FAERE

French Association
of Environmental and Resource Economists

Working papers

Consumer misperception of eco-labels, green market structure and welfare

Dorothée Brécard

WP 2015.01

Suggested citation:

D Brécard (2015). Consumer misperception of eco-labels, green market structure and welfare. FAERE Working Paper, 2015.

ISSN number:

http://faere.fr/working-papers/

Consumer misperception of eco-labels, green market structure and welfare

Dorothée Brécard*

January 2015

Abstract

How does consumer misperception of competing eco-labels affect environmental and economic efficiency of eco-labels? This article provides a theoretical insight into this issue by using a double-differentiation model, where three products are potentially in competition: an unlabeled product and two eco-labeled products of medium and high environmental qualities (with distinct labels). We compare the case of perfect information, where consumers can perfectly assess the environmental quality of the three products, and the case of imperfect information, where consumers cannot fully assess the environmental quality associated with each label while perceiving all eco-labels as a sign of high environmental quality and each label as a particular variety of a product. We show that consumer confusion can affect the market structure by weakening the firm that provides the greenest product. Paradoxically, consumer misperception is not always detrimental to social welfare because, when the perceived quality of both eco-labeled products is relatively high, it can improve the quality of the environment and raise global profits and consumer surplus. Moreover, although firms would harmonize their demanding eco-labeling criteria if they face fully-informed consumers, they turn to greenwashing when they know the way the consumers form their belief on environmental quality. Finally, we show that an NGO faced with consumer misperception will require less stringent standard than in the perfect information case, while conclusions on the regulator eco-labeling strategy are not clear-cut.

Keywords. Eco-label, environmental quality, green consumer, product differentiation.

JEL classification. D11, D62, D83, L15, Q58

Acknowledgments

I would like to thank the participants in the first FAERE Annual Conference in Montpellier for their helpful comments and suggestions.

* *Université de Toulon, LEAD, Faculté de Sciences Économiques et de Gestion, Campus porte d'Italie, 70 avenue Roger Devoucoux, 83000 Toulon, France. Email: brecard@univ-tln.fr, Tel: 33 483 36 63 13.*

1. Introduction

When you face several eco-labeled products in a supermarket shelf, do you know which one is the greenest? Most of us do not know. According to the latest survey of the European Commission (EC, 2013), 59% of Europeans do not think that current product labels provide enough information about their environmental impact, although two-thirds of them are confident that products labeled or indicated as environmentally friendly will cause less damage to the environment than others In other words, European consumers find it difficult to "navigate the green maze".[1] Notwithstanding, one European out of two considers that "environmentally-friendly products are good value for money" and 77% "would be willing to pay more for products if they were confident that they were environmentally friendly" (EC, 2013)

Consumers' confusion arises mainly from eco-label proliferation. The Ecolabel Index[2] currently identifies 458 eco-labels in 197 countries and 25 industry sectors. Gruère (2013) emphasizes that the proliferation of environmental labeling and information schemes since the 1990s could contribute to consumers' confusion. Harbaugh et al. (2011) show that, when consumers are unsure of labeling requirements, the proliferation of eco-labels decreases the informativeness of labels and thereby raises consumers' confusion. "And this confusion makes it harder for business to be green too. Not only are their attempts to communicate with their customers being undermined by greenwashing or free-riders; the proliferation of labels means extra costs and administrative burdens" stated Janez Potočnik, the current European Commissioner for Environment, in his opening speech at the Global Ecolabelling Network (GEN) Conference.[3] Robin Taylor, the chair of GEN, adds that "it is cumbersome for consumers to identify the meaning of ecolabels on the market because of the multiplicity of labels and understanding what they mean. I believe that both Government and Consumer Groups can play a bigger part in finding a solution to this issue."[4] Before dealing with the government role in reducing consumers' confusion, it is worth identifying the effects of confusion on social welfare. Indeed, these effects are not obvious, as consumer misperception of competing eco-labels could favor consumption of green products, when all eco-labeled products are seen as having high environmental qualities. However, this could also discourage the consumption of the greenest products, when consumers are skeptical about their environmentally friendly nature. How do consumers' misperceptions of eco-labels affect firms' strategies? What are the ensuing impacts on welfare, through profits, consumer surplus and the quality of the

[1] See the European Commission press release, entitled "Environment: Helping companies and consumers navigate the green maze" (IP/13/310), that announces the Communication on Building the Single Market for Green Products adopted on the 9th April 2013.

[2] This directory was initiated in 2009 by Big Room Inc., a Vancouver-based company, and the World Resources Institute, a Washington DC-based environmental think tank (www.ecolabelindex.com, accessed 2015/01/05).

[3] *Global Ecolabelling Network* (GEN) Conference in Brussels on 5 November 2013 (http://europa.eu/rapid/press-release_SPEECH-13-879_en.htm, accessed 2014/05/09). The GEN is a non-profit association of third-party, environmental performance recognition, certification and labeling organizations founded in 1994 to improve, promote, and develop the eco-labeling of products and services.

[4] See his interview in *UE Ecolabel News Alert*, Issue n°92, December 2013.

environment? Our paper theoretically addresses these issues, using a differentiation-model framework.

There is a wealth of theoretical literature dealing with optimal policies and corporate strategies for eco-labeling in the case of competition between a labeled product and an unlabeled one (Bonroy and Constantatos, 2014). Papers most often adopt a framework of vertical differentiation model (Arora and Gangopadhyay, 1995, Amacher *et al*., 2004, Ben Youssef and Lahmandi-Ayed, 2008, Bottega and De Freitas, 2009, Bottega *et al*., 2009) or horizontal differentiation model (Eriksson, 20004, Boyer *et al*., 2006, Clemenz, 2010). They emphasize the conditions under which eco-labeling may be an efficient policy, depending on cost structure and abatement method of firms and on environmental consciousness, information and altruism of consumers. However, assuming the existence of only one eco-label, they are not appropriate for modeling consumers' difficulties 'to navigate the increasingly important and complex world of greener products'.[5] Only a few papers deal with consumer misperception of labels (Ben Youssef and Abderrazack, 2009; Harbaugh et al., 2011; Brécard, 2014). Ben Youssef and Abderrazak (2009) consider a situation where consumers face two eco-labeled products and use product prices to assess the probability for an eco-label to guarantee the high environmental quality. In that case, firms are encouraged to provide products of lower environmental quality than in the perfect information case and consumers make their purchasing decision by ignoring eco-labels, which then become useless. Brécard (2014) considers a market where competition occurs between three mono-product firms that supply two eco-labeled products and an unlabeled one. She assumes that consumers see eco-labels as signs of environmentally friendliness, but cannot perceive the difference in the environmental quality they certify. Moreover, beyond price comparison, consumers choose one green product rather than another according to their tastes towards the eco-labels, and not on the basis of an objective comparison of environmental qualities certified by eco-labels. Comparing the case of uniform labeling standards with the case on non-uniform standards, she shows that the unlabeled and the greenest firms are weakened by consumer confusion, to the benefit of the firm providing the eco-labeled product of medium quality. Moreover, the government and Non-Governmental Organizations (NGOs) have an interest in harmonizing labeling criteria and in adopting an exacting standard in order to improve the welfare and quality of the environment. Firms also have an interest in harmonizing labeling criteria, but they prefer an undemanding standard in order to maximize their profits.

This article contributes to this recent literature by looking into the corporate and social consequences of consumer confusion. Our analysis builds on a comparison of the case of consumer confusion with the textbook case of perfect information, where consumers accurately know environmental impacts of all available unlabeled and eco-labeled products. Using a model close to, but more tractable than, Brécard's (2014) one,[6] we provide new insights into consumer-confusion effects on firms' pricing strategies and market structure and on social welfare and eco-labeling strategies of different certifying organizations. Our main results are fourfold. First, consumer confusion can affect market structure by weakening the firm that provides the greenest

[5] See the Environmental Protection Agency web page on 'Greener Products', http://www.epa.gov/greenerproducts/index.html (accessed 2015/01/06)

[6] Brécard's (2014) model cannot be analytically solved, except in the specific case of uniform standard, and does not allow comparison between perfect and imperfect information cases.

product. Second, paradoxically, consumers' confusion is not always detrimental to social welfare because, when the perceived quality of both eco-labeled products is relatively high, it can improve the quality of the environment and raise global profits and consumer surplus. Third, although firms would harmonize their demanding eco-labeling criteria if they were to face fully informed consumers, they turn to greenwashing when they know the way the consumers form their belief on environmental quality. Finally, we show that an NGO faced with consumer misperception will require a less stringent standard than in the perfect information case, while conclusions on the regulator eco-labeling strategy are not clear-cut.

The remainder of the paper is structured as follows. In Section 2, we present the demand side of the model. In Section 3, we analyze the price equilibrium in cases of perfect and imperfect information and we compare market structures in both cases. In Section 4, we infer the consequences of imperfect information on welfare and study eco-labeling strategies of the possible instigators of the eco-labels (firms, the regulator and/or an NGO). Section 5 concludes.

2. Consumer information and demand

Consider a market where three products are potentially in competition, each one differentiating from its competitors by its environmental quality: An unlabeled product of low environmental quality, an eco-labeled product of medium environmental quality and an eco-labeled product of high environmental quality. As environmental impacts of the product life cycle, from cradle to grave, are hidden attributes of the goods, eco-labels are the only ways to allow consumers to "identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and disposal" (EU ecolabel definition of European Commission).[7] We suppose that two distinct eco-labels are used to inform consumers about both green products' higher qualities. Both require minimum quality standards, but one of them demands a higher environmental quality than the other.

We consider two polar cases. In the perfect information case, eco-labels play their full role in informing consumers about the minimal environmental quality of a labeled product. In the imperfect information case, in line with Brécard (2014), we assume that consumers believe that the product quality is the same whatever the label stamped on the product may be. In both cases, eco-labeled products are seen as different varieties of the environmentally friendly goods, in such a way that the labeled products are *horizontally* differentiated. Moreover, consumers identify the presence of a green label on a product as a sign of quality, so that labeled products and the unlabeled one are *vertically* differentiated. Such assumptions fit well with empirical findings on green consumer profile. Indeed, empirical studies reveal that most consumers prefer environmentally friendly products to standard ones (OECD, 2005, EC, 2013, 2014). This is a sign of vertical differentiation between labeled and unlabeled products. However, several factors affect preferences and the willingness to pay for eco-labeled products. For instance, through a systematic review of the relevant literature, Taufique *et al*. (2014) identify ten 'constructs' playing on consumers' understanding and perception of eco-labels, including environmental awareness, knowledge and involvement and trust in eco-label, in addition to socio-demographic features

[7] See http://ec.europa.eu/environment/ecolabel/index_en.htm (accessed 2014/05/09)

(education, gender, age,…). This implies some heterogeneity in preferences for eco-labeled products, which can then be viewed as horizontally differentiated.

2.1. Perfect perception of quality

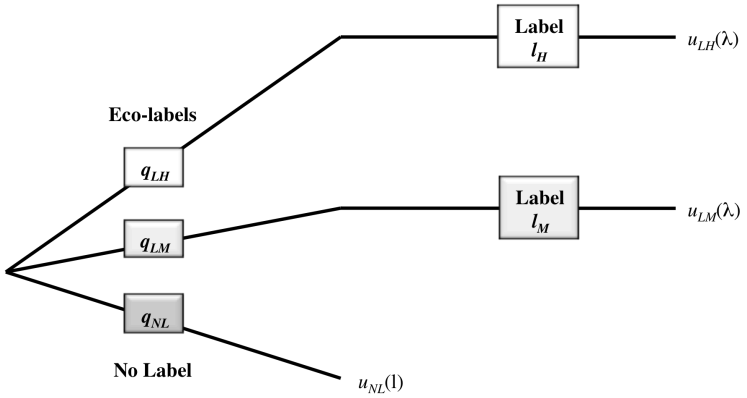


Fig. 1 Consumer decision tree in the perfect information case

The decision tree of a perfectly informed consumer is depicted in Figure 1. A consumer firstly decides whether he consumes the unlabeled product of quality q_{NL}, an eco-labeled product of medium quality q_{LM} or an eco-labeled product of high quality q_{LH}, with $q_i \in \left[\underline{q},\overline{q}\right]$. When he chooses an eco-labeled product, he also selects its associated horizontal characteristic, denoted l_M or l_H, spread on a Hotelling interval $[0,1]$. His choice depends on his marginal willingness-to-pay for quality, θ, which is assumed to be the same for all consumers ($\theta > 0$),[8] and on his 'ideal label', λ, located on a Hotelling interval $[0,1]$. His 'ideal label' depends on his concern for various environmental issues, such as biodiversity, fossil resource depletion, air pollution, climate change, etc, which, in turn, depends on his moral and social values and his socio-demographic characteristics. Accordingly, the Hotelling space represents the scale of environmental concerns, associated with potential eco-labels, from the most specific one (for instance, organic agriculture) to the most general one (for instance, carbon footprint).

The indirect utility Consumer λ derives from the consumption of one unit of the unlabeled product of quality q_{NL}, at price p_{NL}, depends on his gross utility r from consuming one unit of the product[9] and his willingness to pay (WTP) a product of quality q_{NL}, θq_{NL}. It is therefore represented by the following function *à la* Mussa and Rosen (1978):

$$u_{NL}(\lambda) = r + \theta q_{NL} - p_{NL} \tag{1}$$

The gross surplus Consumer λ derives from the consumption of the l_j-labeled product, of quality q_{L_j}, depends not only on r and θq_{Lj}, but also on his gross surplus from the proximity between the variety of the product he consumes, l_j, and the ideal

[8] Assuming that θ is identical for all consumers allows analytical resolution of the game, which would not be achievable if we adopted a more conventional assumption of uniform distribution of parameters θ, as in Brécard (2014).

[9] r is assumed large enough to ensure that the market is covered.

variety he would like to consume, λ. The last element is measured by the interaction between the proximity to his ideal label and the basic WTP for labeled quality q_{Lj}: $\left(1-\lambda-l_j\right)\theta q_{L_j}$.[10] We assume λ is uniformly distributed over $[0,1]$. We also assume, for simplicity, that $l_M = 0$ and $l_H = 1$. Therefore, the indirect utility he derives from the consumption of the l_j-labeled product, of quality q_{L_j}, at price p_{L_j}, is defined by:

$$u_{Lj}(\lambda) = r + \theta q_{Lj} + \left|1 - l_j - \lambda\right|\theta q_{Lj} - p_{Lj} \quad j = M,H. \tag{2}$$

In order to define consumer demand, we characterize Consumer λ_M, indifferent between the unlabeled and the l_M-labeled product, and Consumer λ_H, indifferent between the unlabeled and the l_H-labeled product. In the case of perfect information, their types are defined as follows:

$$\lambda_M = \frac{2\theta q_{LM} - \theta q_{NL} - p_{LM} + p_{NL}}{\theta q_{LM}}, \tag{3}$$

$$\lambda_H = \frac{\theta q_{NL} - \theta q_H + p_{LH} - p_{NL}}{\theta q_H}, \tag{4}$$

and demand are defined by $d_{LM} = \lambda_M$, $d_{NL} = \lambda_H - \lambda_M$ and $d_{LH} = 1 - \lambda_H$.

2.2. Imperfect perception of quality

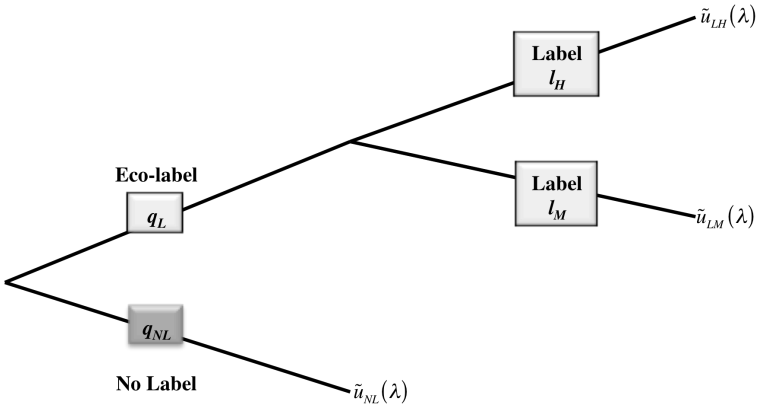


Fig. 2. Consumer decision tree in the imperfect decision case

The decision tree of a misinformed consumer is depicted in Figure 2. He firstly decides whether he consumes the unlabeled product of quality q_{NL} or an eco-labeled product of *perceived* quality q_L, with $q_L \geq q_{NL}$. When he selects a labeled product, he has to choose between the two varieties (eco-labels), l_M or l_H.

The indirect utility derived from the consumption of the unlabeled product is still defined by Equation (1). On the other hand, we can re-write the utility function from the consumption of the l_j-labeled product, of perceived quality q_L, at price $\tilde{p}_{L_j}$, as follows:

[10] This assumption differs from Brécard (2014), who supposes additivity of WTP for environmental quality and WTP for a given label. It is close to Degryse and Irmen's (2001) assumption, that assumes that the indirect utility depends on the product quality not only through the quality level itself, but also through the transportation cost towards the product, proportional to the quality level: $u_i(\lambda) = r + q_i - (1+\delta q_i)\lambda - p_i$, with δ the interaction parameter.

$$\tilde{u}_{Lj}(\lambda) = r + \theta q_L + \left|1 - l_j - \lambda\right|\theta q_L - \tilde{p}_{Lj} \quad j = M,H \,. \tag{5}$$

Therefore, if labeled products were sold at the same price, half of consumers would prefer buying the l_M-labeled product, while others would prefer purchasing the l_H-labeled product. For different prices, indifferent consumers are characterized by:

$$\tilde{\lambda}_M = \frac{2\theta q_L - \theta q_{NL} - \tilde{p}_{LM} + \tilde{p}_{NL}}{\theta q_L}, \tag{6}$$

$$\tilde{\lambda}_H = \frac{\theta q_{NL} - \theta q_L + \tilde{p}_{LH} - \tilde{p}_{NL}}{\theta q_L}, \tag{7}$$

and demand are defined by $\tilde{d}_{LM} = \tilde{\lambda}_M$, $\tilde{d}_{NL} = \tilde{\lambda}_H - \tilde{\lambda}_M$ and $\tilde{d}_H = 1 - \tilde{\lambda}_H$.

In order to compare cases of perfect and imperfect information, Figure 3 illustrates consumers' indirect utility according to their ideal label for given prices and qualities of the three products, when $q_L \in \left[q_{LM}, q_{LH}\right]$ (with perfect information in black and imperfect information in gray). The double-arrows below the *x*-axis symbolize the market shares of the three products (with wide-dotted line for the unlabeled product, dotted line for the l_M–labeled product and the solid line the l_H-labeled product). This highlights that, all other things being equal, consumer misperception leads to utility loss from consuming the l_H-labeled product and utility gain from consuming the l_M-labeled product. This weakens the greenest product, which can be removed from the market.

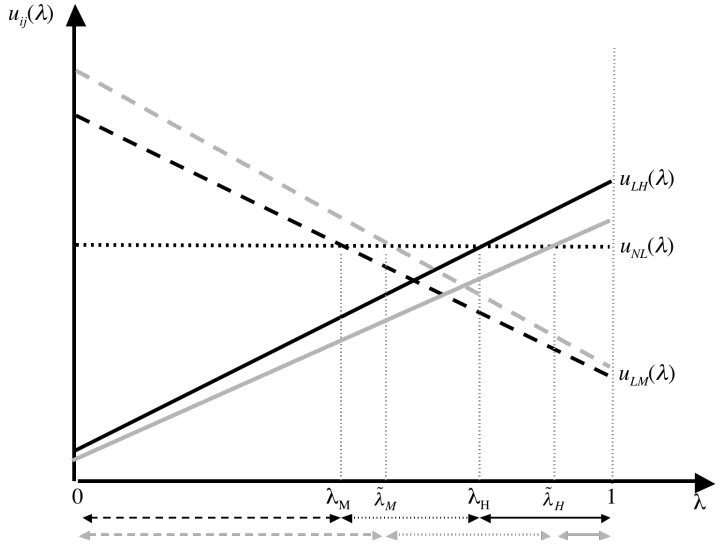


Fig. 3 Utility functions and demands

It is worth noting that, in a vertical differentiation framework with three firms, Scarpa (1998) shows that "*the demand level of a firm depends on the quality and price of the firm itself and of its neighbouring rivals only, while it does not depend on products that are farther away in the product space*." In our model, because of interactions between variety and quality in consumer preferences, the demand for a labeled product does not depend on the quality and price of the other labeled product, but it does depend on the quality and price of the unlabeled product, which is therefore the "*neighbouring rival*" of both eco-labeled products.

3. Price equilibrium and market structure

In this section we study Nash equilibrium in the cases of perfect perception and imperfect perception of environmental quality by consumers. We only consider triopoly competition.

The competition between firms takes place in a two-stage game. In the first stage, firms decide on (real) quality q_i to be produced ($q_i \in \left[\underline{q}, \overline{q}\right]$). In the second stage, prices p_i are chosen. We assume that only one firm produces one variant of a product. A firm has an interest in selecting a variety that differs from those of its competitors, in order to avoid a price war, that would lead to a dramatic fall in profit. It also chooses its variant among the three possible variants: unlabeled, l_M -labeled or l_H -labeled. The latter requires the firms to provide a quality higher than q_{LM} and q_{LH}, with $q_{LH} \geq q_{LM}$. Firm profits are defined by:

$$\pi_i = \left(p_i - c\left(q_i\right)\right)d_i - k_i \quad i = NL, LM, LH, \tag{8}$$

where $c\left(q_i\right)$ is the unit production cost (with $c'\left(q_i\right) > 0$, $c''\left(q_i\right) \geq 0$ and $c\left(0\right) = 0$) and k_i is the certifying cost ($k_i \geq 0$). In order to ensure profitability conditions of the three firms, we assume that the unit production cost of each firm is lower than the maximum willingness to pay for its product. Accordingly, we assume $c\left(q_{Lj}\right) \leq 2\theta q_{Lj}$ and $c\left(q_{NL}\right) \leq \theta q_{NL}$ (j=H,M).

3.1. Perfect perception of quality

In the first stage of the game, firms decide on environmental quality q_i of their products ($q_i \in \left[\underline{q}, \overline{q}\right]$). As quality is costly, a firm chooses either the worst quality $\underline{q}$ or the minimum standard required to stamp a label on its product, q_{LM} or q_{LH}, with $q_{LM} \leq q_{LH}$. In the second stage, firms compete on price. Maximization of profit (1) with respect to price leads to the following Nash equilibrium:

$$p_{NL}^* = \frac{2c\left(\underline{q}\right) + \theta\underline{q}}{3} + \frac{c\left(q_{LM}\right)q_{LH} + c\left(q_{LH}\right)q_{LM} - 2\theta q_{LM}q_{LH}}{3\left(q_{LM} + q_{LH}\right)} \tag{9}$$

$$p_{LM}^* = \frac{c\left(\underline{q}\right) - \theta\underline{q}}{3} + \frac{c\left(q_{LM}\right)\left(4q_{LH} + 3q_{LM}\right) + c\left(q_{LH}\right)q_{LM} + 2\theta q_{LM}\left(2q_{LH} + 3q_{LM}\right)}{6\left(q_{LM} + q_{LH}\right)} \tag{10}$$

$$p_{LH}^* = \frac{c\left(\underline{q}\right) - \theta\underline{q}}{3} + \frac{c\left(q_{LH}\right)\left(3q_{LH} + 4q_{LM}\right) + c\left(q_{LM}\right)q_{LH} + 2\theta q_{LH}\left(3q_{LH} + 2q_{LM}\right)}{6\left(q_{LM} + q_{LH}\right)}. \tag{11}$$

Profits of the three firms are then defined by $\pi_{NL}^* = \frac{\theta q_{LM}q_{LH}}{q_{LM} + q_{LH}} {d_{NL}^*}^2$, $\pi_{LM}^* = \theta q_{LM} {d_{LM}^*}^2 - k_{LM}$ and $\pi_{LH}^* = \theta q_{LH} {d_{LH}^*}^2 - k_{LH}$, with d_{NL}^*, d_{LM}^* and d_{LH}^* the market shares (specified in Appendix A1).

The existence conditions for triopoly can be characterized by thresholds of marginal WTP θ_{NL}, θ_{LM} and θ_{LH} (detailed in Appendix A1) such as $\theta \leq \theta_{NL}$, $\theta \geq \theta_{LM}$, and

$\theta \geq \theta_{LH}$. Assuming a quadratic production-cost function $c(q_i) = q_i^2/2$, it is straightforward to show that $\theta_{LM} \leq \theta_{LH} \leq \theta_{NL}$. Market structure conditions are illustrated with Figure 4 in the perfect information case (black lines) and the imperfect information case (gray lines).[11] This highlights how the market structure depends on two crucial parameters: marginal WTP for environmental quality θ , that is similar for all consumers, and the extent of asymmetry of eco-label standards measured by $\gamma \equiv q_{LH}/q_{LM}$, with $\gamma \geq 1$. In the case of low marginal WTP, only the unlabeled product can benefit from a positive market share. The higher the marginal WTP, the more likely the market structure evolves from a brown monopoly, supplying the unlabeled products, to a vertical duopoly, producing the unlabeled and the l_M -labeled product, a triopoly, providing the three products, or a green duopoly, supplying both labeled products.

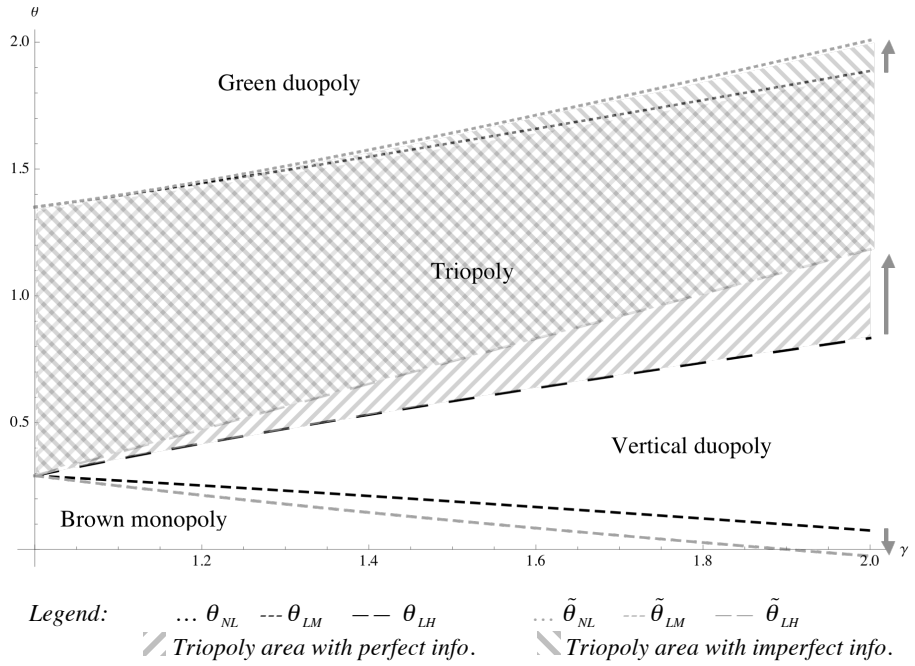


Fig.4 Effects of imperfect information on market structures

3.2. Imperfect perception of quality

In this section, we assume that consumers cannot assess the environmental qualities of the eco-labeled products correctly and only perceive these products as different varieties of the environmentally friendly goods. Hence, he considers that $q_{LM} = q_{LH}$ and perceives environmental quality of eco-labeled products as q_L . We assume, without loss of generality, that $q_L \in [q_{LM}, q_{LH}]$.

We can easily deduce the game equilibrium from the previous section. Denoting q_L as the perceived environmental quality of eco-labeled products, we just have to replace q_{LM} and q_{LH} by q_L , while keeping, obviously, $c(q_{LH})$ and $c(q_{LM})$, in Equations (9) to (11). Accordingly, the game equilibrium is characterized by following prices:

$$\tilde{p}_{NL}^{*} = \frac{1}{6}\left[4c(\underline{q}) + c(q_{LM}) + c(q_{LH}) - 2\theta(q_L - \underline{q})\right] \tag{12}$$

[11] For Figure 2, we have set q_{NL} to 1 and q_{LM} to 1.7 and q_L to the average quality of labeled products.

$$\tilde{p}_{LM}^{*} = \frac{1}{12}\left[4c\left(\underline{q}\right) + 7c\left(q_{LM}\right) + c\left(q_{LH}\right) + 2\theta\left(5q_L - 2\underline{q}\right)\right] \quad (13)$$

$$\tilde{p}_{LH}^{*} = \frac{1}{12}\left[4c\left(\underline{q}\right) + c\left(q_{LM}\right) + 7c\left(q_{LH}\right) + 2\theta\left(5q_L - 2\underline{q}\right)\right] \quad (14)$$

Profits are then defined as $\tilde{\pi}_{NL}^{*} = \theta q_L \tilde{d}_{NL}^{*\,2}/2$ and $\tilde{\pi}_{Lj}^{*} = \theta q_L \tilde{d}_{Lj}^{*\,2} - k_{Lj}$, with $\tilde{d}_{NL}^{*}$ and $\tilde{d}_{Lj}^{*}$ the market shares typified in Appendix A1 (j=*LM, LH*).

By comparing these results with the previous ones in the case of perfect information,[12] we can highlight that consumer misperception of environmental quality tends to favor the firm that supplies the l_M-labeled product to the detriment of its closest competitor, as it benefits from higher demand and profit. Indeed, this firm has a competitive advantage that results from the overstatement of the environmental quality of its product. This competitive advantage is reinforced by its cost advantage (as $c'(q) > 0$), leading to a *perceived* hedonic price, $\tilde{p}_{LM}/q_L$, that is always lower than that of the l_H-labeled product, $\tilde{p}_{LH}/q_L$. Hence, market structure emerging from price competition in a market with imperfect information on environmental quality is likely to differ from that which results from the market with perfect information.

As in the perfect information case, the existence conditions for triopoly can be characterized by marginal WTP $\tilde{\theta}_{NL}$, $\tilde{\theta}_{LM}$ and $\tilde{\theta}_{LH}$ (defined in Appendix A1) such as $\theta \le \tilde{\theta}_{NL}$, $\theta \ge \tilde{\theta}_{LM}$, and $\theta \ge \tilde{\theta}_{LH}$. Assuming a quadratic production cost function $c(q_i) = q_i^2/2$, we can show that $\tilde{\theta}_{LM} \le \tilde{\theta}_{LH} \le \tilde{\theta}_{NL}$. Moreover, Figure 4 shows that incorrect perception of labeled qualities tends to favor firms that supply the l_M-labeled product and the unlabeled product, to the detriment of the firm providing the l_H-labeled product. Although the greenest product is produced and consumed for medium values of marginal WTP θ and label differentiation γ in the perfect information case, it can be removed from the market in the label misperception case. Indeed, it can be shown that $\tilde{\theta}_{NL} \ge \theta_{NL}$, $\tilde{\theta}_{LM} \le \theta_{LM}$ and $\tilde{\theta}_{LH} \ge \theta_{LH}$ for all values of q_{LM}, q_{LH} and q_L. These results are summarized in Proposition 1 below.

Proposition 1. When the perceived quality of eco-labeled products is between real environmental qualities q_{LM} and q_{LH}, the consumers' misperception of eco-labels weakens the firm providing the l_H-labeled product to the benefit of its two competitors and thus can exclude the greenest product from the market.

Let us clarify the mechanism behind this proposition, starting with the triopoly situation. All other things being equal, the overstatement of the quality of the l_M-labeled product allows the firm providing it to increase its price, although the understatement of the l_H-labeled product forces the firm providing it to lower its price. Because the three products are strategic complements, the effect on the price of the unlabeled product depends on the relative scale of these price variations, that in turn is determined by the gap between the perceived quality q_L and the real labeled qualities q_{LM} and q_{LH}. More precisely, a threshold $\hat{q}_L$ exists such as $\tilde{p}_{NL} > p_{NL}$ when $q_L \le \hat{q}_L$, and $\tilde{p}_{NL} < p_{NL}$ otherwise (see Appendix A2).

[12] Demonstrations are provided in Appendix A2.

Consumer misperception of environmental quality tends to divert them from the greenest, undervalued product to the benefit of the unlabeled product, and from the unlabeled product to the benefit of the overvalued l_M-labeled product ($\tilde{d}_{LH} < d_{LH}$, $\tilde{d}_{LM} > d_{LM}$). The net effect on demand for the brown product is positive when the perceived quality of labeled products is close to q_{LM} and negative otherwise. All in all, imperfect information raises profits from the l_M-labeled product, reduces profits from the l_H-labeled product and increases or decreases those from the unlabeled product, according to perceived quality of its competitors.

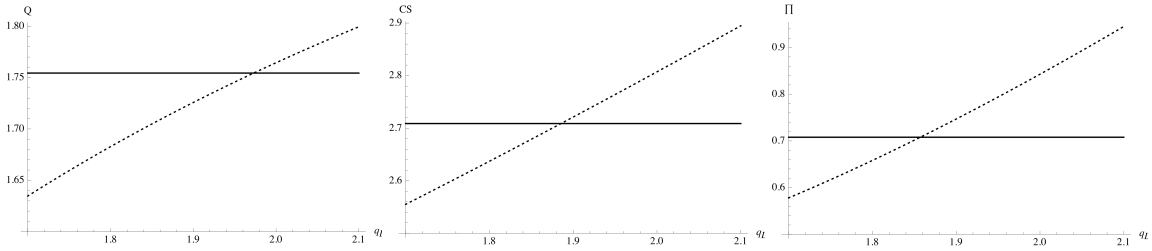
Finally, consumer inability to distinguish environmental quality of products that bear distinct eco-labels impacts market sharing and prices, by favoring the firm providing the eco-labeled product of medium quality.

4. Eco-labeling and welfare

In this section, with regard to welfare, we analyze the consequences of eco-label misunderstanding. Welfare is defined as the sum of consumers' surplus, firms' profits and social benefit of environmental quality. Definition of consumers' surplus can differ according to regulator type (Salanié and Treich, 2009): a paternalistic regulator should base decisions on real environmental qualities of the good, whereas a populist regulator should take into account perceived environmental qualities. In the first case, quality misperception only indirectly affects consumers' surplus through prices and demands. In the second case, the surplus of consumers of the labeled products are based on utility $\tilde{u}_{Lj}(\lambda)$, defined in Equation 5, where perceived quality q_L directly affects Consumer λ's gross surplus. In addition, in both cases, the regulator internalizes the environmental externality by including the global environmental quality of products Q, defined by $Q \equiv q_{NL}d_{NL} + q_{LM}d_{LM} + q_{LH}d_{LH}$, in the social benefit from environmental quality. This is simply assumed to be δQ, with $\delta \geq 0$. δ can be interpreted as the usual marginal environmental damage, that is monetary valuation of marginal degradation (or improvement) of quality of the environment Q. Therefore, by internalizing the externality, the regulator behaves in a paternalistic way. Finally, we adopt an intermediate view of regulator decisions: both populist, based on perceived gross surplus of consumers, $\tilde{u}_{Lj}(\lambda)$, and paternalist, based on internalization of real global environmental quality of products, Q.

We first study impacts of imperfect information on each component of welfare, particularly the quality of the environment. Second, we investigate eco-labeling strategies according to the instigators of both labels (firms, the regulator and/or an NGO) in the benchmark case of perfect information. We also discuss how consumer misperception of environmental quality may affect these eco-labeling strategies and welfare.

4.1. Welfare implications of consumers misperception



(a) Quality of the Environment (b) Consumer Surplus (c) Profits

Fig. 5 Effects of perceived quality q_L on welfare components

In Figure 5, we illustrate the effects of consumer misperception on welfare components according to their assessment of the quality of labeled products in the triopoly case.[13]

In the previous section, we have shown the effects of quality misperception on market sharing. By decreasing demand for the l_H-labeled product and raising demand for l_M-labeled product, consumers' confusion has a detrimental effect on the global quality of the environment. On the other hand, when the perceived quality is sufficiently low (high), the demand for the unlabeled product is increased (decreased). All in all, imperfect information tends to degrade the quality of the environment when perceived quality q_L is not too high. However, when consumers believe that both labels signal high environmental quality, they are pushed to purchase more eco-labeled products and less unlabeled product than in the perfect information case. The environment is then enhanced by consumer error.

Consumer misperception has two opposite effects on their surplus. On the one hand, the *price effect* is favorable for the consumption of the l_H-labeled product, which is cheaper, whereas the effect is unfavorable for the l_M-labeled product, which is more expensive. On the other hand, the *volume effect* harms consumers' surplus of the l_H-labeled product and benefits consumers' surplus of the l_M-labeled product. For the l_H-labeled product, the price effect does not outweigh the volume effect, leading to consumer surplus loss. For the l_M-labeled product, the volume effect offsets the price effect, leading to consumer surplus gain. In addition, price and volume effects play in the same direction for the unlabeled product: positively when the perceived quality is relatively low and positively otherwise. Finally, the global consumer surplus can be favored by imperfect information only when consumers attach a relatively high environmental quality to both labeled products, but it is damaged in case of low valuation of the environmental quality of these certified products.

From previous analyses, we can easily infer that profit gains of the firm that provides the l_M-labeled product can compensate other firms' profit loss, especially when the perceived quality is high.

From these effects of consumer misperception on welfare components, we deduce Proposition 2 below.

[13] For Fih-gure 5, we have set $\theta = 1$, $\underline{q} = 1$, $q_{LM} = 1.7$, $q_{LH} = 2$, fixed costs equal to 0, and assumed a quadratic cost function. Some elements of proof of the effects of perceived quality on welfare components are provided in Appendix A3.

Proposition 2. The consumers' quality misperception of eco-labels can enhance welfare through its positive effect on the profits of the L_M-firm and its potential beneficial effect on the quality of the environment. The higher δ and perceived quality q_L are, the greater welfare is.

Hence, paradoxically, whereas consumers' quality misperception represents a market failure, it can improve welfare-improving. Global effect crucially depends on the value of marginal environmental damage δ and perceived quality q_L, which determine the quality of the environment and competitive advantage of the firm providing the l_M-labeled product. Accordingly, for given eco-labeling standards, it is not necessary in the regulator's stake to foster eco-label transparency and better information for consumers.

However, implications of eco-labeling strategies for welfare components depend on quality standard stringency, which, in turn, depends on the identity of the certifying organizations. Accordingly, we investigate the eco-labeling strategies of diverse organizations, with different eco-labeling objectives, in order to go further in our analysis of consequences of eco-label misperception.

4.2. Eco-labeling strategies with fully-informed consumers

In this section, we study the eco-labeling strategies of the three types of certifying organizations: the regulator, who aims to improve welfare, an NGO, which attempts to improve the quality of the environment, and the firms, which want to maximize their profits. We start from the perfect information case that provides clear results on eco-labeling strategies, and then we will infer, in the next section, possible consequences of eco-label misperception on eco-labeling strategies, market competition and welfare.

In order to ease the analysis, we assume henceforth a quadratic cost function $c(q_i) = q_i^2/2$. Numerical resolutions are performed with θ and $\underline{q}$ normalized to 1.[14] The effects of eco-labeling strategy on prices, demands, profits and welfare components are synthesized in Table 1.

Table 1. Implications of eco-labeling strategies in the perfect information case

	Corporate labels			NGO's & corporate labels			Public & corporate labels			NGO's & public labels		
	NL	LM	LH	NL	LM	LH	NL	LM	LH	NL	LM	LH
q_i	1	1.65	1.65	1	1.70	2.65	1	1.67	2.13	1	2.25	2.77
p_i	0.57	2.12	2.12	0.72	2.28	4.27	0.64	2.19	3.09	0.88	3.46	4.63
d_i	0.09	0.46	0.46	0.22	0.49	0.29	0.15	0.47	0.38	0.30	0.41	0.28
π_i	0.01	0.35	0.35	0.05	0.42	0.22	0.02	0.37	0.31	0.12	0.38	0.23
Π	0.70			0.68			0.70			0.71		
CS	$r + 0.77$			$r + 0.59$			$r + 0.71$			$r + 0.42$		
Q	1.60			1.82			1.75			2.02		
W	$r + 1.47 + 1.60\ \delta$			$r + 1.27 + 1.82\ \delta$			$r + 1.41 + 1.75\ \delta$			$r + 1.14 + 2.02\ \delta$		

Corporate eco-labeling

Consider first the case where two firms stamp two different green labels on their products, with their own certification criteria q_{LM} and q_{LH}, in order to maximize profit.

[14] Robustness of our results has been tested with numerical simulations using various suitable values of θ and $\underline{q}$.

Maximization of $\pi^*_{Lj} = \theta q_{Lj} d^{*2}_{Lj} - k_{Lj}$ with respect to qualities yields to a unique equilibrium where both firms adopt the same standard, defined as (see Appendix A4):

$$q^*_L = \frac{1}{4}\left(3\theta + \sqrt{9\theta^2 + 8\theta - 4}\right) \tag{26}$$

Because consumers have heterogeneous preferences for eco-labels, firms have an interest in harmonizing their standards in order to share the market efficiently. In this case, consumers are right in believing that all eco-labels signal the same environmental quality, better than that of the unlabeled product. Obviously, minimal environmental quality q^*_L rises with marginal WTP for quality θ. When θ and $\underline{q}$ are normalized to 1, the standard is equal to 1.65. The two firms that provide the eco-labeled products share almost all the market, whereas the firm providing the unlabeled product benefits from very low market share and profit.

NGO and corporate eco-labeling

We assume now that an NGO implements an eco-label in order to maximize the quality of the environment, although only one firm sets up its own eco-label to maximize its profit. No analytical solution can be found using the first-order conditions. However, normalizing θ and $\underline{q}$ to 1, numerical resolution highlights that only a consistent equilibrium exists. The firm that provides its own eco-labeled product (hereafter Firm M) sets its standard to $q^{nc}_{LM} = 1.70$, while the NGO implements a much more stringent certification criteria, with $q^{nc}_{LH} = 2.65$.

Complying with the NGO's criteria weakens the firm that provides the l_H-labeled product (hereafter Firm H) with respect to the case of two corporate labels. Firm H is burdened by a high production cost, forcing it to noticeably increase its price. This weighs on its market share and profit. Conversely, Firm M benefits from the NGO's label introduction, through greater market share and profit. Paradoxically, the firm that provides the least environmentally friendly product (hereafter Firm NL) is better off in this situation as it attracts the consumers who are not able to pay high prices for high environmental qualities, especially for the l_H-labeled product. Finally, the quality of the environment is enhanced, to the detriment of global profit and consumer surplus.

Public and corporate eco-labeling

Let us examine the case where the regulator is in charge of eco-label q_{LH}, which aims at maximizing welfare, while a firm manages its own quality, q_{LM}. Numerical resolution yields only one solution fulfilling the triopoly conditions: Firm M sets the minimal quality to $q^{pc}_{LM} = 1.67$ and the regulator claims a greener quality, $q^{pc}_{LH} = 2.13$. The regulator's label is less exacting than the NGO's one. Accordingly, it takes into account the penalizing effect of a rise in q_{LH} on consumers' surplus, due to ensuing price increase, and its damaging impact on Firm H's profit, and meanwhile it internalizes its enhancing outcome on the quality of the environment. In this way, coexistence of a public label and a private one leads to an intermediate equilibrium between those emerging from corporate labels and from coexistence of a NGO's label and a private label.

NGO and public eco-labeling

Finally, certifying criteria can be decided outside the firms. Let us consider the case where q_{LH} is chosen by an NGO that wants to maximize the environmental quality, although q_{LM} is decided by the regulator, with a welfare goal. Numerical resolution shows that only one consistent equilibrium exists. The resulting standards are more stringent than in all other cases, because $q_{LM}^{np} = 2.25$ and $q_{LH}^{np} = 2.77$. Surprisingly, this situation is the better one for Firm NL that is more competitive than in other cases because of relatively high prices of eco-labeled products of very high environmental qualities. Obviously, Firm M is less advantaged than when it can choose its own labeling criteria. Firm H's performances are close to those from which it benefits in the case of coexistence of NGO's and Firm M's labels. From a welfare perspective, certification by the regulator and an NGO leads to the highest global profit and the greatest quality of the environment. Conversely, this is detrimental to consumers, who benefit from the lowest surplus in this situation, because high prices are not offset by high environmental qualities and a large part of consumers is constrained to buy the unlabeled, cheap product.

Comparison of eco-labeling strategies according to the certifying organizations is synthesized in Proposition 3 below.

Proposition 3. When consumers are perfectly informed of environmental quality of eco-labeled products, eco-labeling criteria differ according to the certifying organizations: A corporate eco-label would be less demanding than a public eco-labels, which in turn would be less exacting than an NGO's eco-label. Certification by the regulator and an NGO guarantees the highest environmental quality of eco-labeled products.

4.3. Eco-labeling strategies with consumer misperception of qualities

In the case of imperfect information, eco-labeling strategies depend on information that the certifying organizations have on consumer belief. We examine two polar cases: the case of myopic certifying organizations, which do not see that consumers misperceive the environmental qualities of eco-labeled products, and the case of fully-informed certifying organizations, which perfectly know the perceived quality and the way the consumers form their belief.

Myopic certifying organizations

In the myopic case, we find ourselves in the same situation as in Section 4.1, except when eco-labels are self-declared by firms that harmonize their standards and stamp different eco-labels on their products in order to attract the most consumers possible. In this case, consumers correctly assess the environmental quality of eco-labeled products.

When an NGO and/or the regulator are/is in charge of an eco-label, both eco-labels are differentiated in quality requirements but consumers believe that they both signal the same quality. When the perceived quality is relatively high,[15] consumer surplus, profits and the quality of the environment will be higher than in the perfect information case, leading to a greater social welfare. Accordingly, the best strategy for an

[15] The threshold above which the perceived quality is considered as 'relatively high' differs according to the identity of the certifying organization.

environmental NGO and the regulator is to promote all eco-labeled products with a clear message that enables the creation of a positive image of green products to consumers, instead of attempting to establish the truth about the real environmental quality signaling by the different eco-labels.

Fully-informed certifying organizations

In the case of fully-informed firms, NGO and regulator, we simply assume that q_L is a weighted average of real qualities, $q_L \equiv \mu q_{LH} + (1-\mu) q_{LM}$, with $0 \leq \mu \leq 1$, and that the certifying organizations endogenize the perceived quality. The effects of eco-labeling strategy on prices, demands and profits and welfare components are in Table 2.

Table 2. Implications of eco-labeling strategies in the imperfect information case

	Corporate labels			NGO's & corporate labels (μ=0.2)			NGO's & corporate labels (μ=0.5)			NGO's & corporate labels (μ=0.8)		
	NL	LM	LH	NL	LM	LH	NL	LM	LH	NL	LM	LH
q_i	1	1	1	1	1	1.55	1	1	1.8	1	1	2.15
p_i	-	1.5	1.5	0.58	1.15	1.50	0.55	1.42	1.98	0.49	1.92	2.82
d_i	-	0.5	0.5	0.14	0.58	0.27	0.08	0.66	0.26	0.005	0.74	0.26
π_i	-	0.5	0.5	0	0.38	0.08	0	0.61	0.10	0	1.04	0.14
Π	1			0.47			0.71			1.19		
CS	$r + 0.25$			$r + 0.65$			$r + 0.80$			$r + 1.10$		
Q	1			1.15			1.21			1.31		
W	$r + 1.25 + \delta$			$r + 1.12 + 1.15\ \delta$			$r + 1.51 + 1.21\ \delta$			$r + 2.28 + 1.31\ \delta$		

Replacing q_L by its definition in demand functions, we can easily deduce that consumer demand for an eco-labeled product is a decreasing function of its environmental quality. The reason is that the production cost of this product rises faster than the minimal willingness to pay for the product, θq_L. Because loss in market share cannot be offset by higher prices, the best eco-labeling strategies of firms is greenwashing: Supplying the worst quality, $\underline{q}$, although marking their products with homemade green logos.

Greenwashing leads to the disappearance of the unlabeled product and to Hotelling competition between both firms having the labels. Firms H and M equally share the market and earn a profit $(\theta \underline{q}/2) - k_{Lj}$ higher than in the perfect information case. However, the quality of the environment, simply defined by $\underline{q}$, and consumer surplus, equal to $r + 0.25$, are both lower than in the perfect information case. Finally, unsurprisingly, social welfare is damaged by greenwashing that results from consumer misperception of environmental qualities. This justifies implementation of a system of verification of environmental allegation, in order to avoid that firms untruthfully declare their products as 'environmentally friendly'.

What is the best response of an NGO or the regulator to $\tilde{q}_{LM} = \underline{q}$? Because we cannot provide analytical solutions for this issue either, we continue with numerical resolutions, normalizing θ and $\underline{q}$ to 1.

For a given μ, the quality of the environment is a concave function of q_{LH}, maximized for standard $\tilde{q}_{LH}^{nc}$ all the higher as the perceived quality is close to q_{LH}, namely μ is close to 1. For instance, $\tilde{q}_{LH}^{nc}$ is equal to 1.55 when μ=0.2, 1.80 for μ=1/2

and 2.15 for μ=0.8. Therefore, the NGO's labeling criteria is less demanding than in the perfect information case.

The effects of consumer misperception on profits crucially depend on the perceived quality (see Table 2). When perceived quality is close to $\underline{q}$, the three firms earn lower profits than in the perfect information case. When perceived quality is higher, Firm H is still penalized by its inability to fairly price its eco-labeled product, due to underestimation of its environmental quality, whereas Firm M is favored by consumer misperception and Firm NL sees its market share and its profit tend to zero. As a result, according to μ, the global profit will be lower or higher than in the perfect information case. Moreover, consumers benefit from low prices and greater consumption of eco-labeled product, in such a way as their surplus is enhanced by quality misperception, whatever μ. More importantly, the quality of the environment is always damaged by imperfect information, forcing the NGO to require less stringent certification criteria than in the benchmark case.

Determination of the optimal eco-labeling strategy of the regulator is problematic. For a given q_{LM}, a rise in q_{LH} has contrasting effects on welfare components and, according to μ, its effects on global profit and consumer surplus play in opposite direction. More precisely, when μ is low, an increase in q_{LH} has a U-shaped effect on global profit and decreases global consumer surplus, whereas, when μ is high, both global profit and consumer surplus are enhanced by a higher quality. In addition, it has an inverse U-shaped effect on the quality of the environment. All in all, welfare can be a decreasing, inverse U-shaping or increasing function of q_{LH} when μ varies from 0 to 1. In the same way, for a given q_{LH}, a rise in q_{LM} has contrasting effects on welfare variation according to μ. Therefore, no clear-cut conclusion can be drawn for public eco-labeling strategy when a firm or a NGO certifies the second eco-label.

Main results are described in the following proposition.

Proposition 4. When certifying organizations know how consumers shape their belief on environmental quality, the consumers' quality misperception of eco-labels favors greenwhashing of firms and forces the NGO's to adopt less demanding criteria than in the case of perfect information.

5. Conclusion

Too much of a good thing? Proliferation of eco-labels tends to delete their primary objective, which is to inform consumers of the environmental quality of credence goods. Consumers find it difficult to identify the best eco-labels, rigorously certified by a third-party, among all the more or less serious green claims. Therefore, competition between green products leads to consumers' imperfect information and could have detrimental effects on economic efficiency and environmental benefits of eco-labels.

The aim of this article was to verify this intuition by simply comparing a situation where consumers can assess the environmental quality of products perfectly and another situation where they perceive different eco-labels as a sign of a same environmental quality, but where they would distinguish varieties of green product in such a way that they choose a label according to the image it conveys, rather than the intrinsic quality it guarantees.

Within this original framework, we fist show that consumer confusion can modify the market structure compared with the perfect information case: The greenest firm is weakened by consumers' confusion to the benefit of the firm supplying the eco-labeled product of medium environmental quality, and even sometimes to the benefit of the firm providing the unlabeled product. For medium values of marginal WTP and eco-labeled product differentiation, the greenest product can be evicted from the market in the imperfect information case, whereas it could maintain its standing in the triopoly market in the perfect information case.

The effects of consumers' confusion on social welfare are contradictory. Imperfect information tends to damage the quality of the environment when the perceived quality of eco-labeled products is not too high. However, it can enhance the quality of the environment when consumers believe that both eco-labels signal high environmental quality. Likewise, consumer surplus and global profit suffer from a low perceived quality, but benefit from a highly perceived quality of eco-labeled products. Hence, paradoxically, the combined effect of imperfect information on profits, consumer surplus and environmental quality is likely to improve welfare when consumers appraise the environmental quality of all eco-labeled products highly.

Finally, we have highlighted that eco-labeling strategies differ according to the identity of the certification criteria and to the nature of consumer information. In the case of Type II eco-labels, self-declared by firms, according to the *International Organization for Standardization*'s terminology, if consumers perfectly assess the environmental quality of products, firms would harmonize their eco-labeling criteria and be demanding towards their eco-labeled products. However, in the case of consumer misperception, when firms know the way the consumers form their belief on environmental quality, they will turn to greenwashing, stamping eco-label on their products of the least environmental quality. In the case of Type I eco-labels, certified by a third party, certifying criteria are more exacting, particularly when it is an NGO that is in charge of the eco-label. However, when consumers cannot precisely ascertain the environmental quality of labeled products, an NGO will require less stringent standard than in the perfect information case.

To conclude, implementation of policies that help consumers to correctly assess environmental quality of eco-labeled products, such as publication of eco-label guidelines, is not necessarily welfare improving. In general, promoting green products that favor consumer opinion that environmentally friendly products are a good value for the money, may be more effective. At the same time, greenwashing should be denounced with communication tools such as the "Pinocchio awards" of the Friends of the Earth in France.[16] Notwithstanding, public eco-labeling policies are a perquisite for driving consumers towards greener products.

Appendix

A1. Price equilibrium

Case of perfect perception of quality

From Equations (9) and (11) and definitions of demand functions, we deduce following market shares of the three firms:

[16] http://www.prix-pinocchio.org/en/index.php (accessed 2014/10/03)

$$d_{LM}^{*} = \frac{c(\underline{q}) - \theta\underline{q}}{3\theta q_{LM}} + \frac{c(q_{LH})q_{LM} + (2\theta q_{LM} - c(q_{LM}))(2q_{LH} + 3q_{LM})}{6\theta q_{LM}(q_{LH} + q_{LM})}$$

$$d_{LH}^{*} = \frac{c(\underline{q}) - \theta\underline{q}}{3\theta q_{LH}} + \frac{c(q_{LM})q_{LH} + (2\theta q_{LH} - c(q_{LH}))(3q_{LH} + 2q_{LM})}{6\theta q_{LH}(q_{LM} + q_{LH})},$$

and $d_{NL}^{*} = 1 - d_{LM}^{*} - d_{LH}^{*}$. Profits are $\pi_{NL}^{*} = \frac{\theta q_{LM} q_{LH}}{q_{LM} + q_{LH}} d_{NL}^{*\,2}$, $\pi_{LM}^{*} = \theta q_{LM} d_{LM}^{*\,2} - k_{LM}$ and $\pi_{LH}^{*} = \theta q_{LH} d_{LH}^{*\,2} - k_{LH}$.

The three conditions for triopoly, $d_{NL}^{*} \geq 0$, $d_{LM}^{*} \geq 0$ and $d_{LH}^{*} \geq 0$, can be translated into the conditions $\theta \leq \theta_{NL}$, $\theta \geq \theta_{LM}$ and $\theta \geq \theta_{LH}$, where the thresholds are defined as follows:

$$\theta_{NL} \equiv \frac{c(q_{LH})q_{LM} + c(q_{LM})q_{LH} - (q_{LM} + q_{LH})c(\underline{q})}{2q_{LM}q_{LH} - (q_{LM} + q_{LH})\underline{q}},$$

$$\theta_{LM} \equiv \frac{-c(q_{LH})q_{LM} + c(q_{LM})(2q_{LH} + 3q_{LM}) - 2(q_{LM} + q_{LH})c(\underline{q})}{6q_{LM}^{2} + 4q_{LM}q_{LH} - 2(q_{LM} + q_{LH})\underline{q}},$$

$$\theta_{LH} \equiv \frac{c(q_{LH})(3q_{LH} + 2q_{LM}) - c(q_{LM})q_{LH} - 2(q_{LM} + q_{LH})c(\underline{q})}{6q_{LH}^{2} + 4q_{LM}q_{LH} - 2(q_{LM} + q_{LH})\underline{q}}.$$

Case of imperfect perception of quality

From Equations (12) and (14) and definitions of demand functions, we deduce following market shares of the three firms:

$$\tilde{d}_{NL}^{*} = \frac{c(q_{LM}) + c(q_{LH}) - 2c(\underline{q}) - 2\theta(q_{L} - \underline{q})}{12\theta q_{L}}$$

$$\tilde{d}_{LM}^{*} = \frac{4c(\underline{q}) - 5c(q_{LM}) + c(q_{LH}) + 2\theta(5q_{L} - 4\underline{q})}{12\theta q_{L}}$$

$$\tilde{d}_{LH}^{*} = \frac{4c(\underline{q}) + c(q_{LM}) - 5c(q_{LH}) + 2\theta(5q_{L} - 4\underline{q})}{12\theta q_{L}}.$$

The existence conditions for triopoly are characterized by following marginal WTP $\tilde{\theta}_{NL}$, $\tilde{\theta}_{LM}$ and $\tilde{\theta}_{LH}$ such as $\tilde{d}_{NL}^{*} \geq 0$ when $\theta \leq \tilde{\theta}_{NL}$, $\tilde{d}_{LM}^{*} \geq 0$ when $\theta \geq \tilde{\theta}_{LM}$, and $\tilde{d}_{LH}^{*} \geq 0$ when $\theta \geq \tilde{\theta}_{LH}$:

$$\tilde{\theta}_{NL} \equiv \frac{c(q_{LH}) + c(q_{LM}) - 2c(\underline{q})}{2(q_{L} - \underline{q})}$$

$$\tilde{\theta}_{LM} \equiv \frac{-c(q_{LH}) + 5c(q_{LM}) - 4c(\underline{q})}{10q_{L} - 4\underline{q}}$$

$$\tilde{\theta}_{LH} \equiv \frac{5c\left(q_{LH}\right) - c\left(q_{LM}\right) - 4c\left(\underline{q}\right)}{10q_L - 4\underline{q}}.$$

A2. Effects of consumer misperception on market equilibrium

The l_H-labeled product

From Equation (20), it is easy to show price $\tilde{p}^*_{LH}$ is an increasing function of q_L. Hence, in order to prove that $p^*_{LH} \geq \tilde{p}^*_{LH}$, it is sufficient to demonstrate that this inequality is true for $q_L = q_{LH}$. Because $p^*_{LH} - \tilde{p}^*_{LH}\big|_{q_L = q_{LH}} = \frac{\left(q_{LH} - q_{LM}\right)\left(2\theta q_{LH} - c\left(q_{LH}\right) + c\left(q_{LM}\right)\right)}{12\left(q_{LM} + q_{LH}\right)}$ and $c\left(q_{LH}\right) \leq 2\theta q_{LH}$, then $p^*_{LH} \geq \tilde{p}^*_{LH}$ is always fulfilled.

From Equation (23), it results that $\tilde{d}^*_{LH}$ is an increasing function of q_L because $\frac{\partial \tilde{d}^*_{LH}}{\partial q_L} = \frac{5c\left(q_{LH}\right) - c\left(q_{LM}\right) - 4c\left(\underline{q}\right) + 4\theta\underline{q}}{12\theta q_L^2}$ and triopoly existence requires that $c\left(\underline{q}\right) \leq \theta\underline{q}$. Accordingly, in order to prove that $d^*_{LH} \geq \tilde{d}^*_{LH}$, it is sufficient to demonstrate that this inequality is true for $q_L = q_{LH}$. In this case, $d^*_{LH} - \tilde{d}^*_{LH}\big|_{q_L = q_{LH}} = \frac{\left(q_{LH} - q_{LM}\right)\left(2\theta q_{LH} - c\left(q_{LH}\right) + c\left(q_{LM}\right)\right)}{12\theta q_{LH}\left(q_{LM} + q_{LH}\right)}$ is positive. Thus, $d^*_{LH} \geq \tilde{d}^*_{LH}$ for all $q_L \leq q_{LH}$.

Finally, because consumer misperception decreases both the price and the market share of the l_H-labeled product, it also lowers the profit of the firm providing this product.

The l_M-labeled product

From Equation (19), it follows that $\tilde{p}^*_{LM}$ declines with q_L. Moreover $p^*_{LM} \leq \tilde{p}^*_{LM}$ when $q_L = q_{LM}$ because $p^*_{LM} - \tilde{p}^*_{LM}\big|_{q_L = q_{LM}} = \frac{-\left(q_{LH} - q_{LM}\right)\left(c\left(q_{LH}\right) - c\left(q_{LM}\right) + 2\theta q_{LM}\right)}{12\left(q_{LM} + q_{LH}\right)} \leq 0$.

Consequently, $p^*_{LM} \leq \tilde{p}^*_{LM}$ for all $q_L \geq q_{LM}$.

From Equation (22), the derivative of $\tilde{d}^*_{LM}$ with respect to q_L is characterized by $\frac{\partial \tilde{d}^*_{LM}}{\partial q_L} = \frac{-c\left(q_{LH}\right) + 5c\left(q_{LM}\right) - 4c\left(\underline{q}\right) + 4\theta\underline{q}}{12\theta q_L^2}$. It is positive when $c\left(q_{LH}\right)$ is not too high in comparison with $c\left(q_{LM}\right)$. Note also that $\frac{\partial \tilde{d}^*_{LM}}{\partial q_L} = \frac{5}{6q_L} - \frac{\tilde{d}_{LM}}{q_L}$, which is positive when the l_M-labeled product captures less than 5/6 of the market. Furthermore, $d^*_{LM} - \tilde{d}^*_{LM}\big|_{q_L = q_{LM}} = \frac{-\left(q_{LH} - q_{LM}\right)\left(c\left(q_{LH}\right) - c\left(q_{LM}\right) + 2\theta q_{LM}\right)}{12\theta q_{LM}\left(q_{LM} + q_{LH}\right)}$ is negative. As a result, $d^*_{LM} \leq \tilde{d}^*_{LM}$ for all $q_L \geq q_{LM}$.

All in all, the profit of the firm producing the l_M-labeled product is enhanced by consumer misperception, in relation to the perfect information case.

The unlabeled product

From Equation (18), it appears that $\tilde{p}^*_{NL}$ is a decreasing function of q_L. In addition, when $q_L = q_{LM}$, $p^*_{NL} - \tilde{p}^*_{NL}\big|_{q_L = q_{LM}} = \dfrac{-\left(q_{LH} - q_{LM}\right)\left(c\left(q_{LH}\right) - c\left(q_{LM}\right) + 2\theta q_{LM}\right)}{6\left(q_{LM} + q_{LH}\right)}$ is negative, but, when $q_L = q_{LH}$, $p^*_{NL} - \tilde{p}^*_{NL}\big|_{q_L = q_{LH}} = \dfrac{\left(q_{LH} - q_{LM}\right)\left(2\theta q_{LH} - c\left(q_{LH}\right) + c\left(q_{LM}\right)\right)}{6\left(q_{LM} + q_{LH}\right)}$ is positive. Therefore, there exists a threshold $\hat{q}_L$ such as $\tilde{p}_{NL} > p_{NL}$ when $q_L \le \hat{q}_L$, and $\tilde{p}_{NL} < p_{NL}$ otherwise. This threshold is defined $\hat{q}_L = \dfrac{2\theta q_{LM} q_{LH} + \left(q_{LH} - q_{LM}\right)\left(c\left(q_{LH}\right) - c\left(q_{LM}\right)\right)}{2\theta\left(q_{LM} + q_{LH}\right)}$.

The demand for the unlabeled product decreases with q_L, as $\dfrac{\partial \tilde{d}^*_{NL}}{\partial q_L} = \dfrac{-c\left(q_{LH}\right) - c\left(q_{LM}\right) + 2c\left(\underline{q}\right) - 2\theta\underline{q}}{3\theta q_L^2}$ is negative. Moreover,

$$d^*_{NL} - \tilde{d}^*_{NL}\big|_{q_L = q_{LM}} = \frac{-\left(q_{LH} - q_{LM}\right)\left(c\left(q_{LH}\right) - c\left(\underline{q}\right) + \theta\underline{q}\right)}{3\theta q_{LM} q_{LH}} \le 0$$

$$d^*_{NL} - \tilde{d}^*_{NL}\big|_{q_L = q_{LH}} = \frac{\left(q_{LH} - q_{LM}\right)\left(c\left(q_{LM}\right) - c\left(\underline{q}\right) + \theta\underline{q}\right)}{3\theta q_{LM} q_{LH}} \ge 0.$$

As a consequence, compared with the perfect information case, the unlabeled product benefits from a higher market share when the perceived quality is close to q_{LM} , and suffers from a lower market share when the q_L is close to q_{LH}.

Obviously, the profit of the firm that sells the unlabeled product follows the same development, translating greater performance when q_L is close to q_{LM} and a worse one when q_L is close to q_{LH}.

A3. Effects of consumer misperception on welfare components

In this Appendix, we only provide some elements of proof, because the large number of involved parameters prevents a total analytical demonstration of the effects of perceived quality q_L on welfare components. Notwithstanding, numerical simulations with a large set of relevant values of parameters and a quadratic cost function were used to check the robustness of our results.

Environmental quality

The derivative of global environmental quality in the imperfect information case is characterized by:

$$\frac{\partial \tilde{Q}}{\partial q_L} = \frac{\left(5q_{LH} - q_{LM} - 4\underline{q}\right)c\left(q_{LH}\right) - \left(q_{LH} - 5q_{LM} - 4\underline{q}\right)c\left(q_{LM}\right) + 4\left(q_{LH} + q_{LM} - 2\underline{q}\right)\left(\theta q_{NL} - c\left(\underline{q}\right)\right)}{12\theta q_L^2}$$

.

As the second term of the numerator is necessarily lower than the first term and the third term is positive, the global environmental quality rises with perceived quality q_L.

Note that $Q^* - \tilde{Q}^* = \left(q_{LH} - q_{LM}\right)\left(d^*_{LH} - \tilde{d}^*_{LH}\right) - \left(q_{LM} - \underline{q}\right)\left(d^*_{NL} - \tilde{d}^*_{NL}\right)$. Accordingly, when q_L is close to q_{LM} , $d^*_{NL} \le \tilde{d}^*_{NL}$ and the global environmental quality is worsened by quality

misperception. Conversely, when q_L is close to q_{LH}, $d^*_{NL} \geq \tilde{d}^*_{NL}$ and $Q^* - \tilde{Q}^*$ may be positive or negative according to quality gaps between the three products and their differences in market shares.

The condition for $Q^* < \tilde{Q}^*$ can be expressed as $\left(q_{LH} - \underline{q}\right)\left(d^*_{LH} - \tilde{d}^*_{LH}\right) < \left(q_{LM} - \underline{q}\right)\left(\tilde{d}^*_{LM} - d^*_{LM}\right)$. Therefore, the environment is likely to be of better quality in the imperfect information case than in the perfect information case when the loss in market share of the l_H-labeled product is significantly lower than the gain in market share of the l_M-labeled product (knowing that $q_{LH} - \underline{q} > q_{LM} - \underline{q}$). Although, because of the large number of parameters, we cannot go any further in the analytical demonstration, numerical simulations confirm that, when the perceived quality is high, the global environmental quality is greater than that occurring in the perfect information case.

Consumer surplus

Table A1. Definitions of consumer surplus (with j=M,H)

Perfect information	*Imperfect Information*
$CS_{NL} = \left(r + \theta\underline{q} - c\left(\underline{q}\right)\right)d_{NL} - \frac{\theta q_{LH} q_{LM}}{q_{LH} + q_{LM}} d^2_{NL}$	$C\tilde{S}_{NL} = \left(r + \theta\underline{q} - c\left(\underline{q}\right)\right)\tilde{d}_{NL} - \frac{\theta q_L}{2}\tilde{d}^2_{NL}$
$CS_{Lj} = \left(r + 2\theta q_{Lj} - c\left(q_{Lj}\right)\right)d_{Lj} - \frac{3}{2}\theta q_{Lj} d^2_{Lj}$	$C\tilde{S}_{Lj} = \left(r + 2\theta q_{Lj} - c\left(q_{Lj}\right)\right)\tilde{d}_{Lj} - \frac{1}{2}\theta\left(2q_L + q_{Lj}\right)\tilde{d}^2_{Lj}$

The derivatives of the surplus of the three types of consumers are characterized as follows:

$$\frac{\partial C\tilde{S}_{NL}}{\partial q_L} = \frac{1}{3}\left(3r + 2\theta q_L - c\left(q_{LH}\right) - c\left(q_{LM}\right) + \theta\underline{q} - c\left(\underline{q}\right)\right)\frac{\partial \tilde{d}_{NL}}{\partial q_L} - \frac{\theta}{2}\tilde{d}^2_{NL}$$

$$\frac{\partial C\tilde{S}_{Lj}}{\partial q_L} = \left(r + 2\theta q_{Lj} - c\left(q_{Lj}\right) - \left(2q_L + q_{Lj}\right)\theta\tilde{d}_{Lj}\right)\frac{\partial \tilde{d}_{Lj}}{\partial q_L} - \theta\tilde{d}^2_{Lj}.$$

The surplus of consumers of the unlabeled product decreases with q_L since $\partial\tilde{d}_{NL}/\partial q_L \leq 0$ and the term in parentheses is positive. Indeed, $3r + 2\theta q_L - c\left(q_{LH}\right) - c\left(q_{LM}\right) + \theta\underline{q} - c\left(\underline{q}\right)$ corresponds with the sum of consumer utility $u_{NL}(\lambda) + u_{LM}(1) + u_{LH}(0)$ (with $\lambda \in [0,1]$), when the three products are sold at their marginal costs. This sum is positive under the reasonable assumption that consumer utility is positive when a product is purchased at its marginal cost. Furthermore, it can be shown that $C\tilde{S}_{NL}\big|_{q_L = q_{LH}} < CS_{NL} < C\tilde{S}_{NL}\big|_{q_L = q_{LM}}$.

As $\partial\tilde{d}_{Lj}/\partial q_L \geq 0$, the effects of a rise in perceived quality q_L on $C\tilde{S}_{Lj}$ are less clear and cannot be analytically demonstrated. Numerical simulations prove that the surplus of consumers of the l_M-labeled product decreases with q_L and that, according to quality gaps, $C\tilde{S}_{LM}$ can be higher or lower than CS_{LM} when q_L is close to q_{LM}, but it is always lower than CS_{LM} when q_L is close to q_{LH}. Moreover, the surplus of consumers of the l_H-labeled product increases with q_L and $C\tilde{S}_{LH}$ is always lower than CS_{LH}. Numerical simulations also show that the global surplus decreases with q_L and is below the global surplus of consumers in the perfect information case when q_L is not too low.

A4. Eco-labeling strategies of firms in the perfect information case

Maximization of profit (1) with demand functions (13) and (14) leads to following first-order conditions (FOCs): $\left(d_{Lj}^{*}+2q_{Lj}\frac{\partial d_{Lj}^{*}}{\partial q_{Lj}}\right)\theta d_{Lj}^{*}=0$. Assuming a quadratic cost function and normalizing $\underline{q}$ to 1, the FOCs can be rewritten:

$$\begin{cases}\left(q_{LH}+q_{LM}\right)^{2}\left(4\theta-9q_{LM}^{2}+q_{LH}-2\right)+4\theta q_{LM}\left(2q_{LH}+q_{LM}\right)\left(q_{LH}+3q_{LM}\right)=0\\ \left(q_{LH}+q_{LM}\right)^{2}\left(4\theta-9q_{LH}^{2}+q_{LH}q_{LM}-2\right)+4\theta q_{LH}\left(q_{LH}+2q_{LM}\right)\left(3q_{LH}+q_{LM}\right)=0\end{cases}.$$

Unfortunately, no analytical candidates to Nash equilibrium can be found using the FOC. We also turn to a numerical solution with θ also normalized to 1. The system of equations has 20 candidates for the equilibrium, but only one solution fulfills the existence condition for triopoly, namely $q_{Lj}\le 4\theta$ (j=H,M). The solution is such as $q_{LH}^{*}=q_{LM}^{*}=q_{L}^{*}=1.65$. Therefore, an analytical solution can be found for this symmetric equilibrium, by solving one of the FOCs with $q_{LM}=q_{LH}=q_{L}$, that is $-4q_{L}^{2}+6\theta q_{L}+2\theta-1=0$. As a result, the unique equilibrium is defined by Equation (26).

We can verify that the second-order conditions are fulfilled with the numerical solusion, as $\partial^{2}\pi_{Lj}/\partial q_{Lj}^{2}\big|_{q_{Lj}=q_{L}^{*}}=-0.35$. The solution also satisfies the non-deviation conditions as $\pi_{LH}\left(q_{LH},q_{L}^{*}\right)$ and $\pi_{LH}\left(q_{L}^{*},q_{LM}\right)$ take their maximum in q_{L}^{*}.

References

Amacher, G., Koskela, E., Ollikainen, M. (2004). Environmental quality competition and eco-labeling. Journal of Environmental Economics and Management 47, 284-306.

Arora, S., Gangopadhyay, S. (1995). Toward a theoretical model of voluntary overcompliance. Journal of Economic Behavior and Organization 28, 289–309.

Ben Youssef, A., Lahmandi-Ayed, R., (2008). Eco-labelling, Competition and Environment: Endogenization of Labelling Criteria. Environmental and Resource Economics, 41, 133-154.

Ben Youssef, A., Abderrazak, C. (2009). Multiplicity of Eco-Labels, Competition and the environment. *Journal of Agricultural & Food Industrial Organization* 7, special issue: Quality Promotion through Eco-labeling, article 7.

Bonroy, O., Constantatos, C. (2014). On the economics of labels: how their introduction affects the functioning of markets and the welfare of all participants. *American Journal of Agricultural Economics,* forthcoming.

Bottega, L., Delacote, P., Ibanez, I. (2009). Quality Standard and Voluntary Label Adoption. Journal of Agricultural & Food Industrial Organization 7, special issue: Quality Promotion through Eco-labeling, article 3.

Bottega, L., de Freitas, J. (2009). Public, private and nonprofit regulation for environmental quality. Journal of Economics & Management Strategy, 18(1), 105-123.

Boyer, M., Mahenc, P., Moreaux, M. (2006). Environmental Protection, Consumers Awareness, Product Characteristics and Market Power. in Boyer, M., Hiriart, Y., Martimort, D. (Eds), Frontiers in the Economics of Environmental Regulation and Liability, 121-152.

Brécard, D. (2014). Consumer confusion over the profusion of eco-labels: lessons from a double differentiation model. *Resource and Energy Economics* 37, 64-84.

Clemenz, G. (2010). Eco-Labeling and Horizontal Product Differentiation. Environmental and Resource Economics 45, 481-497.

Degryse, H., Irmen, A. (2001). Attribute dependence and the provision of quality. *Regional Science and Urban Economics 31*(5), 547-569.

Eriksson, C. (2004). Can green consumerism replace environmental regulation? A differentiated product example. Resource and Energy Economics 26, 281-293.

European Commission (2014). Attitudes of Europeans citizens towards the environment. Special Eurobarometer 416.

European Commission (2013). Attitudes of Europeans towards building the single market of green products. Flash Eurobarometer 367.

Gruère, G. (2013). A Characterisation of Environmental Labelling and Information Schemes. OECD Environment Working Papers, No. 62, OECD Publishing.

Harbaugh, R., Maxwell, J. W., Roussillon, B. (2011). Label Confusion: The Groucho Effect of Uncertain standards. *Management Science* 57, 1512-1527.

Mussa, M., Rosen, S. (1978). Monopoly and Product Quality, *Journal of Economic Theory*, 18, 301-317.

OECD (2005). Effects of Eco-labelling Schemes: Compilation of Recent Studies. Joint Working Party on Trade and Environment, COM/ENV/TD(2004)34/FINAL.

Salanié, F., Treich, N. (2009). Regulation in Happyville. *The Economic Journal*, 119(537), 665-679.

Scarpa, C. (1998). Minimum quality standards with more than two firms. *International Journal of Industrial Organization 16*(5), 665-676.

Taufique, K. M. R., Siwar, C., Talib, B., Sarah, F. H., Chamhuri, N. (2014). Synthesis of Constructs for Modeling Consumers' Understanding and Perception of Eco-Labels. *Sustainability*, 6(4), 2176-2200.