Non-linear pricing and conscious consumption

# Non-linear Pricing and Conscious Consumption*

Nadia Burani† and Andrea Mantovani‡

**Abstract**

We consider a duopolistic market in which a green firm competes with a brown rival and both firms offer two quality-differentiated products. We study optimal non-linear contracts offered by the two firms when consumers: (i) are privately informed about their willingness to pay for quality, and (ii) differ in their environmental consciousness. We characterize how consumers with different valuations for quality self-select into firms and show that the ranking of qualities, relative prices and profits all depend on the interplay between consumers' valuations and firms' cost heterogeneity. Interestingly, when consumers' valuations for quality are relatively low, the brown firm does not offer a low-quality variety. This contrasts with the situation of full information, in which both firms commercialize a high- and a low-quality variety. Hence, the lack of information about consumers' valuations may not only favor the green firm in terms of higher prices and profits, but also reduce the product range offered by the brown rival.

**JEL classification:** D43, D82, L13, L15, Q56.

**Keywords**: Non-linear pricing, multi-principals, vertical differentiation, bidimensional asymmetric information, environmental consciousness.

## 1 Introduction

In recent years, environmental awareness and increased sensitivity towards socially responsible consumption has modified the purchasing behavior of many customers in different parts of the world. This shift

*We are indebted to the co-editor José Luis Moraga-González and two anonymous referees, who helped improving the manuscript. We are also grateful to Luca Lambertini, Alfredo Martin-Oliver, Benjamin Shiller, the audiences at Jornadas de Economía Industrial (Barcelona, 2018), ASSET Meeting (Florence, 2018), and IIOC (Boston, 2019) for constructive comments and discussion. Finally, we thank Lucy Scioscia for professional editing. The usual disclaimer applies.

†Department of Economics, University of Bologna, Strada Maggiore 45, 40125 Bologna (Italy). E-mail: nadia.burani@unibo.it. Tel: +39 0512092642. This author gratefully acknowledges the financial support from Alma Mater Studiorum Università di Bologna, grant ALMAIDEA 2017, project #24042. Corresponding author.

‡Department of Economics, University of Bologna, Strada Maggiore 45, 40125 Bologna (Italy). E-mail: a.mantovani@unibo.it. Tel: +39 0512092602. This author gratefully acknowledges the financial support from Alma Mater Studiorum Università di Bologna, grant ALMAIDEA 2017_Fauri.

of mindset has been driven by a combination of factors. The evolution of social norms has helped people realize that caring about the environment also means caring about their own health and that of their families and friends (see Ostrom, 2000; Carrigan and Attalla, 2001; Heffner *et al.*, 2007; Carlsson *et al.*, 2010; Deltas *et al.* 2013). This process has also been the result of informative campaigns carried out in combination with environmental education policies and initiatives (see van der Made and Schoonbeek 2009; Sartzetakis *et al.*, 2012; Kaufman, 2014; Allcott and Rogers, 2014). Examples of such campaigns and initiatives are widespread in different sectors, ranging from automotive and energy to food and textile.[1]

For their part, firms have become increasingly responsive to the new consumers' needs, expanding their range of strategies to include corporate social activities and green practices. Consequently, firms ended up competing across different dimensions of quality in order to attract consumers often characterized by heterogeneous willingness to pay for each dimension (Rosen, 1974). In terms of pure quality, products are typically differentiated along the vertical ladder depending on their intrinsic or hedonic attribute, which is related to the functionality of the product itself. However, goods may also differ in another important dimension of quality, depending on their environmental or social sustainability. For the ease of exposition, in our analysis we will refer to green and brown products (or, to be more precise, to goods delivered by a green and a brown firm), however our main results can be extended to include the distinction between products sold by socially responsible firms and by standard profit-maximizing enterprises. In order to increase customer satisfaction along every possible quality dimension, and ultimately to capture a bigger market share, many firms made their products environmentally-friendlier or adopted environmentally sustainable production processes, though these usually require additional costs.

Understanding the driving factors that affect consumers' sorting across firms according to these different quality dimensions represents therefore a relevant research question. Indeed, while most of the literature focuses on competition between firms in the presence of a one-dimensional quality attribute, we depart from this approach and focus on the interplay between the respective costs of the different production technologies, the degree of consumers' environmental consciousness, and the willingness to pay for intrinsic quality.

We also acknowledge that firms are often unable to collect precise information regarding the willingness to pay (henceforth WTP or, simply, valuation) of the customers they want to reach. For this reason,

[1] The U.S. Environmental Protection Agency (EPA) produced a Green Vehicle Guide, which compares environmental performance across vehicle classes through a 0-10 emissions score (visit https://www.epa.gov/greenvehicles for more information). Again in the U.S., the Opower programme is based on social comparison-based home energy reports that are repeatedly mailed to more than six million energy consumers in order to show how much they can possibly save by using energy appropriately. The European action plan for organic food and farming supports consumer choice through the development of the market for organic food (see https://ec.europa.eu/agriculture/organic/eu-policy/european-action-plan_en for more information).

another important element of our analysis is related to the presence of asymmetric information. Firms are uninformed about both consumers' WTP for intrinsic quality and their environmental consciousness. In particular, we assume that there are two types of consumers, who differ in terms of their WTP for intrinsic quality, and refer to them as high- and low-valuation consumers, respectively. We also assume that environmental consciousness is uniformly distributed across the same population of customers. The latter is interpreted as a 'warm glow' (see Andreoni, 1989) non-monetary benefit a consumer enjoys when purchasing (from the green firm) a good which embodies socially desirable attributes, independently of its intrinsic quality.

In order to formally address our research problem, we embed the Mussa and Rosen (1978) model of quality differentiation and monopolistic non-linear pricing into a richer setup in which there is strategic interaction between two firms, one of them being a green firm that further differentiates its products from the rival by offering environmentally-friendly varieties. We assume that producing green products entails higher costs. We are interested in optimal non-linear contracts offered by the two firms. In particular, following Rochet and Stole (2002), we let each firm offer a menu of at most two incentive-compatible contracts, contingent on consumers' valuations for intrinsic quality. Consumers' other attribute, namely environmental consciousness, does not enter the screening contracts but rather determines how consumers sort themselves between the brown and the green firm. The formal model is outlined in Section 2.

### 1.1 Main results and organization of the article

In Section 3, we characterize the benchmark case in which consumers' valuations for intrinsic quality are observable by both firms. With symmetric information about valuation for quality, in equilibrium each firm offers a high- and a low-quality product. The brown firm produces the highest quality in the market, while the green firm the lowest. Whether the low-quality product of the brown firm is better or worse than the high-quality product of the green firm depends on the cost differences across firms. We then compute equilibrium prices and profits for both firms, and show that the green firm, despite its cost disadvantage, may end up not only charging a higher price (green price premium), but also obtaining a higher profit than the brown rival. This occurs when consumers' valuations are relatively low. Thus, although in our model the firm's decision to carry out green production is not strategic (it is rather taken as given), we provide a rationale for the choice to "go green" or to become socially responsible (see Bénabou and Tirole, 2010, and Kitzmueller and Shimshack, 2012).

Our benchmark model can also provide information about consumers' self-selection, namely about which types of consumers buy from which firm. We show the emergence of different sorting patterns according to the relative weight that intrinsic quality and green consciousness have in consumers' preferences. For instance, when the intensity parameter for the vertical attribute is quite low, so that consumers

care relatively more about the environmental than the intrinsic quality dimension of the good, we find *positive selection* for the green firm. This means that the share of high-valuation consumers buying from the green (brown) firm is higher (lower) than the share of low-valuation ones.

In Section 4, we introduce asymmetric information about consumers' valuations for intrinsic quality and investigate to what extent screening changes the main results of the benchmark model. First of all, optimal contracts in the benchmark model might still be incentive compatible, provided that the cost differential between firms is not particularly large, and the ratio between consumers' types is not too low. In this circumstance, it is possible for firms to elicit consumers' private information without incurring the costs embedded in informational rents. Conversely, when the benchmark contracts are not incentive compatible, firms face the usual rent-extraction/efficiency trade-off and distort quality schedules relative to the first best. Despite allocative distortions, the results about product lines do not differ substantially from the benchmark model. Likewise, under screening, the brown firm produces a higher quality variety than the green rival, given the valuation for intrinsic quality.

In many real instances, green products are perceived by consumers as being characterized by a lower intrinsic quality with respect to their brown counterparts, even though they dominate in terms of environmental performance. For example, electric or hybrid vehicles are characterized by lower polluting emissions than internal combustion engine vehicles, but are still deemed as inferior based on the overall driving experience. Other examples are phyto cosmetics or ecological cleansers and detergents. They are produced without chemical additives that might endanger consumers' health or the environment, but are less effective than standard products. Analogous considerations might apply to organic food, which is healthier and possibly more tasteful; without any doubt, however, non-organic produce has more curb appeal than organically grown one.

As for consumers' sorting patterns, they are not qualitatively different when screening is in place, but they become more pronounced with respect to the benchmark model. Interestingly, our analysis also uncovers an unexpected scenario. When positive selection is in place and the WTP for intrinsic quality is characterized by a relatively low intensity for both types of consumers, the brown firm ends up offering only a high-quality version of the product thus excluding low-valuation consumers from its clientele. A corollary of this last result is that the lack of information about consumers' characteristics may not only favor the green firm in terms of higher prices and profits, but also reduce the product range offered by the brown rival. This could be beneficial for society at large, given that the brown firm abstains from producing its low-quality variant, whose consumption may ultimately be associated with relatively high levels of polluting emissions or low standards of sustainability.

Real-world examples confirm the validity of these results. The evolution of the car sector is not only characterized by a shift towards hybrid and electric vehicles, but also by the progressive elimination of standard internal-combustion engine vehicles, especially at the bottom of the quality scale. Indeed,

producers of electric vehicles are targeting more and more the low-end portion of the market, and in some specific sectors brown vehicles are rapidly disappearing. Electric microcars and low speed personal vehicles are becoming widespread for short travels within cities.[2] Urban transport has also been recently characterized by an increase of electric city bikes and cargo bikes, whereas only few brown motorized rivals have been introduced. Similar dynamics also are emerging in many other sectors. For example, eco and natural paints are replacing conventional ones, especially for Do-It-Yourself customers, whereas high-end quality conventional paints are still targeted to a niche of expert users or professionals.

## 1.2 Related Literature

Our paper mainly contributes to two different strands of literature. The first one is related to firms' strategic behavior in the presence of multi-dimensional product differentiation, *i.e.* when there are more quality dimensions defining a product specification (one of them possibly being environmental sustainability). The second pertains to the design of optimal contracts by heterogeneous principals in the presence of multi-dimensional asymmetric information. Notwithstanding the growing attention devoted to the effect of green consumerism on market equilibrium (see Conrad 2005, Eriksson 2004, García-Gallego and Georgantzís 2009, Moraga-González and Padrón-Fumero 2002, Nyborg *et al.* 2006, *inter alia*) on one side, and to optimal screening with multi-dimensional informational asymmetries (see Stole 1995 and Rochet and Stole 2002, *inter alia*) on the other side, we are the first to analyze in a unified setting a multi-principal game in which two firms compete by differentiating the qualitative attributes of their products in order to attract consumers characterized by two dimensions of private information.

A particular feature of our model is that both firms are allowed to offer quality-differentiated versions of their products. This enables us to endogenize the firms' decision regarding the intrinsic quality offered to customers. In the standard literature, there are two ways to consider the relationship between intrinsic quality and environmental quality, depending on whether consumers' aprioristic preferences are such that either the environmental attribute or the pure performance of the product is valued more. In the first case, in line with most of the literature (Moraga-González and Padrón-Fumero, 2002; Lombardini-Riipinen, 2005; Deltas *et al.*, 2013; among others), the green good is assumed to be of high intrinsic quality and the brown good of low intrinsic quality. In the second case, based on the observation that quite often brown goods have higher performance than green alternatives (Carrigan and Attalla, 2001; Gupta and Ogden 2009; Weatherell *et al.*, 2003; Mantovani *et al.*, 2016), the high-quality good is the one that has lower sustainability whereas the low-quality good is green.

Within the literature on multi-dimensional product differentiation, Vandenbosch and Weinberg (1995), Lauga and Ofek (2011) study two firms that compete by differentiating their goods along two dimensions

[2] See https://www.theguardian.com/sustainable-business/2017/may/11/micro-evs-city-transport-suemens-renault-green-air-pollution.

of vertical quality. They show that, depending on the costs of providing the two qualities, firms can either use only one attribute to differentiate their products, or they can maximally differentiate on one dimension and minimally differentiate on the other. More recently, Garella and Lambertini (2014), find conditions under which either a single firm becomes a quality leader in both attributes or there is cross leadership. Other contributions consider multiple vertical dimensions, such as Barigozzi and Ma (2018) and Chen and Riordan (2015). The former analyzes a scenario in which consumers' valuations are drawn from independent and general distributions, whereas the latter considers consumers' valuations for the different attributes being correlated. We depart from this literature in two main ways. First, our firms strategically choose only one vertical attribute, whereas they are differentiated at the outset with respect to the other attribute (environmental friendliness). Second, and most importantly, our firms resort to screening contracts in order to elicit consumers' valuations for hedonic quality.

From a methodological viewpoint, our paper hinges on both the literature describing optimal contracting with multi-dimensional asymmetric information and that of multi-principals. The analysis of multi-principals was initiated by the seminal contributions of Martimort (1992) and Stole (1992). The papers that are most closely related to ours are Champsaur and Rochet (1989) and Rochet and Stole (2002), which consider two firms competing in non-linear prices in the presence of vertical preference uncertainty. The former is characterized by a two-stage game where firms first offer intervals of qualities and then choose price schedules. The latter extends the analysis carried out in Stole (1995) combining both vertical and horizontal preference uncertainty. As in Rochet and Stole (2002), in our framework bidimensional asymmetric information does not translate into bidimensional screening, given that screening contracts are contingent on one dimension of consumers' private information only (which is used to allocate consumers along the quality spectrum), while the other dimension is used as a self-selection device between firms.[3] We depart from Rochet and Stole (2002) because they consider perfectly symmetric firms, whereby incentive constraints are never binding and efficient quality allocations with cost-plus-fixed-fee pricing emerge at equilibrium. Even though our contribution is not methodological, we add to this literature because we characterize optimal contracts when principals are heterogeneous and incentive compatibility constraints are relevant. In this situation, quality distortions naturally arise.

Finally, this article is related to Mahenc (2008) and Heijnen and van der Made (2012), who adopt the principal-agent framework to address environmental issues. The former considers a monopoly choosing its pricing schedule to signal the (privately known) environmental quality of its good to green consumers. The latter explains the presence of boycotts by consumers whose environmental awareness is not known

[3]Similar setups are considered in both Lehmann *et al.*, (2014) and Barigozzi and Burani (2019). The former analyzes optimal non-linear income taxes levied by two competing governments on citizens who have private information about their earning capabilities and their migration costs. The latter focuses on optimal labor contracts proposed to managers who differ in their skills and motivation.

by a firm which has to decide whether or not to adopt a clean (and costly) technology. An interesting result is that the clean technology is adopted more often than in a situation of full information. Differently from our analysis, however, both articles abstract from issues of strategic interaction between principals as well as multi-dimensionality of hidden information.

## 2 The model

We consider a multi-principal setting with bidimensional asymmetric information. Two firms (principals) compete to sell their products to consumers (agents). Each consumer (she) can buy one unit of the good exclusively from one firm. Firms and consumers are risk neutral.

On the supply side, firms differ in their environmental commitment: one firm is *green* because it produces an environmentally-friendly variety of the good, while the other firm is *brown* because it produces a standard variety of the good.[4] Accordingly, firms are indexed by $i = B, G$. The products sold by the two firms differ in another characteristic, which is a usual attribute of vertical differentiation. We denote by $q_i$ the *observable and measurable* (and thus contractible) hedonic or intrinsic quality level that each firm $i$ provides. Firms have similar technologies and their profit margins (per unit, conditional on the customer buying) are given by

$$\pi_i(q_i) = p_i(q_i) - C_i(q_i), \tag{1}$$

where $p_i(q_i)$ is the (non-linear) price set by firm $i$ for one unit of the good with quality $q_i$ and $C_i(q_i)$ is the unit cost of providing quality $q_i$. As in Mussa and Rosen (1978) and Champsaur and Rochet (1989), for each firm $i = B, G$, marginal cost $C_i(q_i)$ is constant and independent of the number of units sold; moreover, it is an increasing and convex function of quality. For simplicity, we set $C_i(q_i) = \frac{1}{2}k_i q_i^2$ and assume that $k_B = 1 < k_G = k$, with $k$ capturing the cost disadvantage of producing a green good. Indeed, it is natural to imagine that, relative to the brown firm, the green producer faces an extra cost for each possible quality level. For example, a car manufacturer incurs higher costs when it produces hybrid or electric cars rather than traditional combustion engine cars, for each given model.[5] We also assume that $k_G = k < 4$, which guarantees that competition between the two firms is viable.[6]

[4] Firms are differentiated since the outset relative to the environmental dimension in order to avoid being trapped into the conventional Bertrand paradox.

[5] Similar assumptions can be found in Moraga-González and Padrón-Fumero (2002), where the unit marginal cost of producing a given variant is constant, but the cost of producing environmentally-sustainable varieties is higher. Also in Mahenc (2008) it is assumed that the environmental performance raises marginal costs. The alternative hypothesis, namely that products of higher environmental quality are cheaper to produce, is suggested by Porter and van der Linde (1995).

[6] We abstract from 'emission functions' which relate the level of pollution generated by a product to its environmental quality or to the quantity sold (see Mahenc 2008, Boyer *et al.* 2007, Moraga-González and Padrón-Fumero 2002).

On the demand side, consider a population of consumers with unit mass, who differ in two characteristics, WTP for hedonic quality and social or environmental concern, that are independently distributed. For the sake of simplicity, consumers' WTP for quality is assumed to take only two values, high and low, and is denoted as $\theta \in \{\theta_1, \theta_2\}$, where $\theta_2 > \theta_1 > 0$. The fraction $\nu$ of consumers has low valuation $\theta_1$, the fraction $1-\nu$ is instead characterized by high valuation $\theta_2$. Social or environmental consciousness is instead continuous and uniformly distributed in the unit interval $[0,1]$.[7]

Each consumer can buy at most one unit of the good. When a consumer abstains from buying, her utility is zero. When a consumer of type $(\theta, \gamma)$ buys one unit of the good with quality $q_i$ from firm $i = B, G$, her utility is given by

$$u_i(\theta, \gamma) = \theta q_i + \gamma x_i - p_i(q_i),$$

where $x_i$ is an indicator function that takes value 0 for the brown firm and 1 for the green firm. As a consequence, from the brown firm standpoint, consumers' valuation for hedonic quality is the only relevant characteristic. When, instead, a consumer buys from the green firm, her utility is augmented by the premium $\gamma$ for consuming the environmentally-friendly variety.[8] We interpret environmental concern as a non-monetary, warm-glow benefit that a consumer enjoys when buying from the green firm. It is unrelated to the intrinsic quality of the good, and does not directly affect the green firm choice of its intrinsic quality. Methodologically, this implies that bidimensional asymmetric information does not translate into bidimensional screening.

Following Rochet and Stole (2002), we take the consumers' decision to buy from firm $i = B, G$ and the non-linear price schedule $p_i(q_i)$ offered by firm $i$ as given. Then, letting

$$q_i(\theta) \equiv \arg\max_{q_i} \quad \theta q_i - p_i(q_i),$$

we have

$$U_i(\theta) = \theta q_i(\theta) - p_i(q_i(\theta)) \tag{2}$$

which is the *indirect utility* of a consumer of type $\theta$ who buys from firm $i = B, G$, *net* of the benefit accruing from environmental consciousness. We study the direct revelation mechanism such that each firm offers two incentive-compatible contracts, one for each type $\theta$, consisting in a hedonic quality target and a level of indirect utility, $\{q_i(\theta), U_i(\theta)\}_{i=B,G}$, and each customer selects the preferred pair.[9] The

[7] This assumption is made for convenience. It is possible to show that the qualitative nature of the results is robust to the generalization $\gamma \sim U[0, \overline{\gamma}]$ with $\overline{\gamma} \in (0, \infty)$. Moreover, our intuition is that qualitatively our results do not change when considering a more general distribution for $\gamma$. Indeed, its symmetry is not relevant as long as preferences for environmental quality are independent of preferences for vertical quality.

[8] We abstract from customers internalizing the social environmental damage generated by the consumption of the brown variety (which could be a function of the brown firm's market share, as in Lambertini, 2017).

[9] Prior to Rochet and Stole (2002), also Armstrong and Vickers (2001) and Champsaur and Rochet (1989) consider optimal contracts in which utilities rather than prices are offered to consumers.

firms' contract design problem is thus independent of the consumers' environmental consciousness $\gamma$, which is however crucial to determine each firm's market shares. Indeed, given $U_i(\theta)$ for $i = B, G$, a consumer of type $(\theta, \gamma)$ receives indirect utility $U_B(\theta)$ if she buys from the brown firm, whereas, if she buys from the green firm, her *gross* indirect utility becomes $\mathcal{U}_G(\theta) = U_G(\theta) + \gamma$.

**Definition 1** ***Indifferent consumer.*** *The consumer with willingness to pay for intrinsic quality $\theta \in \{\theta_1, \theta_2\}$, who is indifferent between buying from the green or the brown firm, is characterized by environmental concern*

$$\widehat{\gamma}(\theta) \equiv U_B(\theta) - U_G(\theta). \tag{3}$$

Since $\gamma$ is uniformly distributed on the unit interval, the share of consumers with valuation $\theta$ who prefer buying from the brown firm is given by

$$\varphi_B(\theta) \equiv \Pr(\gamma < \widehat{\gamma}(\theta)) = \widehat{\gamma}(\theta) = U_B(\theta) - U_G(\theta); \tag{4}$$

conversely, the share of customers patronizing the green firm is

$$\varphi_G(\theta) \equiv \Pr(\gamma \geq \widehat{\gamma}(\theta)) = 1 - \widehat{\gamma}(\theta) = 1 - (U_B(\theta) - U_G(\theta)). \tag{5}$$

Given firms' market shares $\varphi_i(\theta)$, we set up each firm's maximization problem. Rewrite profit margins (1), relative to each type $\theta$ consumer, replacing price $p_i$ with indirect utility $U_i$, as

$$\pi_i(\theta) = S_i(\theta) - U_i(\theta) = \theta q_i(\theta) - \frac{1}{2} k_i q_i^2(\theta) - U_i(\theta), \tag{6}$$

where

$$S_i(\theta) \equiv \pi_i(\theta) + U_i(\theta) = \theta q_i(\theta) - C_i(q_i(\theta)) = \theta q_i(\theta) - \frac{1}{2} k_i q_i^2(\theta) \tag{7}$$

is the surplus realized when a consumer of type $\theta$ buys hedonic quality $q_i(\theta)$ from firm $i$ (again, net of the benefit accruing from environmental concerns). Then, the program of each firm $i = B, G$ is

$$\max_{q_i(\cdot), U_i(\cdot)} E(\pi_i) = \quad \nu \pi_i(\theta_1) \varphi_i(\theta_1) + (1 - \nu) \pi_i(\theta_2) \varphi_i(\theta_2). \tag{$P_i$}$$

Notice that environmental consciousness $\gamma$ does not appear in the above program, because it is replaced by market shares $\varphi_i(\theta)$, which in turn depend on the difference between indirect utilities (see equations 4 and 5). Moreover, in firm $i$'s payoff, the utility offered by the rival firm, *i.e.* $U_{-i}(\theta)$, is taken as given even though it is endogenous. Thus, firms compete against each other in the utility space: when a firm increases the utility offered to a given type of consumers, it reduces its profit margin, but it increases the probability of serving those consumers.

Because consumers' valuations for quality might not be observable by firms, consumers' incentive compatibility constraints have to be considered: the *downward incentive constraint* (henceforth $DIC$)

requires that high-valuation types be not attracted by the contract offered to low-valuation types, and the *upward incentive constraint* (henceforth $UIC$) requires that low-valuation types be not willing to mimic high-valuation consumers. For each firm $i = B, G$, such constraints are given by

$$U_i(\theta_2) \geq U_i(\theta_1) + (\theta_2 - \theta_1) q_i(\theta_1), \tag{$DIC_i$}$$

and

$$U_i(\theta_1) \geq U_i(\theta_2) - (\theta_2 - \theta_1) q_i(\theta_2), \tag{$UIC_i$}$$

respectively.[10] Putting $DIC_i$ and $UIC_i$ together yields

$$(\theta_2 - \theta_1) q_i(\theta_1) \leq U_i(\theta_2) - U_i(\theta_1) \leq (\theta_2 - \theta_1) q_i(\theta_2), \tag{8}$$

which clarifies that incentive compatible contracts must satisfy: $(i)$ the *monotonicity condition* $q_i(\theta_1) \leq q_i(\theta_2)$, requiring that high-valuation consumers buy a higher hedonic quality than low-valuation types at each firm $i = B, G$; and $(ii)$ condition $U_i(\theta_2) - U_i(\theta_1) \geq 0$, requiring that the indirect utility or information rent of high-valuation consumers be higher than that of low-valuation types, for each firm $i = B, G$. Finally, consumers' participation constraints, *i.e.* $U_B(\theta) \geq 0$ and $\mathcal{U}_G(\theta) = U_G(\theta) + \gamma \geq 0$ for each $\theta \in \{\theta_1, \theta_2\}$, have to be considered in the firms' programs.

To sum up, the program for each firm $i = B, G$ consists in maximizing its expected profits with respect to the quality level $q_i(\theta)$ and the indirect utility $U_i(\theta)$ associated with each type $\theta$ consumer, taking as given the indirect utility $U_{-i}$ that the rival firm leaves to the consumer, and subject to the two incentive compatibility constraints $DIC_i$ and $UIC_i$ and to the participation constraint. Consumers observe the menus of contracts $\{q_i(\theta), U_i(\theta)\}_{i=B,G}$ simultaneously offered by the two firms and select the preferred one, *i.e.* they choose which quality to purchase and which firm to patronize. This yields firms' market shares $\varphi_i(\theta)$ and it enables us to characterize consumers' self-selection between the two firms. Three different sorting patterns are possible.

**Definition 2** ***Consumers' self-selection.*** *The sorting of consumers between the brown and the green firm is such that:*

$(i)$ *there is* ***neutrality*** *when*

$$\widehat{\gamma}(\theta_1) = \widehat{\gamma}(\theta_2) \Longleftrightarrow U_B(\theta_1) - U_G(\theta_1) = U_B(\theta_2) - U_G(\theta_2); \tag{9}$$

$(ii)$ *there is* ***positive sorting into the green firm*** *(or equivalently negative sorting into the brown firm) when*

$$\widehat{\gamma}(\theta_1) > \widehat{\gamma}(\theta_2) \Longleftrightarrow U_B(\theta_1) - U_G(\theta_1) > U_B(\theta_2) - U_G(\theta_2); \tag{10}$$

[10] In what follows, we will say that an incentive constraint is satisfied when it holds with weak inequality. However, we will distringuish between a constraint that is slack, *i.e.* it holds with strict inequality, and one that is binding, *i.e.* it holds with equality. Also notice that firm $G$'s constraints do not depend on $\gamma$ because environmental consciousness enters both sides of each inequality and therefore it cancels out.

(*iii*) *there is* ***negative sorting into the green firm*** *(or equivalently positive sorting into the brown firm) when*

$$\widehat{\gamma}(\theta_1) < \widehat{\gamma}(\theta_2) \Longleftrightarrow U_B(\theta_1) - U_G(\theta_1) < U_B(\theta_2) - U_G(\theta_2). \tag{11}$$

Neutrality captures the situation in which $\varphi_i(\theta)$, *i.e.* the fraction of consumers who self-select into firm $i = B, G$, is constant and does not depend on consumers' valuation. Positive (respectively, negative) selection into the green firm, instead, means that the higher the consumers' valuation for hedonic quality $\theta$, the bigger (resp. smaller) the fraction of consumers served by firm $G$ and, symmetrically, the smaller (resp. bigger) the fraction served by firm $B$.

# 3 The benchmark contracts: full information about consumers' willingness to pay

Let us first consider the benchmark model in which consumers' valuation $\theta$ is fully observable, while environmental consciousness $\gamma$ is private information. This benchmark is particularly relevant for three reasons: (*i*) it characterizes the efficient quality allocations, allowing us to make comparisons with the equilibrium qualities obtained under bidimensional asymmetric information (see the following Section 4); (*ii*) it enables us to distinguish different parametric regions characterized by different sorting patterns of consumers, which will be crucial for the subsequent analysis; finally, (*iii*) it may already provide the solution to the general problem with fully private information about both $\theta$ and $\gamma$.[11]

For each type $\theta \in \{\theta_1, \theta_2\}$, firm $i = B, G$ solves

$$\max_{q_i(\theta), U_i(\theta)} \left( \theta q_i(\theta) - \frac{1}{2} k_i q_i^2(\theta) - U_i(\theta) \right) \varphi_i(\theta), \tag{$Pb_i$}$$

taking $U_{-i}(\theta)$, which enters the expression for $\varphi_i(\theta)$, as given. Provided that $\varphi_i(\theta) \in (0,1)$, the first-order condition with respect to the quality level $q_i(\theta)$ yields

$$q_i^b(\theta) = \frac{\theta}{k_i} = q_i^{fb}(\theta), \tag{12}$$

where the superscripts $b$ and $fb$ stand for *benchmark* and *first best*, respectively. Indeed, the qualities chosen by the two firms are efficient because they maximize the principal-agent surplus $S_i(\theta)$. Notice that $q_B^b(\theta) > q_G^b(\theta)$ for every $\theta \in \{\theta_1, \theta_2\}$, so, fixing the type of consumer, the brown firm always produces

[11] The reader may reckon that there exists another benchmark in which both consumers' valuation $\theta$ and environmental consciousness $\gamma$ are fully observable. In this latter case, however, equilibrium qualities would still coincide with the efficient allocations, the only difference with respect to the results of this section being related to the distribution of surplus $S_G(\theta)$. In particular, the green firm would be able to fully appropriate its consumers' pro-environmental premium, in excess of $\widehat{\gamma}$, by setting a lower indirect utility (and a higher price).

the higher quality variant of the good. Nonetheless, the complete ordering of qualities is such that

$$q_G^b(\theta_1) < \min\left\{q_G^b(\theta_2), q_B^b(\theta_1)\right\} \leq \max\left\{q_G^b(\theta_2), q_B^b(\theta_1)\right\} < q_B^b(\theta_2)$$

with $q_G^b(\theta_2) < q_B^b(\theta_1)$ if and only if $\frac{\theta_2}{\theta_1} < k$. It follows that firm $G$ always produces the two lowest qualities if the heterogeneity in firms' production costs, represented by $k$, is bigger than the heterogeneity in consumers' types, represented by the ratio $\frac{\theta_2}{\theta_1}$.

Using (12), the first-order conditions with respect to utilities $U_i(\theta)$, which are not symmetric because of the asymmetry in market shares $\varphi_i(\theta)$, solve for

$$U_B(\theta) = \frac{1}{2}\left(\frac{\theta^2}{2} + U_G(\theta)\right) \quad \text{and} \quad U_G(\theta) = \frac{1}{2}\left(\frac{\theta^2}{2k} - (1 - U_B(\theta))\right). \tag{13}$$

These expressions represent the reaction functions of the two firms, which characterize the optimal utility left by firm $i = B, G$ to a type $\theta$ consumer for each possible level of utility $U_{-i}(\theta)$. Reaction functions have positive slopes so that utilities can be interpreted as *strategic complements* in this game. In a Nash equilibrium, the utility levels offered by both firms to type $\theta$ consumers solve the two equations in (13) simultaneously, and must be such that: $(i)$ $U_i(\theta) \leq S_i(\theta)$ (or else $\pi_i(\theta) \geq 0$) for all $i = B, G$; $(ii)$ $U_B(\theta) \geq 0$ and $U_G(\theta) + \gamma \geq 0$.[12]

Two different classes of Nash equilibria can emerge, depending on whether an interior or a corner solution realizes. Accordingly, different parametric regions can be singled out. We provide an informal discussion of the different scenarios that may emerge, and refer the reader to Appendix A.1 for additional details.

$(i)$ ***Region I*** When $\theta$ is low, consumers care relatively more about the green than about the hedonic quality dimension. Therefore, consumers with sufficiently high environmental consciousness patronize firm $G$, despite the fact that they are left with negative net utility $U_G(\theta)$. Conversely, consumers who are not particularly environmentally concerned are forced to buy from the brown firm, which is then able to perfectly price discriminate and extract the (already low) total surplus by offering $U_B(\theta) = 0$. In such circumstance, consumers are indifferent between buying from firm $B$ or not buying at all, and we assume indifference is broken in favor of firm $B$, which enjoys a positive market share. Hence, we identify a corner solution characterized by valuations belonging to the interval

$$0 < \theta \leq \sqrt{\frac{2k}{2k+1}} \equiv \underline{\theta} < 1, \tag{14}$$

and by $U_G^{Ib}(\theta) < 0 = U_B^{Ib}(\theta)$, where $U_i^{Ib}(\theta)$ stands for the indirect utility set by firm $i$ at the benchmark $b$ in Region I.

[12] Recall that environmentally-concerned consumers, served by the green firm, enjoy not only net utility $U_G(\theta)$ but also their pro-environmental premium, so their gross indirect utility becomes $\mathcal{U}_G(\theta) = U_G(\theta) + \gamma$.

(*ii*) ***Region II*** When $\theta$ is intermediate, intrinsic quality and green consciousness have a balanced weight in consumers' preferences. Utilities solve the two equations in (13) and we obtain an interior solution, characterized by $U_B^{IIb}(\theta) > 0$, $U_G^{IIb}(\theta) \lesseqgtr 0$, and strictly positive market shares for both firms. This holds in $\theta \in \left(\underline{\theta}, \overline{\theta}\right)$, with $\overline{\theta}$ defined below in (15).

(*iii*) ***Region III*** When $\theta$ is high, consumers' environmental consciousness is outweighed by their taste for hedonic quality and firm $G$ cannot attract consumers, even if it leaves them the whole total surplus. Therefore, firm $G$ makes zero profits and has a null market share, whereas firm $B$ serves the whole market. It follows that, when $\theta$ is sufficiently high, a corner solution realizes, which is characterized by utilities $U_B^{IIIb}(\theta) > 0$ and $U_G^{IIIb}(\theta) = S_G^{IIIb}(\theta)$, and which satisfies

$$\widehat{\gamma}^{IIIb}(\theta) \geq 1 \Longleftrightarrow \theta \geq \sqrt{\frac{4k}{k-1}} \equiv \overline{\theta} > 2. \tag{15}$$

Notice that this case does not occur when firms are identical and $k_i = 1$ for $i = B, G$.

Going back to our leading example of the automotive industry, situations with low values of $\theta$ (Region I) identify consumers with high marginal utility of income, willing to buy utility cars. On the contrary, when $\theta$ is intermediate (Region II), consumers are average earners and seek to purchase family cars or SUVs. Finally, in the case of high values of $\theta$ (Region III), consumers are very wealthy and only buy luxury and sports cars.

## 3.1 Consumers' self-selection

At equilibrium, how do consumers characterized by different valuations for hedonic quality sort between the two firms? It depends on the region to which consumers valuations belong. If both $\theta_1$ and $\theta_2$ are sufficiently low and belong to the interval $(0, \underline{\theta}]$, *i.e.* to Region I, we obtain that $\widehat{\gamma}^b(\theta)$ is decreasing in $\theta$, yielding positive selection into the green firm. In other words, among consumers served by the green firm, the share of high-valuation consumers is bigger than the share of low-valuation ones. Conversely, if both valuations are intermediate and belong to the interval $\left(\underline{\theta}, \overline{\theta}\right)$, *i.e.* to Region II, then $\widehat{\gamma}^b(\theta)$ is increasing in $\theta$, and there is negative sorting into the green firm. For the sake of comparison, notice that, if both firms had the same marginal costs of quality, with $k_i = 1$ for $i = B, G$, then they would produce the same quality levels. As a consequence, $\widehat{\gamma}^b(\theta)$ would be constant and consumer sorting would be neutral. Neutrality actually holds when both $\theta_1$ and $\theta_2$ are above $\overline{\theta}$, *i.e.* in Region III.

The following proposition characterizes consumers' sorting patterns at the benchmark.

**Proposition 1** ***Consumers' sorting patterns at the benchmark contracts.*** *When consumers' willingness to pay for intrinsic quality is observable (and environmental concern is private information), benchmark contracts are such that:* (*i*) *in Region I, i.e. when* $0 < \theta_1 < \theta_2 \leq \underline{\theta}$*, there is positive selection*

*for firm G; (ii) in Region II, i.e. when* $\underline{\theta} < \theta_1 < \theta_2 < \overline{\theta}$*, there is negative selection for firm G; (iii) in Region III, i.e. when* $\overline{\theta} \leq \theta_1 < \theta_2$*, there is neutrality.*

Figure 1 represents the three situations. For simplicity, the figure is drawn as if consumer's valuation $\theta$ were continuous rather than discrete, in such a way that function $\widehat{\gamma}^b(\theta)$ becomes continuous too. Actually we assumed that consumers' valuation for intrinsic quality takes on only two values, namely $\theta_1$ or $\theta_2$. Consequently, within each region, the environmental consciousness of the indifferent consumer can have only two values, namely $\widehat{\gamma}^b(\theta_1)$ or $\widehat{\gamma}^b(\theta_2)$.

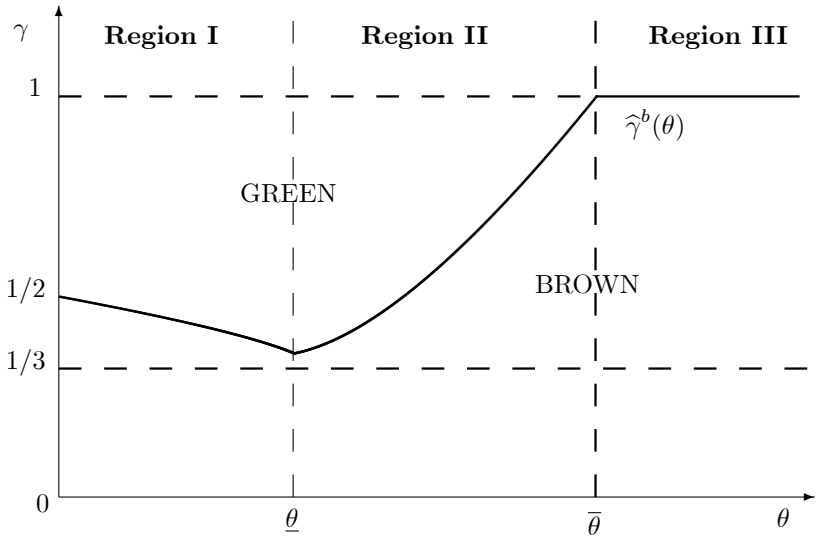


**Figure 1**: Consumers' sorting at the benchmark contracts.

It is worth highlighting that there is an implicit assumption behind Proposition 1, namely that the two valuations for hedonic quality $\theta_1$ and $\theta_2$ are sufficiently close to each other that they fall within the same region. This does not imply that we are only focusing on the case in which consumers' difference in WTP, *i.e.* $\theta_2 - \theta_1$, outweighs their heterogeneity in environmental consciousness, measured by the unit length of the support of the distribution of $\gamma$. Given the thresholds $\underline{\theta} < 1$ and $\overline{\theta} > 2$, this is certainly true in Region I, but need not be the case in the remaining regions.

Furthermore, observe that Proposition 1 is not exhaustive. This is done on purpose, in order to simplify the analysis and to avoid the proliferation of cases. To be more precise, three other mixed regimes should be considered: either $(a)$ low-valuation consumers $\theta_1$ belong to Region I and high-valuation consumers $\theta_2$ belong to Region II, with $\theta_1 < \underline{\theta} < \theta_2 < \overline{\theta}$; or $(b)$ low-valuation consumers $\theta_1$ belong to Region II and

high-valuation consumers $\theta_2$ belong to Region III, with $\underline{\theta} < \theta_1 < \overline{\theta} < \theta_2$; or else $(c)$ low-type consumers $\theta_1$ belong to Region I and high-type consumers $\theta_2$ belong to Region III, with $\theta_1 < \underline{\theta} < \overline{\theta} < \theta_2$. In regimes $(b)$ and $(c)$ we would always observe negative selection, as in Region II. In regime $(a)$ it is not possible to unambiguously assess what kind of sorting pattern would prevail: when $\theta_1$ is close to 0 and $\theta_2$ is slightly above $\underline{\theta}$, positive selection would result, as in Region I; when, instead, $\theta_1$ is slightly below $\underline{\theta}$ and $\theta_2$ is close to $\overline{\theta}$, negative selection would hold, as in Region II. As we will show in Section 4, what is crucial in determining the qualitative features of optimal incentive contracts is the sorting pattern of consumers into firms. Hence, no further insights can be gained by studying the mixed regimes in more detail. This is why, in the remainder of this paper, we only examine Regions I to III separately, with a particular emphasis on the first two, in which valuations are not particularly high.

### 3.2 Firms' price schedules and profits

Our analysis confirms that consumers with a given willingness to pay $\theta$ are always offered a higher intrinsic quality by the brown than by the green firm. We analyze the difference in price schedules, *i.e.* $p_G(\theta) - p_B(\theta)$, to see whether consumers also end up paying more for the brown variety. We find that the price difference may be either positive or negative according to the magnitude of firm $G$'s cost disadvantage. More specifically, in Region I

$$p_G^{Ib}(\theta) > p_B^{Ib}(\theta) \Longleftrightarrow \theta < \sqrt{\frac{2k}{(4k-3)}} \equiv \theta_a,$$

whereas in Region II

$$p_G^{IIb}(\theta) > p_B^{IIb}(\theta) \Longleftrightarrow \theta < \sqrt{\frac{2k}{5(k-1)}} \equiv \theta_b < \overline{\theta},$$

with $\underline{\theta} < \theta_a < \theta_b$ when $k < 2$. Thus, in Region I, a higher price for the green good is always charged provided that the cost disadvantage of the green firm is not too high, *i.e.* if $k \leq 2$; alternatively, if $k > 2$, a price premium for the green firm still emerges when consumers' WTP is sufficiently low and $\theta < \theta_a$ holds. In Region II, a price premium for the green firm is never in place when the cost disadvantage is sufficiently high, *i.e.* when $k > 2$; when instead $k \leq 2$, the green firm is able to charge a higher price than its rival provided that $\theta < \theta_b$. Finally, in Region III, it is always the case that consumers pay more when they buy from the brown firm and $p_G^{IIIb}(\theta) < p_B^{IIIb}(\theta)$.

As for profits, for a given consumer type $\theta$ and for each firm $i = B, G$, we compute per-unit profit margins and multiply them by the fraction of consumers buying from that firm, *i.e.* $\Pi_i^b(\theta) \equiv \pi_i^b(\theta)\,\varphi_i^b(\theta)$. In Region I, one finds that $\Pi_G^{Ib}(\theta) > \Pi_B^{Ib}(\theta)$ always holds. In Region II,

$$\Pi_G^{IIb}(\theta) > \Pi_B^{IIb}(\theta) \Longleftrightarrow \theta < \sqrt{\frac{k}{k-1}} \equiv \theta_c,$$

with $\underline{\theta} < \theta_c < \overline{\theta}$. Finally, in Region III, it is always the case that $\Pi_B^{IIIb}(\theta) > \Pi_G^{IIIb}(\theta) = 0$.

Figure 2 illustrates our findings about firms' prices (left panel) and profits (right panel). The thin curves divide the plane $(k, \theta)$ into the three regions, whereas the thick curves represent the threshold values $\theta_a$ and $\theta_b$ (left panel) or $\theta_c$ (right panel), thus allowing to identify the areas where a price premium/penalty or a positive/negative profit differential emerge for the green firm.

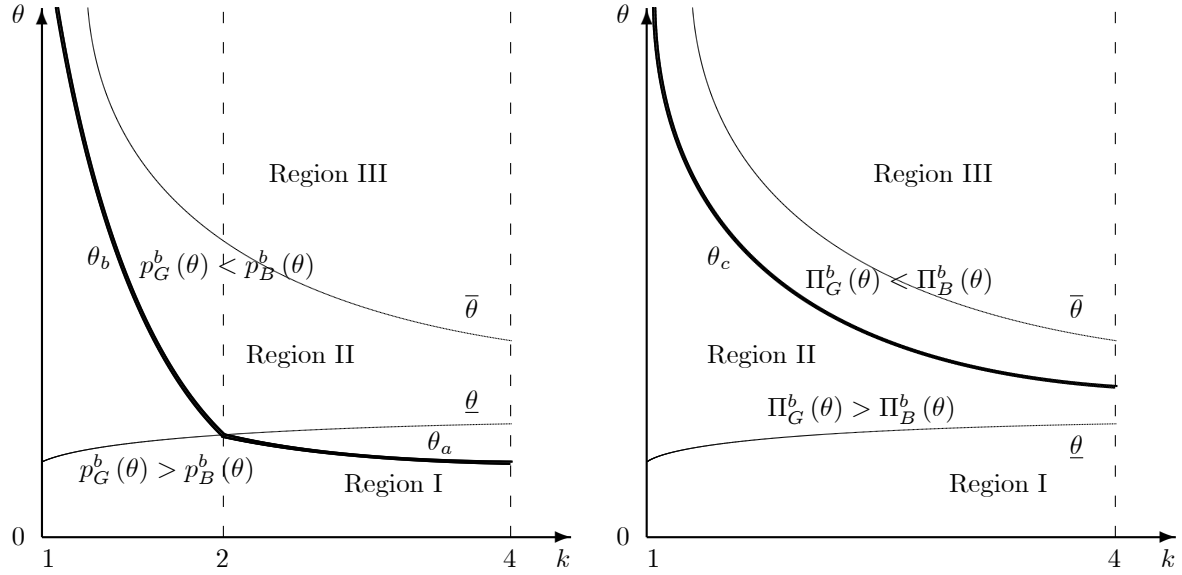


**Figure 2**: Difference in prices (left) and profits (right) at the benchmark contracts.

Considering price and profit differentials together, one can find a set of parameters, spanning both Regions I and II, where the green firm suffers a price penalty while enjoying a positive profit differential with respect to the brown firm. Indeed, it is easy to check that $\theta_c > \max\{\theta_a, \theta_b\}$. Hence, for $\max\{\theta_a, \theta_b\} < \theta < \theta_c$, the green firm is able to keep its prices sufficiently low so as to enjoy a bigger market share and gain higher profits than the brown rival.

# 4 Screening for consumers' willingness to pay and incentive contracts

Let us now consider the more realistic situation in which neither willingness to pay for quality nor environmental concerns of consumers are observable to firms. This requires solving programs $P_B$ and $P_G$ (see Section 2) simultaneously, taking each firm's $DIC$ and $UIC$ constraints into account.[13]

In order to give more structure to the problem at hand, let us present some preliminary results. First, we consider whether and under what conditions the benchmark contracts analyzed in Section

[13] Participation constraints are neglected at the outset and are checked ex-post.

3 are incentive compatible. Secondly, we study how consumers' sorting patterns influence incentive compatibility. Interacting these findings, it is then possible to determine, for each region: $(i)$ which incentive constraints are relevant and which ones can be discarded (because they are always slack or incompatible with others); and $(ii)$ among the relevant incentive constraints, which constraints bind first and which ones bind later (*i.e.* for a wider or a narrower subset of parameters, respectively).

Let us start with the benchmark contracts. Suppose that each firm $i = B, G$ offers a menu of contracts such that consumers of each type $\theta \in \{\theta_1, \theta_2\}$ are given the first-best quality levels $q_i^{fb}(\theta)$ and utilities $U_i^b(\theta)$. Do these contracts satisfy both $DIC_i$ and $UIC_i$ for each firm $i = B, G$? If this is the case, then the benchmark contracts represent full-fledged optimal contracts. This implies that only strategic interaction between firms matters, while information elicitation within each firm is not a problem. Indeed, each firm's program $P_i$ can be treated as two independent (benchmark) problems, one for each quality level, since the presence of types $\theta_1$ does not alter the optimal contract that firm $i$ offers to types $\theta_2$, and vice-versa.

**Lemma 1** $(i)$ *In* ***Region I****, i.e. when* $0 < \theta_1 < \theta_2 \leq \underline{\theta}$*, firm G's benchmark contracts are such that* $UIC_G$ *is always satisfied and* $DIC_G$ *holds if and only if* $\frac{\theta_2}{\theta_1} \geq 3$*; firm B's benchmark contracts are such that* $UIC_B$ *is always satisfied whereas* $DIC_B$ *always fails.* $(ii)$ *In* ***Region II****, i.e. when* $\underline{\theta} < \theta_1 < \theta_2 < \overline{\theta}$*, firm G's benchmark contracts are such that* $DIC_G$ *is always satisfied and* $UIC_G$ *holds if and only if* [14]

$$k < 4 \quad \text{and} \quad \frac{\theta_2}{\theta_1} \geq \frac{2+k}{4-k}; \tag{16}$$

*firm B's benchmark contracts are such that* $UIC_B$ *is always satisfied and* $DIC_B$ *holds if and only if* $\frac{\theta_2}{\theta_1} \geq \frac{4k-1}{2k+1}$*, with* $\frac{4k-1}{2k+1} < \frac{2+k}{4-k}$*.* $(iii)$ *In* ***Region III****, i.e. when* $\overline{\theta} \leq \theta_1 < \theta_2$*, firm G's benchmark contracts are always incentive compatible; firm B's benchmark contracts are such that* $UIC_B$ *is always satisfied and* $DIC_B$ *is satisfied if and only if*

$$\frac{\theta_2}{\theta_1} \geq 2k - 1. \tag{17}$$

**Proof.** See Appendix A.2. ■

The following result follows immediately from Lemma 1.

**Corollary 1** ***Incentive compatible benchmark contracts.*** *Suppose that neither consumers' willingness to pay nor environmental consciousness are observable to firms. Then:* $(i)$ *in* ***Region I****, i.e. when* $0 < \theta_1 < \theta_2 \leq \underline{\theta}$*, benchmark contracts are not incentive compatible;* $(ii)$ *in* ***Region II****, i.e. when* $\underline{\theta} < \theta_1 < \theta_2 < \overline{\theta}$*, optimal incentive contracts coincide with the benchmark contracts if and only if condition (16) is satisfied;* $(iii)$ *in* ***Region III****, i.e. when* $\overline{\theta} \leq \theta_1 < \theta_2$*, optimal incentive contracts coincide with the benchmark contracts if and only if condition (17) is satisfied.*

[14] Condition (16) is always satisfied when firms are symmetric, i.e. $k_i = 1$ for $i = B, G$, whereas it is never satisfied when firm $G$ has a high cost disadvantage and $k \geq 4$.

Parts (*ii*) and (*iii*) in Corollary 1 provide the conditions under which screening for consumers who are privately informed about their preferences for both quality and environment is performed without costs, and competition between two non-identical firms leads to an efficient allocation.[15] This efficiency result is more likely to be attained when the heterogeneity in consumers' types, that is the ratio between the willingness to pay for quality $\frac{\theta_2}{\theta_1}$, is sufficiently high. Indeed, when consumers' types are sufficiently distant from each other, mimicking becomes much less attractive. Moreover, efficiency is also guaranteed when firms' heterogeneity is sufficiently low, *i.e.* when $k_G = k$ is close to $k_B = 1$; then competition between firms becomes intense and both firms strive to attract the best, high-valuation consumers by leaving them a high utility.

Before proceeding further, notice that Lemma 1 again excludes the cases in which consumers' valuations $\theta_1$ and $\theta_2$ belong to two distinct regions. In these mixed regimes, it is more difficult to define conditions guaranteeing that benchmark contracts satisfy incentive compatibility for each firm. Such analysis goes beyond the scope of the present work and is relegated to the Working Paper version of this article (see Burani and Mantovani, 2019).[16] Nonetheless, the general principle stated above remains valid: the difference between consumers' types must be sufficiently high relative to the difference between firms' costs in order for the benchmark contracts to be incentive compatible.

What happens then when benchmark contracts are no longer incentive compatible? The following lemma specifies which are the incentive compatibility constraints that each firm can afford to neglect (because they are slack), depending on the sorting pattern of consumers into firms. The lemma focuses on full participation and full separation of consumers' types, because this is the most profitable situation for both firms, which prefer it to the possible alternatives, namely pooling both types into a single contract or excluding some type of consumer.

**Lemma 2** *Suppose that firms' market shares are such that* $\varphi_i(\theta) \in (0,1)$, *for* $i = B, G$ *and* $\theta \in \{\theta_1, \theta_2\}$, *and consider full participation and full separation of types. Then:* (*a*) *if there is positive selection into firm G, i.e.* $\widehat{\gamma}(\theta_1) > \widehat{\gamma}(\theta_2)$ *holds, optimal contracts are such that neither* $DIC_B$ *nor* $UIC_G$ *are binding;* (*b*) *if there is negative selection into firm G, i.e.* $\widehat{\gamma}(\theta_1) < \widehat{\gamma}(\theta_2)$ *holds, optimal contracts are such that neither* $UIC_B$ *nor* $DIC_G$ *are binding;* (*c*) *under neutrality, both* $UIC_i$ *and* $DIC_i$ *are slack for* $i = B, G$.

**Proof.** See Appendix A.3. ■

Then, different programs prove to be relevant according to which sorting pattern prevails and, in turn, depending on which region consumers' types belong to. In what follows, we examine the different

[15] This result is coherent with Rochet and Stole (2002), where firms are identical and no incentive constraint can ever be binding. Therefore, optimal contracts always entail efficient allocations. The same result is obtained by Armstrong and Vickers (2001) as well.

[16] In particular, we refer the interested reader to the continuation of the Proof of Lemma 1 in Appendix B.1 of our Working Paper.

regions in turn, focusing on allocative distortions and informational rents (*i.e.* on how qualities and utilities offered to the different types of consumers change with respect to the benchmark contracts), while referring the reader to Appendices B.2-B.4 in Burani and Mantovani (2019) for a detailed analysis of each case and for numerical simulations.

## 4.1 Region I

Consider Region I, where $\theta_1 < \theta_2 < \underline{\theta}$ and positive sorting attains. From Lemmata 1 and 2, it follows that $DIC_B$ always fails, thus firm $B$ is not able to prevent high types $\theta_2$ from mimicking low types $\theta_1$, when it extracts all the surplus from its consumers. Its options then become either to bunch low- and high-valuation consumers by offering them the same contact, or to exclude low-valuation consumers by offering them the null contract (*i.e.* zero quality and zero utility). It turns out that firm $B$ prefers to exclude low types $\theta_1$ and serve only high-valuation consumers $\theta_2$ provided that the fraction of low-valuation consumers $\nu$ be not too high.[17] As for firm $G$, there are two different situations to be considered: when $\frac{\theta_2}{\theta_1} \geq 3$, firm $G$'s benchmark contracts are fully incentive compatible; when instead $1 < \frac{\theta_2}{\theta_1} < 3$, the constraint $DIC_G$ starts to bind. In this latter situation, firm $G$ is bound to distort downwards the quality offered to low types and to pay out informational rents to high types, in order to discourage the latter from selecting the contract targeted to low types. This determines an increase in $U_G(\theta_2)$ relative to the benchmark. Moreover, in order to preserve profits, firm $G$ compensates the increase in $U_G(\theta_2)$ with a decrease in $U_G(\theta_1)$, which is then lower than at the benchmark.

The proposition that follows provides the most important qualitative results.

**Proposition 2** ***Optimal incentive contracts in Region I, when*** $0 < \theta_1 < \theta_2 \leq \underline{\theta}$.

- *Firm $B$ only offers the (efficient) high-quality level, i.e.* $q_B^*(\theta_1) = 0$ *and* $q_B^*(\theta_2) = q_B^{fb}(\theta_2)$; *it leaves no surplus to any consumer, i.e.* $U_B^*(\theta_1) = U_B^*(\theta_2) = 0$.
- *Firm $G$ always sets an efficient quality for high types, i.e.* $q_G^*(\theta_2) = q_G^{fb}(\theta_2)$. *Moreover:*
  - $(i)$ *when* $\frac{\theta_2}{\theta_1} \geq 3$, *it offers the benchmark contracts;*
  - $(ii)$ *when* $1 < \frac{\theta_2}{\theta_1} < 3$, *it distorts downward the quality offered to low types, i.e.* $q_G^*(\theta_1) < q_G^{fb}(\theta_1)$. *Relative to the benchmark, it leaves a higher utility to high types and a lower utility to low types, i.e.* $U_G^*(\theta_2) > U_G^b(\theta_2)$ *and* $U_G^*(\theta_1) < U_G^b(\theta_1)$.

**Proof.** See Appendix B.2. ■

In addition to the results highlighted in the above proposition, we also find that positive selection is reinforced because $\widehat{\gamma}(\theta_1)$ increases while $\widehat{\gamma}(\theta_2)$ decreases relative to the benchmark.[18] This implies that

[17] In the simulations we ran, a sufficient condition for exclusion being dominant with respect to pooling is that $\nu < 0.9$.

[18] See also Proposition 4 below.

the overall market share of firm $G$, consisting of the sum of $\varphi_G(\theta_1)$ and $\varphi_G(\theta_2)$, raises with respect not only to the benchmark but also to firm $B$'s market share. Moreover, in this region, there is a positive price differential in favour of the green firm, which is significantly higher for low types $\theta_1$ under screening contracts. Finally, the green firm increases its profit advantage relative to the brown firm for both types of consumers. To sum up, our analysis conveys the following unexpected message.

**Remark 1** *Under screening, when consumers' valuations for intrinsic quality are relatively low, the brown firm abstains from offering the low-quality variety, thereby benefitting the green rival.*

Referring to the real-world example of the automotive sector, our model predicts that, under asymmetric information, the producers of electric vehicles tend to dominate, and thus drive the brown producers out of the market, in the lowest quality segment, *i.e.* for electric bicycles, microcars and small utility cars. Indeed, the most important players in this market (Aixam-Mega SAS, Toyota Motor Corporation, Hyundai Group, Tata Group, Mitsubishi Corporation, and others) are increasingly developing low carbon emission vehicles and micro electric cars. It is also correct to say that they operate in conditions of asymmetric information, as precise data about consumers' valuation for quality are still being collected.

## 4.2 Region II

Suppose that $\underline{\theta} < \theta_1 < \theta_2 < \overline{\theta}$ and that negative sorting attains. Furthermore, suppose that condition $\frac{4k-1}{2k+1} \leq \frac{\theta_2}{\theta_1} < \frac{2+k}{4-k}$ is satisfied, whereby benchmark contracts are still incentive compatible for firm $B$ but no longer for firm $G$. As the ratio between consumers' valuations $\frac{\theta_2}{\theta_1}$ falls short of the quantity $\frac{2+k}{4-k}$, the two types of consumers become closer to each other and this induces mimicking between types. In particular, the contract that firm $G$ offers to consumers with high willingness to pay $\theta_2$ becomes attractive for low-valuation consumers $\theta_1$. Thus, firm $G$ is forced to distort the quality offered to high types upwards in order to make their contract less appealing to low types. Nonetheless, as at the benchmark, the green firm still offers lower quality levels to each type of consumer relative to the brown firm. In addition, the green firm increases $U_G^*(\theta_1)$ above the benchmark $U_G^b(\theta_1)$ in order to discourage low types from mimicking high types, and compensates this change with a decrease in $U_G^*(\theta_2)$.

Eventually, when the ratio between consumers' valuations $\frac{\theta_2}{\theta_1}$ is even lower and condition $\frac{\theta_2}{\theta_1} < \frac{4k-1}{2k+1}$ is relevant, firm $B$ starts to be incentive constrained as well, because the contract offered to low-valuation consumers becomes attractive for high-valuation potential customers. The brown firm then prevents high types from mimicking low types by distorting the quality level offered to low types downwards and giving information rents to high types, whose utility $U_B^*(\theta_2)$ necessarily increases. Moreover, in order to preserve profits, firm $B$ compensates an increase in $U_B^*(\theta_2)$ with a decrease in $U_B^*(\theta_1)$.

The proposition that follows highlights the main features of optimal contracts in Region II.

**Proposition 3** ***Optimal incentive contracts in Region II, when*** $\underline{\theta} < \theta_1 < \theta_2 < \overline{\theta}$ ***and*** $\frac{\theta_2}{\theta_1} < \frac{2+k}{4-k}$.

- *Firm G offers the efficient quality for low types, i.e.* $q_G(\theta_1) = q_G^{fb}(\theta_1)$, *and it distorts upwards the quality offered to high types, i.e.* $q_G^*(\theta_2) > q_G^{fb}(\theta_2)$. *Relative to the benchmark, it leaves a higher utility to low types and a lower utility to high types, i.e.* $U_G^*(\theta_1) > U_G^b(\theta_1)$ *and* $U_G^*(\theta_2) < U_G^b(\theta_2)$.

- *Firm B always sets an efficient quality for high types, i.e.* $q_G^*(\theta_2) = q_G^{fb}(\theta_2)$. *Moreover:*

  (*i*) *when* $\frac{4k-1}{2k+1} \leq \frac{\theta_2}{\theta_1} < \frac{2+k}{4-k}$, *it sets the efficient quality levels also for low types, i.e.* $q_B^*(\theta_1) = q_B^{fb}(\theta_1)$. *Relative to the benchmark, it leaves a higher utility to low types and a lower utility to high types, i.e.* $U_B^*(\theta_1) > U_B^b(\theta_1)$ *while* $U_B^*(\theta_2) < U_B^b(\theta_2)$.

  (*ii*) *when* $\frac{\theta_2}{\theta_1} < \frac{4k-1}{2k+1}$, *it distorts downwards the quality offered to low-valuation consumers, i.e.* $q_B^*(\theta_1) < q_B^{fb}(\theta_1)$. *Relative to the benchmark, it leaves a lower utility to low types and a higher utility to high types, i.e.* $U_B^*(\theta_1) < U_B^b(\theta_1)$ *while* $U_B^*(\theta_2) > U_B^b(\theta_2)$.

**Proof.** See Appendix B.3. ■

Notice that our result concerning the overprovision of quality by firm $G$ to high types $\theta_2$ is somehow unexpected. Usually, one observes underprovision of quality to low types $\theta_1$, which is caused by the downward incentive constraint being binding.[19] In our model, this does not occur because outside options are type-dependent. Indeed, when buying from firm $G$, consumers with low valuation $\theta_1$ are tempted to mimic high-valuation types $\theta_2$ who are more likely to receive attractive offers from firm $B$. The latter, in turn, is more prone to serve high-valuation consumers who guarantee higher profit margins.[20]

Moreover, when consumers' valuations for quality take relatively high values, the green producer gains in terms of market penetration only for low-type consumers, which are however more sophisticated in comparison to the previous region. As an illustrative example, consider Tesla S, a high-performance electric sedan. Its success can be attributed to the fact that its intrinsic performance, in terms of both acceleration and speed, is comparable to that of internal combustion vehicles.

What happens in Region III (when $\overline{\theta} < \theta_1 < \theta_2$) is not particularly insightful, because the green firm leaves all the surplus to its customers and thus its contracts are always incentive compatible. Nonetheless, firm $G$ is unable to serve any customers, and it only plays the role of potential competitor of firm $B$. The latter might have its $DIC_B$ binding and therefore it might distort downwards the quality offered to low-type consumers. Considering the automotive sector, one could identify Region III with the segment of sports cars, in which market penetration by electric car producers like Tesla is still extremely low (despite the efforts made with their Roadster). Brown producers like Ferrari or Porsche, instead, dominate the

[19] See Biglaiser and Mezzetti (2001) and Rochet and Stole (2001) on this point.

[20] See the literature on countervailing incentives (Lewis and Sappington, 1989, and Maggi and Rodríguez-Clare, 1995) and on type-dependent participation constraints (Jullien, 2000).

market, even in the presence of asymmetric information about consumers' WTP. The interested reader is referred to Appendix B.4, where we relegate the analysis of this case.

## 4.3 Consumers' self-selection

Screening contracts entail information rents left by firms to consumers. This alters condition (3) and, in turn, the sorting pattern of consumers into firms.

**Proposition 4** ***Consumers' sorting patterns at the incentive contracts.*** *When incentive contracts are in place, selection (be it positive or negative) is more pronounced than at the benchmark contracts: the function $\widehat{\gamma}(\theta)$ is steeper relative to the benchmark in both Regions I and II.*

In particular, this implies that, under negative selection for firm $G$, firm $G$'s market share of high-valuation consumers (respectively firm $B$'s) decreases (resp. increases), whereas firm $G$'s market share of low-valuation consumers (respectively firm $B$'s) increases (resp. decreases) relative to the benchmark. The converse is true under positive selection. Figure 3 sketches these results.

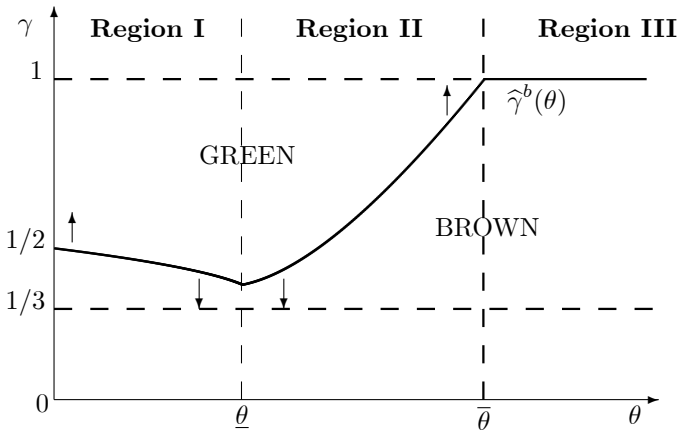


**Figure 3**: Consumers' sorting at the screening contracts.

Proposition 4 suggests that each firm designs its incentive contracts in order to make the sorting pattern of consumers as favorable to itself as possible. Indeed, consider negative selection: when $UIC$ is binding for the green firm, its profit margins are decreasing in consumers' willingness to pay $\theta$.[21] Therefore, the green firm is better-off the higher the share of low-valuation consumers and the lower the share of high-valuation consumers that it is able to serve. The opposite happens when $DIC$ is binding for the brown firm: its profit margins are increasing in $\theta$, therefore this firm is better-off if it

[21] See Result 1 contained in the proof of Lemma 2 in Appendix A.3.

succeeds in serving an increasing share of high-valuation consumers and a decreasing share of low-valuation consumers. Thus, under negative selection, it becomes relatively more convenient for the brown firm to attract high-type consumers and for the green firm to attract low-type consumers. For this reason, the effect of selection is strengthened at the incentive contracts. A similar logic applies to positive selection when $DIC_G$ is binding.

Before concluding, let us mention that in Appendix B.5 of our Working Paper (Burani and Mantovani, 2019) the interested reader can find a section devoted to the analysis of the price differential between the two firms under screening, which extends the results obtained in Section 3.2.

# 5 Concluding remarks

In this paper, we analyzed competition patterns along different dimensions of quality in presence of asymmetric information. In particular, we considered a vertically differentiated duopoly in which a green firm produces an environmentally-friendly variety of a product, whereas the brown rival produces a standard variety. A particular feature of our model is that both firms are allowed to offer quality-differentiated versions of their products. We studied optimal contracts offered by the two firms both in the benchmark case of full information about consumers' willingness to pay for intrinsic quality and assuming that firms were uninformed about both consumers' WTP and their degree of environmental consciousness.

An important finding we obtained is that, under asymmetric information, there exist situations in which the brown firm only offers a high quality and the green firm not only captures all consumers buying the low quality but also charges higher prices than its competitor, thereby reaping higher profits. This occurs when consumers' valuations for quality are relatively low. An interesting policy implication, we touch upon though not formally develop, is that consumers' private information may represent a substitute for environmental regulation and/or the introduction of minimum (environmental) quality standards. Moreover, these results can be interpreted in terms of the potential bright side of asymmetric information, especially in a period where firms struggle to obtain information regarding consumers' tastes and preferences. Indeed, under full information about consumers' WTP for intrinsic quality, we would observe a proliferation of brown products, also at the bottom of the quality ladder, in order to cater for customers willing to buy the low quality. This might not be beneficial for society at large, as the low-quality variety commercialized by the brown firm is often associated to relatively high levels of polluting emissions, and/or does not meet the standards of social responsibility. On the other hand, when consumers' valuations are relatively low and firms resort to screening, some mutually beneficial exchanges are not carried out, thereby producing a welfare loss. Eventually, the underprovision of quality by the green firm further reduces welfare. Navigating these trade-offs would require additional assumptions

about how to relate the emissions generated by a product to its hedonic quality, to its volume of sales, and eventually to the loss in consumers' satisfaction that they cause. Therefore, we decided not to develop the welfare implications of our model to a greater extent.

A limitation of our model is that we only consider consumers with two possible WTP. It would be interesting to extend our analysis to include the case in which consumers' valuations for intrinsic quality are continuous. However, the standard Hamiltonian technique would not prove sufficient to provide a solution. Our preliminary work in this direction enables us to state the following facts. First, efficient allocations are never incentive compatible. Hence, benchmark contracts are no longer optimal screening contracts. Second, it is possible that distortions in quality disappear both at the top and at the bottom (*i.e.* efficient qualities are offered both to the lowest and to highest possible types). Third, firms might well offer pooling contracts such that the same quality is offered to some subset of types. Finally, exclusion of some types of consumers, namely the ones with the lower willingness to pay, is also possible. Despite the additional technical difficulties, this confirms the robustness of our main result, namely that the brown firm might be willing to abstain from producing the low-quality variant of the good.

Another restrictive assumption that we adopt is related to consumers' valuations and environmental consciousness being independently distributed. This is crucial for our results, because our definitions about consumer sorting patterns do not readily lend themselves to problems involving a statistical association between the two consumers' characteristics. Indeed, consider the case of a perfect positive (respectively negative) correlation between WTP and green consciousness, in which the type space would become a positively (resp. negatively) sloped straight line. Then, the green firm would simply serve the consumers with the highest environmental consciousness, who are also the ones with the highest (resp. lowest) valuations for intrinsic quality. However, notice that our main result, concerning the advantage of the green relative to the brown firm in Region I, holds *despite* the assumed independence, and not thanks to it. The introduction of positive correlation to eventually compensate for the additional cost borne by the green firm would simply enhance its advantage.

# A Appendix

## A.1 The benchmark contracts: Nash equilibria

Consider reaction functions (13). At the interior solution, they intersect when they are both strictly positively sloped, and this identifies Region II. As we know, there also exist two corner solutions: in Region I, firm $G$'s reaction function is strictly positively sloped and it intersects firm $B$'s reaction function which is constant at $U_B(\theta) = 0$; in Region III, firm $B$'s reaction function is strictly positively sloped and it intersects firm $G$'s reaction function which is constant at $U_G(\theta) = S_G(\theta) = \theta^2/2k$. Let us consider

these three situations with additional analytical details.

($i$) Considering the space $(U_B, U_G)$, the vertical-axis intercept of firm $G$'s reaction function can not only be negative, but also weakly smaller than the (negative) vertical-axis intercept of firm $B$'s reaction function. Analytically, this means that $\frac{\theta^2}{2k} - 1 \leq -\frac{\theta^2}{2} < 0$, which leads to the definition of interval $\theta \in (0, \underline{\theta}]$. In this region, a Nash equilibrium exists and is such that

$$U_B^{Ib}(\theta) = 0 \quad \text{and} \quad U_G^{Ib}(\theta) = -\tfrac{1}{2}\left(1 - \tfrac{\theta^2}{2k}\right) < 0 \ .$$

Using (3), the marginal consumer of type $\theta$, who is indifferent between the two firms, is

$$\widehat{\gamma}^{Ib}(\theta) = U_B^{Ib}(\theta) - U_G^{Ib}(\theta) = \frac{1}{2}\left(1 - \frac{\theta^2}{2k}\right).$$

Thus, the fractions of type $\theta$ consumers served by firm $B$ and firm $G$, respectively, are

$$\varphi_B^{Ib}(\theta) = \Pr\left(\gamma < \widehat{\gamma}^{Ib}(\theta)\right) = \tfrac{1}{2} - \tfrac{\theta^2}{4k} \quad \text{and} \quad \varphi_G^{Ib}(\theta) = 1 - \varphi_B^{Ib}(\theta) = \tfrac{1}{2} + \tfrac{\theta^2}{4k} \ .$$

Finally, prices can be recovered using (2) and are equal to

$$p_B^{Ib}(\theta) = \theta^2 \quad \text{and} \quad p_G^{Ib}(\theta) = \tfrac{\theta^2}{k} + \tfrac{1}{2}\left(1 - \tfrac{\theta^2}{2k}\right) = \tfrac{1}{2}\left(1 + \tfrac{3\theta^2}{2k}\right) \ .$$

($ii$) Secondly, consider interior solutions, in which utilities solve the two equations in (13) and are equal to

$$U_B^{IIb}(\theta) = \tfrac{1}{3}\left(\tfrac{\theta^2(1+2k)}{2k} - 1\right) \quad \text{and} \quad U_G^{IIb}(\theta) = \tfrac{1}{3}\left(\tfrac{\theta^2(2+k)}{2k} - 2\right) \ . \tag{18}$$

The indifferent consumer is therefore given by

$$\widehat{\gamma}^{IIb}(\theta) = U_B^{IIb}(\theta) - U_G^{IIb}(\theta) = \frac{1}{3}\left(1 + \frac{\theta^2(k-1)}{2k}\right)$$

and market shares equal

$$\varphi_B^{IIb}(\theta) = \tfrac{1}{3}\left(1 + \tfrac{\theta^2(k-1)}{2k}\right) \quad \text{and} \quad \varphi_G^{IIb}(\theta) = \tfrac{1}{3}\left(2 - \tfrac{\theta^2(k-1)}{2k}\right) \ .$$

Finally, one can compute the equilibrium prices

$$p_G^{IIb}(\theta) = \tfrac{1}{3}\left(\tfrac{\theta^2(4-k)}{2k} + 2\right) \quad \text{and} \quad p_B^{IIb}(\theta) = \tfrac{1}{3}\left(\tfrac{\theta^2(4k-1)}{2k} + 1\right) \ .$$

Interior solutions emerge in the interval $\theta \in \left(\underline{\theta}, \overline{\theta}\right)$, with $\overline{\theta}$ being obtained for high values of $\theta$ which define the second corner solution.

($iii$) Finally, considering again the space $(U_B, U_G)$, firm $B$'s reaction function can intersects firm $G$'s reaction function when the latter is flat at $U_G(\theta) = \theta^2/2k$, which corresponds to the total surplus generated by firm $G$ for type $\theta$ consumers. Firm $G$ is not able to attract consumers of type $\theta$,

notwithstanding the fact that it may give them the whole total surplus. As we already know, it yields zero profits and has a null market share. Firm $B$, on the contrary, serves the whole market. This occurs when $\theta > \overline{\theta}$, and in the interval $\theta \in \left[\overline{\theta}, \infty\right)$ a Nash equilibrium is now characterized by utilities

$$U_B^{IIIb}(\theta) = 1 + \tfrac{\theta^2}{2k} \quad \text{and} \quad U_G^{IIIb}(\theta) = \tfrac{\theta^2}{2k} \ ,$$

and market shares

$$\varphi_B^{IIIb}(\theta) = \widehat{\gamma}^{IIIb}(\theta) = 1 \quad \text{and} \quad \varphi_G^{IIIb}(\theta) = 0 \ .$$

Prices are equal to

$$p_B^{IIIb}(\theta) = \theta^2 - \left(1 + \tfrac{\theta^2}{2k}\right) = \tfrac{\theta^2(2k-1)}{2k} - 1 \quad \text{and} \quad p_G^{IIIb}(\theta) = \tfrac{\theta^2}{2k} \ .$$

## A.2 Proof of Lemma 1: Incentive compatible benchmark contracts

We check whether the incentive compatibility constraints are satisfied by the benchmark contracts: for each $i = B, G$, we rewrite constraints $DIC_i$ and $UIC_i$ substituting for the equilibrium qualities $q_i^b(\theta)$ and utilities $U_i^b(\theta)$ of the benchmark in Section 3. For expositional clarity, we will denote by $IC_i^b$ the incentive constraint evaluated at the benchmark. Given that there are different classes of Nash equilibria, characterized by different equilibrium utilities $U_i^b(\theta)$, let us consider the different regions in turn and let us examine incentive constraints accordingly.

($i$) Suppose that both $\theta_1$ and $\theta_2$ belong to Region I, *i.e.*, assume that $\theta_1 < \theta_2 \leq \underline{\theta} = \sqrt{\frac{2k}{2k+1}} < 1$. For firm $G$, one has

$$UIC_G^b \text{ is satisfied} \iff \frac{(\theta_2 - \theta_1)(4\theta_2 - (\theta_2 + \theta_1))}{4k} \geq 0$$

that is if and only if $\frac{\theta_2}{\theta_1} \geq \frac{1}{3}$, which is always true given that $\frac{\theta_2}{\theta_1} > 1$ by assumption. Moreover,

$$DIC_G^b \text{ is satisfied} \iff \frac{(\theta_2 - \theta_1)((\theta_2 + \theta_1) - 4\theta_1)}{4k} \geq 0,$$

or else if and only if

$$\frac{\theta_2}{\theta_1} \geq 3. \tag{19}$$

Consider now firm $B$. One has

$$UIC_B^b \text{ is satisfied} \iff (\theta_2 - \theta_1)\,\theta_2 \geq 0,$$

which is always the case, and

$$DIC_B^b \text{ is satisfied} \iff -(\theta_2 - \theta_1)\,\theta_1 \geq 0,$$

which is impossible, implying that $DIC_B^b$ is always violated by the benchmark contracts of firm $B$ and that types $\theta_2$ have an incentive to mimic types $\theta_1$. This follows from the fact that firm $B$ offers the same null utility to both types of consumers.

(*ii*) Suppose now that both $\theta_1$ and $\theta_2$ belong to Region II, *i.e.*, assume that $\underline{\theta} < \theta_1 < \theta_2 < \overline{\theta} = \sqrt{\frac{4k}{k-1}}$. For firm $G$, one has

$$UIC_G^b \text{ is satisfied } \iff \frac{(\theta_2-\theta_1)((\theta_2+\theta_1)(4-k)-6\theta_1)}{6k} \geq 0 \ ,$$

that is if and only if $k < 4$ and[22]

$$\frac{\theta_2}{\theta_1} \geq \frac{2+k}{4-k}. \tag{20}$$

Moreover,

$$DIC_G^b \text{ is satisfied } \iff \frac{(\theta_2-\theta_1)(6\theta_2-(\theta_2+\theta_1)(4-k))}{6k} \geq 0$$

which is always true when $\frac{\theta_2}{\theta_1} > 1$.

Considering firm $B$, one has

$$UIC_B^b \text{ is satisfied } \iff \frac{(\theta_2(4k-1)-\theta_1(2k+1))(\theta_2-\theta_1)}{6k} \geq 0$$

which is always the case when $\frac{\theta_2}{\theta_1} > 1$, and

$$DIC_B^b \text{ is satisfied } \iff \frac{((2k+1)\theta_2-(4k-1)\theta_1)(\theta_2-\theta_1)}{6k} \geq 0$$

which holds if and only if

$$\frac{\theta_2}{\theta_1} \geq \frac{4k-1}{2k+1}. \tag{21}$$

Given that inequality

$$\frac{4k-1}{2k+1} < \frac{2+k}{4-k}$$

holds, both firms' benchmark contracts are incentive compatible when condition (20) is satisfied, whereas only firm $B$'s benchmark contracts are incentive compatible when

$$\frac{4k-1}{2k+1} \leq \frac{\theta_2}{\theta_1} < \frac{2+k}{4-k},$$

because $UIC_G^b$ fails to be satisfied. Finally, when

$$\frac{\theta_2}{\theta_1} < \frac{4k-1}{2k+1},$$

neither firm's benchmark contracts are incentive compatible because both $UIC_G^b$ and $DIC_B^b$ fail to hold.

(*iii*) Suppose, then, that both $\theta_1$ and $\theta_2$ belong to Region III, *i.e.*, we assume that $2 < \overline{\theta} < \theta_1 < \theta_2$. For firm $G$, one has

$$UIC_G^b \text{ is satisfied } \iff \frac{(\theta_2-\theta_1)(2\theta_2-(\theta_2+\theta_1))}{4k} \geq 0 \ ,$$

[22] Note that, when $k \geq 4$, benchmark contracts are never upward incentive compatible for firm $G$ because types $\theta_1$ consumers always have incentive to mimick types $\theta_2$. We will henceforth rule out this event assuming that $k < 4$ holds.

which is always the case, and

$$DIC_G^b \text{ is satisfied } \iff \frac{(\theta_2-\theta_1)((\theta_2+\theta_1)-2\theta_1)}{4k} \geq 0 \ ,$$

which is always true: in this Region, firm $G$ leaves all the surplus to consumers and thus its benchmark contracts are incentive compatible.

As for firm $B$,

$$UIC_B^b \text{ is satisfied } \iff \frac{(\theta_2-\theta_1)(2k\theta_2-(\theta_2+\theta_1))}{2k} \geq 0 \ ,$$

which is true for any $\frac{\theta_2}{\theta_1} > 1$ and

$$DIC_B^b \text{ is satisfied } \iff \frac{(\theta_2-\theta_1)((\theta_2+\theta_1)-2k\theta_1)}{4k} \geq 0 \ ,$$

that is if and only if

$$\frac{\theta_2}{\theta_1} \geq 2k-1. \tag{22}$$

Summing up, for $\frac{\theta_2}{\theta_1} \geq 2k-1$ all benchmark contracts in Region III are incentive compatible, whereas for $1 < \frac{\theta_2}{\theta_1} < 2k-1$ firm $B$'s benchmark contracts are not downward incentive compatible.

Mixed regimes are considered in Appendix B.1, which can be found in the Working Paper version of this article.[23]

## A.3 Proof of Lemma 2

In order to prove Lemma 2, let us first consider a preliminary step. Let us express incentive constraints in terms of profit margins on each type $\theta$ (see expression 6) and surplus. Then $DIC_i$ becomes

$$\pi_i(\theta_2) - \pi_i(\theta_1) \leq S_i(\theta_2) - S_i(\theta_1) - \Delta\theta q_i(\theta_1)$$

and $UIC_i$ takes the form

$$S_i(\theta_2) - S_i(\theta_1) - \Delta\theta q_i(\theta_2) \leq \pi_i(\theta_2) - \pi_i(\theta_1).$$

**Result 1** *(i) If $DIC_i$ is binding for firm $i = B, G$, then profit margins are strictly increasing in $\theta$ and $\pi_i(\theta_1) < \pi_i(\theta_2)$. (ii) If $UIC_i$ is binding for firm $i = B, G$, then profit margins are strictly decreasing in $\theta$ and $\pi_i(\theta_1) > \pi_i(\theta_2)$. (iii) If neither $DIC_i$ nor $UIC_i$ is binding for either firm, then profit margins can be either decreasing or increasing in $\theta$.*

**Proof.** The proof of this result follows an argument similar to the one developed by Rochet and Stole (2002). When $DIC_i$ is binding for firm $i = B, G$, quality levels are such that $q_i(\theta_2) = q_i^{fb}(\theta_2)$ and

[23] We recall that the Working Paper version is available at: https://papers.ssrn.com/abstract=3465981?? .

$q_i(\theta_1) \leq q_i^{fb}(\theta_1)$; namely, the high type gets the first best while the quality of the low type is downward distorted. Moreover, when $DIC_i$ is binding, one has

$$\pi_i(\theta_2) - \pi_i(\theta_1) = S_i(\theta_2) - S_i(\theta_1) - \Delta\theta q_i(\theta_1).$$

The right-hand-side of the above equality is minimized when $q_i(\theta_1)$ is the highest possible, that is when it equals the first-best quality level. Substituting for such quality level yields

$$\pi_i(\theta_2) - \pi_i(\theta_1) = S_i(\theta_2) - S_i(\theta_1) - \Delta\theta q_i(\theta_1) \quad \geq \frac{\theta_2^2}{2k_i} - \frac{\theta_1^2}{2k_i} - \frac{\theta_1(\theta_2-\theta_1)}{k_i} = \frac{(\theta_2-\theta_1)^2}{2k_i} > 0 \ .$$

Thus, when $DIC_i$ is binding, $\pi_i(\theta_2) > \pi_i(\theta_1)$ and profit margins are strictly increasing in $\theta$.

Similarly, when $UIC_i$ is binding for firm $i = B, G$, quality levels are such that $q_i(\theta_2) \geq q_i^{fb}(\theta_2)$ and $q_i(\theta_1) = q_i^{fb}(\theta_1)$; namely, the low type gets the first best while the quality designed for the high type is distorted upwards. Moreover, when $UIC_i$ is binding, one has

$$S_i(\theta_2) - S_i(\theta_1) - \Delta\theta q_i(\theta_2) = \pi_i(\theta_2) - \pi_i(\theta_1).$$

The left-hand-side of the above equality is maximized when $q_i(\theta_2)$ is the lowest possible, that is when it equals the first-best level. Substituting for such quality level yields

$$\pi_i(\theta_2) - \pi_i(\theta_1) = S_i(\theta_2) - S_i(\theta_1) - \Delta\theta q_i(\theta_2) \quad \leq \frac{\theta_2^2}{2k_i} - \frac{\theta_1^2}{2k_i} - \frac{\theta_2(\theta_2-\theta_1)}{k_i} = -\frac{(\theta_2-\theta_1)^2}{2k_i} < 0 \ ,$$

showing that $\pi_i(\theta_2) < \pi_i(\theta_1)$, i.e. that profit margins are strictly decreasing in $\theta$. When neither $DIC_i$ nor $UIC_i$ is binding, then each firm sets all effort levels at the first best and the difference in profit margins $\pi_i(\theta_1) - \pi_i(\theta_2)$ can be either positive or negative. ■

Let us then move to the actual proof of Lemma 2. Consider full participation and full separation of types. Assume that both firms' market shares are such that $\varphi_i(\theta) \in (0,1)$, with $i = B, G$ and $\theta \in \{\theta_1, \theta_2\}$, and consider negative selection for firm $G$ so that $0 < \widehat{\gamma}(\theta_1) < \widehat{\gamma}(\theta_2) < 1$ holds, whereby $\varphi_B(\theta_1) < \varphi_B(\theta_2) \Longleftrightarrow \varphi_G(\theta_1) > \varphi_G(\theta_2)$. Take the problem $P_G$ of the green firm (see Section 2) subject to $DIC_G$ and $UIC_G$. Build the Lagrangian associated with this problem, where $\lambda_G^D$ and $\lambda_G^U$ are the multipliers corresponding to $DIC_G$ and $UIC_G$, respectively

$$\begin{aligned}\mathcal{L}_G = \ & \nu\left(\theta_1 q_G(\theta_1) - \tfrac{1}{2}kq_G^2(\theta_1) - U_G(\theta_1)\right)\left(1 - (U_B(\theta_1) - U_G(\theta_1))\right) \\ & + (1-\nu)\left(\theta_2 q_G(\theta_2) - \tfrac{1}{2}kq_G^2(\theta_2) - U_G(\theta_2)\right)\left(1 - (U_B(\theta_2) - U_G(\theta_2))\right) \\ & + \lambda_G^D\left(U_G(\theta_2) - U_G(\theta_1) - \Delta\theta q_G(\theta_1)\right) + \lambda_G^U\left(U_G(\theta_1) - U_G(\theta_2) + \Delta\theta q_G(\theta_2)\right)\end{aligned} \quad . \tag{23}$$

The first-order conditions relative to utilities are

$$\begin{aligned}\frac{\partial \mathcal{L}_G}{\partial U_G(\theta_1)} = \ & -\nu\left(1 - (U_B(\theta_1) - U_G(\theta_1))\right) \\ & + \nu\left(\theta_1 q_G(\theta_1) - \tfrac{1}{2}kq_G^2(\theta_1) - U_G(\theta_1)\right) - \lambda_G^D + \lambda_G^U = 0\end{aligned} \tag{G1}$$

$$\begin{aligned}\frac{\partial \mathcal{L}_G}{\partial U_G(\theta_2)} = \ & -(1-\nu)\left(1 - (U_B(\theta_2) - U_G(\theta_2))\right) \\ & + (1-\nu)\left(\theta_2 q_G(\theta_2) - \tfrac{1}{2}kq_G^2(\theta_2) - U_G(\theta_2)\right) + \lambda_G^D - \lambda_G^U = 0\end{aligned} \tag{G2}$$

Consider the following two cases.

($a$) Suppose that $\lambda_G^U > 0$ while $\lambda_G^D = 0$. Then $DIC_G$ is slack while $UIC_G$ is binding and equations ($G1$) and ($G2$) become

$$\begin{array}{rl} \frac{\partial \mathcal{L}_G}{\partial U_G(\theta_1)} = & -\nu\left(1-\left(U_B\left(\theta_1\right)-U_G\left(\theta_1\right)\right)\right) \\ & +\nu\left(\theta_1 q_G\left(\theta_1\right)-\frac{1}{2}kq_G^2\left(\theta_1\right)-U_G\left(\theta_1\right)\right)+\lambda_G^U=0 \end{array} \quad (G1a)$$

$$\begin{array}{rl} \frac{\partial \mathcal{L}_G}{\partial U_G(\theta_2)} = & -\left(1-\nu\right)\left(1-\left(U_B\left(\theta_2\right)-U_G\left(\theta_2\right)\right)\right) \\ & +\left(1-\nu\right)\left(\theta_2 q_G\left(\theta_2\right)-\frac{1}{2}kq_G^2\left(\theta_2\right)-U_G\left(\theta_2\right)\right)-\lambda_G^U=0 \end{array} . \quad (G2a)$$

Solving both ($G1a$) and ($G2a$) for $\lambda_G^U$ and considering that $\lambda_G^U > 0$ yields

$$1-\left(U_B\left(\theta_1\right)-U_G\left(\theta_1\right)\right) > \theta_1 q_G\left(\theta_1\right)-\frac{1}{2}kq_G^2\left(\theta_1\right)-U_G\left(\theta_1\right) \equiv \pi_G\left(\theta_1\right)$$

and

$$\pi_G\left(\theta_2\right) \equiv \theta_2 q_G\left(\theta_2\right)-\frac{1}{2}kq_G^2\left(\theta_2\right)-U_G\left(\theta_2\right) > 1-\left(U_B\left(\theta_2\right)-U_G\left(\theta_2\right)\right).$$

Given that, by Result 1, profit margins are decreasing in $\theta$ when $UIC_G$ is binding, one has that

$$1-\left(U_B\left(\theta_1\right)-U_G\left(\theta_1\right)\right) > \pi_G\left(\theta_1\right) > \pi_G\left(\theta_2\right) > 1-\left(U_B\left(\theta_2\right)-U_G\left(\theta_2\right)\right)$$

which requires negative selection for firm $G$. In other words, our initial assumption about negative selection is compatible with $UIC_G$ being binding and $DIC_G$ being slack for firm $G$.

($b$) Conversely, assume that $UIC_G$ is slack while $DIC_G$ is binding whereby $\lambda_G^U = 0$ while $\lambda_G^D > 0$. Now, first-order conditions ($G1$) and ($G2$) specify as

$$\begin{array}{rl} \frac{\partial \mathcal{L}_G}{\partial U_G(\theta_1)} = & -\nu\left(1-\left(U_B\left(\theta_1\right)-U_G\left(\theta_1\right)\right)\right) \\ & +\nu\left(\theta_1 q_G\left(\theta_1\right)-\frac{1}{2}kq_G^2\left(\theta_1\right)-U_G\left(\theta_1\right)\right)-\lambda_G^D=0 \end{array} \quad (G1b)$$

$$\begin{array}{rl} \frac{\partial \mathcal{L}_G}{\partial U_G(\theta_2)} = & -\left(1-\nu\right)\left(1-\left(U_B\left(\theta_2\right)-U_G\left(\theta_2\right)\right)\right) \\ & +\left(1-\nu\right)\left(\theta_2 q_G\left(\theta_2\right)-\frac{1}{2}kq_G^2\left(\theta_2\right)-U_G\left(\theta_2\right)\right)+\lambda_G^D=0 \end{array} . \quad (G2b)$$

Solving both ($G1b$) and ($G2b$) for $\lambda_G^D > 0$ yields

$$\pi_G\left(\theta_1\right) \equiv \theta_1 q_G\left(\theta_1\right)-\frac{1}{2}kq_G^2\left(\theta_1\right)-U_G\left(\theta_1\right) > 1-\left(U_B\left(\theta_1\right)-U_G\left(\theta_1\right)\right)$$

and

$$1-\left(U_B\left(\theta_2\right)-U_G\left(\theta_2\right)\right) > \theta_2 q_G\left(\theta_2\right)-\frac{1}{2}kq_G^2\left(\theta_2\right)-U_G\left(\theta_2\right) \equiv \pi_G\left(\theta_2\right).$$

Profit margins are increasing in $\theta$ when $DIC_G$ is binding and thus

$$1-\left(U_B\left(\theta_2\right)-U_G\left(\theta_2\right)\right) > \pi_G\left(\theta_2\right) > \pi_G\left(\theta_1\right) > 1-\left(U_B\left(\theta_1\right)-U_G\left(\theta_1\right)\right)$$

contradicting the fact that there's negative selection for firm $G$.

By the same reasoning, considering the problem $P_G$ of the brown firm, the following result holds: the assumption of negative selection for firm $G$ is compatible with the situation in which $DIC_B$ is binding and $UIC_B$ is slack, because profit margins are increasing in $\theta$ for firm $B$ when $DIC_B$ is binding; such assumption is instead not compatible with the case in which $DIC_B$ is slack and $UIC_B$ is binding, given that profit margins are decreasing in $\theta$ for firm $B$ when $UIC_B$ is binding.

All results are reversed if the initial assumption is that selection is positive for firm $G$. Finally, when neutrality holds, all incentive constraints should be slack for both firms.

# References


[1] Allcott, H. and T. Rogers (2014), "The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation", *American Economic Review*, **104**, 3003-3037.

[2] Andreoni, J. (1989), "Giving with impure altruism: Applications to charity and Ricardian equivalence", *Journal of Political Economy*, **97**, 1447-1458.

[3] Armstrong, M. and J. Vickers (2001), "Competitive Price Discrimination", *The RAND Journal of Economics,* **32**(4), 1-27.

[4] Barigozzi, F. and N. Burani (2019), "Competition for talent when firms' mission matters", *Games and Economic Behavior*, **116**, 128-151.

[5] Barigozzi, F. and C. A. Ma (2018), "Product differentiation with multiple qualities", *International Journal of Industrial Organization*, **61**, 380-412.

[6] Bénabou, R. and J. Tirole (2010), "Individual and Corporate Social Responsibility", *Economica*, **77**, 1-19.

[7] Biglaiser, G. and C. Mezzetti (2000), "Incentive Auctions and Information Revelation", *The RAND Journal of Economics,* **31**(1), 145-164.

[8] Boyer, M., Mahenc, P. and M. Moreaux (2007), "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*, Ashgate Pub.

[9] Burani, N. and A. Mantovani (2019), "Non-linear Pricing and Conscious Consumption", SSRN Working Paper No. 3465981, available at: https://papers.ssrn.com/abstract=3465981**??** .

[10] Carlsson, F., Garcia, J. and Å. Löfgren (2010), "Conformity and the Demand for Environmental Goods", *Environmental and Resource Economics*, **47**(3), 407-421.

[11] Carrigan, M. and A. Attalla (2001), "The Myth of the Ethical Consumer - Do Ethics Matter in Purchase Behavior", *Journal of Consumer Marketing,* **18**, 560-577.

[12] Champsaur, P. and J.-C. Rochet (1989), "Multiproduct Duopolists", *Econometrica*, **57**(3), 533-557.

[13] Chen, Y. and M. H. Riordan (2015), "Prices, Profits, and Preference Dependence", *The Journal of Industrial Economics*, **63**(4), 549-568.

[14] Conrad, K. (2005), "Price Competition and Product Differentiation When Consumers Care for the Environment", *Environmental and Resource Economics*, **31**, 1-19.

[15] Deltas, G., Harrington, D. R. and M. Khanna (2013), "Oligopolies with (Somewhat) Environmentally Conscious Consumers: Market Equilibrium and Regulatory Intervention", *Journal of Economics and Management Strategy*, **22**(3), 640-667.

[16] Eriksson, C. (2004), "Can Green Consumerism Replace Environmental Regulation? a Differentiated Products Example", *Resource and Energy Economics*, **26**, 281-293.

[17] García-Gallego, A. and N. Georgantzís (2009), "Market Effects of Changes in Consumers' Social Responsibility", *Journal of Economics and Management Strategy*, **18**, 235-262.

[18] Garella, P. G. and L. Lambertini (2014), "Bidimensional vertical differentiation", *International Journal of Industrial Organization*, **32**(C), 1-10.

[19] Gupta, S. and G. T. Ogden (2009), "To buy or not to buy? A social dilemma perspective on green buying", *Journal of Consumer Marketing*, **26**, 376-391.

[20] Heffner, R., Kurani, K. S. and T. S. Turrentine (2007), "Symbolism in California's Early market for Hybrid Electric Vehicles", *Transportation Research Part D*, **12**(6), 396-413.

[21] Heijnen, P. and A. van der Made (2012), "A Signaling Theory of Consumer Boycotts", *Journal of Environmental Economics and Management*, **63**(3), 404-418.

[22] Jullien, B. (2000), "Participation Constraints in Adverse Selection Models", *Journal of Economic Theory*, **93**(1), 1-47.

[23] Kaufman, N. (2014), "Overcoming the barriers to the market performance of green consumer goods", *Resource and Energy Economics*, **36**(2), 487-507.

[24] Kitzmueller, M. and J. Shimshack (2012), "Economic Perspectives on Corporate Social Responsibility", *Journal of Economic Literature*, **50**, 51-84.

[25] Lambertini, L. (2017), "Green Innovation and Market Power", *Annual Review of Resource Economics*, **9**, 231-52.

[26] Lauga, D. and E. Ofek (2011), "Product Positioning in a Two-Dimensional Vertical Differentiation Model: The Role of Quality Costs", *Marketing Science*, **30**(5), 903-923.

[27] Lehmann, E., L. Simula and A. Tannoy (2014), "Tax Me if You Can! Optimal Nonlinear Income Tax Between Competing Governments", *Quarterly Journal of Economics*, **129**(4), 1995-2030.

[28] Lewis, T.R. and D. Sappington (1989), "Countervailing incentives in agency problems", *Journal of Economic Theory*, **49**(2), 294-313.

[29] Lombardini-Riipinen, C. (2005), "Optimal Tax Policy under Environmental Quality Competition", *Environmental and Resource Economics*, **32**, 317-336.

[30] Maggi, G. and A. Rodríguez-Clare (1995), "On Countervailing Incentives", *Journal of Economic Theory*, **66**(1), 238-263.

[31] Mahenc, P. (2008), "Signaling the environmental performance of polluting products to green consumers", *International Journal of Industrial Organization*, **26**, 59-68.

[32] Mantovani A., O. Tarola and C. Vergari (2016), "Hedonic and Environmental Quality: a hybrid model of product differentiation", *Resource and Energy Economics,* **45**, 99-123.

[33] Martimort, D. (1992), "Multi-principaux avec anti-selection", *Annales d'Economie et de Statistique*, **28**, 1-37.

[34] Moraga-González, J. L. and N. Padrón-Fumero (2002), "Environmental Policy in a Green Market", *Environmental and Resource Economics*, **22**, 419–447.

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

[36] Nyborg, K., Howarth R.B. and K.A. Brekke (2006), "Green Consumers and Public Policy: On Socially Contingent Moral Motivation", *Resource and Energy Economics,* **28**, 351-366.

[37] Ostrom, E. (2000), "Collective Action and the Evolution of Social Norms", *The Journal of Economic Perspectives*, **14**(3), 137-158.

[38] Porter, M.E. and C. van der Linde (1995), "Toward a new conception of the environment-competitiveness", *Journal of Economic Perspectives* **9**(4), 97-118.

[39] Rochet, J.-C. and L.A. Stole (2002), "Nonlinear Pricing with Random Participation", *Review of Economic Studies*, **69**, 277-311.

[40] Rosen, S. (1974), "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition", *Journal of Political Economy*, **82**(1), 34-55.

[41] Sartzetakis, E. S., A. Xepapadeas, and E. Petrakis (2012), "The role of information provision as a policy instrument to supplement environmental taxes", *Environmental and Resource Economics*, **52**(3), 347-368.

[42] Stole L.A. (1992), "Mechanism Design Under Common Agency", mimeo, University of Chicago.

[43] Stole L.A. (1995), "Nonlinear pricing and oligopoly", *Journal of Economics & Management Strategy*, **4**, 529-562.

[44] van der Made, A. and L. Schoonbeek (2009), "Entry Facilitation by Environmental Groups", *Environmental and Resource Economics*, **43**(4), 457-472.

[45] Vandenbosch, M.B. and C. B. Weinberg (1995), "Product and Price Competition in a Two-Dimensional Vertical Differentiation Model", *Marketing Science*, **14**(2), 224-249.

[46] Weatherell, C., Tregear, A. and J. Allinson (2003), "In Search of the Concerned Consumer: UK Public Perceptions of Food, Farming and Buying Local", *Journal of Rural Studies,* **19**, 233-244.