PUBLIC LABELING REVISITED: THE ROLE OF TECHNOLOGICAL CONSTRAINTS UNDER PROTECTED DESIGNATION OF ORIGIN REGULATION

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Abstract

This paper takes into account technological and output constraints for firms to analyse PDO regulation. We first examine an original dataset of French Brie cheese producers and compare the cost structure of PDO producers with non-PDO ones. The paper also finds that PDO firms face a more costly production technology and do not profit from scale economies. Then, based on a theoretical model, the paper shows a clear tradeoff between the sunk advertising costs (net of certification costs) and the degree of diseconomies of scale. This tradeoff affects both the firms' incentive to certify, and the efficiency of public certification.

Keywords: Economies of Scale, Cost Functions, Public Labeling, Protected Designation of Origin, Product Differentiation.

JEL Classification: D2, L13, L15, Q13.

1. Introduction

This paper studies a particular type of public labeling program, the Protected Designation of Origin (PDO). Numerous agricultural and food products benefit from PDO regulation in the EU, including wines, meat, olive oils, fruits and vegetables, dairy products and more particularly cheese. Thirteen European countries have adopted this regulation for cheese (see Babcock (2003) for an overview).

The empirical literature on PDO labeling shows that PDO label may not always be valued by consumers. Consumers seem to value more the brand of the product than the PDO label (refer to Bonnet and Simioni, 2001). However, Hassan and Monier-Dilhan (2002) have shown using a hedonic approach that PDO is valued by consumer but is more valued for hard discount products than for national brand products. The theoretical literature argues that PDO regulation may be an efficient public way of certification to signal quality when some characteristics of a commodity cannot be observable by consumers before or after its purchase (Shapiro, 1983 and Auriol and Schilizzi, 1999).

The efficiency of public certification has been widely analyzed in the literature. This literature shows that cartels of high quality producers are welfare-improving when the cost of PDO labeling is high (Marette *et al.*, 1999). Conversely, when the cost of PDO labeling is low, the society is worse-off. Zago and Pick (2002) have shown that, public regulation may be welfare-detrimental in competitive markets. This occurs when the quality difference is low and certification costs are high, because both consumers and the high quality producers benefit from the regulation, whereas producers of the low quality good are worse-off. When high quality producers have some market power, regulation favors producers and consumers are worse off. Auriol and Schilizzi (2003) point out the importance of certification cost for market structure, and determines the conditions for which public certification is better than private quality provision. A high certification cost leads to a highly concentrated market for certification and when the certification cost is too high, the market for quality may collapse.

None of these studies analyzes the particular case of PDO regulation for which quality attributes concern not only raw materials and production, but also the processing technology that have to be specific to the region: "its quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors, and the production, processing and preparation of which take place in the defined geographical area."(European Economic Council (EEC) Regulation N° 2081/92, Article2, Para.2).

Contrary to quality certification, PDO regulation induces technology constraints linked to a specific processing requirement and production area. One of the main characteristics of the PDO quality signal is that, because of the geographical area definition, it excludes some producers, which 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 (Refer to Arnaud *et al.*, 1999). When studying the impact of PDO labeling, it therefore becomes important to consider the underlying production technology. To our knowledge, studies in the literature (Crampes and Hollander, 1995, Motta, 1993 and Ronnen, 1991) have taken into account the fact that quality acts on either the fixed cost or the variable cost of production but not that cost may switch above a certain capacity level. This is even truer in the case of PDO regulation because the geographical area is limited. This means that producing above the capacity threshold requires more effort (more inputs, increased labor force...), which implies some extra variable cost. This paper tries to capture this specific technology processing requirements that are most of the time not fulfilled above a production threshold.

The paper first presents a case study of PDO Brie cheese in France through a data set containing individual firm cost and production information. This case study enables an analysis of the technological differences between PDO and non-PDO cheese. Then, to better assess the impact of PDO regulation, we present in the second part of the paper a model where producers have the choice of privately signaling the level of quality through advertising, in order to apply for a PDO certification or to produce a low quality good. The paper shows how the technology inherent to PDO certification affects equilibrium and the choice of signaling. Finally, the paper analyzes the implications for producers, consumers and total welfare.

2. Exploring Cost Differences: Evidence from the French Brie Cheese Industry

We begin by conducting a comparative study on the French Brie cheese 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. The data set covers the French dairy industry from 1980 till 2000. Within this data set, we concentrate on the Brie cheese sector, because it has witnessed the co-existence of PDO Brie producers with other non-PDO Brie manufacturers since 1981. Therefore, this sector seems a perfect candidate for a comparative empirical study of the structural impacts of the Protected Designation of Origin legislation. We concentrate on investigating the following questions:

1- Does PDO legislation lead to an indirect output constraint on PDO producing firms?
2- What, if any, are the differences between PDO and non-PDO firms?
3- Does a PDO product imply a higher production cost? Do PDO firms face extra costs because they don't enjoy scale economies?

We start by describing the Brie cheese industry and its production technology.

2.1 Brie cheese

Brie is a soft cow milk cheese named after the French province in which it originated. The French government officially certifies two types of Brie to be sold under that name: *Brie de Meaux* and *Brie de Melun*. From a production technology point of view, the principal difference between the manufacturing of PDO Brie and non-PDO (casual) Brie is that the first is done with exclusively manual techniques while the other is not. Such technological limitations explain why PDO Brie producers face an extra production cost. The manual labor-intensive technology increases the cost of production of PDO Brie. In addition, PDO Brie must be produced in a given geographical area, which indirectly imposes an output constraint on firms. We seek to explore these two predictions by estimating the cost function for each group of producers.

2.2 The framework for estimating average cost functions

We model the production decision of Brie cheese producers, given that each sub-group (PDO and non-PDO) may employ a different technology. We focus on a single output production function: $Q = f(X)$, where Q is output and X a vector of inputs.

Since we are interested in determining the existence of scale economies for the production of each sub-group, we follow Ringstad (1979) and Ringstad and Loyland (2001), by using a production function specification that allows for positive but limited economies of scale. We thus concentrate on homothetic production functions, which exhibit a scale elasticity that decreases with production from values above unity to values below unity. This implies a U-shaped average cost function, with a minimum where the scale elasticity is exactly unity. Moreover, homothetic production functions have fewer parameters to estimate than more flexible forms such as translog production functions, and provide single estimates of optimal scale (or Minimum Efficient Scale MES) at the level where average cost is minimized. We use the following specification for the cost function:

$$\ln C = a + b_1 \ln Q + b_2 (\ln Q)^2 + b_3 Q \qquad (1)$$

where C denotes costs.

A serious problem with direct OLS estimation of the cost function in equation (1) is that output is treated as exogenous, when its level is in fact decided by the producers. This causes a simultaneity problem, and correlation between output and the cost error term can render the estimates inconsistent. Where endogeneity is a problem, consistent estimates can be obtained by suitably instrumenting the relevant variable. On the other hand, where endogeneity is not a significant problem, the least squares estimator is more efficient than instrumental variables. Thus, if endogeneity is not severe, the use of the original variable in the empirical analysis is preferred to the use of the instrumental variable. Accordingly, we perform a Hausman (1978) test to test for the endogeneity of output. The output level is first regressed on a set of instruments. The residual from this regression is then added to the original model as an additional regressor. If the OLS estimates are consistent, then the coefficient on the first stage residual should not be significantly different from zero.
We use variable costs *CV* as a dependent variable, and define it as the sum of labor expenses and costs of raw materials (cf. appendix). The instruments we use to conduct the Hausman test are the book value of assets (in logs), the level of investment (in logs) and the investment to sales ratio. The reason we choose these instruments is that they correlate quite well with production and not with variable costs, and that investment is often used in applied models to circumvent the endogeneity problem of the production process (see Olley and Pakes (1996) and Levinsohn and Petrin (2000) for more details).

2.3 The data

Data on the Brie cheese industry was obtained by merging two statistical sources. The first is the Annual Firm Survey which is conducted by the French Ministry of Agriculture, and compiles accounting and firm specific data. The second is the Annual Dairy Production Survey which is also conducted by the Ministry of Agriculture, and surveys 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 thus obtain a panel of Brie producers by grouping together the producers of the two types of PDO Brie: *Brie de Meaux* and *Brie de Melun*. Figure 1 shows the evolution of Brie production from 1981 to 2000 (the PDO Brie product started to enter the statistical survey as of 1981 following the certification). As it can be noticed on figure (1), the total production of PDO Brie remained bound below 10 million tons, with a somewhat stable tendency. On the other hand, the non-PDO Brie total output was always increasing, reaching almost ten times the PDO Brie total output. This shows that PDO firms had an implicit production constraint.

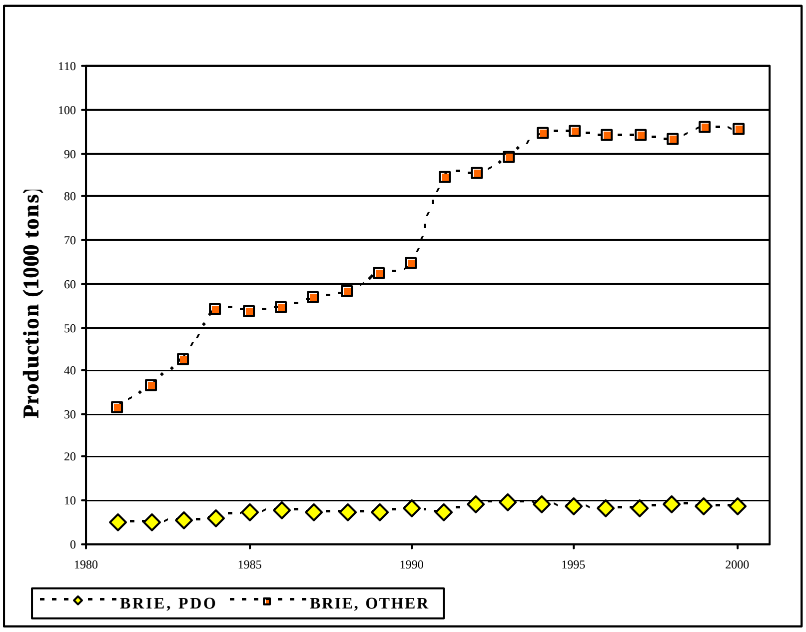


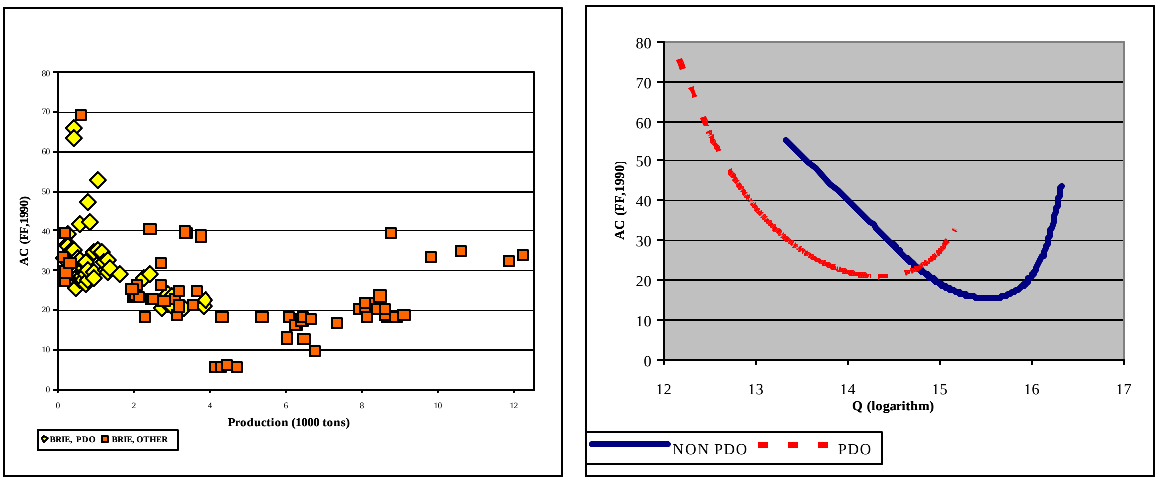
Figure 1. Comparative evolution of Brie cheese production.

In order to assess cost differences between PDO and non-PDO Brie producers, we select a sample of 128 observations on single product firms, which contain 67 PDO observations and 61 non-PDO observations. 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). This makes it impossible to disentangle costs attributed to each activity in multi-product companies. Working with single product firms also enables focusing on a single production technology, thus abstracting from issues related to multi-product cost economies of scope.

	PDO Brie	**Non-PDO Brie**
Number of observations	67	61
Q : Production (1000 tons)	1.1 *(0.9)*	5.13 *(3.08)*
CV: Total Variable Cost (MF)	32 *(22)*	364 *(576)*
Average Cost (FF/KG)	32 *(8.3)*	23 *(10.4)*
Average Price (FF/KG)	37 *(9)*	30 *(21)*
Profitability	0.04 *(0.05)*	0.06 *(0.12)*
Number of Employees	46 *(27)*	185 *(292)*
IMC : Physical Assets (MF)	12.7 *(13.4)*	106 *(163)*
INV : Total Investment (MF)	1.1 *(1.9)*	10.7 *(19.3)*

Standard deviations are indicated in parentheses.
Table 1. Summary statistics, single product brie cheese sample (means of variables).

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, as measured both by actual production and the value of total assets. Non-PDO producers also possess a higher number of employees, and achieve a lower average cost. Although PDO producers sell their product at a higher wholesale price on average, they also have a higher average cost of production. In this sample, non-PDO firms appear to have, on average, a slightly higher profitability than their PDO counterparts. Figure 2 below presents the plot of the sample's observed average cost, with the two groups of firms (PDO and non-PDO).



Costs are computed in 1990 prices, using the minimum wage and the raw milk price indices.
Figure 2: Average Cost Plot, PDO vs. non-PDO Brie producers and estimated Average Cost Curves

2.4 Estimation results

Figure 2 shows the estimated average cost curves under the retained specifications (c.f. Appendix for the results of different estimated specifications), both for the PDO and the non-PDO groups. As expected, both curves are U-shaped with a single minimum, with non-PDO firms minimizing average cost at a higher level of output than their PDO counterparts. Notice also that, at the minimum of both curves, the non-PDO firms achieve an average cost almost 25 per cent lower than the PDO firms. These estimated average cost curves thus confirm that Protected Designation of Origin legislation might cause firms not only to produce at a higher cost, but also to potentially benefit from diseconomies of scale. To see this, we calculate the Minimum Efficient Scale (MES) implied by the estimated average cost curve for PDO firms. The MES turns out to be situated at around $q^* = 1800$ tons, which is much higher than the average PDO production of 1100 tons in our sample. We use these two facts in the theoretical model we develop next to analyze the effects of PDO legislation on firm profits and welfare.

3. A Theoretical Model

We consider a modified version of Shapiro's (1983) reputation model, which is an infinitely repeated game. A good of quality $s \in \{\underline{s}, \overline{s}\}$ with $\overline{s} > \underline{s}$ can be produced at each period by a set of firms that behave collectively as a single entity. In this sense, we consider that they collude to maximize profits (similar to the approach followed by Marette et al., 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, and producing only the low quality good in each period. The marginal cost of producing both types of good is $c \in \{\underline{c}, \overline{c}\}$ with $\underline{c} < \overline{c}$. Without loss of generality, we assume that producing a higher quality good implies higher costs, and normalize $\underline{c} = 0$.

Since consumers do not have information about the quality offered by the cartel, the cartel can choose between two mechanisms to inform them when the quality produced is high. It can decide to certify the quality through a PDO policy, or to sink money in collective advertising. We assume that the quality produced by the cartel is chosen at the beginning of each period. If the cartel begins producing a high quality good in the first period, it can deviate and produce the low quality good in the following period. However, consumers discover the deviation in the next period, and then the cartel's reputation is lost. We will also consider below the case where deviation under certification is not feasible, due to a high detection cost that the certifying authority might impose.

Consumers have an indirect utility function $U = q s - p$ as in Mussa and Rosen (1978) and Shaked and Sutton (1982), where q is randomly distributed. The number of consumers is normalized to one without loss of generality. In particular, we assume that q is uniformly distributed in $[0,1]$, so demand functions become linear in price and quality. Straightforward computations show that demand, when only the low variety is produced by all players, becomes:

$$\underline{D}^1(\underline{p}) = 1 - \frac{\underline{p}}{\underline{s}}$$

Demand for the two varieties will be determined according to the mechanism chosen to signal quality (certification or advertising) in the next sections.

3.1 Public Certification

We reported earlier that the production of low non-PDO Brie grew by 150 per cent during the last 20 years, while the production of PDO Brie did not exceed 10 million tons/year. These empirical facts from the French Brie cheese industry support the idea that PDO certification can also play a secondary role by introducing capacity constraints. This would be the case if, for instance, firms are land constrained or technologically constrained by a given production process. For this, PDO certification does not only lead to rents, as only producers with this label have the access to consumers with high valuation. PDO certification also makes it optimal for firms to increase production, although this is too costly and may not even be feasible.

It can certainly be argued that producers of the high quality good are artificially constraining the market by setting a small quantity. However, this idea seems to be difficult to support if we assume that both goods are price substitutes. In effect, as it can be observed in the case of the Brie industry, the price and quantity of the low quality good have increased in the period under consideration. Therefore, demand of high quality shifts to the right following the Mussa and Rosen model. In such a case, it can be expected that producers will adjust production to artificially constrain the market, but this effect is not observed.

On top of that, we support that, in the long run, the technology exhibits some economies of scale. However, PDO legislation does not allow firms to benefit from such economies. Therefore, with this type of certification, an extra marginal cost denoted g is added to $\bar{c}$ when the high quality good is produced. This increment captures, as an approximation, the economies of scale lost due to the PDO policy. We can motivate this assumption by arguing that, in the absence of technological constraints, the best production technology leads to a marginal cost $\bar{c}$. However, this production process cannot be achieved, and the best technology attainable thus implies a marginal cost $\bar{c} + g$. This argument is similar in spirit to the one employed in Boccard and Wauthy (1999). The study assumes that marginal cost is constant up to a capacity K, and that producing beyond this capacity implies a higher constant unit marginal cost. We also assume, as in Marette et al. (1999), that PDO certification costs the cartel a fixed fee C. Straightforward computations show that demands when both varieties are produced become:

$$\bar{D}^{\bar{s}}(\bar{p}, \underline{p}) = 1 - \frac{\bar{p} - \underline{p}}{\bar{s} - \underline{s}}$$

$$\underline{D}^{\underline{s}}(\underline{p}, \bar{p}) = \frac{\bar{p} - \underline{p}}{\bar{s} - \underline{s}} - \frac{\underline{p}}{\underline{s}}$$

3.2 Advertising

Advertising, in contrast to public certification, does not constrain long-run technology, and marginal cost is still $\bar{c}$. However, we assume that consumers' perception about quality differs between the two mechanisms to signal quality. In particular, we assume that under advertising, consumers

perceive that quality is not as high as when the good is certified. This perceived quality is denoted by $\tilde{s}$ with $\tilde{s} > \underline{s}$. It can be interpreted as $\tilde{s} = \alpha \bar{s}$ with $\alpha \in (\frac{\underline{s}}{\bar{s}}, 1)$. α then captures inefficiency in the advertising campaign, or other wasteful expenditures. We assume that advertising costs some fixed amount A to the cartel. This type of advertising can be seen as a collective one, where it is in the cartel's interest to spend some money on improving the image of their product with respect to consumers.
Straightforward computations show that, when both varieties are produced, the demand functions become:

$$\bar{D}^{\tilde{s}}(\bar{p}, \underline{p}) = 1 - \frac{\bar{p} - \underline{p}}{\tilde{s} - \underline{s}}$$

$$\underline{D}^{\underline{s}}(\underline{p}, \bar{p}) = \frac{\bar{p} - \underline{p}}{\tilde{s} - \underline{s}} - \frac{\underline{p}}{\underline{s}}$$

In sum, certification allows for a better signal, but introduces a constraint in the set of technologies available. On the other hand, advertising cannot signal with the same intensity, yet grants the cartel access to better technologies (given some fixed advertising expenses).

4. Market Equilibrium and Welfare Implications

4.1 Equilibrium

We compute the Nash equilibrium of the dynamic game played by the cartel. In the first period, the cartel decides whether to certify, to opt for advertising or to produce the low quality good. 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: $\underline{p} = \underline{c} = 0$. Therefore, if the cartel produces this low quality, its profit becomes equal to zero. We consider the following strategy. The cartel in period $t = 0$ chooses to certify the good, and thus obtains the signal of good quality (certification of the low quality good is meaningless). The cartel then produces the same quality without deviation in all the following periods. The cartel therefore maximizes profit in the first period:

$$\underset{\bar{p}}{Max} \quad \bar{D}^{\bar{s}}(\bar{p}, 0)\left[\bar{p} - \bar{c} - g\right] - C$$

We denote the maximum profit (gross of the cost of certification) as $\bar{\pi}^C(\bar{c} + g)$. When the strategy is followed infinitely, $\bar{\pi}^C(\bar{c} + g)$ will be obtained in each period (discounted at $\delta = 1/(1 + r)$ where r is the interest rate). Total profits evaluated in the first period become:

$$\bar{\Pi}^C(\bar{c} + g, C) = \frac{\bar{\pi}^C(\bar{c} + g)}{1 - \delta} - C$$

We consider the same type of strategy (without deviation) when advertising is the instrument to signal quality. The cartel maximizes:

$$\underset{\bar{p}}{Max} \quad \bar{D}^{\tilde{s}}(\bar{p}, 0)\left[\bar{p} - \bar{c}\right] - A$$

We denote the maximum profit (gross of the cost of advertising) as $\bar{\pi}^A(\bar{c})$. Total profits evaluated in the first period become:

$$\bar{\Pi}^A(\bar{c}, A, \alpha) = \frac{\bar{\pi}^A(\bar{c}, \alpha)}{1 - \delta} - A$$

Comparing both results, and assuming that deviation to the low quality good is not profitable, we get the following:

Lemma 1. *In the first period of the game, certification dominates advertising if:*

$$\tilde{A} \geq \bar{s}\left(\frac{2g(\Delta-\bar{c})-g^2}{4(1-d)\Delta}\right)+(1-a)k(a) \qquad (2)$$

where $\tilde{A}=A-C$, $k(a)=\frac{\bar{c}^2-\Delta(\tilde{s}-\underline{s})}{4(1-d)\Delta(\tilde{s}-\underline{s})}$ =0 and $\Delta=\bar{s}-\underline{s}$.

Proof. This condition expresses that the discounted benefit under advertising cannot be larger than the one under certification: $\bar{\Pi}^C(\bar{c}+g,C)\geq\bar{\Pi}^A(\bar{c},A,a)$. This condition can be rewritten $\tilde{A}\geq\frac{\bar{p}^A(\bar{c},a)-\bar{p}^C(\bar{c}+g)}{(1-d)}$, Define $\tilde{A}$ as the difference between the fixed cost of advertising and the fixed cost of certification, we can re-write it as in equation (2). ¦

However, lemma 1 does not give the equilibrium, since the cartel may find it profitable to deviate in the following periods. Given the perception of quality of an advertised good relative to PDO certification, equation (1) expresses the tradeoff between the net cost of advertising and the extra cost linked to the PDO technology. There exists a level of the degree of diseconomies of scale $g^{\max}$ such that for all $g=g^{\max}$, $\bar{\Pi}^C(\bar{c}+g,C)<0$, and $\tilde{A}^{\max}$ such that for all $\tilde{A}=\tilde{A}^{\max}$, $\bar{\Pi}^A(\bar{c},A,a)<0$.
In figure 6, we show the relation between the net cost of advertising and the diseconomies of scale g for =1 and for =1.

To interpret this relation, we fix an arbitrary value of $\tilde{A}$. When g is equal to zero, certification dominates advertising. This is the case because there is no extra marginal cost distortion, consumers believe that quality is $\bar{s}$, and the fixed costs of advertising are larger than certification. As g increases, this marginal effect diminishes profits under certification, and thus advertising dominates certification. Suppose that a tends to one. Everything else being equal, the profitability of advertising increases as a tends close to 1, and the curve in figure 5 intercepts the origin (the dotted curve).
In addition, the cartel may find it optimal to deviate to the production of the low quality variety. In such a case, it benefits from its goodwill and from a reduction in marginal cost, but it looses its reputation.

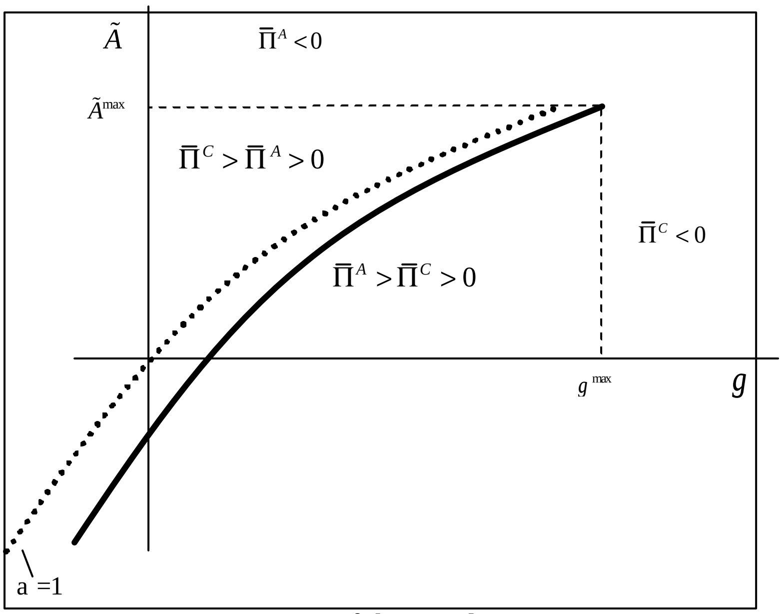


Figure 3. Private incentives of the cartel.

Consider now a possible deviation to a low quality product if certification has been chosen in the first period. Consumers expect a high quality good and demand is $\bar{D}^{\bar{s}}(\bar{p}, \underline{p})$, but marginal cost is equal to zero. We denote such a profit as $\bar{p}^{C,d}(\underline{c})$. The deviation is not profitable if:

$$\frac{\bar{p}^{C}(\bar{c}+g)}{1-d} \geq \bar{p}^{C}(\bar{c}+g)+d\bar{p}^{C,d}(\underline{c}).$$

Since profits when consumers discover the deviation become zero. Similarly, in the case of advertising, a deviation cannot be predicted, and leads to a demand $\bar{D}^{\bar{s}}(\bar{p}, \underline{p})$ with zero marginal cost. We denote such a profit $\bar{p}^{A,d}(\underline{c})$. The deviation is not profitable when:

$$\frac{\bar{p}^{A}(\bar{c},a)}{1-d} \geq \bar{p}^{A}(\bar{c},a)+d\bar{p}^{A,d}(\underline{c},a).$$

To be profitable, both deviation strategies (following certification or advertising) require different discount factors:

$$d^{C} \geq 1-\frac{\bar{p}^{C}(\bar{c}+g)}{\bar{p}^{C,d}(\underline{c})}$$

$$d^{A} \geq 1-\frac{\bar{p}^{A}(\bar{c},a)}{\bar{p}^{A,d}(\underline{c},a)}$$

Note that $\bar{p}^{C,d}(\underline{c}) > \bar{p}^{C}(\bar{c}+g)$ and $\bar{p}^{A,d}(\underline{c},a) > \bar{p}^{A}(\bar{c},a)$, but $d^{A} > or < d^{C}$. At the limit, when $a \to 1$, it is possible to conclude that $\bar{p}^{A}(\bar{c},1) > \bar{p}^{C}(\bar{c}+g)$. This is because, in the first case, marginal cost is equal to $\bar{c}$. Whereas in the second case, due to the diseconomies of scale, it is equal to $\bar{c}+g$, with $\bar{p}^{C,d}(\underline{c}) = \bar{p}^{A,d}(\underline{c},1)$. We thus get: $d^{A}(a \to 1) > d^{C}(a \to 1)$
This inequality indicates that reputation by certification can be supported with a lower discount rate if advertising perfectly signals the quality of the good.

We can now determine the Subgame Perfect Nash Equilibrium (SPNE) of this game using Condition 1 and the value of d given that $d^{A} > or < d^{C}$. The cartel has 4 strategies. It can choose a Public Certification (denoted by PC) or an Advertising Campaign (AC). It can produce the high quality good at each period $\{\bar{s}_t\}_{t=0}^{\infty}$, or it can produce the high quality good in the first period and then deviate to a low quality good in the following periods $\{\bar{s}_0, \underline{s}_t\}_{t=1}^{\infty}$. Each strategy is therefore a combination of a mechanism to signal quality and a per-period production decision. The following table characterizes the Subgame Perfect Nash Equilibrium (SPNE) of this game.

	$\bar{\Pi}^{C} \geq \bar{\Pi}^{A}$	$\bar{\Pi}^{C} < \bar{\Pi}^{A}$
$d \geq d^{A} > d^{C}$	$PC,\{\bar{s}_t\}_{t=0}^{\infty}$	$AC,\{\bar{s}_t\}_{t=0}^{\infty}$
$d^{A} > d \geq d^{C}$	$PC,\{\bar{s}_t\}_{t=0}^{\infty}$	$AC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$
$d^{A} > d^{C} > d$	$PC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$	$AC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$
$d \geq d^{C} > d^{A}$	$PC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$	$AC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$
$d^{C} > d \geq d^{A}$	$PC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$	$AC,\{\bar{s}_t\}_{t=0}^{\infty}$
$d^{C} > d^{A} > d$	$PC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$	$AC,\{\bar{s}_0,\underline{s}_t\}_{t=1.}^{\infty}$

Table 2. SPNE of the repeated game.

Given the audit mechanism required by the PDO legislation, the cartel may not be able to deviate under PDO certification. This could be observed by considering the discounted profits of the cartel as the expected value of producing the good, with the probability of being detected and not allowed to produce exactly equal to the discount rate d .A high detection probability would make the cartel never consider deviating.

Proposition 1. *When public certification entails a costly punishment in case of deviation, the SPNE is characterized by the cartel opting for public PDO certification or private advertising (depending whether Lemma 1 holds or not), and it never deviates from the production of high quality to low.*

Proof. From the subgame Perfect Nash Equilibrium outcome. ¦

4.2 Welfare

Having studied the cartel's incentive to opt for public certification or collective advertising, we now focus on the welfare impacts of PDO regulation as compared to private advertising.
We first determine the per-period consumer surplus when only the low variety is produced as:

$$\underline{cs}^1 = \int_{q_0}^{1} \left(q\underline{s} - \underline{p}^1 \right) dq$$

where $q_0 : \{q | q\underline{s} - \underline{p}^1\}$ by definition.
When certification is implemented the consumers' surplus becomes:

$$\overline{cs}^C = \int_{\tilde{q}^c}^{1} \left(q\overline{s} - \overline{p}^C \right) dq$$

$$\underline{cs}^C = \int_{q_0}^{\tilde{q}^c} \left(q\underline{s} - \underline{p}^C \right) dq$$

where $\tilde{q}^c : \{q | q\underline{s} - \underline{p}^C = q\overline{s} - \overline{p}^C\}$ by definition and $\overline{p}^C = \frac{1}{2}\left(\overline{c} + g + \Delta\right)$.
Finally, consumer surplus with advertising is equal to:

$$\overline{cs}^A = \int_{\tilde{q}^A}^{1} \left(qa\overline{s} - \overline{p}^A \right) dq$$

$$\underline{cs}^A = \int_{q_0}^{\tilde{q}^A} \left(q\underline{s} - \underline{p}^A \right) dq$$

Where $\tilde{q}^c : \{q | q\underline{s} - \underline{p}^A = qa\overline{s} - \overline{p}^A\}$ by definition, and $\overline{p}^A = \frac{1}{2}\left(\overline{c} + a\overline{s} - \underline{s}\right)$.

Note that, in any case, $\underline{p}^1 = \underline{p}^c = \underline{p}^A = \underline{c}$, since the market of the low quality good is competitive by assumption. We summarize the welfare effects of the PDO common labeling policy versus private collective advertising in the following proposition.

Proposition 2.
i) Low quality consumers are better-off under certification than under advertising, while the high quality consumers can be better or worse-off. The difference between total consumer surplus under certification and advertising becomes ambiguous.
ii) If aggregate consumer surplus is lower when there are two qualities on the market, eliminating the second variety (through deviation) improves overall consumer welfare (however, the high valuation consumers are worse-off).
iii) Denoting $g(a) = \frac{3\overline{s}}{8} \frac{\overline{c}^2 - \Delta(\tilde{s} - \underline{s})}{(1-d)\Delta(\tilde{s} - \underline{s})}$. *Welfare is larger under certification if and only if:*

$$\overline{\Pi}^C + CS^C \geq \overline{\Pi}^A + CS^A$$

or

$$A \geq \frac{3(2g(\Delta - \overline{c}) - g^2)}{8(1-d)\Delta} + (1-a)g(a)$$

iv) Total profits can be larger under certification than under advertising, while consumers' surplus may be the other way.

Proof. *i)* We compare the difference in per-period consumer surplus under certification and advertising:

$$\overline{cs}^C + \underline{cs}^C - \left[\underline{cs}^A + \underline{cs}^A\right] =$$

$$\int_{\tilde{q}^c}^{1}\left(q\bar{s} - \bar{p}^C\right)dq + \int_{q_0}^{\tilde{q}^c} q\underline{s}dq - \left[\int_{\tilde{q}^A}^{1}\left(q\bar{s} - \bar{p}^A\right)dq + \int_{q_0}^{\tilde{q}^A} q\underline{s}dq\right] =$$

We use $\tilde{q}^c = \bar{p}^C/\Delta$, $\tilde{q}^A = \bar{p}^A/\Delta$, in addition to $\bar{p}^C = \left(\bar{c} + g + \Delta\right)/2$ and $\bar{p}^A = \left(\bar{c} + \Delta\right)/2$, to find that:

$$\overline{cs}^C + \underline{cs}^C - \left[\underline{cs}^A + \underline{cs}^A\right] = \frac{g\,(g - 2(\Delta - \bar{c})}{8\Delta} > or < 0$$

ii) Independently of the mechanism used to signal quality, if total consumer surplus is lower when the high quality good is introduced, the loss of reputation may help to improve this surplus.
iii) A complex manipulation would show this result.
iv) We have $g < 2(\Delta - \bar{c})$, which guarantees positive quantities. This means that $\Delta > \bar{c}$, which implies $CS^A > CS^C$. When $a < 1$, a value $g > 0$ can be found such that, even without the fixed costs of advertising, $\Pi^C > \Pi^A$. We consider $a = 1$. We choose any $g \in (0, 2(\Delta - \bar{c}))$., and call this value $\hat{g}$. Therefore, and given equation2, $\Pi^C > \Pi^A$ for fixed costs of advertising larger than

$$\frac{2\hat{g}\,(\Delta - \bar{c}) - \hat{g}^2}{4(1-d)\Delta};$$

The following figure compares the welfare impact under advertising and PDO certification.

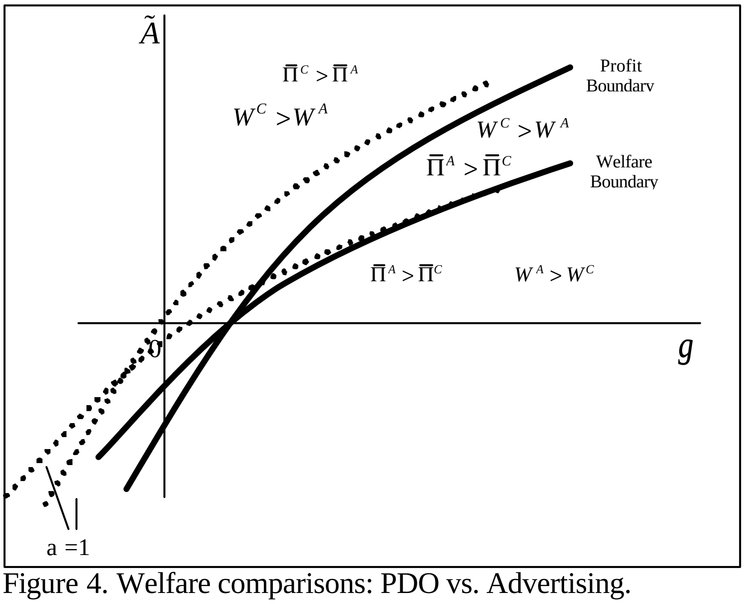


Figure 4. Welfare comparisons: PDO vs. Advertising.

It can be shown that both curves intersect at zero fixed costs. On top of that, when $a = 1$, that is when the efficiency of advertising on the willingness to pay of the high quality consumers is as good as in the case of certification, the intersection of both curves occurs at $g = 0$ (the dotted curves).
As it can be observed, there are regions where the optimal mechanisms between private benefit and social welfare coincide. However, for intermediate values of diseconomies of scale and sunk costs, the optimal mechanisms differ with respect to private benefit (cartel's profit) and social welfare. In this last case, there is room for public intervention to restore the efficiency of PDO certification.

5. Conclusion

This paper studies a particular type of public labeling program, the Protected Designation of Origin (PDO). Unlike other policies, we have argued that PDO regulation induces technology constraints on firms linked to a specific processing requirement and production area. This type of certification implies technological requirements that are most of the time not fulfilled above a production threshold. To motivate this fact, we have evaluated the average cost functions of PDO versus non-PDO firms. Our econometric estimation results clearly indicate that PDO firms face a costlier technology and do not enjoy economies of scale.

We used this empirical finding to construct a simple model to analyze the efficiency of PDO certification. To inform consumers about its high quality product, a group of firms (assumed to behave as a cartel) can certify its product through a PDO process or advertise it. A key ingredient in our model is that we capture the degree of diseconomy of scale which indicates the increment in marginal cost the cartel faces when operating under the PDO certification. We find that the cartel chooses to certify its product or advertise based on a tradeoff between the sunk costs of advertising (net of certification costs) and the degree of diseconomies of scale.

Second, we show that when public certification entails a costly punishment in case of deviation, the Sub-game Perfect Nash Equilibrium (SPNE) of the repeated game is characterized by the cartel opting for public PDO certification or private advertising, and it never deviates from the production of high to low quality. Moreover, we find that low quality consumers are better off under certification than under advertising, while the high quality consumers can be better or worse off. However, the difference between total consumer surplus under certification and advertising is ambiguous. Finally, total welfare under certification can be higher or lower than under advertising, depending on the tradeoff between sunk advertising costs and the degree of diseconomies of scale (for a given set of consumer perceptions on advertising). For large diseconomies of scale and intermediate difference between advertising and PDO certification cost, government intervention may restore efficiency.

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Appendix: Cost Function Estimation Results

Variables		PDO *(PDO)*	Non PDO *(NP)*
Dependent	Variable cost (logs) CV	LNCVPDO	LNCVNP
Independent	Production (tons) Q	QPDO	QNP
	Production (logs)	LNQPDO	LNQNP
	Production (square logs)	LNQSQUPDO	LNQSQUNP
Instruments	Size of assets (logs) IMC	LNIMCPDO	LNIMCNP
	Investment (logs) INV	LNINVPDO	LNINVNP
	Ratio : Investment/Sales	IRPDO	IRNP

Table A.1. Definitions of variables used.

Dependent Variable: LNCVNP			***NP***
Variable	Coefficient	Std. Error	t-Statistic
C	-107.913	28.158	-3.832
QNP	0.068	0.014	4.863
RESIDNP	**-0.005**	**0.007**	**-0.787**
LNQNP	18.234	4.255	4.284
LNQSQUNP	-0.667	0.160	-4.165
R-squared	0.852		

Table A.2.a. OLS regression, LNCVNP on variables including residual.

Dependent Variable: LNCVNP			***NP***
Variable	Coefficient	Std. Error	t-Statistic
C	-113.683	27.099	-4.195
QNP	0.0642	0.012	4.954
LNQNP	19.088	4.101	4.653
LNQSQUNP	-0.696	0.154	-4.498
R-squared	0.851		

Table A.3.a Retained: OLS regression, LNCVNP.

Dependent Variable: LNCVPDO			***PDO2***
Variable	Coefficient	Std. Error	t-Statistic
C	31.066	26.826	1.158
QPDO	-0.037	0.032	-1.150
RESIDPDO	**-0.012**	**0.014**	**-0.895**
LNQPDO	-3.381	4.202	-0.804
LNQSQUPDO	0.174	0.165	1.055
R-squared	0.924		

Table A.2.b: OLS regression, LNCVPDO on variables including residual

Dependent Variable: LNCVPDO			***PDO3***
Variable	Coefficient	Std. Error	t-Statistic
C	29.079	26.692	1.089
QPDO	-0.046	0.030	-1.536
LNQPDO	**-3.042**	**4.178**	**-0.728**
LNQSQUPDO	**0.160**	**0.164**	**0.979**
R-squared	0.923		

Table A.3.b. OLS regression, LNCVPDO.

Dependent Variable: LNCVPDO			***PDO4***
Variable	Coefficient	Std. Error	t-Statistic
C	16.387	0.057	283.883
QPDO	0.058	0.004	14.445
R-squared	0.762		

Table A.3.c. Retained: OLS regression, LNCVPDO with parameter restrictions.