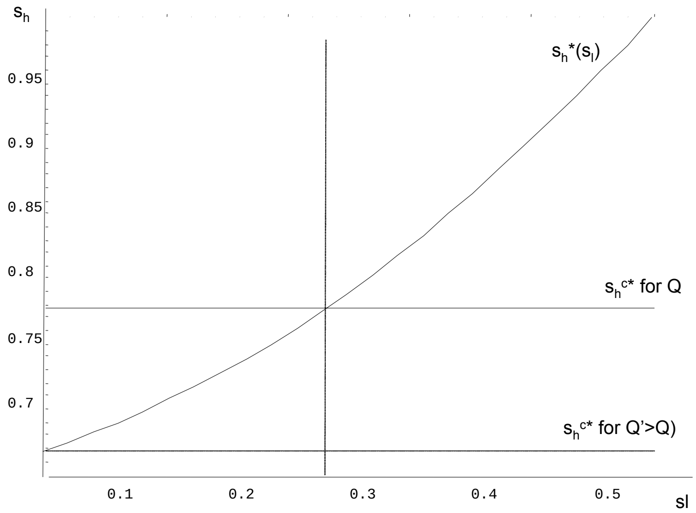

Figure 1: Optimal quality under certification with and without capacity constraint

>From (7), we get the optimal price $p_h^{c*}(s_l)$ with capacity constraint as well as the corresponding maximim profit $\pi_h^{c*}(s_l, C)$:

$$\begin{aligned} p_h^{c*}(s_l) &= (1-Q)(\frac{1-Q}{2a} - s_l) \\ \pi_h^{c*}(s_l, C) &= \frac{1}{4a}Q(1-Q)(1-Q-4as_l) - C. \end{aligned}$$

with $\frac{\partial p_h^{c*}(s_l)}{\partial s_l} = Q - 1 < 0$ and $\frac{\partial p_h^{c*}(s_l)}{\partial Q} = s_l + \frac{Q-1}{a} < 0$ under restrictive capacity constraint. When s_l increases, the differentiation between the two products is decreased, which decreases the price of the certified good (cf. equation 2). On the other hand, as shown in figure (2), when the constraint becomes more restrictive, the production is reduced wich tend to increase the price. However, the increase in the price is not sufficient to compensate for the decrease in quantity and thus the profit decreases. Then, prices are higher when the certification process requires a production constraint and generates lower profits for producers. Then, certification becomes less profitable for producers that will choose not to certify for lower level of certification cost.

2.1.3 Welfare Implications

We now focus on the welfare impacts of the PDO regulation. We first determine the consumers' surplus when only the low variety is produced:

$$CS_l = \int_{\theta_0}^{1} (\theta s_l - p_l)\, d\theta$$

where $\theta_0 : \{\theta |\, \theta s_l - p_l\}$ by definition.

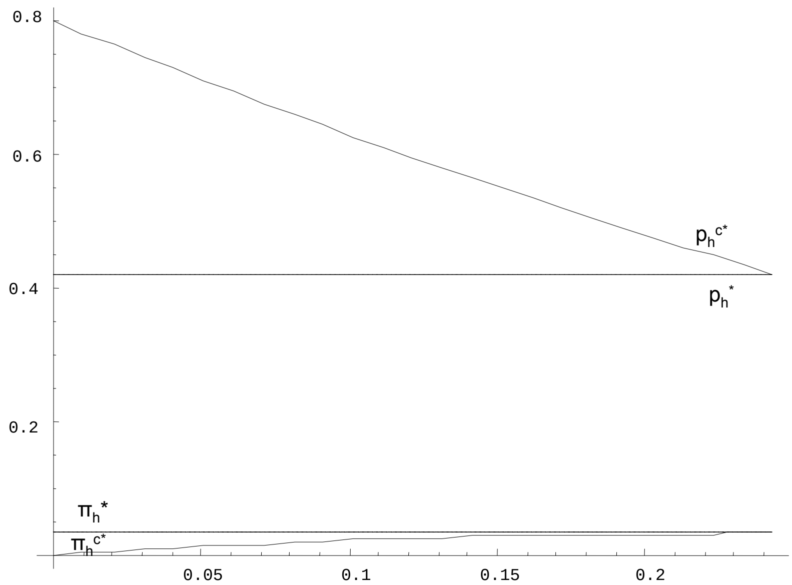

Figure 2: Opimal price and variable profit with and without capacity constraint

When certification is implemented the consumers'surplus becomes:

$$\begin{aligned} CS_h^C &= \int_{\widetilde{\theta}^c}^{1} \left(\theta s_h^* - p_h^{C*}\right) d\theta \\ CS_l^C &= \int_{\theta_0}^{\widetilde{\theta}^c} \left(\theta s_l - p_l\right) d\theta \end{aligned}$$

where $\widetilde{\theta}^c : \{\theta | \, \theta s_l - p_l = \theta s_h^* - p_h^{C*}\}$.

We can show that both consumers and producers gain when the cartel certifies his product but when the capacity of production are taken into account this decreases both producer and consumer surplus because the price of the certified product increases but this increase in price does not compensate the decrease in quantity for the cartel. Thus, when deciding of the producing area, public authorities have to keep in mind that if it generates restrictive capacity constraint, this will tend to increase the quality of the PDO product on the one hand but it will generate losses in welfare compared tot the case where the production is not restricted by the production area. It thus has a trade-off between increasing the quality and decreasing welfare.

2.2 Fixed cost of quality

2.2.1 Sub-game Nash equilibrium

Assume now that instead of opting for a certified quality, the cartel choose to opt for investing in R&D and/or to advertise its good such that he can produce a product of higher quality by incuring a fixed cost of quality rather than a variable cost. In this case, it is not restricted in quantity and does not pay for a certification cost. However, it now faces a fixed cost that will depend on the level of the chosen quality. We thus consider the following game. In the first stage, the cartel choose to invest or not in a higher quality of its product. Then, it chooses the quality and the quantity produced for this level of quality.

With a fixed cost of quality $F(s_h) = bs_h^2$, its profit function if it produces the certified good is given by:

$$\begin{aligned} \pi_h^I(x_h, s_l, s_h, C) &= P_h(x_h, s_l, s_h)x_h - F(s_h) \\ &= (s_h - s_l)x_h(1 - x_h) - bs_h^2. \end{aligned} \tag{8}$$

We can check that $\frac{\partial^2 \pi(.)}{\partial x_h^2} < 0$. Now the subgame perfect equilibrium quantities do no more depend on the quality levels. The cartel get half of the market share ($x_h^{I*} = \frac{1}{2}$) leaving half of the market for the low quality ($x_l^{I*} = \frac{1}{2}$). Then the cartel produces more when investing in fixed cost than when certifying as now it does no more incur the variable cost of quality underlying the certification good technology. On the other hand, the production of the low quality good is lower than the production in the certification case. We can also derive the subgame equilibrium price for the advertised good:

$$p_h^I(s_l, s_h) = \frac{1}{2}(s_h - s_l). \tag{9}$$

For given level of quality s_h, this price is lower than under certification as now the marginal cost of producing the high quality good is lower (equal to zero in our setting). It only depends on the vertical differentiation between the high and the low quality good.

Replacing x_h^{I*}, x_l^{I*} and $p_h^I(s_l, s_h)$ in (8) and maximising (8), we get the unique equilibrium for the level of the high quality when the cartel chooses to invest in R&D or/and advertising:

$$s_h^{I*} = \frac{1}{8b} \tag{10}$$

which is a decreasing function of the fixed cost of quality parameter. Again here, the optimal quality does not depend on the quality of the low quality good. From (9) and (10), we derive the corresponding price for the high quality good:

$$p_h^{I*}(s_l) = \frac{1}{16b} - \frac{1}{2}s_l, \tag{11}$$

which will be a decreasing function of b because when b increases, the level of the quality of the R&D/ advertised good that is chosen decreases, which decreases the wedge between the high and the low quality. Similarly, the optimal price of the advertised good is a decreasing function of the low quality level as the vertical differentiation wedge decreases with s_l.

We can now solve the first stage of the game and derive the condition under wich the cartel will decide to producer a higher quality good. Replacing s_h by its optimal value given in (10), we can write the maximum profit of the cartel when it chooses to produce a higher quality by investing in fixed cost: $\pi_h^{I*}(s_l, b) = \frac{1}{64b} - \frac{1}{4}s_l$, which is a decreasing function of both b and s_l as the price is a decreasing function of b and s_l, the fixed cost is an increasing function of b and the quantity produced does not depend on parameters b and s_l. This could be summarised in the following lemma.

Lemma 2 *The cartel chooses to invest in R&D and/or advertising to differentiate its product from the low quality good if the fixed cost parameter for quality is not too high compared to the low quality level, that is if* $b \leq \frac{1}{16s_l}$*. Otherwise, the cartel does not invest in quality and continue to produce the low quality good.*

When $b \leq \frac{1}{16s_l}$, the fixed cost at the equilibrium is such that $F(s_h^{I*}) = \frac{1}{64b} \leq \frac{1}{1024}\frac{s_l}{b}$, which clearly shows the trade-off between the low quality level and the marginal cost for quality. Contrary to the certification case, wathever the level of quality, the cartel if it invests in quality always faces a positive demand and produces the level of quantity $x_h^{I*} = \frac{1}{2}$. It is thus not limited in his choice of quality as far as the quantity is concerned. However the price it will get for it depends on the level of quality. There is thus a tradeoff between the fixed cost for quality and the level of differentiation. As long as the fixed cost is not to high, it can charge a higher price for quality to make profits but if this cost becomes to high then it has no more incentive to produce the high quality.

2.2.2 Welfare Implications

Assume that $b \leq \frac{1}{16s_l}$ and then that the cartel decides to invest in quality trough fixed cost. We can derive the surplus of consumers who buy the low quality good, $CS_l^I = \frac{1}{8}s_l$ and the surplus of consumers who buy the high quality good, $CS_h^I = \frac{1}{64b} + \frac{1}{4}s_l$. As the price for the low quality is normalised at 0 and the quantity demanded does not change whatever the cost of quality (because it does not infer on the the quantity produced by the cartel), the surplus for the low quality consumers does only depend on the level of the low quality s_l and is increasing with s_l. However, the surplus of the consumers of the high quality depends both on the low quality and on the marginal fixed cost for quality through the price the cartel charges to them. Their surplus decreases with the cost for quality because it tends to increase the price and increases with the level of the low quality because it tends to decrease the price while consumption remains unchanged. Compared to the case where the cartel does not produce the high quality, consumers globally gain but the surplus for low quality consumers is reduced while it is overcompensated by the gain for high quality consumers.

The total firms'profit corresponds to the cartel's profit as the low quality firms do not make profits. Then, total firms' profits increase. This profit is a decreasing function of both b and s_l. Then, both high quality consumers and firms are harmed by a high cost of quality but consumer and producer benefits diverge with respect to the level of the low quality. Then, the total welfare, $W^I = \frac{1}{32b} + \frac{1}{8}s_l$, is a decreasing function of b but an increasing function of s_l, which means that the increase in the total gain of consumers from a higher level of the low quality more than compensates for the larger loss incured by producers.

2.3 Better to certify or to advertise?

2.3.1 No capacity constraint

Choice of quality We compare in this section the quality chosen by the cartel when he decides to certify its product or when he prefers to invest in fixed cost. As shown in figure (3), the certified quality may be higher or lower given the relative marginal cost of certification relative to the marginal cost of quality engaged in fixed cost. When a is very small and close to zero, there is no or only small cost to produce the high quality and then the optimal quality is higher than under investment in fixed cost whatever the value of b. When a increases,

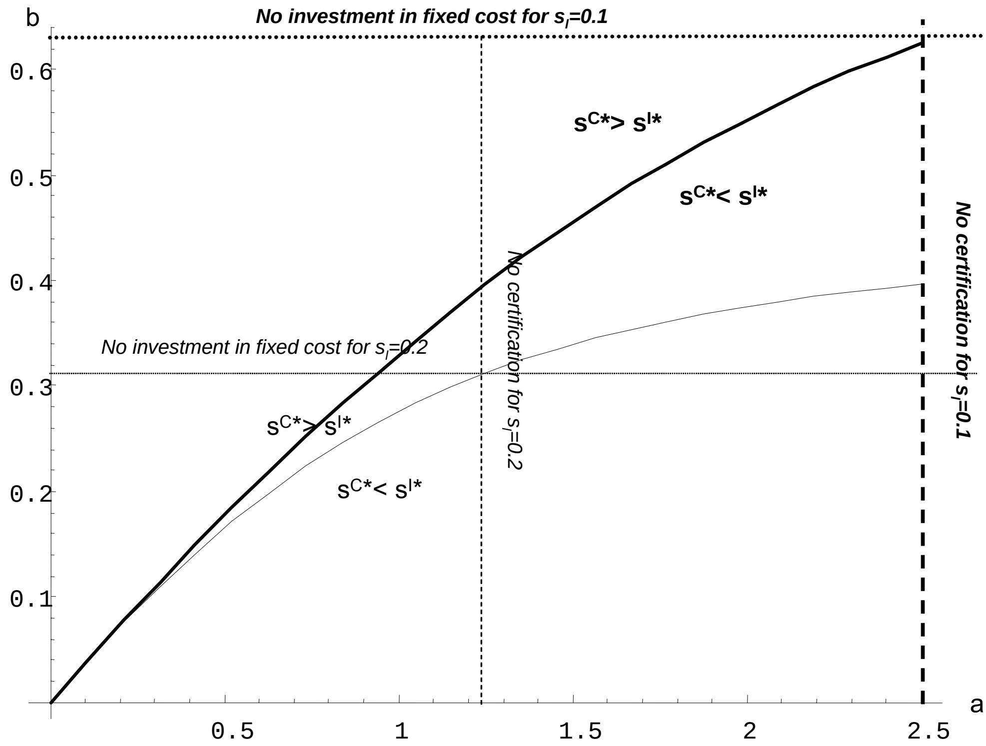

Figure 3: Comparison of optimal qualities: certification vs. investment in fixed cost

the marginal cost of furnishing a given level of certified quality increases, which reduces the optimal quality of the certified good. Then, for relatively high value of a relative to b, the certified quality becomes lower than when the cartel invests in fixed cost as the level of the high quality in this case does not depend on the cost of quality engaged in fixed cost. Now, if we consider a higher level of the low quality, this does not influence the level of quality decided by the cartel if it invests in fixed cost but this tends to increase the level of certified quality as the certified quality is an increasing function of the low quality level. As a result, the frontier determining the sign of the difference in quality is under the previous one. On the other hand, the range of possible $\{a, b\}$ values is reduced. However, for the remaining possible values, the range of $\{a, b\}$ values for which the certified quality is higher is increased.

Private incentives of the cartel For the cartel, certification dominates investment in fixed cost if and only if $\pi_h^*(s_l, a, C) \geq \pi_h^{I*}(s_l, b)$. The conditions under which this inequality is verified are summurized in the following proposition.

Proposition 3 *i) If $a \geq \frac{1}{4as_l}$ and $b \geq \frac{1}{16s_l}$, the cartel decides neither to certify nor to invest in fixed cost.*

ii) If $a \geq \frac{1}{4as_l}$ and $b < \frac{1}{16s_l}$, the cartel decides to invest in fixed cost and make positive profits.

iii) If $a < \frac{1}{4as_l}$ *and* $b \geq \frac{1}{16s_l}$*, the cartel decides to certify and make positive profits if and only if* $C \leq f(s_l, a) = \frac{1}{54a} - \frac{s_l}{27}(3+12as_l-32a^2s_l^2)+\frac{1}{54a}[1-4as_l+(4as_l)^2]^{\frac{3}{2}}$.

iv) If $a < \frac{1}{4as_l}$ *and* $b < \frac{1}{16s_l}$*, the cartel always choose to produce the high quality and certification dominates investment in fixed cost if and only if:*

$$C \leq \frac{1}{16b} + \frac{5}{36}s_l + \frac{1}{54a}\left(1 - 24a^2s_l^2 + 64a^3s_l^3 + \left(1 + 16a^2s_l^2 - 4as_l\right)^{\frac{3}{2}}\right).$$

that is for $b \geq \frac{27a}{16\left[2-108aC+15as_l-48a^2s_l^2+128a^3s_l^3+2\left(1+16a^2s_l^2-4as_l\right)^{\frac{3}{2}}\right]}$.

We illustrate the above proposition in figure (4) which illustrates the trade-off between certification and investment in fixed cost.[3] It shows the relation between the marginal cost of quality engaged in fixed cost and the marginal cost of certifying (quality cost engaged in variable cost). Consider first the case where there is no cost of certification, that is when public authorities pay for the certification cost. To interpret this relation, we fix an arbitrary value of b ($b = 0.2$ for example). When a is equal to zero, certification dominates investment in fixed cost. This is the case because there is no extra marginal cost to produce the high quality for the cartel, consumers believe that quality is high and the fixed cost under investment in advertising/R&D is too high. As a increases, this marginal effect reduces profits under certification and investing in fixed cost becomes the best strategy for the cartel for large value of a relative to b. Note that when there is no cost for quality (neither in fixed cost and in variable cost), then we get the same outcome. Now assume that the cartel have to bear the certification cost. In this case, for a given value of b, a has to be lower than in the previous case for certification to dominate investment in fixed cost and the higher b, the larger the reduction in a has to be, which reduces the area under which the certification dominates advertising.

Consumer surplus We summarize the consumer surplus effects of the PDO certification policy versus private collective advertising strategy in the following proposition.

Proposition 4 *i) Low quality consumers are better-off under certification than under advertising, the larger the low quality, the larger the difference in surplus. This difference also increases with the marginal cost for quality.*

ii) High quality consumers can be better or worse-off.

iii) The difference between total consumers' surplus under certification and advertising becomes ambiguous.

Figure (5) illustrates the impact for consumers of the cartel choice. In the range of values of a and b such that the cartel has the choice to certify or to advertise, for a given level of the low quality[4], consumers will be better off under certification for relatively low values of a even if b is also relatively low. However, when a becomes larger, the consumers become better off under advertising on the possible range of b such that $b \leq \frac{1}{16s_l}$. For higher values of b, consumers would have been better off under advertising but the fixed cost is too high for the cartel to make positive profits and the cartel prefer to certify. In this case, consumers still gain but they gain less than what they will have gained under advertising.

[3] We assume here that $s_l = 0.1$.

[4] We assume here that $s_l = 0.1$.

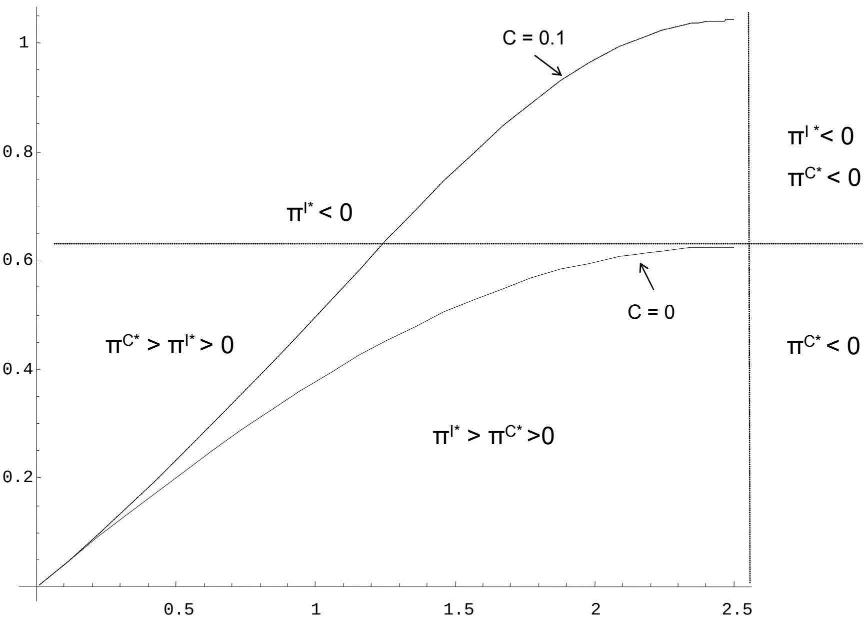

Figure 4: Private incentives of the cartel

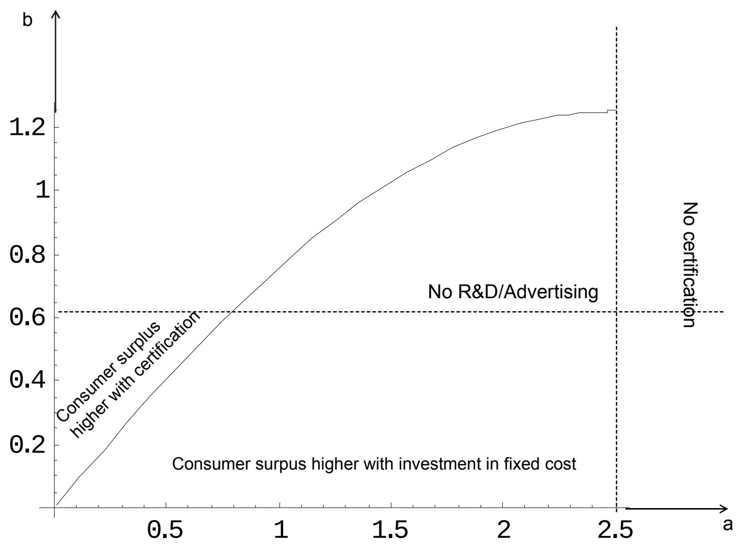

Figure 5: Consumer surplus comparison: certification vs. investment in fixed cost

Total welfare Having studied the cartel's incentive to opt for certification or advertising, we now focus on the welfare impact of PDO regulation as compared to private advertising/R&D investment. We summarise the welfare of the PDO labeling policy versus the investment in fixed cost strategy in the following proposition.

Proposition 5 *Welfare under certification is larger than under advertising/R&D if and only if for $a < \frac{1}{4as_l}$ and $b < \frac{1}{16s_l}$:*

$$C \leq \frac{1}{288ab}\left[8b + 8b\left(1 + 16a^2s_l^2 - 4as_l\right)^{\frac{3}{2}} - 9a + 4abs_l\left(15 + 16as_l(8as_l - 3)\right)\right]$$

that is for

$$b \geq \frac{9a}{4\left[2 - 72aC + 15as_l - 48a^2s_l^2 + 128a^3s_l^3 + 2\left(1 + 16a^2s_l^2 - 4as_l\right)^{\frac{3}{2}}\right]}.$$

Profits under certification can be larger than under advertising/R&D while welfare may be lower.

The proposition results are represented in figure (6) where the plain lines represent the case with no certification cost and the dotted line represent the case of positive certification cost (the bold line represents the welfare frontier while the other one represents the profit frontier). We first consider the case where the cartel does not pay for a fixed cost. As it can be observed, there is a region where the optimal outcomes differ with respect to private incentives (cartel's profit) and social welfare. In this region, the cartel's profit would be higher under certification but does not compensate for the loss in consumer surplus under certification (in this area consumers are better off under investment in fixed cost). If now, the cartel faces positive certification cost, both the profit and the welfare frontiers are above the previous ones, which reduces the region where the profit is higher under certification but also the one for which welfare is higher. Moreover, the region under which the private incentives for the cartel differ with social welfare is also reduced.

2.3.2 Capacity constraint

Here we illustrate graphically the impact on the capacity constraint on the arbitrage between certification and investment in fixed cost. The difference in surplus for low quality consumers under production rstriction is given by: $CS_l^C - CS_l^I = \frac{1}{8}s_l\left[3 + 4Q(Q-2)\right]$ with $\frac{\partial(CS_l^C - CS_l^I)}{\partial Q} = s_l(Q-1) < 0$. The more restrictive the constraint, the larger the difference in surplus for a given level of the low quality. Moreover, the difference $CS_l^C - CS_l^I$ is a linear function of s_l,which implies that it can intersect the difference in surplus curve without capacity restriction for larger values of Q (cf. Figure 7). In this case, the difference in surplus is higher with the capacity constraint for relatively low values of s_l but is lower for larger values of s_l.

The qualitative impact for high quality consumer surplus and thus for the total consumer surplus depends on the restrictiveness of the capacity constraint. This is illustrated in figure (8). If the capacity constraint is low ($Q = 0.2$ on the figure), there is no ambiguity and the zone where the consumer surplus is higher under certification is reduced compared to the non constrainted outcome. Now if Q becomes higher, the outcome is slightly different. For

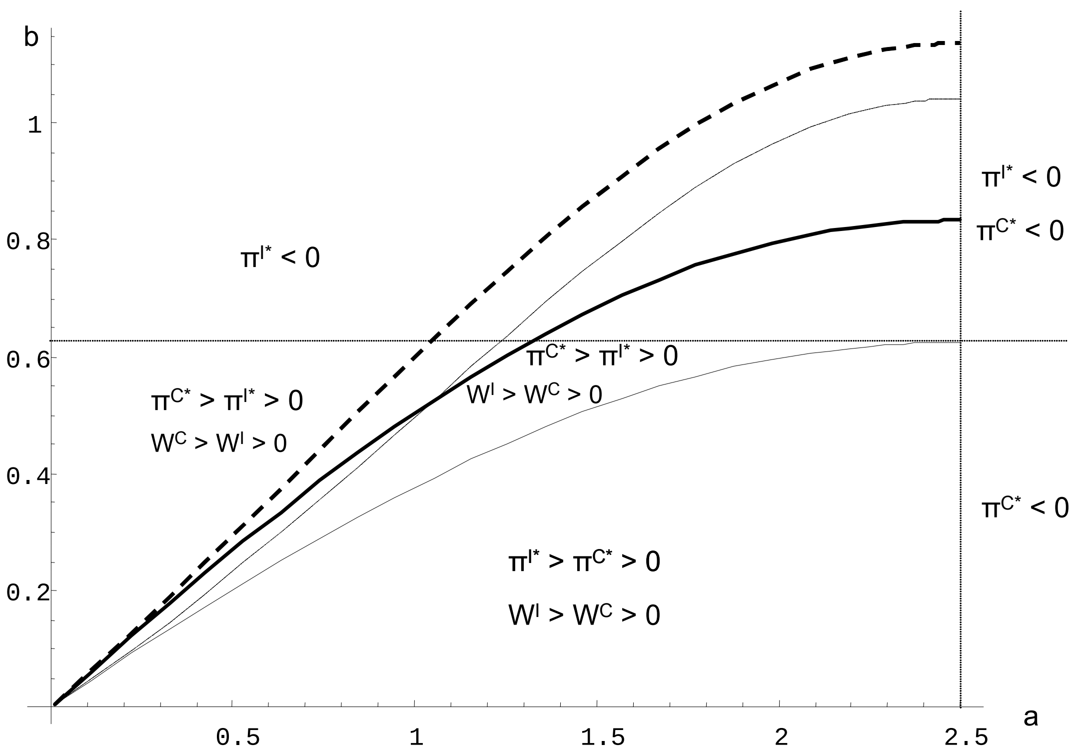

Figure 6: Welfare comparison: certification vs. investment in fixed cost

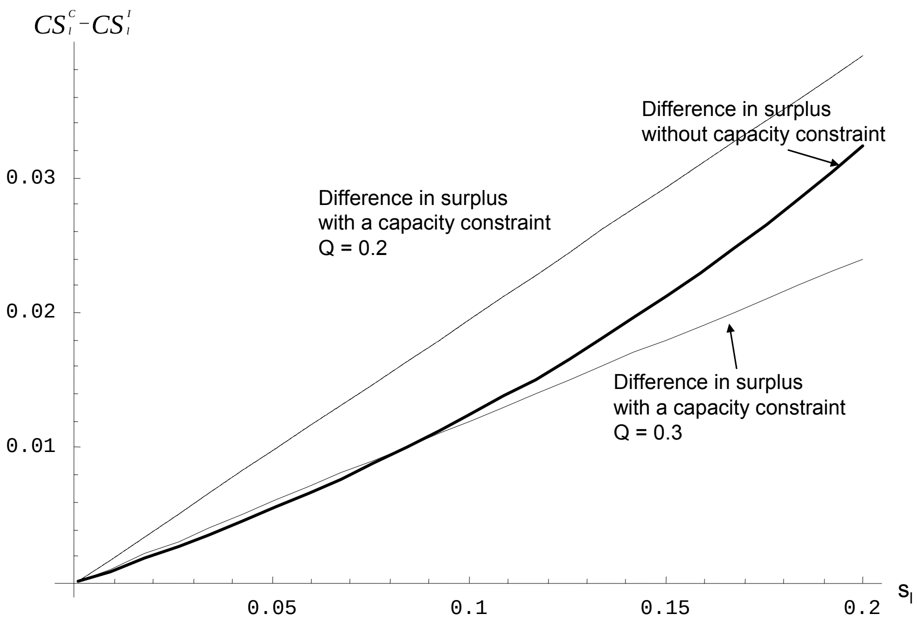

Figure 7: Impact of the capacity constraint on the surplus comparison for low quality consumers

relatively small values of a, there is an area where the surplus was larger under certification but becomes lower with the capacity constraint and on the contrary there are larger values of a such that the surplus was lower under certification but becomes larger with the capacity constraint.

However, the impact of the capacity contraint on the cartel's profit is always negative, then the incentives to certify are reduced under a binding capacity constraint and as shown in figure (9) the area where the cartel will choose to certify is decreased. Finally, certification will dominate advertising from a welfare perspective for a lower range of $\{a, b\}$ values.

3 Exploring the Choice of PDO: Evidence From the French Brie Cheese Industry

In this section we illustrate the theoretical findings above by conducting an empirical study on an industry which contains both PDO and non-PDO products. We make use for the first time to our knowledge of a detailed data set containing firm-level cost and production information, surveying the French dairy industry from 1980 till 2000. Within this data set we chose to concentrate on the Brie cheese sector, because it has witnessed since 1981 the co-existence of PDO Brie producers with other non-PDO Brie manufacturers. This sector seems therefore a perfect candidate for a comparative empirical study of the structural impacts of the Protected Designation of Origin legislation. We concentrate on investigating the determinants of the choice of PDO certification, within a switching regression model with a structural choice equation. First we being by briefly describing the Brie cheese industry in France.

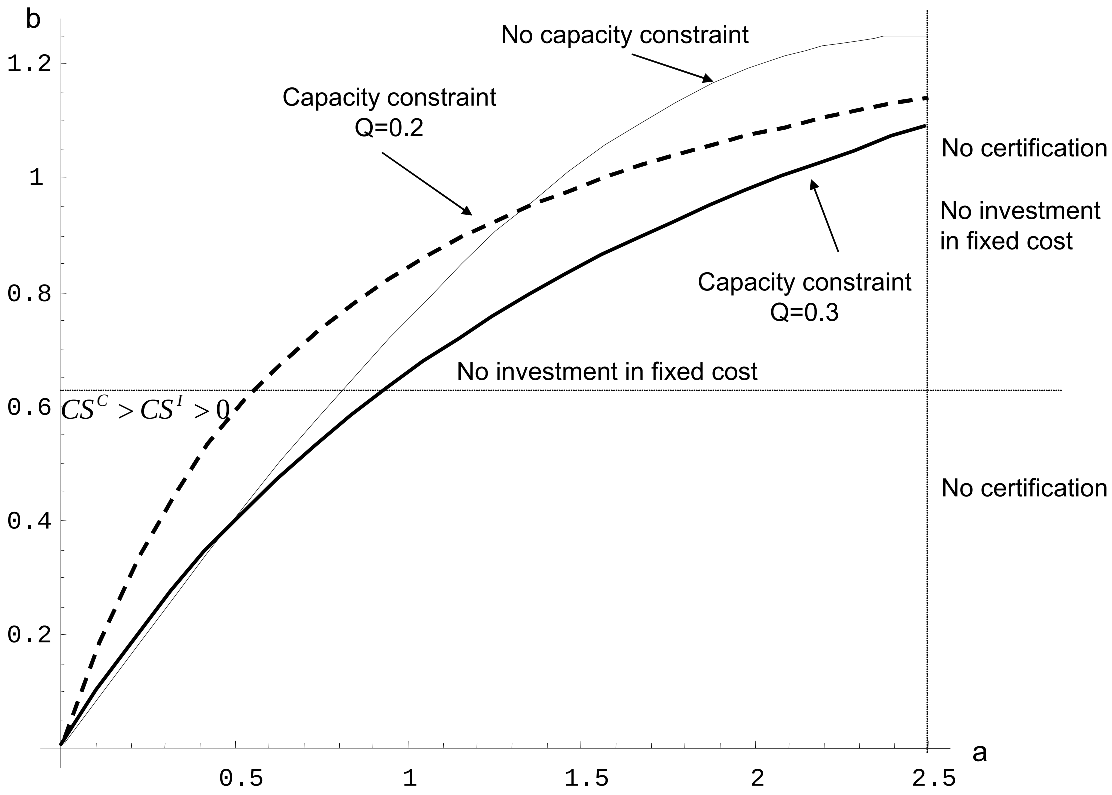

Figure 8: Impact of the capacity constraint on the total consumer surplus difference

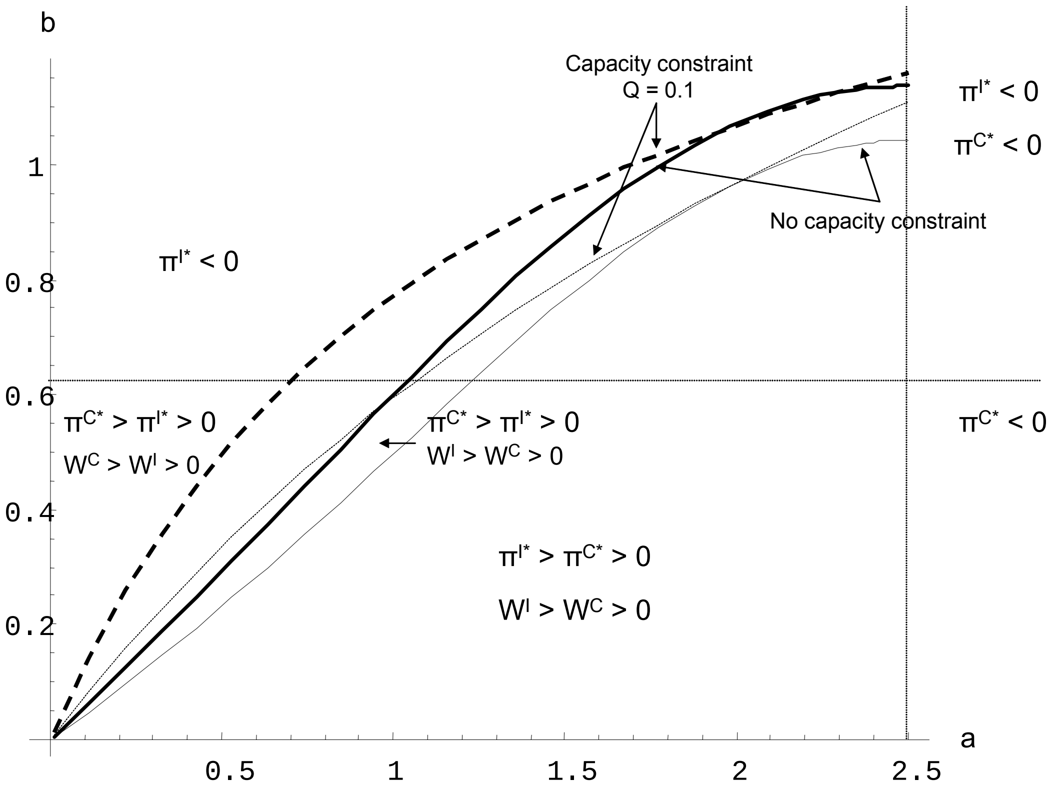

Figure 9: Impact of the capacity constraint on profits and welfare

3.1 Brie cheese

Brie is a soft cow's milk cheese named after Brie, the French province in which it originated (roughly corresponding to the modern department of Seine-et-Marne). There are now many varieties of Brie made all over the world, including plain Brie, herbed varieties, and versions of Brie made with other types of milk. Brie is perhaps the most well-known French cheese, and is popular throughout the world. Despite the variety of Bries, the French government officially certifies only two types of Brie to be sold under that name: Brie de Meaux and Brie de Melun. These two types of Brie obtained the 'Appellation d'Origine Contrôlée' in August 1980, application having been made in 1978. They have both been famous for a long time. Brie de Meaux is originated from the "Brie country", geographical area that has been known for a long time for Brie production and Brie de Melun is produced on a fertile clay plateau in Brie region (Seine-et-Marne), plus some adjacent communes belonging to the départments of Aube and Yvonne.[5]

They are both made from raw cow's milk as requested by the PDO legislation while other Brie could be produced from raw or pasteurised milk. Both PDO bries have to contain more than 45% of fat in the dry content while other brie only have to content 40%. The PDO Brie crust is characterised by a crust covered in a fine coating of white downy for Brie de meaux and by a crust covered in a felt-like white coating lightly marked with red for Brie de Melun. On the other hand, other Brie needs only to have a crust formed by superficial mould . PDO Brie is produced in the form of a flat cylinder with an average weight of 2.6 kilogrammes for Brie de Meaux and of 1.5 kilogrammes for Brie de Melun. Moreover, The curds obtained after the addition of rennet to the raw milk, which has been heated to a temperature below 37°C, is then put into a mould. In accordance with the traditional technique, moulding is done manually with the aid of a "Brie shovel" for Brie de Meaux (the mould being filled with a succession of fine layers) and with a ladle for Brie de Melun. After draining for at least 18 hours, the cheeses are removed from the moulds, dry-salted by hand, treated with mould spores and put into cellars, where they ripen slowly for at least four weeks.

Given this, from a production technology point of view, it seems that the principal difference between the manufacturing of the PDO Brie and the non-PDO Brie is the underlying technology. The first is not pasteurized and exclusively done with manual techniques contrary to non-PDO Brie. This motivates the fact that PDO producers face an extra variable production cost due to technological limitations: the manual labor-intensive technology can play a role in increasing the cost of production of the PDO product. In addition to this, because the PDO Brie cheese must be produced in a given geographic area, this indirectly imposes an output constraint on firms due to this limited production area. Cost functions for PDO and non-PDO Brie cheese are thus structurally different, and it would be useful to evaluate these costs, and to also determine how they impact the choice of PDO certification.

3.2 Modeling the choice of PDO and non-PDO technology

[5]Brie de Meaux has been known since the time of Charlemagne. It was enjoyed by kings and nobility as well as by the common people. In 1793 the revolutionary Lavallée noted that "the cheese of Brie, loved by rich and poor, was preaching equality before it was ever imagined to be possible". Nevertheless, in 1814, at the Congress of Vienna, Brie de Meaux celebrated its greatest triumph, thereby earning its nickname of "king of cheeses and cheese of kings". It seems that Brie de Melun, of very ancient origin, is the ancestor of all Brie cheeses and that, like its cousin the Brie de Meaux, it was appreciated by rulers and eulogized by writers and poets.

The choice of PDO production process is described by a switching model and a criterion function, following the methodology in Willis and Rosen (1979) and Huang et al. (2002). Consider the i-th producer's choice of certification. The farmer could either choose PDO certification or private labeling (non-PDO). The variable costs of PDO (VC_{PDO}) and non-PDO (VC_{OTH}) are determined by:

PDO: $VC_{PDOi} = X_{PDOi}\ \beta_{PDO} + U_{PDOi}$ (1)

Non-PDO: $VC_{OTHi} = X_{OTHi}\beta_{OTH} + U_{OTHi}$ (2)

where $X_{PDOi}$and X_{OTHi} are the vectors of cost determinants of the PDO and non-PDO options, respectively, and $U_{PDOi}$and U_{OTHi} are the corresponding unobservable errors with mean zero and the variances, σ^2_{PDO} and σ^2_{OTH} , respectively. Thus $X_{PDOi}\ \beta_{PDO}$ and $X_{OTHi}\beta_{OTH}$ are the farmer's expectation of Brie cheese production cost at the time the choice is made. The producer's decision depends on the criterion function,

$I^*i = Zi\gamma + \delta(VC_{PDOi}\text{-}VC_{OTHi})\text{-}Ui$ (3)

where Zi is a vector of variables not exclusively X_{PDOi} or XOTHi, and γ and δ are coefficients. The random error Ui reflects unobservable factors influencing the selection of the production process. The vector (U_{PDOi},U_{OTHi},Ui) of the random errors is assumed to be jointly normal with zero mean and unrestricted variance-covariance matrix.

The criterion function (3) implies that the ith producer's decision about certification technology depends on the cost differential between PDO and Non-PDO technologies, as well as the non-cost considerations represented by the variables Zi . The Zi variable in our empirical analysis is the number of firm employees, since it has been found in recent studies (see) to be a major determinant of the adoption of quality practices in food processing industries. Since the ith producer may choose either PDO or Non-PDO, only one of the cost variables VC_{PDOi} or VC_{OTHi} is observed, depending on whether $I^*\ i > 0$ or $I * i \leq 0$. The observed cost thus depends on the probability of self-selection, $Pr(I^*\ i > 0)$ or $Pr(I^*\ i \leq 0)$.

The estimation of the model, cost equations (1), (2), and the criterion function (3) is a standard two-stage procedure of Willis and Rosen (1979) and Huang et al. (2002). By substituting the cost equations VC_{PDOi} and VC_{OTHi} into $I^*\ i$, the reduced form criterion function can be written as,

$$I^*i = Zi\gamma + \delta(X_{PDOi}\beta PDO - X_{OTHi}\beta_{OTH}) + \delta(U_{PDOi} - U_{OTHi}) - Ui \equiv Z^*i\ \gamma^* - U^*i \quad (4)$$

where $Z^*i = (Zi\ ,\ X_{PDOi},\ X_{OTHi})$, and the corresponding reduced form error $U^*\ i$ is normalized to have unit variance. The normalized coefficient $\gamma\ ^*$ is defined accordingly. The reduced form criterion function is a typical probit choice model with the selection index

$Ii = 1$ and $VCi = VC_{PDOi}$ is observed, if $I^*\ i > 0$

$Ii = 0$ and $VCi = VC_{OTHi}$ is observed, if $I^*\ i \leq 0$

The cost equations (1) and (2) are a standard self-selection model. As in Huang et al. (2002), define two inverse Mill ratios,

$wPDOi=\phi(Z^*i\ \gamma\ ^*)/\phi(Z^*i\ \gamma\ ^*)$ and $wOTHi=\phi(Z^*i\ \gamma\ ^*)/(1\text{-}\phi(Z^*i\ \gamma\ ^*))$ (5)

where $\phi(.)$ and $\Phi(.)$ are the standard normal density and distribution functions, respectively.Given the observations on PDO producers, VCi = VCPDOi, the PDO equation (1) can be written as:

$VC_{PDOi} = X_{PDOi}$ βPDO -σPDO*w_{PDOi}+ϵ_{PDOi}, for Ii = 1 (6)

where σPDO* = Cov(U_{PDOi},U* i) and $\epsilon_{PDOi} = U_{PDOi}$+$\sigma$PDO*$w_{PDOi}$ with E(ϵ_{PDOi} | I * i > 0) = 0. Similarly given the observations on non-PDO, VCi = VCOTHi, the non-PDO equation becomes

$VC_{OTHi} = X_{OTHi}$ β_{OTH}+$\sigma^*{}_{OTH}$$w_{OTHi}$+$\epsilon_{OTHi}$, for Ii = 0 (7)

where $\sigma^*{}_{OTH}$= Cov(U_{OTHi},U* i) and ϵ_{OTHi}= U_{OTHi}-$\sigma^*{}_{OTH}$ w_{OTHi}. Since E(ϵ_{OTHi} | I* i ≤ 0) = 0, the conditional mean of VC_{OTHi}, E(VC_{OTHi} | Ii = 0) = $X_{OTHi}\beta_{OTH}$+$\sigma^*{}_{OTH}$ w_{OTHi}, is the self-selected, expected non-PDO cost.

In the first-stage of estimating the model, the probit estimate $\hat{\gamma}$ * of the reduced form coefficient γ^* is obtained from (4) and the two estimates $\hat{w}_{PDOi}$ and $\hat{w}_{OTHi}$ of the inverse Mill ratios are computed from (5). Replacing w_{PDOi} and wOTHi with $\hat{w}_{PDOi}$ and $\hat{w}_{OTHi}$, the estimates ($\hat{\beta}_{PDO}$, $\hat{\beta}_{OTH}$, $\hat{\sigma}^*{}_{PDO}$, $\sigma^*{}_{OTH}$) of the coefficients in (6) and (7) can be obtained by a least-squares method. With these estimates, the coefficients (γ, δ) of the structural decision criterion function (3) can then be consistently estimated in the second stage by replacing (VC_{PDOi},VC_{OTHi}) with the estimates ($X_{PDOi}\hat{\beta}_{PDO}$, $X_{OTHi}\hat{\beta}_{OTH}$). Once the model of the choice is estimated, the cost differential in the certification technology can be compared based on the predicted costs, $VC_{PDOi} = X_{PDOi}\hat{\beta}_{PDO}$ and VC_{OTHi}= $X_{OTHi}\hat{\beta}_{OTH}$.

3.3 Data description

Data on the Brie cheese industry was obtained by merging two statistical sources: the Annual Firm Survey (EAE) conducted by the French Ministry of Agriculture, which compiles accounting and firm specific data ; and the Annual Dairy Production Survey (EAL-PRODCOM) also conducted by the Ministry of Agriculture, surveying dairy production by all firms operating on the French territory. This survey contains detailed information about the quantities produced by each firm, according to a very narrow product definition. Merging these two datasets allowed the construction of a detailed firm-specific production process database (inputs, outputs, cost, and other firm characteristics), for the years 1980 through 2000. We could thus obtain an unbalanced panel of Brie producers. We group together the producers of the two types of PDO Brie: Brie de Meaux and Brie de Melun.
Figure (10) shows the evolution of Brie production from 1981 to 2000 (as in 1981 the PDO Brie product started to enter the statistical survey following the certification). As it can be noticed, the total production of the PDO Brie remained bounded below 10 million tons, with somewhat a stable tendency, while the non-PDO Brie total output was always increasing, reaching almost ten times the PDO one. This clearly shows that the PDO firms either restrict their level of production or face an implicit production constraint.

In order to assess cost differences between PDO and non-PDO Brie producers, we choose to select a sample of 125 observations on single product firms containing 67 and 58 PDO

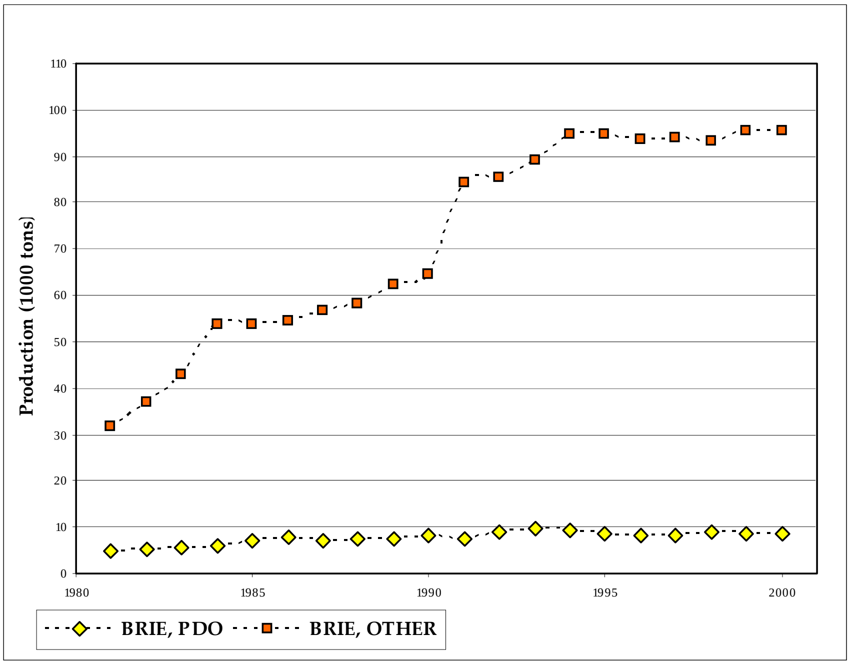

Figure 10: Comparative evolution of Brie cheese production

and non-PDO observations respectively. The choice of working with single product firms is guided by the fact that only the total cost of production for each input is reported (through individual income statements), which makes it impossible to disentangle costs attributed to each activity in multiproduct companies. Working with single product firms also allows to concentrate on a single production technology, thus abstracting from issues related to multi-product economies of scope.

Table 1 presents some summary statistics about the sample at hand. Notice that significant differences arise between the two groups of firms. On average, non-PDO producers have a larger production capacity (measured both by actual production and the value of total assets); possess a higher number of employees and achieve slightly higher average production cost. More importantly, non-PDO firms seem to invest more than PDO ones, and this gives an indication into the possible uses of higher investments to use a private certification technology.

TABLE 1: Summary statistics, single product brie cheese sample (means of variable)

	PDO Brie	Non-PDO Brie	*All*
Number of observations	67	58	*125*
Brie cheese production (1000 tons)	1,06 *(9,52)*	5,18 *(3,22)*	*2,98 (3,08)*
Total Production Variable Cost VC (MF)	321 *(229)*	250 *(367)*	*133 (272)*
Average Production Variable Cost (FF/KG)	33.7 *(12.4)*	38.1 *(10.4)*	*35.7 (27.7)*
Number of Employees	45.8 *(26.8)*	117.5 *(90.7)*	*79.1 (73.9)*
Value of Physical Assets (MF)	12,71 *(13,55)*	78,63 *(117,47)*	*43,30 (86,78)*
Total Investment (MF)	1,10 *(1,92)*	6,49 *(10,57)*	*3,60 (7,79)*
Value of Capital plus Investment as % of Sales	0.35 *(0.19)*	0.50 *(1.04)*	*0.41 (0.73)*

Standard deviation in parantheses.

3.4 Empirical estimation and results

Definitions and summary statistics of the variables used in the empirical analysis are given in table 2. Variable production costs (VC) include only wages and raw materials and are expresssed in FF/KG. Wages (average salaries per firm) is denoted by W, costs of raw materials (raw materail cost divided by output) by MAT, the proxy for investment in R&D (value of fixed capital +investment as percentage of sales) by K anf finally the number of full time employees in the firm by NEMP.

TABLE 2: Sample statistics

Variable	PDO		Non PDO		*All*	
	Mean	Sd	Mean	Sd	*Mean*	*Sd*
VC	33.7	12.4	38.1	38.6	*35.8*	*27.8*
W	150.9	34.2	148.1	49.9	*149.6*	*42.1*
MAT	0.65	0.08	0.73	0.18	*0.69*	*0.14*
K	0.35	0.19	0.50	1.04	*0.42*	*0.73*
NEMP	45.8	26.8	117.5	90.8	*79.1*	*73.9*

Estimation results for equations (6) and (7) are summarised in table 3.

TABLE 3: Estimated cost equations of PDO and non-PDO Brie cheese producers (with robust standard errors)

PDO cost function (lnVCPDO)

Variable	Coef.	Std. Error	t-Stat
Constant	-7.874	12.8	-0.62
lnW	5.286	5.197	1.02
$(\text{lnW})^2$	-0.516	0.520	-0.99
lnMAT	8.18	2.872	2.85
$(\text{lnMAT})^2$	8.657	2.893	2.99
lnK			
$(\text{lnK})^2$			
w_{PDO}	-1.04	0.581	-1.79
R-squared		0.3106	
Observations		67	

Non PDO cost function (lnVCOTH)

Variable	Coef.	Std. Error	t-Stat
Constant	17.98	14.97	1.2
lnW	-6.73	6.37	-1.06
$(\text{lnW})^2$	0.78	0.66	1.19
lnMAT	5.51	1.60	3.44
$(\text{lnMAT})^2$	3.67	1.21	3.02
lnK	0.04	0.015	2.5
$(\text{lnK})^2$	-0.001	0.003	-0.4
w_{OTH}	0.56	0.42	1.32
R-squared		0.556	
Observations		58	

Predicted average cost of PDO producers: 32.6 FF/Kg.
Predicted average cost of non-PDO producers: 31.59 FF/Kg.

TABLE 4: Probit estimates of the criterion equations with dependent variable: $I_i = 1$ for PDO cheese producers and $I_i = 0$ for non-PDO cheese producers.

Reduced Form Equation

Variable	Coef.	Std. Error	z-Stat
Constant	-52.57	32.86	-1.6
lnW	18.62	13.58	1.37
$(\text{lnW})^2$	-1.72	1.4	-1.22
lnMAT	-20.97	4.56	-4.6
$(\text{lnMAT})^2$	-21.81	4.69	-4.65
lnK	0.037	0.039	0.93
$(\text{lnK})^2$	-0.002	0.009	-0.27
NEMP	-0.19	0.005	-3.66
McFadden R-squared		0.6044	
LR Statistic		-34.15	
Observations		125	

Structural Form Equation

Variable	Coef.	Std. Error	z-Stat
Constant	1.69	0.31	5.38
NEMP	-0.18	0.004	-4.69
lnVCPDO-lnVCOTH	0.76	0.25	3.07
McFadden R-squared		0.3078	
LR Statistic		-59.75	
Observations		125	

Results of the structural model: a one percent increase in the cost differential between non-PDO and PDO technology leads to 0.3 percent increase in the probability of choosing the PDO certification process (computed using the marginal probability effects). A unit increase in workers leads to a 0.007 percent decrease in the probability of choosing PDO certification.

4 Conclusion

In this paper, we have analysed two possible ways for groups of producers to signal the quality of their products. They can signal their quality either by certifying their product and opting for a PDO label or by developping a common brand. In the first case, we take into account the technical requirements linked to PDO production, the certification cost as well as the possible capacity constraint they could face given the geographical constraint. On the other hand, if it chooses to develop a common brand, a group of producers has to invest in R&D and advertising. We focused on the role of these different cost parameters in the decision of producers and show the impact for consumers and for welfare. We also have investigated the incidence on the optimal level of quality. The quality of the product will be higher under PDO certification if the marginal cost for quality a (incured in the variable cost of production in this case) is not to high compared to the marginal cost of advertising b (incured in the fixed cost of production). The ranking will also depend on the quality of the product produced by the competitive fringe. When it increases, it tends to increase the range of cost values for which the quality is higher under PDO certification. Then, if the quality produced by the competitive fringe is relatively high (which would be the case if we can observe the private brands on the competitive segment), this would require a even higher level of quality for PDO certification and this level could be to high for producers to be able to produce it. In this case, the market for PDO product collapses and the best option will be to rather invest in a common brand.

The signal decision will also depend on the relative values of a and b. If the marginal cost of quality a is to high, then the group of producers will obviously not produce the PDO quality and in the same way if the marginal cost of quality b is too high, producers will not invest in a common brand. High values of a could reflect either too restrtictive technical constraint to produce PDO or low consumers' willingness to pay for PDO quality. In the latter case, for a same level of quality, the marginal cost for producers has to be larger and could be to high that it could be no optimal to produce the PDO quality. Then, there is a range of values for which there is a trade off between the two, depending on the value of a relative to b. The certification cost also plays a role in the signaling choice. When the certification cost increases, choosing PDO certification is optimal for the group of producers for lower values of a compared to b. The benefit for consumers differ according to the level of quality of the product they buy. Low quality consumers are better off under certification than under advertising. However, high quality consumers can be better off or worse-off. Then, the impact on total consumers is ambigues. For a given level of the low quality, for low values of a (even ib b is low), consumers will prefer that the group of producers produce the PDO products. When a is larger than a given threshold on the contrary, consumer surplus becomes higher when the group of producers opts for the common brand. Then from a welfare point of view, the signaling choice is rather obvious for low values of a (relative to b) and for high values of a (relative to b). In these cases, the cartel's incentive is compatible with consumer surplus. However, for intermediate levels of a (compared to b), the incentives for the group of producer are non compatible with the the interest of consumers. They will prefer to certify their product and produce the PDO products while consumers will be better off under the common brand option (even if low consumers are worse off). However, when producers have to pay a certification cost to produce the PDO, the range of marginal cost values for which there is a divergence between the cartel incentives and global welfare shrinks. Finally because a capacity constraint will reduce the incentive of producers to opt for PDO certification (it decreases their profit) and will decrease consumer surplus, a restrictive capacity constraint will change this range of values but do not help shrinking the gap between the cartel profits and total welfare.

5 Appendix:

5.1 Derivation of the unique optimal quality s_h^*

We derive the unique optimal quality s_h^* when the cartel decides to certify its product by replacing the subgame quantity (4) into the profit function (6) and maximizing (3) with respect to s_h. Solving the profit maximisation programs leads to four potential solutions for s_h:

$$\begin{aligned}
s_h^1 &= \frac{1-\sqrt{1-4as_l}}{2a} \\
s_h^2 &= \frac{1+\sqrt{1-4as_l}}{2a} \\
s_h^3 &= \frac{1+4as_l-\sqrt{1+16a^2s_l^2-4as_l}}{6a} \\
s_h^4 &= \frac{1+4as_l+\sqrt{1+16a^2s_l^2-4as_l}}{6a}
\end{aligned}$$

We withdraw the two first solutions $s_h^1$and s_h^2 because the demand for the certified good at these levels of quality is equal to zero and thus $s_h^1$and s_h^2 can not be subgame perfect equilibrium quanlities. Second, we check for the concavity of the profit function for $s_h^3$and s_h^4. The second derivative of the profit function using $s_h^3$and s_h^4 are respectively given by:

$$\begin{aligned}
\frac{\partial \pi_h(x_h(s_l, s_h^3), C)}{\partial x_h^2} &= -2(s_h^3 - s_l) = \frac{-1+2as_l+\sqrt{1+16a^2s_l^2-4as_l}}{3a} \\
\frac{\partial \pi_h(x_h(s_l, s_h^4), C)}{\partial x_h^2} &= -2(s_h^4 - s_l) = \frac{-1+2as_l-\sqrt{1+16a^2s_l^2-4as_l}}{3a}.
\end{aligned}$$

The second derivative with s_h^3 is always positive while it is negative for s_h^4 if and only if $s_l < \frac{1}{4a}$. Otherwise the demand for the high quality becomes null.

5.2 Proof of proposition 1

Proof: i) We compare the difference in consumer surplus for low quality consumers under certification and advertising:

$$\begin{aligned} CS_l^C - CS_l^I &= \int_{\theta_0}^{\widetilde{\theta}^c} (\theta s_l)\, d\theta - \int_{\theta_0}^{\widetilde{\theta}^c} (\theta s_l)\, d\theta \\ &= \frac{1}{72} s_l \left[4\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right)^2 - 9 \right] \end{aligned}$$

This difference is positive for

$$\begin{aligned} 4\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right)^2 - 9 &= \\ \left(2\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right) + 3\right)\left(2\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right) - 3\right) &\geqslant 0, \end{aligned}$$

which is verified only if $2\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right) - 3 \geqslant 0$. Define x such that $x = 4as_l > 0$. This condition can also be written $f(x) = 2x + 2\sqrt{1+x^2-x} - 1 \geqslant 0$ where $1 + x^2 - x > 0$ for all $x > 0$. We can check that $f'(x) = 2 + \frac{2x-1}{\sqrt{1+x^2-x}} > 0$ with $f(0) = 1$ and $f'(0) = 1$ and $f''(x) = \frac{3}{2(1+x^2-x)^{3/2}} > 0$. We thus have $f(x) > 0$.

We can calculate the derivative of the difference $CS_l^C - CS_l^I$ with respect to s_l:

$$\frac{\partial\left(CS_l^C - CS_l^I\right)}{\partial s_l} = \frac{\sqrt{1+16a^2 s_l^2 - 4as_l}\,[32as_l(1+12as_l) - 1] + 8\,[1 + 2as_l(1 + 4asl\,(24as_l - 1))]}{72\sqrt{1+16a^2 s_l^2 - 4as_l}}.$$

The denominator is positive. This equality can be written $\frac{\partial\left(CS_l^C - CS_l^I\right)}{\partial s_l} = \frac{\sqrt{1+x^2-x}g(x)+f(x)}{72\sqrt{1+16a^2s_l^2-4as_l}}$. From $g(x) = \sqrt{1+x^2-x}(24x^2+8x-1)$, we get $g'(x) = \frac{17+2x(72x^2-44x+35)}{2\sqrt{1+x^2-x}} > 0$ for $x > 0$, $g''(x) = \frac{157+8x\left(72x^3-112x^2+141x-57\right)}{4(1+x^2-x)^{\frac{3}{2}}} > 0$, $\lim_{x\to 0} g(x) = -1$ and $\lim_{x\to 1} g(x) = 31$. From $h(x) = 24x^3 - 4x^2 + 4x + 8$, we get $h'(x) = 72x^2 - 8x$, $h'(\frac{1}{9}) = 0$, $h'(x) \leq 0$ for $x \leq \frac{1}{9}$, $h'(x) \geq 0$ for $x \geq \frac{1}{9}$ and $h''(x) = 144x > 0$ for $x > 0$. Moreover, the minimum of the function $h(x)$ is obtained for $h(\frac{1}{9}) = \frac{2048}{243} \approx 8.42$, which is greater than the minimum of the function $g(x) = \lim_{x\to 0} g(x) = -1$. Then, $\frac{\partial\left(CS_l^C - CS_l^I\right)}{\partial s_l} > 0$.

The derivative of the difference $CS_l^C - CS_l^I$ with respect to a is:

$$\frac{\partial\left(CS_l^C - CS_l^I\right)}{\partial a} = \frac{2}{9} s_l^2 \left(2 + \frac{8as_l - 1}{\sqrt{1+16a^2 s_l^2 - 4as_l}}\right)\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right).$$

As $\frac{2}{9}s_l^2\left(1 + 4as_l + \sqrt{1+16a^2 s_l^2 - 4as_l}\right)$ is always positive, then $\frac{\partial\left(CS_l^C - CS_l^I\right)}{\partial a} > 0$ if and only if $k(x) = \frac{2x-1}{\sqrt{1+x^2-x}} > -2$. We have $k'(x) = \frac{3}{2(1+x^2-x)^{\frac{3}{2}}} > 0$ with $\lim_{x\to 0} g(x) = -1$ and $\lim_{x\to 1} g(x) = 1$. Then $k(x)$ is always greater than -2.

ii) We compare the difference in consumer surplus for high quality consumers under certification and advertising:

$$\begin{aligned} CS_h^C - CS_h^I &= \int_{\widetilde{\theta}^c}^{1} \left(\theta s_h^{C*} - p_h^{C*}\right) d\theta - \int_{\theta_0}^{\widetilde{\theta}^c} \left(\theta s_h^{I*} - p_h^{I*}\right) d\theta \\ &= \frac{1}{108a}\left(1 + 36as_l - 48a^2s_l^2 - 128a^3s_l^3 + (1 - 16as_l - 32a^2s_l^2)\sqrt{1 + 16a^2s_l^2 - 4as_l}\right) \\ &\quad - \frac{1 + 16bs_l}{64b}. \end{aligned}$$

We can calculate b such that $CS_h^C - CS_h^I = 0$. There is a unique solution for b that depends on the level of the low quality good s_l and on the marginal cost for quality a:

$$b^0 = -\frac{27a}{16\left[-1 - 9as_l + 48a^2s_l^2 + 128a^3s_l^3 + (16asl + 32a^2s_l^2 - 1)\sqrt{1 + 16a^2s_l^2 - 4as_l}\right]}$$

For values of $b > b^0$, the consumer surplus is higher when the cartel certify, for $b = b^0$, consumers are indifferent between certification and advertising and for $b < b^0$ and $b \leq \frac{1}{16s_l}$, consumers benefit more from advertising. However if $b \geq \frac{1}{16s_l}$, the cartel has no incetive to produce the high quality but consumers still benefits from high quality trough the certified good.

iii) We compare the difference in total consumer surplus under certification and advertising:

$$CS_h^C - CS_h^I = \frac{1}{1728ab}\left[16b + 16b\left(1 + 16a^2s_l^2 - 4as_l\right)^{\frac{3}{2}} + a\left(8bs_l(15 - 48as_l + 128a^2s_l^2) - 27\right)\right].$$

We can calculate b such that $CS_h^C - CS_h^I = 0$. There is a unique solution for b that depends on the level of the low quality good s_l and on the marginal cost for quality a:

$$b^{00} = \frac{27a}{8\left[2 + 15as_l - 48a^2s_l^2 + 128a^3s_l^3 + 2\left(1 + 16a^2s_l^2 - 4as_l\right)^{\frac{3}{2}}\right]}$$

For values of $b > b^{00}$, the total consumer surplus is higher when the cartel certify, for $b = b^{00}$, consumers are indifferent between certification and advertising and for $b < b^{00}$ and $b \leq \frac{1}{16s_l}$, consumers benefit more from advertising. However if $b \geq \frac{1}{16s_l}$, the cartel has no incetive to produce the high quality but consumers still benefits from high quality trough the certified good. ■

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