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Product Ecolabeling, Competition and the Environment

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Abstract

The paper explores the impact of a third-party product ecolabel (i.e. green label) on competition and the environment, and the firms' strategies during the negotiation of the minimum environmental requirements underlying a product's eligibility for the ecolabel. The introduction includes some empirical observation about the development of the European ecolabel. The second part presents the model. We assume Cournot competition in a homogenous industry made up of multi-product firms each selling the whole range of product-variants, from green to brown. Green consumers "trust" the ecolabel. We derive demand, supply, prices and profits at the equilibrium before and after ecolabel. We first assume that firms do not innovate on their products. We then introduce environmental innovation into the model. The third part analyses the impact of the ecolabel on competition (firms' profits) and the environment (green innovation and market shares). The conclusion contrasts the results with the ones obtained in the case of a heterogeneous industry – i.e., an industry made up of mono-product firms each selling a product having a environmental profile different than that of the other firms' products- and draws policy considerations. The paper expands the literature on product ecolabeling by considering imperfect competition, giving thus the possibility for the firms to undertake green innovations affecting non marginal costs, and by taking into account the type of industry concerned by the ecolabel. We find that firms in a homogenous industry are better off with an ecolabel than without and might even be willing to adopt environmentally effective criteria if the green demand is important and innovation costs are low. This contrasts with results obtained in a previous paper for a heterogeneous industry, in which part of the firms will always loose from the implementation of an environmentally effective ecolabel and oppose its development. Cross-industry comparison suggests that regulators should start developing ecolabeling programs with homogenous industry in which innovation costs are likely to be negligible as compared to the costs of production.

Non-Technical Abstract

In 1992, the European Union (EU) adopted an ecolabeling (i.e. green label) program (CEE, 1992). This decision was part of a broader trend towards the development of these programs, which has taken place since the beginning of the nineties. There are approximately twenty national ecolabeling programs in effect in the OECD. Countries like China, India, South Korea, Malaysia, Singapore, Taiwan, and Thailand have also implemented such programs.

Ecolabeling programs are an instance of Public Voluntary Programs. They are targeted at a product's environmental quality: firms can voluntarily participate in them in order to signal to the consumers that their products are more friendly to the natural environment than non-ecolabeled products. The ecolabeling process

is made up of two phases. The first one, the "negotiation phase", is aimed at devising minimum environmental requirements that any product eligible for the ecolabel has to meet. These requirements are called the ecolabeling criteria. When these criteria are adopted, firms can apply for ecolabeling their products and ecolabeled products can be exchanged in the market place: this is the second phase or "market phase". By dividing the market into two segments - the green (ecolabeled) and the brown (non-ecolabeled) segments, the implementation of the ecolabel modifies the competition and the firms' profits. On the green segment, firms can benefit form green consumers' willingness to pay extra for the green products but the firms whose products do not already meet the criteria have to innovate on their product in order to enter into this segment. Hence green firms profits depend on the importance of the green demand, on the importance of the costs of innovation in the industry, and on the stringency of the ecolabeling criteria. As these criteria also determine 'How Green' ecolabeled products will be, they impact on the environmental effectiveness of the ecolabel. A major question for the policy makers is what strategy to adopt during the negotiation of the criteria in order to: obtain firms co-operation to their development during the negotiation phase, entice firms to innovate during the market phase, or reduce the overall ratio of green over brown market share.

The paper explores the impact of a product ecolabel on competition and the environment, and the firms' strategies during the negotiation of the ecolabeling. The introduction includes some empirical observation about the development of the European ecolabel. The second part presents the model. We consider a homogenous industry made up of multi-product firms each selling the whole range of product-variants, from green to brown. Green consumers "trust" the ecolabel. We derive demand, supply, prices and profits at the equilibrium before and after ecolabel. We first assume that firms do not innovate on their products. We then introduce environmental innovation into the model. The third part analyses the impact of the ecolabel on competition (firms' profits) and the environment (green innovation and market shares). The conclusion contrasts the results with the ones obtained in the case of a heterogeneous industry – i.e., an industry made up of mono-product firms each selling a product having a environmental profile different than that of the other firms' - and draws policy considerations. The paper expands the literature on product ecolabeling by considering imperfect competition, giving thus the possibility for firms to earn positive profits and undertake green innovations affecting non marginal costs, and by taking into account the type of industry concerned by the ecolabel. We find that firms in a homogenous industry are better of with an ecolabel than without and might even be willing to adopt environmentally effective criteria if the green demand is important and innovation costs are low. This contrasts with results obtained in a previous paper for a heterogeneous industry, in which part of the firms will always loose from the implementation of an environmentally effective ecolabel and oppose its development. Cross-industry comparison suggests that regulators should start developing ecolabeling programs with homogenous industry in which innovation costs are likely to be negligible as compared to the costs of production.

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1. Introduction

The relationship between competition and the efficiency of voluntary approaches to regulation is a concern that has recently emerged in the field of environmental regulation (OECD, [20]). Some papers have already explored through formal models the feasibility and the environmental effectiveness of voluntary agreements (e.g. Segerson and Miceli, [27] ; Wu and Babcock, [25]) but the question of competition in relation to these issues has retained less attention (Arora S., Gangopadhyay S., [1]).

This paper examines the relationship between competition, environmental efficiency and the feasibility of voluntary approaches based on the evidence of product environmental labeling.

National ecolabeling programs started proliferating worldwide at the beginning of the nineties. They are probably the most common type of expert label at the current time. Regulators have implemented them in order to induce green innovations or to increase the market share of green products. More than twenty programs are in effect in the OECD (OECD, [19]). According to the US, some of the most developed ones are currently in place in the US (e.g. the “Energy Star” Program) (EPA, [8]). In 1992, the European Union (EU) adopted an ecolabeling program (CEE, [3]). Brazil, China, India, South Korea, Malaysia, Singapore, Taiwan, and Thailand also adopted national schemes over the past decade.

Ecolabeling programs are an instance of voluntary environmental program. Firms can voluntarily participate into them and ecolabel the products meeting some minimum environmental requirements called the *ecolabeling criteria*. This allows the firms to signal to the consumers that these products are more respectful of the natural environment than non-ecolabeled products. Ecolabeling criteria are negotiated between interest groups, including industrial trade associations, and the regulator (OECD, [19]).

Economists have examined the relation between competition and the environmental effectiveness of these programs. They suggest that green demand might provide firms with incentive to comply beyond regulatory requirements (Arora and Gangopadhyay, [1]; Crampes and Ibanez, [7]; Kirchhoff, [10]). They also argue that green (ecolabeled) firms might always gain from the implementation of an ecolabel while its impact on brown (non-ecolabeled) firms depended on the ecolabel *selectivity* – i.e., the percentage of products granted with the eligibility for the ecolabel without any change in their environmental performance (Mattoo and Singh, [12]; Sedjo and Swallow, [24]). While these models provide insight on the impact of product ecolabels on competition and the environment, their shortcomings have also been discussed (Nadaï and Morel, [15]). First, by assuming perfect competition on each market segment (green and brown), they only allow taking account of green innovations that affect marginal costs (Sedjo and Swallow, [24]). Second, these analyses are based on signaling, reputation, or market differentiation models. Such models rely on the ability of the consumer to assess product quality and drive the market to an efficient equilibrium. Either they suppose that consumers know the product quality beforehand or that they get to experience it after purchase and if need be will sanction fraudulent sellers by no longer purchasing the products from them (or by publicly criticizing the product). Recent psychological and anthropological approach to green consumerism has shown that such assumptions overstate the consumers' ability to assess green quality (Wagner, [26]). Even the most educated green consumers rely on proxies such as brand names or labels in order to select green products. Rarely are they able to assess the relevance of the environmental requirements underlying these labels. In turn, these requirements are a key variable for the suppliers, because they set the minimum technical standard that their products have to meet in order to capture the 'trusting' green demand. The negotiation of the ecolabeling criteria proves to be a key step in the development of product ecolabels. For instance, successes and failures in the development of the European ecolabels have been related to the type of strategy undertaken by industry during this negotiation (Nadaï, [17]). While economists have focused on the market stage, they have overlooked this institutional dimension of product ecolabeling. Even more interestingly, the degree of technological heterogeneity in the concerned industry - i.e., the extent to which the environmental performance of the products sold by the different firms are different – has been found to influence industry's strategy vis-a-vis the ecolabel. In a heterogeneous industry, in which each firm is selling a product having a different environmental profile than that of the other firms, the negotiation of the ecolabeling criteria raises tension among firms. It triggers the opposition of part of them and renders the development of the ecolabel difficult. This has been illustrated with the negotiation of the European ecolabel for detergent products (Nadaï, [16])[1]. It has also been modeled by the means of a two-stage model including the negotiation of the ecolabeling criteria and a Cournot competition on the market segmented by the ecolabel (Nadai & Morel, [15]). Results show that in such an industry stringent ecolabeling criteria might generate positive environmental effects by inducing green innovation[2] or increasing the ratio of green over brown products. On the contrary, non-selective criteria might increase negative environmental spillovers by boosting the product market volume and decreasing the ratio of green over brown products. It is also confirmed that green firms' profits will increase with the implementation of the ecolabel, while brown firms' profits might decrease. As a consequence, environmentally effective criteria (i.e., selective criteria) will exclude most of the firms of the industry and trigger their opposition since they might loose from its implementation.

In this paper, we examine the case of a homogenous industry. This case has been illustrated with the negotiation of the EU ecolabel for indoor paints and varnishes (Nadaï, [18]). Stakeholders have regarded this negotiation as an exemplary case of co-operation between industry and public authorities in the development of product ecolabels. As of June 1998, this ecolabel accounted for 50% of the products ecolabeled at the European level, making it the most successful in this ecolabeling program. A salient feature in this case study was that leading paint producers did not have opposing interests in the devising of the ecolabeling criteria. Except for the brand names, they were all selling identical sets of products - from the greenest to the brownest - and expecting at least some of them to be eligible for the ecolabel (as well as some not to be). Hence, they cooperated in the development of this ecolabel because they expected to share the benefit, if any, that it could generate.

The model presented in this paper is an extension of Nadaï & Morel [15] to the case of a homogenous industry, that is *an industry made up of multi-product firms each selling the whole range of product environmental profiles*. Firms are engaged in a Cournot competition. They have the possibility to undertake green innovation in order to render their product eligible for the ecolabel. Incentive to do so is provided by the fact that part of the consumers is willing to pay-extra for green products. These green consumers are assumed to trust the ecolabel, meaning that ecolabeled products are perceived as green regardless of the content of the criteria. Nadaï & Morel [15] have extensively discussed the relevance of this assumption.

Results show that all firms gain from the implementation of an ecolabel: they will agree on profit maximizing criteria, even if some of them might increase their profits to a lower extent than others. It is also shown that only stringent criteria might increase the ratio of green over brown market shares or entice firms to innovate on their products. While such criteria will not always maximize private profits, firms will prefer a compromise with the regulator on sub-optimal criteria to no ecolabel. As a result, there is room for a compromise that will be beneficial to both private firms and the environment, and the more important the green demand, the broader the window for "win-win" criteria. More importantly, it is shown that under the current values of the green demand in most developed countries, an ecolabel will induce green innovations only if the costs of innovation in the concerned industry are of an order of magnitude that is negligible as compared to the costs of production.

The paper is structured as follows. The second part presents the model. We derive demand, supply, prices and profits at the equilibrium before and after ecolabel. We first assume that firms do not innovate on their products. We then introduce environmental innovation into the model. The third part analyses the impact of the ecolabel on competition (firms' profits) and the environment (green innovation and market shares). The conclusion contrasts the results with the ones obtained in the case of a heterogeneous industry and draws policy considerations.

2. Model

The ecolabel is modeled as a two-stage game. In a first stage, the criteria are given and firms compete in the market place. In a second stage, firms optimize the value of the criteria so as to maximize their individual profits.

We suppose a K-firm homogeneous industry that is all firms are each selling the whole range of T products from the greenest to the brownest. Hence, there are KT products on the market. As firms are multi-product each *firm* is described by a subscript $i\in[0,K]$, each *product* by a subscript $i\in[0,K]$ referring to the firm producing it and a superscript $t\in[0,T]$ referring to the product's environmental profile.

We present the elementary assumptions regarding demand, supply, and derive the market equilibrium before and after ecolabel. This is undertaken in two contexts: without innovation and with innovation. Under each context, we examine if there is any value of the criteria that can maximize firms' profits and lead to a compromise of criteria between the regulator and the firms.

2.1. Demand

Surveys concerning the structure of green demand (Coddington [4], p83/84)[3] show that about one-quarter of the Americans qualify as genuinely green, one half of that group appearing to be deep-green. The remaining three-quarters of the population is either "*green-ish*", expressing a willingness to buy or pay green but *"... only sometimes putting their wallets where their mouths are*", or brown and overlooking green quality. Figures are less coherent regarding the value of consumers' willingness to pay extra for green products. While Coddington [4] and Scarlett [23] report that green consumer do not seem ready to pay any premium for green products, other sources report positive willingness up to 20-30% higher (e.g. Morris J., [14] ; Ropper Organization Inc., [22]).

Such values are generally taken as valid for most developed countries and the situation is generally modeled by dividing the population of consumers into two types (e.g. Mattoo and Singh, [12]). A population of green consumers considering green products and displaying a willingness to pay extra for them, and a population of brown consumers who are indifferent to green quality. Provided the other features of green and brown products are similar, brown consumers will buy the cheapest variant of the product, be it green or not.

2.11. The general form of consumers utility function: basic assumptions

There are N consumers, m of them being green ($m<N$). Two qualities of products are proposed by the firms: green or brown products. Green consumers buy green products. Brown consumers buy the cheapest product. Each consumer purchases *at most one unit of product*, an assumption that is standard in the product differentiation literature and in the product ecolabel literature (Coestier, [5]; Hotelling, [9]; Mattoo and Singh, [12]; Sedjo and Swallow, [24]).

For each group of consumers, individual utility is a linear function of the price. It displays features that are also standard in the product differentiation literature (Beath and Kastoulacos, [2]), the environmental differentiation literature (Linnemer and Perrot, [11]; Maxwell, J.W., [13]; Coestier B., [5]), and the consumer research literature (Corneo and Jeanne, [6]; Raman and Chhajed, [21]):

$$U = \vartheta k - p$$

where k describes the quality of the product as the consumers perceive it. The preference parameter ϑ characterizes a consumer's taste for the quality. It is assumed that consumers vary in their taste for the quality, that is, in each population of consumers, ϑ is uniformly distributed between 0 and 1.

The utility derived by green consumers from green products is given by:

$$U_g = \vartheta k_g - p_g$$

where k_g designates the green quality and p_g the price on the green (ecolabeled) market segment. Consumers' "trust" in the ecolabel is reflected by the fact that *k_g keeps the same value even if the criteria and, hence, the environmental profile of ecolabeled products are modified.*

The utility that brown consumers derive from any product is given by:

$$U_b = \vartheta k_b - p_b$$

with similar notation and $k_b < k_g$.[4]

As the final demand is modified by the implementation of the ecolabel, we have to distinguish between the situations before and after the ecolabel is implemented.

2.12. Final demand before ecolabel

Before ecolabel, the environmental quality is not signaled to the consumers. Therefore, all products appear as if they were brown and green consumers cannot garner additional utility by buying green products. If the equilibrium price is p_o, the utility of all consumers is:

$$U_o = \vartheta k_b - p_o$$

Demand is equal to the fraction of consumers, whose utility U_0 is positive, i.e. such that: $\frac{p_o}{k_b} \le \vartheta \le 1$, that is:

$$D_o = N\left(1-\frac{p_o}{k_b}\right) \qquad 2.1$$

Hence, each of the KT products receives the same demand equal to:

$$D_o^t = \frac{N}{KT}\left(1-\frac{p_o}{k_b}\right)$$

2.13. Final demand after ecolabel

After the implementation of the ecolabel, both supply and demand become differentiated. Green consumers purchase products on the ecolabeled segment; brown consumers purchase the cheapest type of product. Firms choose whether or not to ecolabel their products. The market is divided into two segments, the green (ecolabeled) and the brown (non-ecolabeled) segments, with two prices at equilibrium: p_b and p_g.

The N-m brown consumers, indifferent to the ecolabel, will each buy one unit of the cheapest product if this leaves them with a positive utility. That is, if $p_0 = \min(p_g, p_b)$, the brown demand is given by:

$$D_b = (N-m)\left(1-\frac{p_0}{k_b}\right)$$

Yet, if $p_g < p_b$, brown consumers will shift to green products until $p_g = p_b$. Therefore, we always have $p_o = p_b$, and:

$$D_b = (N-m)\left(1-\frac{p_b}{k_b}\right) \qquad 1.2$$

For similar reasons, the green demand is given by:

$$D_g = m(1-\frac{p_g}{k_g}) \qquad 1.3$$

Total demand is:

$$D = D_b + D_g = (N-m)(1-\frac{p_b}{k_b}) + m(1-\frac{p_g}{k_g}) \qquad 1.4$$

2.2. Costs, supply, price and profits before ecolabel

As a general matter, profit for firm "i" is given by the sum of the profits on its T products, that is:

$$\pi_i = \sum_{t=1}^{T} q_i^t \left[P(\sum_{i=1}^{K} \sum_{t=1}^{T} q_i^t) - C_i \right] \qquad 2.1$$

We suppose a Cournot competition. Total supply is derived by maximizing each firm's profit given the other firms' output, and by adding individual supply at the equilibrium. We assume that each firm optimizes independently the output of each of its products, taking the output of its other own products as given. Hence, a firm's total output is calculated by maximizing the firm's profit on each of its product and by aggregating its output on all of its products.

All firms are assumed to have identical unit production cost *before* ecolabeling, that is: $\forall$i, $\forall$t, C_i^t=C.

Since firms have identical cost conditions and the products are identical for the consumers, there is a unique price on the market: $P(D_0)=p_o$. Output and profit are also identical on all products. Denoting q_0 and π_0 a firms' outcome and profit *on a product* at equilibrium, we have:

$$\pi_0 = q_0 \left[P(Kq_0) - C \right]$$

Standard Cournot calculation (cf. Appendix A1) gives:

$$p_0 = \frac{KTC + k_b}{KT + 1} \qquad 2.6$$

$$q_0 = \frac{N}{k_b} \left(\frac{k_b - C}{KT + 1} \right) \qquad 2.6bis$$

$$\pi_0 = \frac{N}{k_b} \left(\frac{k_b - C}{KT + 1} \right)^2 \qquad 2.7$$

2.3. Cost functions after ecolabel

We distinguish between green (ecolabeled) and brown (non-ecolabeled) products. We assume that «t», a product's superscript, describes its environmental profile, with increasing superscripts corresponding to increasingly polluting products. While the cost of producing a brown product remains unchanged with the implementation of the ecolabel, this is not the case for green products. Indeed, some products will have to be modified in order to become eligible for the ecolabel and enter in the ecolabeled segment.

If e is the value of the ecolabeling criteria, $e \in [0,T]$, any product $t \leq e$ is eligible for the ecolabel without modification. On the contrary, any product $t > e$ has to be converted into a "e" product in order to become eligible for the ecolabel. [5] The innovation allowing a product to *become* eligible for the ecolabel is called "*environmental innovation*". Accordingly, $C_{t,e}$, the *cost of environmental innovation* is a firm's cost of entrance with product t in the ecolabeled segment.

We assume that the unitary cost of innovation is proportional to the change in index allowed by the concerned innovation. The innovation allowing product t to be converted into product j has a unitary cost $C_{t,j} = |t-j|/V$, where V is a constant specific to the industry ($V \geq 1$)[6].

Accordingly, the *cost of environmental innovation* is given by:

$C_{t,e} = 0$ if $t \leq e$,
$C_{t,e} = (t-e)/V$, if $t > e$,

And unitary costs of production after ecolabel are:

On the brown segment:	C	
On the green segment:	C	for products $t \leq e$
	$C+(t-e)/V$	for products $t > e$

As each product is produced by K firms under similar cost conditions (including increasing costs of environmental innovation with t), all K firms will enter in the green segment with product "t" before any of them can undertake an entry in this segment with a product "t+1".

If e is the adopted environmental criteria and G_{te} is the number of product undergoing innovations to meet the criteria, $e+G_{te}+1$ designates the maximum subscript among green products. Then at equilibrium:

1. The K firms have products $t \leq e$ into the green segment without any innovation,
2. The K firms have innovated on products $e < t \leq e+G_{te}$ in order to sell them in the green segment,
3. n of the K firms ($0 < n \leq K$) have innovated in order to sell product "$e+G_{te}+1$" in the green segment.
4. The other products are sold in the brown segment.

The distribution of the products at equilibrium is given by Table 1 (Cf. Tables section at the end of the paper), that is:

. Ke products enter into the green segment without requiring any green innovation.

. $K(G_{te})+n$ products are submitted to environmental innovation in order to enter into the green segment (with $0 < n \leq K$).

. $K(T-e-G_{te})-n$ products are sold in the brown segment (with $0 \leq n < K$).

The model has been normalized against the pre-ecolabel situation, assuming C=1 and k_b=C+1.[7] Hence, the relevant parameters for the discussion are: the number of firms K, the number of products per firm T, the quality ratio k_g/k_b, the population ratio m/(N-m), and, when there is innovation, the constant of innovation 1/V.[8]

We first examine the equilibrium assuming there is no innovation and then introduce innovation in the model.

2.4. Supply, prices, and profits without innovation after ecolabel

As firms are not assumed to innovate, they will sell the products having a profile t≤e on the green segment and the other products on the brown segment. We derive total supply and price by maximizing a firm's profit on each of its products and by equalizing total supply with total demand. On each market segment, products are identical for the consumers and there is a unique price: p_g on the green segment and p_b on the brown segment. As there is no innovation, firms also have identical cost conditions on all products. Hence, outputs and profits are identical over each group of products. Cournot calculation on the green segment gives (cf. Appendix A2):

$$p_g = \frac{k_g + KCe}{Ke + 1} \qquad 4.1$$

$$q_g = \frac{m}{k_g}\left(\frac{k_g - C}{Ke + 1}\right) \qquad 4.1bis$$

$$\pi_g = \frac{m}{k_g}\left[\frac{k_g - C}{Ke + 1}\right]^2 \qquad 4.2$$

In the same way, on the *brown* segment, we obtain:

$$p_b = \frac{k_b + KC(T - e)}{K(T - e) + 1} \qquad 4.3$$

$$q_b = \frac{(N - m)}{k_b}\left(\frac{k_b - C}{K(T - e) + 1}\right) \qquad 4.3bis$$

$$\pi_b = \frac{N-m}{k_b}\left[\frac{k_b - C}{K(T-e)+1}\right]^2 \qquad 4.4$$

It can be demonstrated that:

i. The green price p_g is a decreasing functions of e and the brown price p_b is an increasing function of e.
ii. Both p_g and p_b are superior to p_o the price before ecolabel.

(Cf. Proof in Appendix A3.)

Consequently, there is a value of the criteria e_p for which the green and brown price curves will cross. Beyond e_p the criteria allow so many firms to enter into the green segment at no cost that, were all these firms to enter into it, p_g would fall below p_b. Such a situation would not be a equilibrium, for brown consumers would then prefer to buy green products until both prices equalize, that is p_b=p_g. At equilibrium, this results in *a cannibalization of the brown segment induced by the brown demand-side*.

Computation through Mathematica for a large spectrum of values of K, T and k_g/k_b shows that e_p only depends on the quality ratio k_b/k_g and the number of products T (Cf. Figure 1).

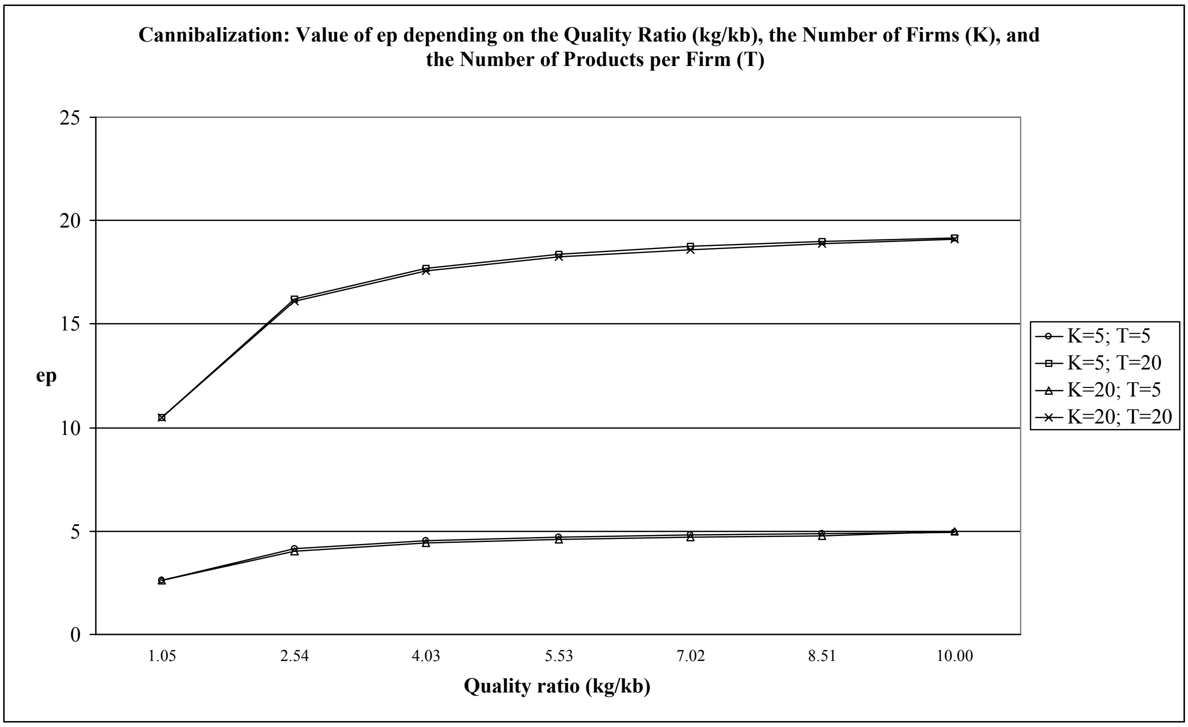

Figure 1

Equalizing p_g and p_b gives:

$$e_p = \frac{(k_g - k_b)}{K(k_g + k_b - 2C)} + \frac{T(k_g - C)}{(k_g + k_b - 2C)}$$

which shows that e_p depends also on K but as K appears at the numerator, its influence on the value of e_p is negligible.

Beyond e_p, the final demand can be written as follows:

$$D_b = (1-\beta)(N-m)(1-\frac{p_{bc}}{k_b})$$

$$D_g = m(1-\frac{p_{gc}}{k_g}) + \beta(N-m)(1-\frac{p_{gc}}{k_b})$$

Where β is the proportion of brown consumers purchasing a green product at the equilibrium; p_{bc} and p_{bc} are the green and brown price under cannibalization. At equilibrium $p_{gc}=p_{bc}$.

We have to slightly distort the Cournot paradigm in order to catch the effect of cannibalization in the analysis. As shown by equations 4.1, the Cournot price on the brown segment only depends on the number of firms K, the number of products T, and on k_b. The reason for this is that, under a Cournot competition, firms consider the population of consumers they serve as constant. They optimize quantities so as to maximize their profits on this population[9]. While relevant when the market is segmented, such a strategy becomes obsolete when competition from green products induces part of the brown consumers to leave the brown market segment.

In what follows, we consider that the decrease in the brown demand may appear to brown firms as a decrease in brown consumers' willingness to pay for the product. We define k_{bc} as the value of brown quality such that the final demand from a reduced (1-ß)(N-m) population of brown consumers valuing brown quality at νk_b is equal to the final demand from the entire (N-m) population of brown consumers valuing the brown quality at νk_{bc}.

The brown demand can be written:

$$D_b = (1-\beta)(N-m)\left(1-\frac{p_{bc}}{k_b}\right) = (N-m)\left(1-\frac{p_{bc}}{k_{bc}}\right) \quad 4.5$$

which gives,

$$p_{bc} = \frac{k_{bc} + KC(T-e)}{K(T-e)+1} \qquad 4.6$$

Equalizing total demand and supply on the green segment, we obtain:

$$D_g = m(1 - \frac{p_{gc}}{k_g}) + \beta(N-m)(1 - \frac{p_{gc}}{k_b}) = Keq_g$$

with $q_g = -\frac{\partial q_g}{\partial p_g}(p_{gc} - C) = -(\frac{m}{k_g} + \frac{\beta(N-m)}{k_b})(p_{gc} - C)$

that is $m(1 - \frac{p_{gc}}{k_g}) + \beta(N-m)(1 - \frac{p_{gc}}{k_b}) = Ke(\frac{m}{k_g} + \frac{\beta(N-m)}{k_b})(p_{gc} - C)$

this gives $p_{gc} = \frac{KeC}{Ke+1} + \frac{\left(\frac{m}{N-m} + \beta\right)}{(Ke+1)\left(\frac{m}{(N-m)k_g} + \frac{\beta}{k_b}\right)}$ 4.7

Profits are first examined under cannibalization, then under market segmentation.

Under cannibalization ($e>e_p$), a firm's total profit is given by:

$$\pi = \left[\frac{m}{k_g} + \frac{(N-m)}{k_b}\right](p_{gc} - C)^2$$

It can be demonstrated that:

iii. The profit under cannibalization is a decreasing function of e. Hence, firms will be better off with criteria equal to e_p than with criteria superior to e_p.

(Cf. Proof in Appendix A3)

The intuition behind this result is that cannibalization increases the competition on price and erodes both the market price and firms' profits. Indeed, as e increases firms are allowed to sell more products on the green segment. Supply increases on this segment. This depresses the green price, attracts additional brown consumers in this segment, and induces browns firms to react by decreasing the brown price in order to limit the leak of brown consumers.

Under market segmentation, ($e \leq e_p$) a firm's aggregate profit is given by:

$$\pi = e\pi_g + (T - e)\pi_b$$

It can be demonstrated that:

iv. A firm's profit on the green segment $e\pi_g$ is a decreasing functions of e while a firm's profit on the brown segment $(T\text{-}e)\pi_b$ is an increasing function of e.

v. A firm's total profit under ecolabel is superior to its profit before ecolabel.

vi. π is convex($\partial^2\pi/\partial e^2>0$), so that maximum profit will be earned by firms with extreme criteria, that is either e=1 or $e=e_p$.

(Proofs for results iv to vi are provided in the Appendix A3.)

Moreover, computation through Mathematica for different values of K, T shows that:

vii. For low values of the final green demand, firms will be better off with very permissive criteria ($e=e_p$). For high values of the final demand, firms will be better off with very stringent criteria (e=1).

Figure 2 provides the value of the population and quality ratios (resp. m/(N-m) and k_g/k_b) for which the profits are equal in e=1 and $e=e_p$, depending on the number K of firms and T of products per firm. It shows that for firms to be interested in e=1, it is necessary that the green demand reaches a minimum value.

Figure 2

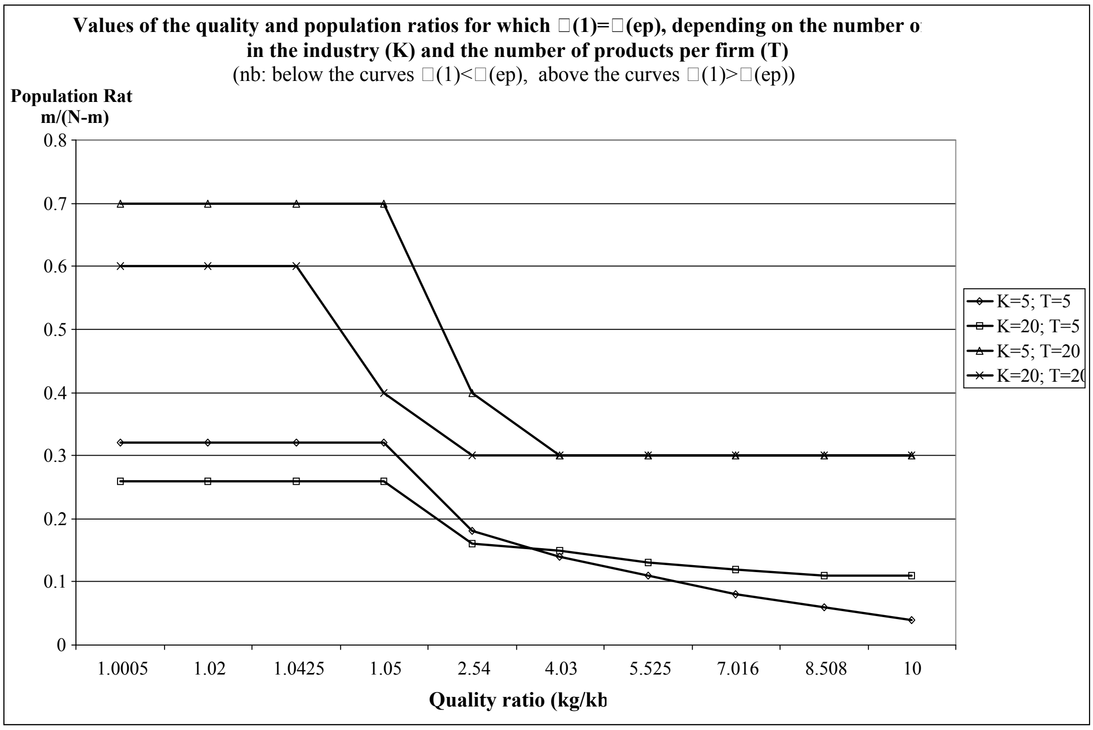

Table II (cf. Tables section) expresses the results as a minimum condition on the population ratio. When these conditions are not met, firms will seek for criteria equal to e_p.

The logic behind these results is that when the green demand is high the green profit drives the total profit and when it is low, the brown profit drives the total profit. Hence, results can be explained as follows. Prices and profits under Cournot competition are proportional to the number of products in competition. When firms have no possibility to innovate on their products, criteria determine this number in each segment. At each extreme of the spectrum of criteria, supply on one segment is restricted. When criteria are very stringent (e.g. e=1), supply is restricted on the green segment, green profits are high and brown profits are low. When criteria are not selective (e.g. $e=e_p$), supply is restricted on the brown segment, green profits are low and brown profits are high. As total profit is the sum of green and brown profit, depending on the importance of the green demand, either the green or the brown profit will prevail in making up total profit. Simulation shows that for low values of both the quality and population ratio (weak green demand), the total profit tends to increase with e, as does the brown profit. On the contrary, when the green demand is high, the total profit tends to decrease with e, as does the green profit. Accordingly, when the total profit is a decreasing function of e (strong green demand), firms will be better off with e=1; when it is an increasing function of e (weak green demand), firms will be better off with $e=e_p$.

2.5. Supply, prices and profits with innovation after ecolabel

On the Green segment, firms $i_{|1\leq i\leq n}$ innovate on product G_{te}+e+1 while firms $i_{|n<i\leq K}$ do not (cf. Table I, Tables section). The first ones sell this product on the green segment while the second ones keep on selling it on the brown segment. We have thus to distinguish between these two groups of firms as follows:

$$\pi_{1<i\leq n,g} = \sum_{t=1}^{e} q_i^t(p_g - C) + \sum_{t=e+1}^{e+G_{te}} q_i^t(p_g - C - \frac{(t-e)}{V})$$

$$\pi_{n<i\leq K,g} = \sum_{t=1}^{e} q_i^t(p_g - C) + \sum_{t=e+1}^{e+G_{te}+1} q_i^t(p_g - C - \frac{(t-e)}{V})$$

Standard Cournot calculation gives:

For t≤e, $$q_i^t = \frac{m}{k_g}\sum_{i=1}^{K}(p_g - C)$$

For e<t≤e+G_{te}, $q_i^t = \frac{m}{k_g}\sum_{i=1}^{K}(p_g - C - \frac{(t-e)}{V})$

For t=e+G_{te}+1, $q_i^t = \frac{m}{k_g}\sum_{i=1}^{n}(p_g - C - \frac{(G_{te}+1)}{V})$

and $$p_g = \frac{k_g + C\left[K\left(e+G_{te}\right)+n\right] + \frac{K}{2V}G_{te}(G_{te}+1) + \frac{n}{V}\left(G_{te}+1\right)}{K\left(G_{te}+e\right)+n+1}$$

On the *brown segment*, the same reasoning gives:

For e+G_{te}+2≤t≤T, $q_i^t = (\frac{N-m}{k_b})\sum_{i=1}^{K}\left(p_b - C\right)$

For t=e+G_{te}+1, $q_i^t = (\frac{N-m}{k_b})\sum_{i=n+1}^{K}\left(p_b - C\right)$

and $$p_b = \frac{k_b + C\left[K(T-e-G_{te})-n\right]}{K(T-e-G_{te})-n+1}$$

Profits are then calculated by introducing prices in expression of total profits, that is:

$$\pi_{1\le i\le n} = \sum_{t=1}^{e} q_i^t(p_g - C) + \sum_{t=e+1}^{e+G_{te}+1} q_i^t(p_g - C - \frac{(t-e)}{V}) + \sum_{t=e+G_{te}+2}^{T} q_i^t(p_b - C)$$

$$\pi_{n\le i\le K} = \sum_{t=1}^{e} q_i^t(p_g - C) + \sum_{t=e+1}^{e+G_{te}} q_i^t(p_g - C - \frac{(t-e)}{V}) + \sum_{t=e+G_{te}+1}^{T} q_i^t(p_b - C)$$

The equilibrium condition is that *firm n is indifferent between innovating on product $G_{t,e}$+e+1 or not* (Cf. Table 1, Tables section), which gives:

$$\sum_{t=1}^{e} q_n^t(p_g\left(G_{t,e},n,e\right) - C) + \sum_{t=e+1}^{e=G_{te}+e+1} q_n^t(p_g\left(G_{t,e},n,e\right) - C - \frac{(t-e)}{V}) + \sum_{t=G_{te}+e+2}^{e=T} q_n^t(p_b\left(G_{t,e},n,e\right) - C)$$
$$= \sum_{t=1}^{e} q_n^t(p_g\left(G_{t,e},n-1,e\right) - C) + \sum_{t=e+1}^{e=G_{te}+e} q_n^t(p_g\left(G_{t,e},n-1,e\right) - C - \frac{(t-e)}{V}) + \sum_{t=G_{te}+e+1}^{e=T} q_n^t(p_b\left(G_{t,e},n-1,e\right) - C)$$

denoting p_g and p_b as $p_g(G_{t,e},n,e)$ and $p_b(G_{t,e},n,e)$, in order to make clear that they are function of $G_{t,e}$, n, and e.

Given the complexity of this equation, it has been solved by the means of a two-stage simulation through Mathematica. In a first stage, it is supposed that n=0 and the model is solved for G_{te}. In a second stage, the value of G_{te} is introduced as an exogenous variable and the model is solved for n. Simulations show that profit curves displays the same shape than when there is no innovation. Green profit is a decreasing function of e while brown profit is an increasing function of e. These profit curves cross at a point e_{π} whose location depends on the population and quality ratio. Total profit is a concave function that remains superior to the profit before ecolabel. When the green demand is not important, the total profit tends to increase with e, and *vice versa*. For intermediary values of the quality and population ratios, the total profit first decreases and then increases when e increases.

Hence, the general results obtained when there was no innovation remain valid when firms have the possibility to innovate on their products - i.e., profit maximizing criteria are either in e=1 or $e=e_p$ depending on the value of the green demand.

However, when $n \neq 0$, some firm innovate on product $e+G_{te}+1$ while others do not, and profits are no longer identical for all firms. For reasons that will be made clear below (Cf. impact of the ecolabel on innovation), this occurs under selective criteria and increases the profits of innovating firms in e=1, hence expanding the range of green demand configurations under which firms will seek for selective criteria.

Table III (Cf. Tables section) gives the difference of value between the total profit of the firms for the two extreme values of e: e=1 and $e=e_p$. The K firms are divided in two sets: those which innovate and those which do not innovate the product e+Gte+1. The difference between the two profits reflect the interplay between the dependence of the profits in k_g/k_b , K and the ratio m/(N-m).

The larger k_g/k_b, the larger e_p. This is due to the fact that the green price is larger when k_g is larger. e_p eventually gets so close to T (around kg/kb=5), that the product e_p+1 is the same as the "T" product. For those values, there may be boundary effects.

Important is what happens for lower values of k_g/k_b. If the prices do not depend strongly on the number of firms K, the same is not true with the profits. (e.g. see eq. 4.2 and 4.4 in a context without innovation). The green profit is maximum for e small and decreases monotically with e, whereas the brown profit is maximum for e large and decreases when e decreases. So the green profit is maximum at e=1 and drives the profits for this value of criteria. Symmetrically, the brown profit is maximum and drives the total profit at $e=e_p$. The smaller the number of firms the larger the profit in both cases. The value and sometimes even the sign of the difference between the profits in e=1 and $e=e_p$ is modulated by the value of the population ratio m/(N-m).

Moreover, the green profit is proportional to m, whereas the brown profit is proportional to N-m. So when m/(N-m) is small, the green profit is multiplied by a smaller number than the brown profit. As a result the brown profit at $e=e_p$ can even become larger than the green profit at e=1, for low values of m/(N-m). Whereas when m/(N-m) is large the green profit at e=1 tends to be larger the brown profit at $e=e_p$.

3. The impact of the ecolabel on competition and the environment

We examine in this part the impact of the ecolabel on green innovation, competition, and market shares depending on the values of parameters K, T, k_g/k_b, m/(N-m), and 1/V.

3.1. Innovation

Innovation allows firms to match supply and demand in each market segment and to eventually increase total profit. Yet, green innovation has multiple effects that might conflict with each other. It changes the profit on the modified product (from brown to green profit, minus innovation cost). It increases the brown price and profit by reducing the supply on the brown segment. It decreases the green price and profits by increasing the supply on the green segment.

Accordingly, depending on where the crossing point e_π between green and brown profit curves is located, two mechanisms induce innovation in the model (Cf. Figure 2bis). When the green profit curve is *above* the brown profit curve ($e<e_\pi$), higher green profits might induce innovation by *"pulling"* additional products into the green segments. When the green profit curve is *below* the brown profit curve ($e_\pi<e<e_p$), the prospect of higher brown profits might induce innovation by *"pushing"* additional products outside of the brown segment into the green segment.

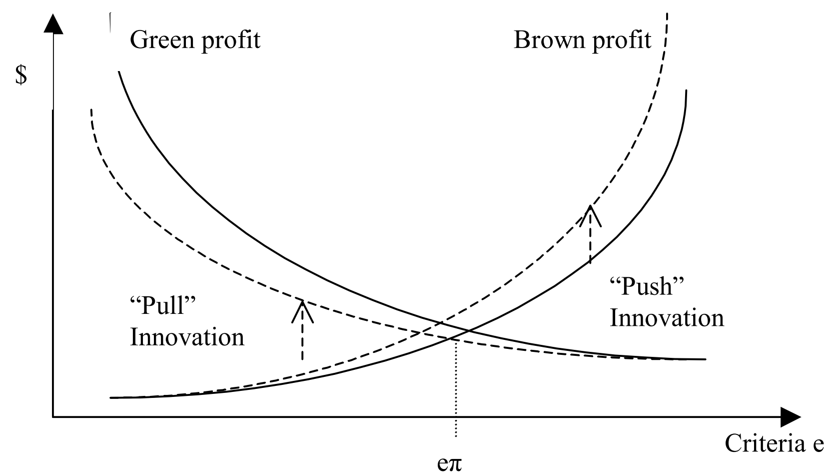

Figure 2bis: The pull and push mechanisms behind green innovation

The *"pull" mechanism* takes place for high values of the green profit. This corresponds to the region of selective criteria over which the green profit steeply decreases and the brown profit slowly increases as the criteria become more permissive[10]. As any additional entry in the green segment dramatically reduces the green profit in this region, the green profit curves tends to meet very quickly the brown profit curve. As a result, the number of "pull" innovations is always potentially limited.

By contrast, the *"push" mechanism* can be significant. It takes place for high values of the brown profit, which correspond to permissive criteria, a region over which the brown profit steeply increases and the green profit slowly decreases as the criteria become more permissive. As over this region any additional entry in the green segment significantly increases the brown profit without noticeably reducing the green profit, this mechanism is potentially significant. It is limited either by the decrease in the green price, or by cannibalization in e_p. Indeed, as supply increases in the green segment, p_g decreases. It might become equal to p_b, at which point there is no longer any incentive for innovation. Alternatively, it might become inferior to C-(t-e)/V, point at which firms can no longer recover innovation costs.

Some results are recurrent in the simulations:

ix. When the green demand is very low (i.e., k_g/k_b and m/(N-m) small enough), e_π is small and the "push" mechanism is predominant. A significant number of innovations can be obtained for high values of the criteria if e_p is high enough (i.e., k_g/k_b important enough). In turn, an ideal configuration for this is the one in which m/(N-m) is very small (0,005 to 0,05) and k_g/k_b very high (2 or higher).

x. When the green demand is important (i.e., k_g/k_b and m/(N-m) important), e_π is high and the "pull" mechanism is predominant. Some green innovations are obtained for selective criteria. Yet, as the green profits are steeply decreasing over this range of criteria, the number of green innovations is always limited. Typically, the "pull" mechanisms generates equilibria in which $G_{te}=0$ and n=1 for very selective criteria ($e<e_\pi$).

While these are the main insight provided by the model, another salient result is that:

xi. The lower the value of innovation cost the greater the number of green innovations at equilibrium.

This result is quite intuitive since, other things being equal, low innovations costs makes it more likely for innovations to be profitable. In the model, the constant *V* captures this effect and plays a critical role. For instance, under realistic values of the population and quality ratio[11], "pull" innovations are only obtained for values of V equal or superior to 20 (Cf. Tables 4.1 to 4.3 in Tables section) , innovation is induced for selective values of e only for V>10).

3.2. Competition

The competitive position of the firms is approximated by their profits. We examine the change in profits induced by the ecolabel, depending on the criteria and according to two dimensions: i) the change in a firm's profit before and after ecolabel, ii) the differences between different firm's profit under ecolabel (hereafter called "relative competitiveness"). We then derive the criteria that each firm might seek to obtain in order to maximize its profits after ecolabel.

When firms do not have the possibility to innovate, they all have identical profits at equilibrium and profits are higher than before ecolabel. The implementation of the ecolabel results in an increase in green consumers' willingness to pay for the products, which is equally split among firms. Yet, profit-maximizing criteria depend on the importance of the final green demand. When the green demand is important, firms will seek for very stringent criteria (i.e., e=1); when it is not important, firms will seek for criteria equal to e_p.

When firms have the possibility to innovate, results are only slightly modified. While profit maximizing criteria are still either in e=1 or in $e=e_p$, the ecolabel might generate some heterogeneity among firms' profits. This is the case when $n\neq0$, that is when only some firms find it profitable to innovate on the marginal product $e+G_{te}+e$. These firms will earn higher profits at equilibrium[12].

3.3. Products' market shares

Detractors of the ecolabel suspect it to increase the overall environmental spillover generated by a product by boosting the product's market volume. While this question is difficult to examine when the ecolabel induces a modification in the environmental profile of some products (i.e., $G_{te}\neq0$ or $n\neq0$)[13], it is possible to answer it *when there is no green innovation* (i.e., $G_{te}=0$ and n=0). In such a case, the evolution of green and brown products market shares allows answering the question of the environmental impact of the ecolabel. Indeed, the ecolabel has only two effects: i) it modifies the total market volume and changes the relative market shares of green and/or brown products. We disentangle these effects by examining two ratios over the region of criteria leading to market segmentation with no innovation.

These ratios are:

. R_1 = Total Demand After Ecolabel/Total Demand Before Ecolabel

R_1 indicates the *quantitative* impact of the ecolabel on the *total market volume*.

. R_2 = (Green demand After Ecolabel/Total Demand After Ecolabel) / (Green (implicit) Demand Before Ecolabel / Total Demand Before Ecolabel)

R_2 reflects the *qualitative impact of the ecolabel.* It indicates the change in the qualitative composition (i.e. green market share /total market volume)[14] of the market induced by the ecolabel. "Implicit" green demand designates the demand that was served by the green firms before ecolabel. As before ecolabel all firms had identical market shares, the mathematical expression of this ratio is $R_1=(D_g/D)/(e/T)$. When $R_2>1$, the ecolabel improves the environmental quality of the market by increasing the relative market share of green products, and *vice versa.*

It can be demonstrated that:

xii. R_1 is a concave function of e (i.e. $\partial^2 R_1/\partial e^2<0$)

(Cf. proof in Appendix A6).

Intuitively, the variation of R_1 can be understood by noting that the brown demand is always reduced by the ecolabel while the green demand might be higher or lower than the demand before ecolabel. Under Cournot competition, demand is inversely proportional to the ratio "price/willingness to pay for the product" (cf. eq 1.2 to 1.4, demand = population.(1-p/k)). As the prices after ecolabel are always superior to the price before ecolabel, the change in demand ultimately depends on the change in consumers' willingness to pay (WTP) for the products relatively to this price increase. Accordingly, as brown consumers willingness to pay or the product remains unchanged, the brown demand is always reduced by the ecolabel ($p_b>p_0$ and k_b is unchanged). The higher p_b the greater the reduction. Different from this, as green consumers' WTP is increased, the green demand might be increased or decreased by the ecolabel depending on the value of p_g/k_g as compared to p_o/k_b. Other things being equal, the higher p_g the more likely the green demand is decreased (or the less likely it is increased to a great extent). As p_g or p_b are steeply increasing when the criteria become extreme, it is understandable that R_1 is convex. When criteria are very stringent, p_g is very high and the green demand can be decreased or less increased than with more permissive criteria. When criteria are very permissive, p_b is very high. This reduces the brown demand and depresses R_1.

Computation for different values of the parameters also shows that:

xiii. When the green demand is low, R_1 maximum is inferior to 1, so that the ecolabel always reduces the market volume. On the contrary, when the green demand is important, $R_1=1$ has two solutions in e, hereafter called "min" and "max" solutions. In between these two values of criteria, the ecolabel will increase the market volume; outside of them it will reduce it.

xiv. R_2 is a concave function of e. Other than e =T [15], $R_2=1$ has one solution "e_2" that located in its decreasing part. This means that, when criteria are set beyond this value, the implementation of the ecolabel decreases the ratio of green over brown products.

Contrary to the other results obtained in a context without innovation, no analytical proof is provided in order to generalize results xiii and xiv for all values of the parameters. They have been obtained through simulations with Mathematica over quite a large range of values of the parameters, values for which they hold.

Different from other results, these results have not been backed by general analytical or intuitive considerations.

Result xiii stems from the fact that, when the population or quality ratios are high, it is more likely that the increase in the green demand will be important enough so as to more than compensate the decrease in the brown demand ($R_1 > 1$), and *vice versa*.

Concerning result *xiv*, analytical exploration suggests that $\partial R_2/\partial e$ is increasing, decreasing, and increasing again when e increases. Whether or not the decreasing part of R_2 curve is located over the values of e under consideration seems to depend on the values of the parameters**.** When the case, having R_2 decrease means that, as e increases, the ratio "Green Market Share/Total Market Volume" becomes increasingly smaller after ecolabel as compared to what it would have been before ecolabel, *had the same definition of "greenness" be taken into account*.

This result might seem puzzling. Indeed, while the green market share increases and the brown market share decreases as e increases, the qualitative composition of the market becomes worse compared the pre-ecolabel situation. The reason for this is that the analytical expression of R_2 *compares the pre- and post-ecolabel market according the same definition of "greenness": e.* Indeed, when deciding on "How Green is Green", the negotiation phase ends up also assessing the "greenness" of the pre-ecolabel market (i.e., among the K firms, "e" were already green in the pre-ecolabel situation). The benchmark to which to compare D_g/D is then this assessment, that is e/K[16]. The decrease in the qualitative composition of the market as e increases reflects the fact that relaxing the value judgement about "How Green is Green" increases *more* the "implicit" green market share in the pre-ecolabel market than it increases the actual green market share in the post-ecolabel market.

Figure 3 and 4[17] display the results of the simulations for T=20 (K = 5 and 20). They show that e_2 is most often located in between the "min" and "max" solutions to R1=1. Consequently, criteria superior to e_2 might increase environmental spillovers by boosting the market volume and decreasing the ratio of green/brown products. For most values of the quality and population ratio, e_2 is also comprised between 1 and e_p.

As was shown in Table II (cf. Tables section), firms might prefer $e=e_p$ if the green demand is not significant. This means that:

xv. When there is no innovation, for low values of the green demand firms will seek for environmentally ineffective criteria ($e=e_p$), and vice-versa.

For instance, in the case where T=20, firms will only prefer e=1 if m/(N-m)≥0,7 when kg/kb≤1,05, or if m/(N-m)≥0,3 when kg/kb>1,05 (i.e., more than 25% green consumers willing to pay 5% or more extra for green products). If not the case, they will seek for $e=e_p$.

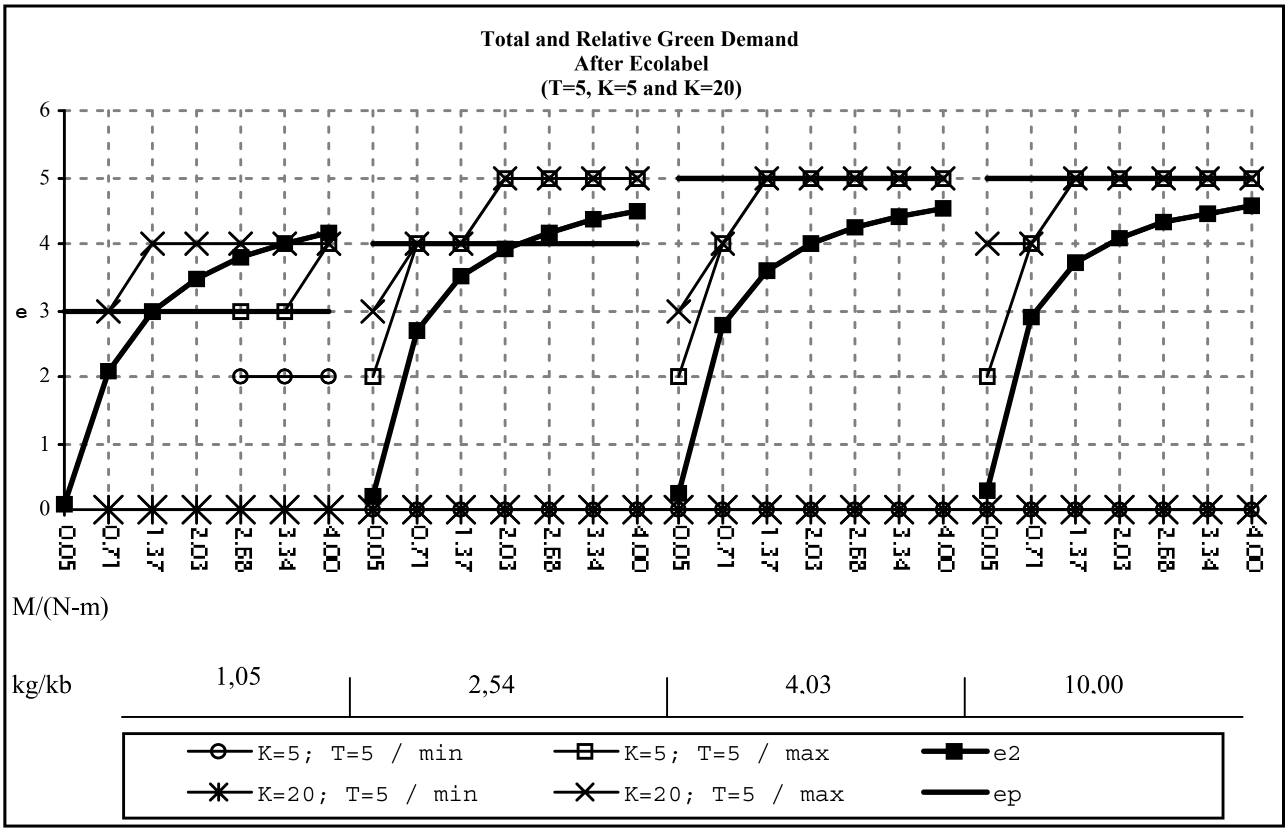

Figure 3

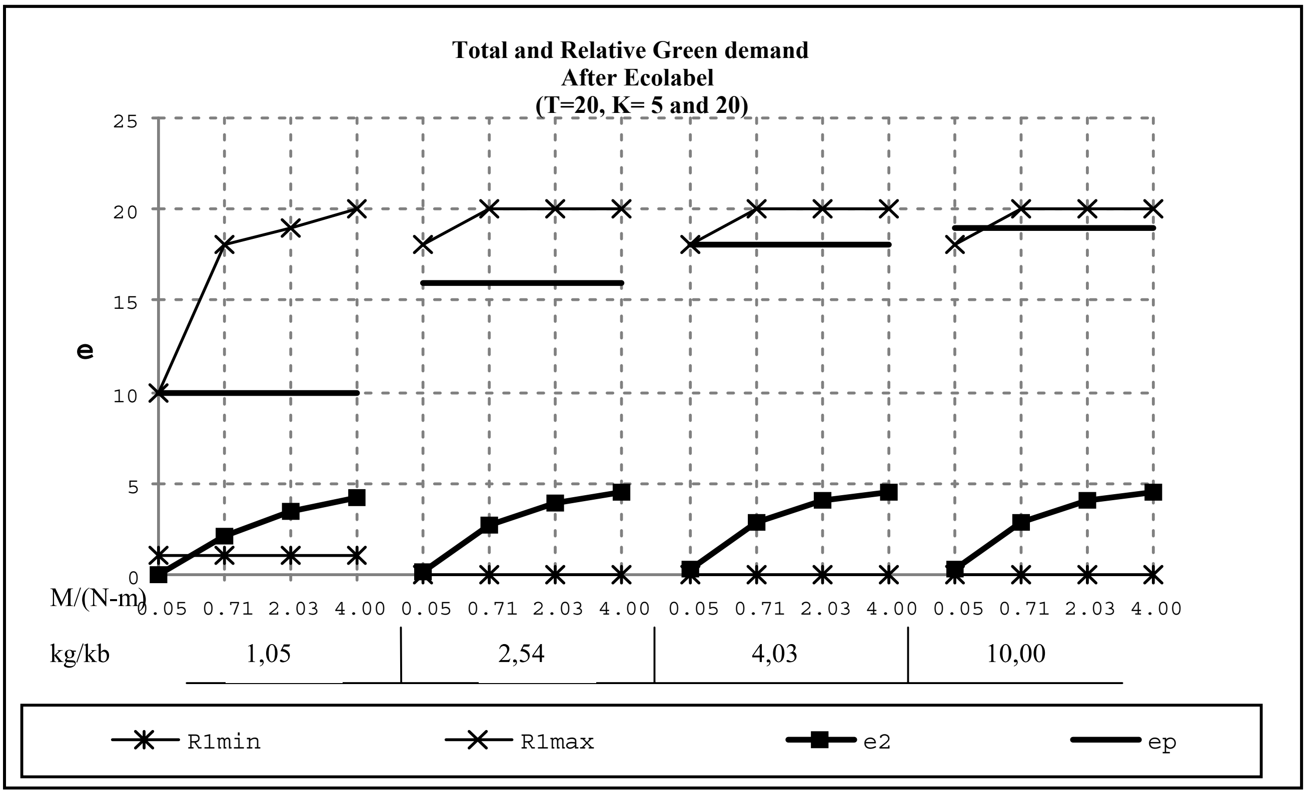
Total and Relative Green demand
After Ecolabel
(T=20, K= 5 and 20)
25
20
15
10
5
0
e
M/(N-m)
0.05 0.71 2.03 4.00 0.05 0.71 2.03 4.00 0.05 0.71 2.03 4.00 0.05 0.71 2.03 4.00
kg/kb
1,05
2,54
4,03
10,00
R1min
R1max
e2
ep

Figure 4

4. Conclusion

Results leads to policy considerations that are interesting to contrast with the case of a heterogeneous industry (Nadaï & Morel, [15]). Three key variables determine the feasibility and the environmental effectiveness of an colabel: innovation costs, green demand, and the degree of technical heterogeneity in industry.

As far as the *homogenous industry* is concerned, a major result is that the ecolabel will leave all firms better off, even if it might affect the relative competitiveness of some them. Despite of these possible differences in profits after ecolabel, firms will most often converge on the criteria maximizing their individual profit. There will be few or no tension among them and the industry will be willing to co-operate with the regulator in order to develop the ecolabel. This includes a possible compromise on sub-optimal (i.e., non-profit maximizing) criteria, if industry's interest is not aligned with the regulator's one (i.e., increasing the ratio green/brown products or inducing green innovation). In short*, there is room for a compromise on win-win criteria*, beneficial to both private firms and the environment.

However, if innovation costs are of an order of magnitude that is comparable to production costs, there is no way an ecolabel can generate green innovation under the actual values of the green demand in most developed countries (i.e., $m/(N-m) \leq 0.2$ or 0.3; $k_g/k_b \leq 1.2$). An increase in the ratio green/brown market shares might be obtained, with no modification of the products' environmental profiles. Only selective criteria might guarantee such an outcome but firms will prefer lax criteria ($e=e_p$) under the actual values of the green demand. Hence, a negotiating strategy seeking for very selective criteria might be the only safe proxy for environmental effectiveness.

If innovation costs are very small as compared to production costs (e.g. $1/V \leq 1/20$), the ecolabel may induce green innovation but the criteria have to be properly chosen. The importance of the green demand is then decisive for the regulator's strategy.

If the green demand is important, "*pull*" innovation, resulting from expectation of high profits on green products, may be induced by very selective criteria. As such criteria are also profit-maximizing (i.e., the total profit is a decreasing function of e), firms' and regulator's interests are identical. In this ideal configuration, the regulator might only act as a facilitator (i.e., producing information about the product's market, LCA, and informing value judgements on trade-off between environmental spillover, etc) and let the industry decide on the content of the ecolabeling criteria. In short, these are conditions under which industry self-regulation might potentially be successful and environmentally efficient. Unfortunately, such conditions are quite rare, if not inexistent at the current time.

Under the current state of the green demand, "*push*" innovation may be induced by intermediary criteria (e_π<e<e_p). It results from the expectation of a rise in brown profits consecutive to a reduction in brown supply. "Push" innovation may even be significant if the criteria are closer to e_π rather than to e_p. As e_p are profit-maximizing criteria (i.e., total profit is an increasing function of e until the point of cannibalization), firms' and regulator's interests are not identical. In order to obtain environmental effectiveness, the regulator will have to ask for more stringent criteria than the one proposed by industry.

Interestingly, these results are different than the ones obtained in the case of a heterogeneous industry. In the homogenous industry, green innovation is a flexibility allowing firms to maximize their total profit by playing on the number of products they supply in each market segment. In a heterogeneous industry, firms are mono-product, each selling a product having a different environmental profile, and they have to choose in which market segment to sell. The firms having a product browner than the criteria are at a disadvantage because they have to finance innovation in order to enter in the green segment. Green innovation is a drawback and each firm seeks for criteria allowing it to get a free entry in the green segment while minimizing the number of its competitors that will do so. As a result, a salient difference with the case of the homogenous industry is that profit-maximizing criteria are not identical for the different firms, and brown firms always loose from the implementation of an ecolabel and oppose it. Moreover, as firms are mono product pull innovation is the only type of innovation that can take place and selective criteria are the only safe proxy the regulator can choose in order to guarantee environmental effectiveness. These criteria exclude part of the firms from the program, making them into brown firms, and triggering their opposition to the ecolabel. Low innovation cost and high green demand might smoothen these tensions by allowing for some profitable green innovation, making more firms into the green type and gaining their cooperation in the development of the ecolabel. Yet, the opposition of part of the firms remain since it is unlikely that all firms will find it profitable to innovate under the current state of the green demand.

Cross-industry comparison suggests that regulators should start developing ecolabeling programs with homogenous industry in which innovation costs are likely to be negligible as compared to the costs of production. This might allow regulators to establish these programs, before facing more difficult configuration of negotiation in heterogeneous industry. This result is coherent with what has been observed in the development of the European ecolabel (cf. in the introduction of this paper, the comparison of the development of the paint and varnishes ecolabel with that of the detergent ecolabel in the European Union).

Regarding the selectivity issue, no robust strategy steam out of the results. Indeed, under the current values of the green demand, selective criteria are the only relevant strategy for inducing environmental effectiveness in a heterogeneous industry with small innovation costs. This is not necessarily the case in a homogenous industry: selective criteria might ensure “static” environmental effectiveness by increasing the relative market share of green products but might miss the window of “push” innovations.

Beyond these conclusions the model casts light on some pre requisite for successful industry self-regulation, namely: i) low innovation cost as compared to the final demand for the quality under consideration, ii) technological homogeneity among the firms of the industry, so as to limit the divergence of interests on the minimum quality standard that underlies such a voluntary program.

Appendix

A1. Calculation of price, output and profit before ecolabel

We have $\pi_0 = q_0\left[P(Kq_0) - C\right]$

The first order condition for profit maximization on each product is:

$$0 = \frac{\partial \pi_0}{\partial e} = \left[P(Kq_0) - C\right] + q_0 \frac{\partial P(Kq_0)}{\partial q_0} = \left[P(D_0) - C\right] + q_0 \frac{\partial P(D_0)}{\partial q_0} \qquad 2.2$$

Assumptions about Cournot competition and the way firms adjust the output on each product means that, locally, total demand only depends on the output of product t: $\frac{\partial D}{\partial q_i^t} = 1$

that is $$\frac{\partial P(D)}{\partial q_i^t} = \frac{\partial P(D)}{\partial D} \cdot \frac{\partial D}{\partial q_i^t} = \frac{\partial P(D)}{\partial D} \qquad 2.2bis$$

which means that

$$q_0 = -\left(\frac{\partial D_0}{\partial P(D_0)}\right)\left[P(D_0) - C\right] \qquad 2.3$$

and $$\pi_0 = -\left(\frac{\partial D_0}{\partial P(D_0)}\right)\left[P(D_0) - C\right]^2 \qquad 2.4$$

Given equation 1.1, we have: $\left(\frac{\partial D_0}{\partial P(D_0)}\right) = -\frac{N}{k_b}$

This gives: $$q_0 = \frac{N(p_0 - C)}{k_b} \qquad 2.5$$

The price before ecolabel (eq. 2.6) is derived by equalizing total supply and total demand, that is:

$$KTq_0 = D_0$$

or $$KTN\frac{(p_0 - C)}{k_b} = N\left(1 - \frac{p_0}{k_b}\right)$$

Introducing p_0 in the expressions of π_0 and q_0 gives eq. 2.6bis and 2.7.

A2. Calculation of prices, outputs and profits without innovation after ecolabel

Firm-*i's* profit on a *green product* t is equal to:

$$\pi_{i,g} = q_i^t\left[P^t(D_g) - C\right]$$

First order condition for profit maximization on this product is:

$$0=\left(\frac{\partial \pi_{i,g}}{\partial q_j^t}\right)_{j\neq i}=\left[P^t(D_g)-C\right]+q_i^t\left(\frac{\partial P^t(D_g)}{\partial q_i^k}\right)_{k\neq t}$$

For the same reason as before ecolabel, $\left(\frac{\partial P^t(D_g)}{\partial q_i^k}\right)_{k\neq t}=\frac{\partial P^t(D_g)}{\partial q_i^t}=\frac{\partial P^t(D_g)}{\partial D_g}.\frac{\partial D_g}{\partial q_i^t}=\frac{\partial p_g}{\partial D_g}=\frac{m}{k_g}$

Hence:

$$q_i^t=-\left(\frac{\partial q_i^t}{\partial p_g}\right)(p_g-C)=\frac{m}{k_g}(p_g-C)$$

Equalizing total green supply with total green demand, we have:

$$Keq_i^t=\frac{Kem}{k_b}(p_g-C)=\frac{m}{k_g}(p_g-C)$$

which gives the expression of p_g (eq. 4.1). Introducing this expression in q_i^t and $\pi_{i,g}$ gives the full expression of q_g and π_g (eq. 4.1bis and 4.2).

A similar calculation on the brown segment gives the expressions of the brown price, output and profit eq.4.3, 4.3bis and 4.4.

A3. Proofs of results i to vi

Proof of result i: The green price p_g is a decreasing functions of e and the brown price p_b is an increasing function of e

We have $p_g=\frac{KCe+k_g}{Ke+1}$ and $\frac{\partial p_g}{\partial e}=\frac{K(C-k_g)}{(Ke+1)^2}$, which is negative given that $k_g>C$. *Q.E.D.*

We have $p_b=\frac{KC(T-e)+k_b}{K(T-e)+1}$ and $\frac{\partial p_b}{\partial e}=\frac{K(k_b-C)}{[K(T-e)+1]^2}=\frac{K(p_b-C)}{[K(T-e)+1]}$, which is positive given that $k_b>C$. *Q.E.D.*

Interestingly, when e approaches 0, p_g converges towards k_g, and when e approaches T, p_g converges towards C if $KCT>>k_g$. Similarly, when e approaches 0, p_b converges towards C if $KCT>>k_b$, and when e approaches T, p_b converges towards k_b.

Proof of result ii: Both p_g and p_b are superior to p_o the price before ecolabel.

We have $p_g=\frac{KCe+k_g}{Ke+1}$ and $p_0=\frac{KTC+k_b}{KT+1}$

Therefore $p_g-p_0=\frac{KCe+k_g}{Ke+1}-\frac{KTC+k_g}{KT+1}=\frac{K(T-e)(k_g-C)}{(Ke+1)(KT+1)}$, which is positive given that $k_g>C$. *Q.E.D*

In the same way, $p_b-p_0=\frac{KC(T-e)+k_b}{K(T-e)+1}-\frac{KTC+k_b}{KT+1}=\frac{Ke(k_b-C)}{(K(T-e)+1)(KT+1)}$, which is positive given that $k_b>C$. *Q.E.D*

Proof of result iii. The profit under cannibalization is a decreasing function of e.

We have $\frac{\partial \pi}{\partial e} = 2\left[\frac{m}{k_g} + \frac{(N-m)}{k_b}\right](p_{gc} - C)\frac{\partial p_{gc}}{\partial e}$, with $\frac{\partial p_{gc}}{\partial e} = \frac{\partial p_{gc}}{\partial \beta}\frac{\partial \beta}{\partial e}$.

∂ß/∂e is positive. Indeed, ß is the share of brown consumers enticed to buy green products until p_g and p_b equalize. Beyond e_p, $|p_g - p_b|$ increases with e because p_g is inferior to p_b, while p_g decreases and p_b increases. Hence, an increasing number of brown consumers will be enticed to buy green products until $p_g = p_b$.

$\partial p_{gc}/\partial$ß is negative. Indeed, equation 4.7 means that:

$$\frac{\partial p_{gc}}{\partial \beta} = \frac{(Ke+1)\frac{m}{N-m}\left(\frac{1}{k_g} - \frac{1}{k_b}\right)}{\left[(Ke+1)\left(\frac{m}{(N-m)k_g} + \frac{\beta}{k_b}\right)\right]^2}$$

, which is negative since m<N and $k_g > k_b$.

p_{gc} is superior to C, so that p_{gc}-C>0. Indeed, when β=0 (i.e. in e_p), $p_{gc} = \frac{k_g + KeC}{Ke+1} = p_g$, which is superior to C. When β approaches 1, p_{gc} decreases towards $\frac{k_b + KeC}{Ke+1} = \frac{k_b - C}{Ke+1} + C$, which is superior to C (but inferior to both p_g and p_b). As p_{gc} is a decreasing function of ß, this means that $p_g \geq p_{gc} > C$ and p_{gc}-C>0. *Q.E.D.*

Proof of result iv. A firm's profit on the green segment $e\pi_g$ is a decreasing functions of e while a firm's profit on the brown segment (T-e)π_b is an increasing function of e.

Green profit is $e\pi_g = e\frac{m}{k_g}(p_g - C)^2$

Therefore, $\frac{\partial(e\pi_g)}{\partial e} = \frac{m}{k_g}\left[(p_g - C)^2 + 2e(p_g - C)\frac{\partial p_g}{\partial e}\right]$

As $\frac{\partial p_g}{\partial e} = \frac{K(C-k_g)}{(Ke+1)^2} = -\frac{K(p_g - C)}{(Ke+1)}$

We have,

$$\frac{\partial(e\pi_g)}{\partial e} = \frac{m}{k_g}\left[(p_g - C)^2 - 2e(p_g - C)\frac{K(p_g - C)}{(Ke+1)}\right] = \frac{m}{k_g}\left[1 - \frac{2Ke}{(Ke+1)}\right](p_g - C)^2$$

that is $\frac{\partial(e\pi_g)}{\partial e} = \frac{m}{k_g}\left[\frac{1-Ke}{(Ke+1)}\right](p_g - C)^2$ which is negative for e>0 and K≥1. *Q.E.D.*

Brown profit is $(T-e)\pi_b = (T-e)\frac{(N-m)}{k_b}(p_b - C)^2$

Therefore, $\frac{\partial\left((T-e)\pi_b\right)}{\partial e}=\frac{(N-m)}{k_b}\left[-(p_b-C)^2+2(T-e)(p_b-C)\frac{\partial p_b}{\partial e}\right]$

$$\frac{\partial\left((T-e)\pi_b\right)}{\partial e}=\frac{(N-m)}{k_b}\left[-(p_b-C)^2+2(T-e)(p_b-C)\frac{K(p_b-C)}{(K(T-e)+1)}\right]$$

that is $\frac{\partial\left((T-e)\pi_b\right)}{\partial e}=\frac{(N-m)}{k_b}\left[\frac{K(T-e)-1}{(K(T-e)+1)}\right](p_b-C)^2$, which is always positive since e<T and K≥1. *Q.E.D*

Proof of result v: $\forall e<e_{p,}\pi>\pi_o$***, a firm's total profit under ecolabel is superior to its profit before ecolabel.***

$$\forall e<e_{p,}\pi-\pi_0=e\frac{m}{k_g}(p_g-C)^2+(T-e)\frac{N-m}{k_b}(p_b-C)^2-\frac{N}{k_b}(p_0-C)^2$$

Since $\forall e<e_{p,}$ $p_g>p_b>p_0$, we have:

 EMBED Equation.2

that is $\pi-\pi_0\succ\left[e\frac{m}{k_g}+(T-e-1)\frac{N-m}{k_b}-\frac{m}{k_b}\right](p_0-C)^2$

and $\pi-\pi_0\succ\left[e\frac{m}{k_g}+(T-e-1)\frac{N-m}{k_b}\right](p_0-C)^2$, which is positive for any e<T. *Q.E.D.*

Proof of result vi: π is convex ($\partial^2\pi/\partial e^2>0$) so that maximum profit will be made at the extremes, that is either in e=1 or in e=e_p.

$$\frac{\partial^2\pi}{\partial e^2}=\frac{\partial^2}{\partial e^2}(e\pi_g)+\frac{\partial^2}{\partial e^2}((T-e)\pi_b)$$

with $\frac{\partial(e\pi_g)}{\partial e}=\frac{m}{k_g}\left[\frac{1-Ke}{(Ke+1)}\right](p_g-C)^2$ and $\frac{\partial(T-e)\pi_b}{\partial e}=\frac{(N-m)}{k_b}\left[\frac{K(T-e)-1}{(K(T-e)+1)}\right](p_b-C)^2$

(Cf. proof of result i).

Introducing $\frac{\partial p_g}{\partial e}=-\frac{K(p_g-C)}{(Ke+1)}$ (Cf. proof result i) in the calculation of $\partial p_g/\partial e$, we obtain:

$$\frac{\partial^2(e\pi_g)}{\partial e^2}=\frac{m}{k_g}\frac{\partial}{\partial e}\left(\frac{1-Ke}{(Ke+1)}(p_g-C)^2\right)=\frac{m}{k_g}\frac{\partial}{\partial e}\left(\frac{-2K}{(Ke+1)^2}-\frac{2K(1-Ke)}{(Ke+1)^2}\right)(p_g-C)^2$$

that is $\frac{\partial^2(e\pi_g)}{\partial e^2}=\frac{m}{k_g}\left(\frac{2K(Ke-2)}{(Ke+1)^2}\right)(p_g-C)^2$, which is always positive for e≥2/K, a condition that will be satisfied as long as e≥1 in a non-monopolistic industry (i.e. K>1).

In the same way, $\dfrac{\partial^2(e\pi_b)}{\partial e^2}=\dfrac{N-m}{k_b}\left(\dfrac{2K^2(T-e)}{(K(T-e+1)^2}\right)(p_b-C)^2$ is always positive for e<T.

Hence, $\partial^2\pi/\partial e^2 \geq 0$ for any $e \geq 1$ and $K>1$. $\prod$ is a convex function between and has its maximum *Q.E.D.*

A5. Calculation of prices, outputs and profits with innovation after ecolabel

We distinguish between firms $i_{|1\leq i\leq n}$ and firms $i_{|n<i\leq K}$:

$$\pi_{1<i\leq n,g}=\sum_{t=1}^{e}q_i^t(p_g-C)+\sum_{t=e+1}^{e+G_{te}}q_i^t(p_g-C-\frac{(t-e)}{V})$$

$$\pi_{n<i\leq K,g}=\sum_{t=1}^{e}q_i^t(p_g-C)+\sum_{t=e+1}^{e+G_{te}+1}q_i^t(p_g-C-\frac{(t-e)}{V})$$

First order condition for profit maximization gives:

For $t\leq e$, $$q_i^t=\sum_{i=1}^{K}-\left(\frac{\partial q_i^t}{\partial p_g}\right)(p_g-C)$$

For $e<t\leq e+G_{te}$, $$q_i^t=\sum_{i=1}^{K}-\left(\frac{\partial q_i^t}{\partial p_g}\right)(p_g-C-\frac{(t-e)}{V})$$

For $t=e+G_{te}+1$, $$q_i^t=\sum_{i=1}^{n}-\left(\frac{\partial q_i^t}{\partial p_g}\right)(p_g-C-\frac{(G_{te}+1)}{V})$$

with $-\left(\dfrac{\partial q_i^t}{\partial p_g}\right)=-\left(\dfrac{\partial D_g}{\partial p_g}\right)=\dfrac{m}{k_g}$, (Cf. eq. 2.2bis).

Equalizing total green supply and total green demand, we obtain:

$$m(1-\frac{p_g}{k_g})=-(\frac{\partial q_i^t}{\partial e})\left[\sum_{t=1}^{e}\sum_{i=1}^{K}\left(p_g-C\right)+\sum_{t=e+1}^{e+G_{te}}\sum_{i=1}^{K}(p_g-C-\frac{(t-e)}{V})+\sum_{i=1}^{n}\left(p_g-C-\frac{(G_{te}+1)}{V}\right)\right]$$

$$m(1-\frac{p_g}{k_g})=\frac{m}{k_g}\left[Ke\left(p_g-C\right)+KG_{te}\left(p_g-C\right)-\frac{K}{2V}G_{te}(G_{te}+1)+n\left(p_g-C-\frac{(G_{te}+1)}{V}\right)\right]$$

which gives the expression of p_g.

On the *brown segment*, the same reasoning gives:

$$\pi_{1<i\leq n,b}=\sum_{t=e+G_{te}+2}^{T}q_i^t(p_b-C)$$

$$\pi_{n<i\leq K,b}=\sum_{t=e+G_{te}+1}^{T}q_i^t(p_b-C)$$

Maximizing profits, we obtain:

For e+G_{te}+2≤t≤T, $q_i^t = \sum_{i=1}^{K} -\left(\frac{\partial q_i^t}{\partial p_b}\right)(p_b - C)$

For t=e+G_{te}+1, $q_i^t = \sum_{i=n+1}^{K} -(\frac{\partial q_i^t}{\partial e})(p_b - C)$

with $-\left(\frac{\partial q_i^t}{\partial p_b}\right) = -\left(\frac{\partial D_b}{\partial p_b}\right) = \frac{(N-m)}{k_b}$, (Cf. supra).

Equalizing total brown supply and total brown demand, we have:

$$(N-m)(1-\frac{p_b}{k_b}) = \frac{(N-m)}{k_b}\left[\sum_{t=e+G_{te}+2}^{T} \sum_{i=1}^{K}(p_b - C) + \sum_{i=n+1}^{K}(p_b - C)\right]$$

which gives the expression of p_b.

A6. Proof of result xii

Result xii: R_1 is a concave function of e.

$$R_1 = (\frac{D}{D_0}) = \frac{(N-m)(1-p_b/k_b) + m(1-p_g/k_g)}{N(1-p_0/k_b)}$$

$$\frac{\partial R_1}{\partial e} = \frac{N(1-p_0/k_b)\frac{\partial}{\partial e}\left[(N-m)(1-p_b/k_b) + m(1-p_g/k_g)\right]}{\left[N(1-p_0/k_b)\right]^2}$$

$$\frac{\partial R_1}{\partial e} = \frac{-N(1-p_0/k_b)\left[\frac{(N-m)}{k_b}\frac{\partial p_b}{\partial e} + \frac{m}{k_g}\frac{\partial p_g}{\partial e}\right]}{\left[N(1-p_0/k_b)\right]^2}$$

$$\frac{\partial^2 R_1}{\partial e^2} = \frac{-N(1-p_0/k_b)\left[\frac{(N-m)}{k_b}\frac{\partial^2 p_b}{\partial e^2} + \frac{m}{k_g}\frac{\partial^2 p_g}{\partial e^2}\right]}{\left[N(1-p_0/k_b)\right]^2}$$

$\frac{\partial^2 p_g}{\partial e^2} = \frac{\partial}{\partial e^2}\left(-\frac{K}{(Ke+1)}(p_g - C)\right) = \frac{2K^2}{(Ke+1)^2}(p_g - C)$, which is positive.

$\frac{\partial^2 p_b}{\partial e^2} = \frac{\partial}{\partial e^2}\left(-\frac{K}{(K(T-e)+1)}(p_b - C)\right) = \frac{2K^2}{(K(T-e)+1)^2}(p_g - C)$, which is positive.

We know that $p_b = \frac{KTC + k_b}{KT+1} = k_b + \frac{KT(C-k_b)}{KT+1}$. As k_b>C, 1-p_0/k_b>0 and $\partial^2 R_1/\partial e^2 \leq 0$. *Q.E.D.*

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Tables

Table I: Equilibrium after Ecolabel

	Green Segment			Brown Segment	
Green Innovation	No	Yes	Yes	No	No
Products' profiles	[1,e]	[e+1, e+G_{te}]	e+G_{te}+1	e+G_{te}+1	[e+G_{te}+2, T]
Firms index	[1,K]	[1,K]	If n=0, no firm If n≠1, [1,n]	[n+1,K]	[1,K]
Number of firms selling the product profile	K	K	n 0≤n<K	K-n 0≤n<K	K

Table II: Condition on the green demand for firms to prefer selective criteria (e=1)

Quality ratio → **Number of products ↓**	**kg/kb≤1,05**	**kg/kb>1,05**
T=5	m/(N-m)≥0,3	m/(N-m)≥0,1 or 0,2
T=20	m/(N-m)≥0,6 or 0,7	m/(N-m)≥0,3

Table III: Differences in profit in e=1 and e=e_p, depending on k_g/k_b, m/(N-m), K, T and whether or not the firms innovates on product "e+G_{te}+1"*

kg/kb	**M/(N-m)**	**Δ profit Firms 1 to n (K=5;T=20)**	**Δ profit Firms 1 to n (K=20;T=20)**	**Δprofit Firms n+1 to K (K=5;T=20)**	**Δprofit Firms n+1 to K (K=20;T=20)**
1.05	0.05	-0.0001	0.0000	-0.0003	0.0000
	4.00	0.0133	0.0009	0.0083	0.0009
2.04	0.05	0.0013	0.0001	-0.0005	0.0000
	4.00	0.0649	0.0053	0.0339	0.0036
3.03	0.05	0.0027	0.0004	-0.0009	0.0002
	4.00	0.1225	0.0110	0.0614	0.0066
4.03	0.05	0.0040	0.0007	-0.0014	0.0003
	4.00	0.1822	0.0170	0.0898	0.0096
5.02	0.05	0.0023	0.0009	-0.0050	0.0003
	4.00	0.2422	0.0231	0.1181	0.0126
6.01	0.05	0.0059	0.0012	-0.0033	0.0004
	4.00	0.3030	0.0293	0.1470	0.0156
7.00	0.05	0.0095	0.0016	-0.0016	0.0006
	4.00	0.3641	0.0355	0.1760	0.0187

[a] Δ profit = (Profit in e=1) minus (profit in e=e_p)

[b] Firms 1 to n are innovating product "e+G_{te}+1"; firms n to K are not innovating product "e+G_{te}+1".

Tables IV.1 to IV.3

Table IV.1: Maximum number of innovations in a twenty-firm industry, five products per firm (K=5; T=20) depending on the relative value of innovation costs (V= 2 to 50)

kg/kb	m/(N-m)	V=2	V=5	V=10	V=20	V=50
1.005	0.05	0	0	0	1	2
	0.10	0	0	0	1	2
	0.15	0	0	0	0	1
	0.20	0	0	0	0	1
1.05	0.05	0	0	1	1	2
	0.10	0	0	1	1	1
	0.15	0	0	1	1	1
	0.20	0	0	1	1	1

Table IV.2: Minimum value of e for which the ecolabel induces innovation in a twenty-firm industry, five products per firm (K=5; T=20) depending on the relative value of innovation costs (V= 2 to 50)

kg/kb	m/(N-m)	V=2	V=5	V=10	V=20	V=50
1.005	0.05				3	3
	0.10				3	4
	0.15					5
	0.20					5
1.05	0.05			2	3	4
	0.10			2	4	5
	0.15			2	4	5
	0.20			2	4	6

Table IV.3: Maximum value of e for which the ecolabel induces innovation in a twenty-firm industry, five products per firm (K=5; T=20) depending on the relative value of innovation costs (V= 2 to 50)

kg/kb	m/(N-m)	V=2	V=5	V=10	V=20	V=50
1.005	0.05				3	9
	0.10				3	9
	0.15					9
	0.20					9
1.05	0.05			2	4	10
	0.10			2	4	10
	0.15			2	4	10
	0.20			2	4	10

Footnotes:

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[1] During the negotiation of this ecolabel, the detergent industry split into two trade organizations. The pre-existing one, now made up of the leading detergent producers, and a new "Environmental Detergent Manufacturers Association" (EDMA) structured by a fringe of green small and medium enterprises such as Ecover. This scission resulted from a divergence regarding the content of the ecolabeling criteria that each group of firms wanted to obtain during the negotiation. The conflict hampered the development of the EU ecolabel on detergent products. At the present time, this ecolabel has only been adopted by one firm on its product. It raises anti-competitive concerns for the EU Commission, making the EU ecolabel into one of the few voluntary approaches to environmental regulation to raise such concerns. The leading detergent producers have explicitly opposed the EU ecolabel during its development and they later on developed their own private ecolabel. Following this, several retailers have attempted to exclude the only EU-ecolabeled brand from their shelves. The Competition General Directorate has recently been asked to assess if this resulted from a coalition of the main detergent manufacturers against the EU detergent ecolabel.

[2] This is only the case when innovation costs in the concerned industry are negligible as compared to production costs.

[3] Coddington [4] surveys the results derived from the available polls on the subject.

In 1992, the population of US consumers could be divided into four categories:

. 10 to 20% of deeply committed green consumers,

. 5 to 10% of reasonably active and dedicated greens,

. 40 to 50% of softly or light green consumers. Albeit they express high degrees of concern for the environment, they only inconsistently translate that concern into actual buying behavior,

. 20 à 35% of brown consumers.

[4] We assume that the product's characteristics are separable. Changing the environmental profile of a product does not affect its other characteristics. No particular assumptions are made concerning k_b, for the set of non-environmental characteristics is supposed to remain unchanged.

[5] In the case of two polluting emissions, the same reasoning could be undertaken in the two-dimensional space defined by the level of each polluting emission per unit of product. θ_τ would be the polar coordinate

of a product t. The criteria, which are based on a weighing out of polluting emissions thresholds, could be described by a unique polar environmental profile θ_e. Any product t such that $\theta_t \leq \theta_e$ could then be ecolabeled without any modification of its environmental profile, whereas any product $\theta_t > \theta_e$ would have to be improved - i.e., at least changed into a "e" product - in order to become eligible for the ecolabel. In such a case, the criteria would refer to a value judgement prioritizing the two polluting emissions under consideration.

[6] For instance, the paper producers opposed the ecolabel in the European Union on the ground that their costs of environmental innovation were too high. They argued that given these costs, the ecolabel would divide the paper products market into two segments without inducing any improvement in the environmental quality of the products. V is introduced in the model in order to capture this aspect, the higher V, the lower the cost of environmental innovation and the more "flexible" the industry in improving the environmental quality of its products.

[7] Hence, before ecolabel, at least some consumers can purchase one unit of product.

[8]As the model is calibrate against production cost, by assuming C=1, 1/V is also the value of the cost of environmental innovation *relatively to the cost of production*.

[9] As a matter of fact, standard Cournot calculation under cannibalization would lead to:

$$pb=(kb+CK(T-e))/(K(T-e)+1)$$

a formula, which does not take account of the fact that brown firms are now facing the competition of green products.

[10] The steepness of the profit curves at the extremes (very selective criteria for the green profit or very permissive ones for he brown profit) is accentuated as either K or T increased since increased supply tends to faster depress price.

[11] (i.e., for developed countries: 5 to 10% of green consumers or m/(N-m)= 0,05 to 0,1; willingness to pay-extra % for green products from 0 to 20 or k_g/k_b=1,01 to 1,2) (Coddington, [4]).

[12] As all firms face similar cost conditions, they all can pretend to benefit from innovating on the marginal product when n≠0. Yet, if they all do so, they will be worse off. As a result, any equilibrium at which n≠0 might not be stable. The Cournot paradigm used in this paper is not "strategic" enough to analyze this question.

[13] In such a case, one would have to take into account the modification in the nature and quantities of the environmental spillovers generated by each of these products before and after ecolabel.

[14] R_2 can also be written: R_2=(Green demand After Ecolabel/Total Demand After Ecolabel)/R_1 = Index of Green Production/R_1

[15]e=T is always another solution, since in that point there is no brown product and D_g=D. Yet, we do not consider this solution here, for e=T means that the ecolabel no longer divides the market into two market segments.

[16]This benchmark is given ex-post and there is no ex-ante optimal value for e. In a different theoretical setting, let say if we would have assumed that consumers were endowed with subjective preferences over the products' environmental characteristics –i.e. able to assess green quality - the benchmark for evaluation would have been these preferences. It would have pre-existed to the negotiation phase. In such a case, the results would have been different and the notion of an "optimal" value for e, derived from these preferences, would have made sense.

[17] Comment on Fig.3 and 4. For the sake of clarity, curves have been approximated by: 1) Grouping the curves for K=5 and K=20 when the differences between both of them were not significant, and 2) Considering the integer number just inferior when the solution was not itself an integer number. Figures 3 and 4 should be rd as follows. For very low values of the population ratio firms will be interested in e=1, for higher values in $e=e_p$. e_p depends on kg/kb. For most of the realistic values of the population ratio (below 1,2), it is located above the minimum solution to R_1=1 and above the R_2=1 curve. This means that firm's objective ($e=e_p$) will lead to an ecolabel that will boost the market of the product (R_1max>e_p>R_1min) and increase the ratio brown/green product (e_p> e_2).