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Vera Danilina

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Polarisation of Eco-Labelling Strategies*

Vera Danilina[†]

Aix-Marseille Univ., CNRS, EHESS, Centrale Marseille, AMSE

Abstract

This research investigates two main types of voluntary eco-labels - multiple-criteria-based programmes (ISO Type I) and self-declared environmental claims (ISO Type II) - both of which are simultaneously introduced due to the environmental concerns of consumers. The model illustrates the polarisation of eco-labels when the least productive firms tend to avoid green strategies, and the most efficient firms are incentivized to greenwash. The choice of middle-productive firms is determined by the stringency of the environmental programmes and the eco-sensitivity of consumer demand. The paper also indicates the increase of promotion activity and the decrease of application and licence fees of the Type I programme as the most efficient policy tools to narrow greenwashing market segments.

Keywords: eco-labelling, firm heterogeneity, environmental policy, greenwashing.

JEL code: Q58 - Government Policy.

1 Introduction

Environmental labels are one of the most widely applied voluntary policy instruments. They can be introduced by different economic agents - firms, non-governmental organisations (NGOs), industry and trade associations, government - at their own discretion to distinguish particular products or technologies as environmentally-friendly. Eco-labels are supposed to push the producer beyond

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[†]PhD candidate, vera.danilina@univ-amu.fr

the official regulation threshold strengthening the reputation and widening the market niche. The diversity and flexibility of this type of regulation led to its rapid dissemination: Gruère (2013) reports a fivefold increase in the number of environmental labelling and information schemes from 1970 to 2012.

Eco-labelling strategies can be introduced in a wide range of industries. Thus, the first nation-wide label the *Blue Angel* provides 125 basic award criteria for a wide range of goods from toys and computers to car sharing and clean services[1]. And the first multinational label the *Nordic Ecolabel* establishes criteria for 63 product groups, covering both goods and services from coffee services and candles to hotels, restaurants, and conference facilities[2]. The global directory *Eco-label Index* contains 465 eco-labels grouped in 25 industry sectors with the widest representation of labelling products in the categories Food (148 labels), Building products (120 labels), and Textiles (108 labels)[3].

Eco-labels development raises issues about their possible economic outcomes. This paper aims to discover the productivity effects of voluntary environmental labelling in autarky. The framework is based on the three key elements: (1) heterogeneity across producers; (2) heterogeneity across eco-labels; and (3) one source of eco-concerns. (1) The heterogeneity of producers relies on the difference in their productivity *à la* Melitz (2003). (2) The model investigates two types of eco-labels, multiple-criteria-based third-party programmes (ISO Type I), and self-declared environmental claims (self-declarations, ISO Type II), simultaneously existing in the market and voluntarily chosen by producers. (3) Generally, producers can be encouraged to introduce green programmes by the government, their business partners, the staff, or/and consumers. The present model relies on the environmental bias in consumers' preferences as the only incentive for firms to implement eco-labels while other economic agents remain eco-indifferent.

Consumers environmental preferences are based on the country-specific level of *eco-concerns* that disclose the interactions between environment and society and corresponding changes in consumer behaviour.[4] Particularly, the model introduces

[1] Retrieved from https://www.blauer-engel.de 07.10.2017.

[2] Retrieved from http://www.nordic-ecolabel.org/ 07.10.2017.

[3] Retrieved from http://www.ecolabelindex.com/ 07.10.2017.

[4] The studies of these patterns form the core of environmental sociology, a relatively new research domain that emerged in the 1970s (Catton Jr. and Dunlap, 1978).

eco-quality as an environmental characteristic of any product variety that is defined by eco-concerns and the promotion activity of label stakeholders. Conditional to the type of eco-label, eco-quality acts as an external or an internal stimulus shifting producers' influence to consumers' purchasing decisions.

The eco-indifference of the government implies the lack of public monitoring of the quality of environmental regulation. This leaves room for *greenwashing*, or eco-cheating strategy of firms shaped in the model by ISO Type II standards. The only control within the present model is provided by NGOs who act as stakeholders of ISO Type I standards.

The model delivers three major results. First, it shows the polarisation of eco-labels when the least productive firms avoid green labelling, lower-middle and the most productive firms tend to greenwash (or introduce *internal labels*), and the upper-middle productive firms opt for the green products of verified quality (*external labels*). Thus, the lack of public monitoring increases the attractiveness of false environmental labels for producers from different productivity segments. Meanwhile, conditional to the particular characteristics of external labels and eco-bias on consumer preferences, firms can avoid eco-labelling. The only exception is the most productive producers who are motivated to greenwash even when environmental concerns in the society are relatively modest.

The second major result discloses the impact of eco-concerns in the market. The increase in green bias preferences yields tougher market competition forcing the least productive firms to leave the industry and the more productive to introduce eco-friendly programmes. Meanwhile, the labelled (green) segment faces efficiency decline.

The third result indicates the type of environmental policy that can be used to narrow the greenwashing market segments. Particularly, the proposed framework considers the increase in promotion activity and the decrease of application and licence fees of the external labelling programme as the most efficient policy strategy.

The focus of the research links the present paper to the two main strands of studies. First, to the numerous literature on voluntary environmental programmes, particularly, on the role of NGO and firm-level eco-labelling. A recent comprehensive review of the theoretical research on labels is provided by Bonroy and Constantatos (2014). Second, to the growing but still relatively scarce studies aiming to investigate the trade and environment issues from the perspective of Melitz's heterogeneous firms approach (Melitz, 2003). Cherniwchan et al. (2016) provide a comprehensive overview of the relevant studies, both theoretical and empirical. Among other research questions, these studies are focused on exploring the relationship between productivity, the green behaviour of producers, and the corresponding welfare and environmental effects[5]. This paper contributes to the literature by focusing on the impact of consumers' eco-concerns on the environmental choices made by firms in a framework that mirrors the current structure of voluntary environmental regulation. To the best of my knowledge, it is the first attempt to design the model that captures two types of environmental labelling, in order to investigate the market sorting and market efficiency patterns.[6]

The rest of the paper is organised as follows. Section 2 describes the development of eco-labelling. Section 3 introduces the eco-quality concept and corresponding types of eco-labels. Section 4 outlines the model. Section 5 focuses on the results of comparative statics. Section 6 presents the numerical example. Section 7 proposes policy implications. And Section 8 concludes.

2 Eco-Labelling

Product labelling can be defined "*as any policy instrument of a government or other third party that somehow regulates the presentation of product-specific information to consumers*" (Teisl and Roe, 1998). Accordingly, eco-labelling indicates any type of environmental "*cradle-to-grave*" impact of products.

Whereas the labelling itself is not a new phenomenon[7], eco-labelling is a part

[5]See Batrakova and Davies (2012), Cui et al. (2012), Kreickemeier and Richter (2014), Rodrigue and Soumonni (2014), Forslid et al. (2015), Scott Holladay (2016).

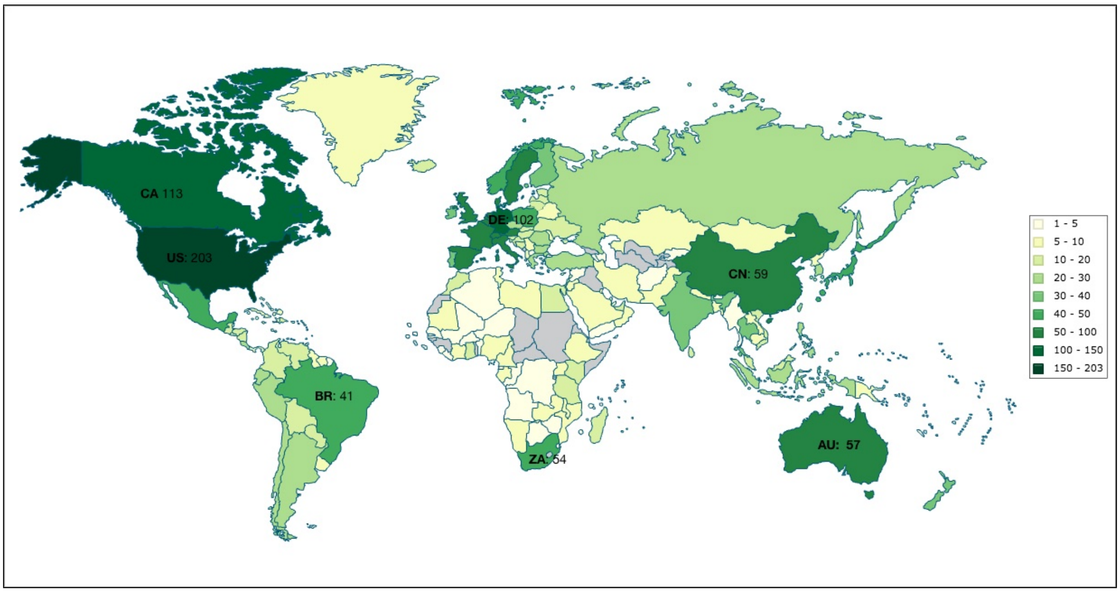
[6]Therefore, this research is also partially related to the eco-labels competition. Meanwhile, I do not introduce any strategical behaviour of a NGO stakeholder. One of the possible approaches touching upon this aspect is represented by Fischer and Lyon (2014) who explore the rivalry between eco-labels developed by a NGO and an industry association. They illustrate a range of possible outcomes conditional on the distribution of abatement costs and consumers' willingness to pay.

[7]The first documented initiative of labelling was the White Label Campaign in cotton underwear production implemented in 1898 (Boström and Klintman, 2008).

of the recent trends in the world green development.[8] Wide discussions of this initiative started in the 1970s and 80s on the occasion of the German *Blue Angel (Der Blaue Engel)* label[9] implementation and the activity of the International Federation of Organic Agriculture Movements (IFOAM)[10] (Boström and Klintman, 2008). The first multinational eco-label the *Nordic Ecolabel (Nordic Swan)* was established in 1989 in Norway.

Figure 1: *Distribution of Eco-Labels: World*

(number of eco-labels available in the market)



Source: Ecolabelindex http://www.ecolabelindex.com/ 13.08.2016.

In 2016 the Ecolabel Index, a global directory of eco-labelling, contained 465 eco-labels represented in 199 countries and 25 industry sectors[11]. Eco-labelling

[8] In some sectors eco-labelling initiatives started relatively early. In Germany, Italy, and France eco-labels were introduced in the food industry in the 1920s (Basu et al., 2007).

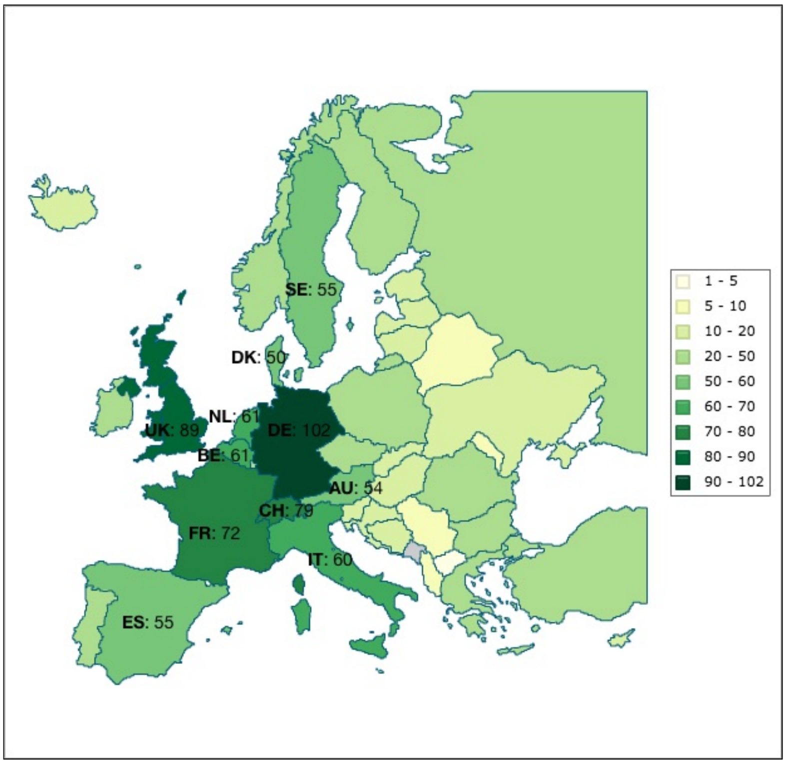
[9] The *Blue Angel* label was implemented in Germany in 1978 as the first fully developed nationwide eco-labelling scheme in the world.

[10] International Federation of Organic Agriculture Movements (IFOAM) was established in 1972 on the initiative of French farmer organisation *Nature et Progrès* with the support of different institutions from the UK, the USA, Sweden, and South Africa. It is an international umbrella organization that helps to facilitate any organic initiatives all over the world.

[11] Gruère (2013) and Gruère (2015) provide a comprehensive overview of environmental labelling and information schemes worldwide - its development and classification approaches.

Figure 2: *Distribution of Eco-Labels: Europe*

(number of eco-labels available in the market)



Source: Ecolabelindex http://www.ecolabelindex.com/ 13.08.2016.

programmes are unevenly distributed in the world, with the largest concentration in North America (with the leadership of the USA - 203 eco-labels) and Europe (the leaders are Germany - 102 eco-labels, the UK - 89 eco-labels, Switzerland - 79 eco-labels, and France - 72 eco-labels) (see Figures 1 and 2)[12]. The most significant ecolabelling systems serve from 5% to 20% of the market (Amacher et al., 2004).

The significance of eco-labelling is non-negligible in light of the *credence* goods concept (Darby and Karni, 1973) which applies to products in a relationship with their environmental footprint. Green quality of a particular variety cannot be verified by consumers on the basis of their experience or knowledge forcing them to rely on additional information. Accordingly, eco-labels are often a subject of

[12]The data was retrieved from http://www.ecolabelindex.com/ on 13.08.2016.

wide informational campaigns (Comas Martí and Seifert, 2012). These campaigns aim to overcome the information overload and to fill the *attitude-behaviour gap* caused by a lack of clear patterns for consumers to translate their eco-concerns into eco-friendly activities (Young et al., 2010).

Empirical evidence of eco-labelling as a factor influencing consumer choice has been steadily growing. At the same time, the majority of these studies deals with stated rather than with revealed preferences. In other words, most of the studies are focused on a hypothetical consumer willingness to choose environmentally-friendly varieties rather than on their actual behaviour. Empirical evidence of stated eco-preferences is provided, for example, by Teisl et al. (1999), Imkamp (2000), Johnston et al. (2001), Roe et al. (2001), Moon et al. (2002), Gadema and Oglethorpe (2011), Echeverría et al. (2014). In general, they report the existence of potential green bias in consumption.

Relatively scarce is the analysis of *revealed* eco-preferences. Investigations of this type illustrate the actual choice of consumers. Table 1 summarises the results of the selected empirical studies estimating the revealed eco-preferences. In general, they also show the existence of green bias in consumer purchases which varies conditionally on the type of goods, the significance of the label, and/or the size of the price premium. For example, studying the impact of one of the most developed European eco-labels, the *Nordic Ecolabel*, Bjørner et al. (2004) report that consumers pay a 13%-18% premia for the certified varieties.

The existing empirical evidence shows the significance of eco-labelling for consumers' purchasing decisions. At the same time these studies do not explore the roots of green-biased preferences and related eco-concerns as well as the reasons for their possible variation. This research question belongs in the range of issues studied in environmental sociology, a relatively recent research domain emerged in the 1970s (Catton Jr. and Dunlap, 1978). Accordingly to the recent findings, consumers' eco-concerns can be individual- or country-specific and determined by the stage of the social development, national and/or individual wealth, quality of environment, population density, age, gender, education, and other sociodemographic characteristics[13]. For the purpose of the current research I follow a country-specific

[13]Franzen and Meyer (2010) provide a comprehensive overview of the main hypotheses. For the analysis of particular influential factors see, for example, Dunlap and Van Liere (1978), Van Liere

hypothesis assuming consumers to be eco-homogeneous within the country.

Table 1: *Selected Empirical Evidence of Revealed Eco-Preferences*

Study	*Country*	*Products/Label*	*Period*	*N. of obs.*	*Results*
Henion (1972)	USA	detergent/ experimental*	1970	n/a	+
Nimon and Beghin (1999)	USA	apparel / organic	1996	794	+/-**
Teisl et al. (2002)	USA	canned tuna/ dolphin-safe	1988-95	2 mln.	+
Bjørner et al. (2004)	Denmark	toilet paper, paper towels, detergents/ Nordic Swan	1997-2001	1,596	+
Vanclay et al. (2011)	Australia	food/ experimental*	2008	2,890	+
Hallstein and Villas-Boas (2013)	USA	fish/ experimental*	2006	3,942	+/-***
Elofsson et al. (2016)	Sweden	milk/ experimental*	2013	4,13 mln.	+

* specially invented for a field experiment

** price premium for organic cotton, no premium for the environmentally friendly dyes, and a discount for "no-dyes" varieties

*** statistically significant decline in sales of mid-eco-destructive varieties, no effect for the most and the least eco-destructive varieties.

+ positive green bias in consumer purchases

− no green bias in consumer purchases

3 Eco-Quality Within Different Types of Eco-Labelling

In order to link environmental concerns to green-biased preferences of consumers underpinning eco-labels, I introduce the *eco-quality* concept. For the purpose of this research eco-quality is defined as *a set of pronounced characteristics of any product variety referring to its environmental impact.* Thus, it indicates the

and Dunlap (1980), Inglehart (1995), Diekmann and Franzen (1999), Franzen and Meyer (2010), Meyer (2015).

promoted ecological image of the variety rather than its real environmental impact (*e.g.*, its carbon footprint, related emissions, type of the production technology). At the same time, if the relationship between green technological and promotional activities is determined by the design of environmental regulation, eco-quality also refers to the actual environmental footprint of the production process.

Let's denote eco-quality as $\chi^\omega \geq 0$, a value assigned to each variety ω produced in the economy. In notation I reserve a superscript for a firm/variety and a subscript for a type of the labelling programme. The model defines *eco-quality* $\chi^\omega = \chi(a^\omega, \epsilon)$ as a differentiable strictly concave continuous function increasing in advertising activity of eco-label stakeholders[14] $a \geq 0$ and in the level of environmental concerns (or eco-appreciation level) in the country $\epsilon \geq 0$ such that $\chi(0,\epsilon) = \chi(a,0) = 0$, $\chi^{'}_a > 0$, $\chi^{'}_\epsilon > 0$, $\chi^{''}_{aa} < 0$, $\chi^{''}_{\epsilon\epsilon} < 0$, $\chi^{''}_{a\epsilon} > 0$, $\chi^{''}_{aa}\chi^{''}_{\epsilon\epsilon} - (\chi^{''}_{a\epsilon})^2 > 0$.[15] Accordingly, the model considers a class of functional forms that reflect the hypothesis stating the positive relationship between the promotion effect and the eco-appreciation level. Meanwhile, the elasticity of the eco-quality with respect to advertising $\Xi_a = a\frac{\chi^{\prime}_a(a,\epsilon)}{\chi(a,\epsilon)}$ is assumed to vary such that the efficiency of promotion and the power of eco-concerns decrease with their growth.

Eco-appreciation denoted by ϵ is an external parameter reflecting the country-specific degree of environmental concerns. It captures cross-country differences in environmental problems evaluation: in societies with a higher level of environmental concerns the same signals cause more significant positive shift in preferences. For the purpose of this research let's assume non-zero eco-appreciation level ($\epsilon > 0$) to motivate the introduction of eco-labels.

Eco-quality is independent of the size of technological efforts made by firms because of *credence* nature of the majority of goods' environmental characteristics and the assumption of governmental eco-indifference. As far as consumers are not able to distinguish between eco-friendly and eco-destructive varieties without corresponding advertising, the model assumes them to trust the information

[14]The role of an eco-label stakeholder can be played by an institution responsible for a voluntary environmental programme or by a firm who introduces the eco-label.

[15]Thus, the model allows consumer preferences to depend on firm-level promotion investments. Amacher et al. (2004) introduce a similar assumption within the duopoly model of vertical product framework differentiation but they do not make the distinction between fixed and variable components of investments.

they obtain from producers. It also implies zero transaction costs: signals concerning eco-quality of varieties are perfectly diffused in the economy and equally appreciated by all consumers.

Types of Voluntary Environmental Labelling

The general classification of environmental labelling is based on the ISO approach that defines three major types of eco-labels. *Type I* is environmental labelling defined as "*voluntary, multiple-criteria-based third party programme that awards a licence which authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations*" (ISO 14024: 1999). *Type II* are eco-labels related to the self-declared environmental claims defined as "*statement, symbol or graphic that indicates an environmental aspect of a product, a component or packaging that is made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim*" (ISO 14021: 1999, 2016). And the most recent is the *Type III - environmental declarations* that provide "*quantified environmental data using predetermined parameters and, where relevant, additional environmental information*" (ISO 14025: 2006).

The model allows for the two types of voluntary activities, *external* and *internal* programmes, which correspond to ISO 14024 (Type I) and ISO 14021 (Type II) international standards respectively. The parameters of eco-labelling programmes are summarised in the Table 2. In notation I reserve majuscule letters for the external programme and minuscule letters for the internal programme.

External voluntary environmental labelling (ISO 14024: 1999 Type I) can be supported by any institution, e.g. NGO, industry association, or government. To join an external labelling programme firms need to meet the requirements of the programme: they pay the application fee $\Phi_a > 0$ as additional fixed costs (for the rest of the paper all expenditures that are related to fixed costs contains the letter Φ) and a licence fee as a share of revenues $0 < 1 - R < 1$; they also develop a production process that changes marginal input by a factor of $T > 1$. The latter implies the environmentally-friendly technology to require higher variable production costs for any firms in comparison with the *status quo*. I assume the parameters of the external labelling programme to be constant over the time period of the model. Meanwhile, they can be subject to changes due to NGOs' willingness to adjust the programme according to the market response. This possibility is ruled out from the present model.

The proposed structure of external programme generally mirrors the selected eco-labels, particularly, the Nordic Eco-Label, the Blue Angel, and EU Ecolabel, which use one of the most sophisticated fee structures. They also introduce special criteria for different types of products (the Nordic Eco-Label) or countries (EU Ecolabel). To the best of my knowledge, the majority of existing eco-labelling programmes follow the same fee structure or simplify it.

Members of the programme benefit from the promotion activity of the eco-labelling supporting institution that is much greater than the fixed spending of a firm ($A \gg \Phi_a$). The eco-quality of any labelled variety is represented by the parameter $\chi = \chi(A, \epsilon)$.

Table 2: *Eco-Labelling Parameters*

	technology	application/ licence fees	advertising expenditures	eco-quality
External label ISO 14024 (Type I)	$T > 1$	$\Phi_a > 0$ $0 < 1 - R < 1$	$A \gg \Phi_a$	$\chi(A, \epsilon)$
Internal label ISO 14021 (Type II)	$t^\omega \geq 1$	-	$a^\omega > 0$	$\chi(a^\omega, \epsilon)$

Internal voluntary environmental labelling (ISO 14021:2016 Type II) referring to *self-declarations* is developed individually by firms who make the decision concerning green technological changes that increase the marginal input by $t^\omega \geq 1$ and corresponding promotional activity $a^\omega > 0$. The model considers any green technology to be more costly assuming that any available more efficient technology has been already implemented by any firm. In contrast with external labels, the producer is totally responsible for the advertisement a^ω: if $a^\omega = 0$ consumers are not informed about the green quality of the variety. The eco-quality is represented by $\chi^\omega = \chi(a^\omega, \epsilon)$.

Environmentally-friendly technology and firm productivity. External and internal labelling programmes imply identical green technologies to be less costly to implement by more productive firms. This assumption relies on the empirical findings of negative relationship between productivity and pollution reported by Batrakova and Davies (2012) (data on Ireland), Cole et al. (2008) (data on China), Forslid et al. (2015) (data on Sweden), Cui et al. (2012) and Scott Holladay (2016) (data on the US). Technological restrictions of labelling programmes are related to lower emissions. Due to the assumption that more productive firms pollute less, they are able to comply with the labelling standard environmental restrictions at lower costs.

4 The Model

4.1 General Assumptions

This model extends a framework with heterogeneous firms (Melitz, 2003) by introducing *environmental quality of varieties*, or *eco-quality.* It considers a one-factor economy populated by L consumers. There are two industries that produce an *eco-destructive* (dirty) good D and a clean outside good C.

Preferences capture environmental concerns and represented by a nested Cobb-Douglas-CES utility function with the Cobb-Douglas parameter $0 < \alpha < 1$ and elasticity of substitution between varieties $\sigma > 1$[16]:

$$U = D^\alpha C^{1-\alpha}, \qquad D = \left[\int_{\omega \in \Omega} (\chi^\omega + 1)^{\frac{1}{\sigma}} (q^\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where D and C represent the amount of corresponding goods consumed, Ω is the

[16]The eco-quality parameter is introduced to the utility function in such a way that higher elasticity of substitution devalues promotion: if consumers are more prone to switch from one variety to another, higher promotion expenditures are needed to motivate them to choose green varieties persistently.

measure of varieties of good D available in the market, χ^ω indicates the perceived eco-quality[17] of ω-variety, and q^ω stands for the demand for ω-variety of good D. Solving the consumer maximisation problem s.t. a budget constraint $\sum_{\omega\in\Omega} p^\omega q^\omega = I$, where I stands for consumer income, one can obtain a CES type eco-quality adjusted price index

$$P^{1-\sigma} = \int_{\omega\in\Omega} (\chi^\omega + 1)(p^\omega)^{1-\sigma} d\omega \tag{2}$$

that also accounts for the consumer green goods price perception.

Thus, consumer satisfaction increases with the share of consumed green goods. This assumption is in line with at least two concepts in economics. First, it follows Lancaster (1966) who states that particular attributes of goods but not goods *per se* determine the purchasing decision. Second, it is also related to the *impure altruism* concept introduced by Andreoni (1989) that implies an increase in utility from the act of giving: by buying green varieties consumers contribute to environmental improvement.

The design of the utility function also fits a wide strand of literature on quality.[18] Meanwhile, this research allows the quality parameter to be independent from the productivity of firms but shaped by an external eco-concerns parameter and promotional activity that can be internal or external conditionally on the type of eco-labelling programme.

Industry C is used as a numéraire: it is perfectly competitive and exhibits constant returns to scale. All costs are measured in labour (the only production factor in the economy) that is homogeneous and perfectly mobile across industries. Production in industry C does not cause any negative environmental effects. Industry C can also be considered environmentally-unfriendly. Since it is modelled in a perfect competitive setting where the technology is identical across firms, their output remains constant yielding environmental effect that can be treated as a shifter. Accordingly, it does not influence the final results. Let's normalise wages $w = 1$. Then, by construction, if the output of the industry is positive, $P_C = 1$.

Industry D is modelled according to the approach of Melitz (2003) that is extended by introducing a choice of environmental labelling programme made by each

[17]See Section 3 for the definition of eco-quality.

[18]See, for example, Hallak (2006), Kugler and Verhoogen (2011), Crinò and Epifani (2012), Crozet et al. (2012), Johnson (2012), Hallak and Sivadasan (2013).

firm. Thus, the industry it represented by a continuum set of firms heterogeneous in productivity, each of which produces one variety of good D in monopolistic competition with the same increasing returns to scale technology such that each firm faces fixed overhead costs $\Phi > 0$. They pay fixed (sunk) costs $\Phi_e > 0$ to enter the market. Upon entry, firms draw their productivity φ from a non-degenerate distribution $G(\varphi)$ and then make two consecutive decisions, to stay or leave the market immediately, and to choose any type of environmental labelling programme or remain brown.

4.2 Environmental Segments

Accordingly, there are three possible market segments: a *brown segment* formed by firms preserving the initial technology, a *green external segment* formed by firms complying the rules of the external labelling programme, and a *green internal segment* formed by firms designing their own internal labelling programme. I assume that only green firms implement promotion programmes to influence consumer choice.

Brown segment. Any firm ω opting for a *brown* strategy in autarky faces the demand $q_B(p^\omega_B) = \alpha L P^{\sigma-1}(p^\omega_B)^{-\sigma}$, where P represents a CES price index of all varieties available in the market (2), and sets the price $p^\omega_B = \frac{\sigma}{\sigma-1}(\varphi^\omega)^{-1}$ Then the optimal profit is increasing and convex in φ and represented as

$$\pi^*_B(\varphi^\omega) = \Lambda P^{\sigma-1}(\varphi^\omega)^{\sigma-1} - \Phi, \quad \Lambda \triangleq \alpha L(\sigma-1)^{\sigma-1}\sigma^{-\sigma} \tag{3}$$

Green external segment. Any firm ω opting for a *green external* strategy faces the demand $q_E(p^\omega_E) = \alpha L P^{\sigma-1}[\chi(A,\epsilon)+1](p^\omega_E)^{-\sigma}$. Maximising the profit $\pi_E(p^\omega_E) = (Rp^\omega_E - T(\varphi^\omega)^{-1})\, q(p^\omega_E) - \Phi_a - \Phi$, they set the optimal price $p^\omega_E = \frac{\sigma}{\sigma-1}\frac{T}{R}(\varphi^\omega)^{-1}$. Assumptions of the model imply a positive green price premium $\frac{T}{R} > 1$. The optimal profit is increasing and convex in φ and represented as

$$\pi^*_E(\varphi^\omega) = \Lambda P^{\sigma-1}\mathcal{E}(\varphi^\omega)^{\sigma-1} - \Phi_a - \Phi, \quad \mathcal{E} \triangleq R^\sigma T^{1-\sigma}[\chi(A,\epsilon)+1] \tag{4}$$

Green internal segment. The demand for goods labelled with self-declarations is represented by $q_I(p_I^\omega) = \alpha L P^{\sigma-1}[\chi(a^\omega, \epsilon) + 1](p_I^\omega)^{-\sigma}$. Firms make the decision on price p_I^ω, technological t^ω and promotional a^ω activities maximising the profits $\pi_I(p_I^\omega, a^\omega, t^\omega) = (p_I^\omega - t^\omega(\varphi^\omega)^{-1})\, q_I(p_I^\omega) - a^\omega - \Phi$ s.t. $t^\omega \geq 1$, $a^\omega > 0$, that is concave due the assumption of the eco-quality function concavity. Accordingly, green internal firms set the optimal price $p_I^\omega = \frac{\sigma}{\sigma-1}(\varphi^\omega)^{-1}$ and make no additional technological changes $t^\omega = 1$ that can be related to the *greenwashing* phenomena as a result of the lack of public monitoring assumption.[19]

Green internal firms set the promotion activity according to

$$\Lambda P^{\sigma-1}\chi_a'(a(\varphi^\omega, \epsilon), \epsilon)(\varphi^\omega)^{\sigma-1} = 1,\ a(0, \epsilon) = 0 \tag{5}$$

The equation (5) defines the function $a(\varphi, \epsilon)$ as increasing in $\varphi > 0$ (Appendix A). Thus, more productive firms spend more on advertising.

Optimal profit represented as

$$\pi_I^*(\varphi^\omega) = \Lambda P^{\sigma-1}(\chi(a(\varphi^\omega, \epsilon), \epsilon) + 1)(\varphi^\omega)^{\sigma-1} - a(\varphi^\omega, \epsilon) - \Phi \tag{6}$$

is increasing and convex when

$$\sigma > 1 + \frac{1}{1 - X_a/\mathcal{X}_a}, \tag{7}$$

where $X_a \triangleq \frac{a\chi_a'(a,\varepsilon)}{\chi(a,\varepsilon)+1} \geq 0$ and $\mathcal{X}_a \triangleq \frac{a\chi_{aa}''(a,\varepsilon)}{\chi_a'(a,\varepsilon)} \leq 0$ denote the elasticity and the elasticity of the slope of the eco-quality shifter respectively (see Appendix B for the details). The condition (7) is in line with the empirical findings generally estimating the elasticity of substitution $\sigma > 2$ (see, for example, Disdier and Head (2008), Head and Mayer (2014)). If the inequality (7) does not hold (*i.e.*, the elasticity of substitution is low), internal eco-labelling programmes are inefficient to influence the consumer choice.

4.3 Environmental Market Segmentation

The relative parameters of eco-labels determine the environmental structure of the market. The current framework is able to generate all possible segmentations but,

[19] At the same time, the firms who choose green internal segment can already produce with environmentally-friendly technologies and do not need to make additional changes to the production process. Therefore, they opt for the internal labelling strategy to inform consumers properly.

following the observations of existing markets, I consider only the environmentally-mixed cases with at least two different non-empty environmental segments one of which is brown.

Proposition 1. *If a brown segment exists, it is served by the least productive firms.*

Due to $\frac{\partial[\pi_B^*(\varphi)-\pi_I^*(\varphi)]}{\partial\varphi} < 0$ and $\frac{\partial[\pi_B^*(\varphi)-\pi_E^*(\varphi)]}{\partial\varphi} < 0$ (see Appendix C for the details), one can observe the self-selection effect when the least efficient firms remain brown while the more productive firms can introduce eco-label of any type. The existence of brown segment requires the external labelling programme to be costly to implement $1 + \Phi_a/\Phi > \mathcal{E}$, and the internal labelling programme to be ineffective for relatively low productive firms $a(\varphi^\omega, \epsilon)/\Phi > \chi(a(\varphi^\omega, \epsilon), \epsilon)$. Accordingly, I assume that the least productive firms are not big enough to run a sufficiently noticeable environmental promotion programme to influence consumer behaviour.

The cutoff brown productivity that coincides with the cutoff productivity for the market in general is determined by the zero profit condition

$$\pi_B^*(\varphi_B^*) = 0 \tag{8}$$

Proposition 2. *The most productive firms always choose internal labelling programmes.*

The proposition is due to $\frac{\partial[\pi_I^*(\varphi)-\pi_B^*(\varphi)]}{\partial\varphi} > 0$ and $\frac{\partial[\pi_I^*(\varphi)-\pi_E^*(\varphi)]}{\partial\varphi} > 0$ (see Appendix D for the details). It relies on the assumptions that government does not control for the quality of labels and that the most productive and, accordingly, the largest firms are able to introduce more costly promotional programmes than the stakeholders of external labelling programmes ($a(\varphi, \epsilon) > A$).

On the basis of the propositions 1 and 2 three possible market segmentations can be considered, (i) when no firms choose external labelling programme (*Two-Segment Market*, Figure 3), (ii) when middle-productive firms implement external labelling (*Three-Segment Market*, Figure 4), and (iii) when the lower-middle productivity firms introduce internal labels while the upper-middle productive firms join external programmes (*Four-Segment Market*, Figure 5).

Two-Segment Market is represented by brown firms with productivity $\varphi \in [\varphi_B^*, \varphi_I^*]$ and green internal firms with productivity $\varphi \in [\varphi_I^*, \infty)$ (Figure 3). The green internal cutoff productivity is determined by the indifference condition

$$\pi_B^*(\varphi_I^*) = \pi_I^*(\varphi_I^*) \tag{9}$$

Free entry assumption drives *ex-ante* expected profits to the market entry costs:

$$\int_{\varphi_B^*}^{\varphi_I^*} \pi_B^*(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \pi_I^*(\varphi) dG(\varphi) = \Phi_e \tag{10}$$

This type of segmentation holds when the external labelling programme is highly stringent while the promotion activity and/or the consumer response are low $\mathcal{E} \leq 1$. If the external labelling programme is less stringent $1 < \mathcal{E} < 1 + \Phi_a/\Phi$ it is still avoided by firms if internal programme is more profitable than an external one $\forall \varphi^\omega, \pi_I^*(\varphi^\omega) > \pi_E^*(\varphi^\omega)$ that implies $\chi(a(\varphi^\omega, \epsilon), \epsilon) + 1 > \mathcal{E}$. Accordingly, the shift in consumer preferences due to the labelling programme activity should be higher for the internal labelling strategy. Notice that if $\mathcal{E} \geq 1 + \Phi_a/\Phi$, then $\varphi_E^* \leq \varphi_B^*$, and all firms choose a green external labelling strategy.

Three-Segment Market is served by brown firms with productivity $\varphi \in [\varphi_B^*, \varphi_E^*]$, green external firms with productivity $\varphi \in [\varphi_E^*, \varphi_I^*]$, and green internal firms with productivity $\varphi \in [\varphi_I^*, \infty)$ (Figure 4). Green cutoff productivities are determined by two indifference conditions

$$\begin{aligned} \pi_B^*(\varphi_E^*) &= \pi_E^*(\varphi_E^*) \\ \pi_E^*(\varphi_I^*) &= \pi_I^*(\varphi_I^*) \end{aligned} \tag{11}$$

Accordingly, free entry condition implies

$$\int_{\varphi_B^*}^{\varphi_E^*} \pi_B^*(\varphi) dG(\varphi) + \int_{\varphi_E^*}^{\varphi_I^*} \pi_E^*(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \pi_I^*(\varphi) dG(\varphi) = \Phi_e \tag{12}$$

Three-segment market requires the external labelling programme to be relatively less stringent such that $1 < \mathcal{E} < 1 + \Phi_a/\Phi$. The segmentation is also determined by the relative efficiency of external and internal labelling. Thus, the middle productive firms find the switching from the brown strategy to the external strategy more efficient than to the internal. Particularly, it is true for the firm with productivity $\varphi = \varphi_E^*$: $\frac{\mathcal{E}-1}{\Phi_a} > \frac{\chi(a(\varphi_E^*,\epsilon),\epsilon)}{a(\varphi_E^*,\epsilon)}$.

Figure 3: *Two-Segment Market*

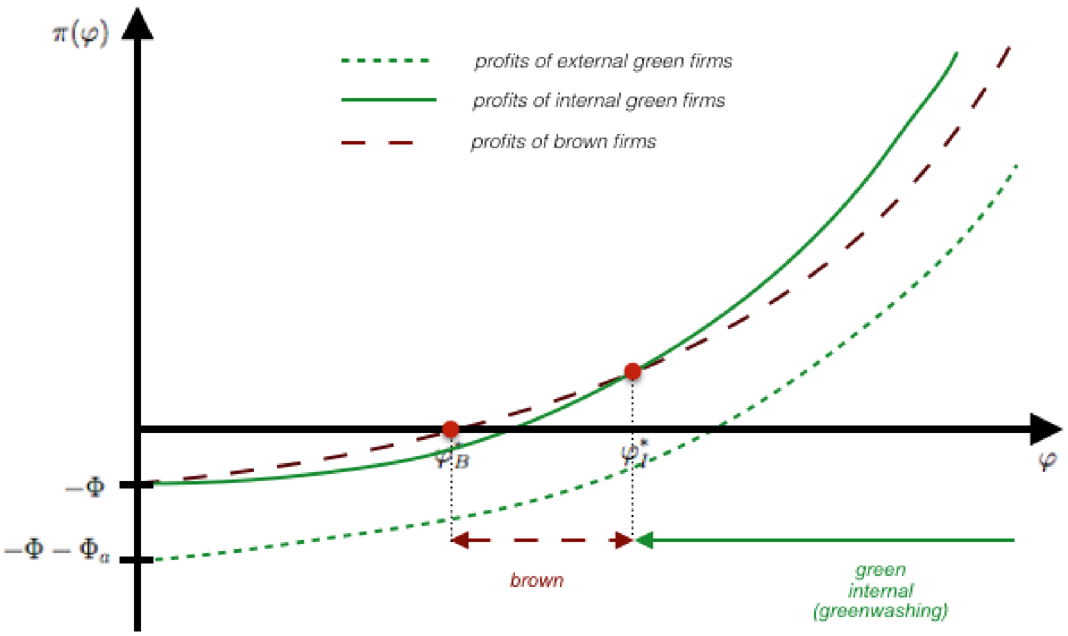
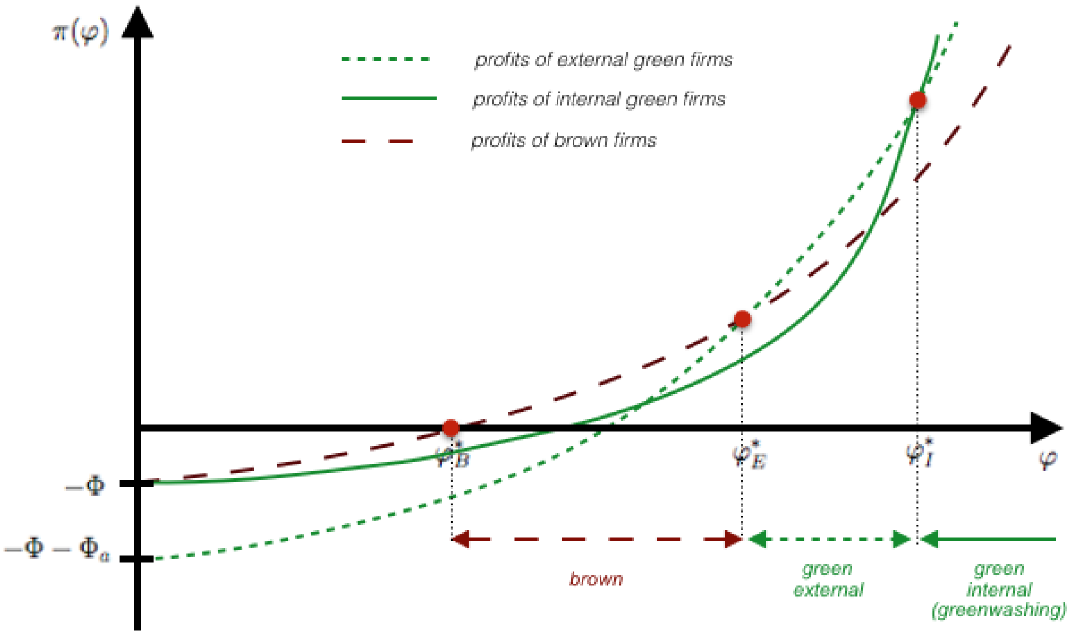


Figure 4: *Three-Segment Market*



Four-Segment Market is represented by brown firms with productivity $\varphi \in [\varphi_B^*, \varphi_\iota^*]$, green internal firms with productivity $\varphi \in [\varphi_\iota^*, \varphi_E^*]$, green external firms with productivity $\varphi \in [\varphi_E^*, \varphi_I^*]$, and green internal firms with productivity $\varphi \in [\varphi_I^*, \infty)$ (Figure 5). Green cutoff productivities are determined by three indifference conditions

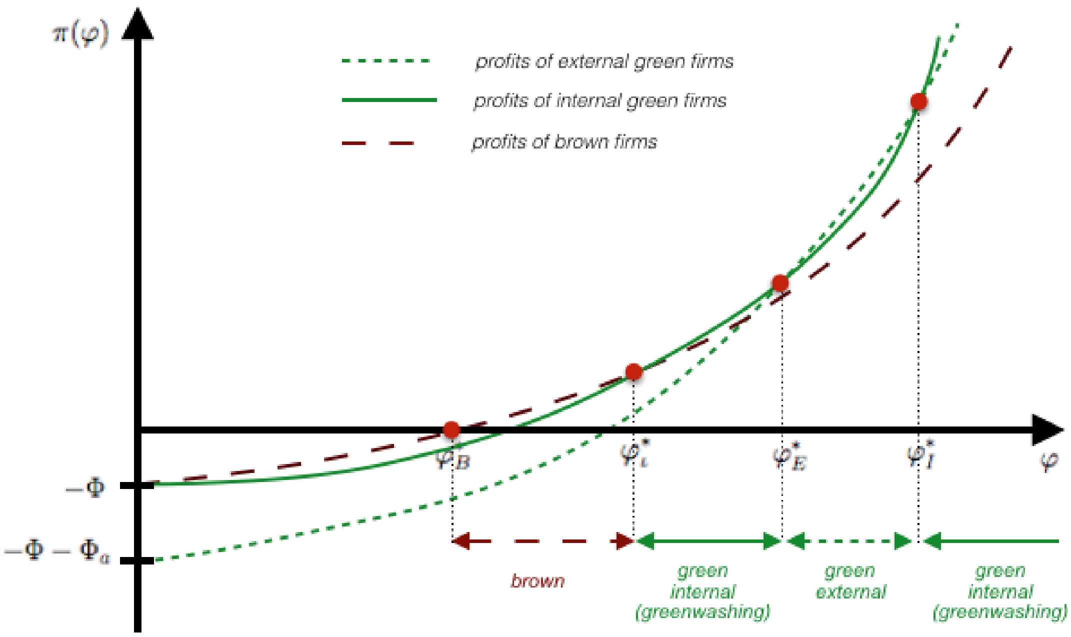
$$\begin{aligned} \pi_B^*(\varphi_\iota^*) &= \pi_I^*(\varphi_\iota^*) \\ \pi_I^*(\varphi_E^*) &= \pi_E^*(\varphi_E^*) \\ \pi_E^*(\varphi_I^*) &= \pi_I^*(\varphi_I^*) \end{aligned} \tag{13}$$

And free entry condition implies

$$\int_{\varphi_B^*}^{\varphi_\iota^*} \pi_B^*(\varphi) dG(\varphi) + \int_{\varphi_\iota^*}^{\varphi_E^*} \pi_I^*(\varphi) dG(\varphi) + \int_{\varphi_E^*}^{\varphi_I^*} \pi_E^*(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \pi_I^*(\varphi) dG(\varphi) = \Phi_e \tag{14}$$

As in the case of the three-segment market, the four-segment market also requires the external labelling programme to be relatively less stringent $1 < \mathcal{E} < 1 + \Phi_a/\Phi$. Switching from brown to internal labelling programme is more efficient for the lower-middle productive firms than from brown to external labelling programme due to the stringency of the external programme. Particularly, it is true for the the firm with productivity $\varphi = \varphi_\iota^*$: $\frac{\chi(a(\varphi_\iota^*,\epsilon),\epsilon)}{a(\varphi_\iota^*,\epsilon)} > \frac{\mathcal{E}-1}{\Phi_a}$. Meanwhile, in this case it is necessary to consider that the impact of even relatively small advertising expenditures ($a(\varphi, \epsilon) < \Phi_a$) can be significant enough to influence consumer behaviour. The strategy of the upper-middle and the most productive firms depends on their productivity relative to the parameters of the labelling programmes and the market. Thus, firms with the lower productivity $\Lambda^{-1} P^{1-\sigma} \frac{\Phi_a - a(\varphi_E^*,\epsilon)}{\mathcal{E}-\chi(a(\varphi_E^*,\epsilon),\epsilon)-1} < \varphi^{\sigma-1} < \Lambda^{-1} P^{1-\sigma} \frac{\Phi_a - a(\varphi_I^*,\epsilon)}{\mathcal{E}-\chi(a(\varphi_I^*,\epsilon),\epsilon)-1}$ opt for the external programme as far as they are productive enough to meet the requirements of the external programme that allows to benefit from its wide promotion campaign. And the most productive and, accordingly, the largest firms with productivity $\varphi^{\sigma-1} > \Lambda^{-1} P^{1-\sigma} \frac{\Phi_a - a(\varphi_I^*,\epsilon)}{\mathcal{E}-\chi(a(\varphi_I^*,\epsilon),\epsilon)-1}$, such that $\chi(a(\varphi, \epsilon), \epsilon) + 1 > \mathcal{E}$, can afford an internal programme.

Figure 5: *Four-Segment Market*



4.4 Equilibrium

I describe the equilibrium for the four-segment market as it accounts for the most sophisticated possible segmentation allowed within the current framework. The cases of two- and three-segment markets are represented in Appendices E and F respectively.

Equilibrium requires the good and the labor markets to be clear over time. For the four-segment market good market clearing implies the zero profit (8), the free entry (14), and the three indifference conditions (13) to hold.

The mass of producing firms (number of varieties of good D available in the market) is defined as

$$\Omega = \Omega_B + \Omega_\iota + \Omega_E + \Omega_I \tag{15}$$

such that

$$\Omega_k = \frac{G(\overline{\varphi}_k^*) - G(\underline{\varphi}_k^*)}{1 - G(\varphi_B^*)}\Omega, \quad k = B, \iota, I, E, \tag{16}$$

where $\underline{\varphi}_k^*$ and $\overline{\varphi}_k^*$ determine the lower and the upper productivity bounds of the segment k respectively.

The total mass of varieties available in the market Ω is determined by the labor market clearing condition. Industry C spends on labor $(1-\alpha)L$ and the dirty industry D, αL. Accordingly,

$$\alpha L = L_B + L_\iota + L_E + L_I + L_e, \tag{17}$$

where

$$\begin{aligned} L_B &= \Omega_B \Phi + \int_{\varphi_B^*}^{\varphi_\iota^*} \varphi^{-1} q_B(\varphi) dG(\varphi) \\ L_\iota = \Omega_\iota \Phi + \int_{\varphi_\iota^*}^{\varphi_E^*} a(\varphi) dG(\varphi) &+ \int_{\varphi_\iota^*}^{\varphi_E^*} \varphi^{-1} q_I(\varphi) dG(\varphi) \\ L_E &= \Omega_E(\Phi + \Phi_a) + T \int_{\varphi_E^*}^{\varphi_I^*} \varphi^{-1} q_E(\varphi) dG(\varphi) \\ L_I = \Omega_I \Phi + \int_{\varphi_I^*}^{\infty} a(\varphi) dG(\varphi) &+ \int_{\varphi_I^*}^{\infty} \varphi^{-1} q_I(\varphi) dG(\varphi), \end{aligned} \tag{18}$$

and L_e denotes the labor required to cover the sunk costs of entering firms such that $L_e = \Phi_e \Omega_e$, where Φ_e represents fixed entrance costs, and Ω_e is a mass of entrants such that $\Omega = (1 - G(\varphi_B^*))\Omega_e$.

5 Comparative Statics

Comparative statics analysis allows to discover productivity effects of eco-concerns and external labelling programme design changes in the neighbourhood of the initial equilibrium. Let's study each of the above mentioned three possible market segmentations discovering the effects on cutoff and average productivities within each segment and for the market in general. The average productivity within the k-segment is represented as a weighted average such that $\widetilde{\varphi_k}^{\sigma-1} = \frac{1}{G(\overline{\varphi}_k) - G(\underline{\varphi}_k)} \int_{\underline{\varphi}_k}^{\overline{\varphi}_k} \varphi^{\sigma-1} dG(\varphi)$, where $\underline{\varphi}_k$ and $\overline{\varphi}_k$ denote the minimum and maximum productivity cutoffs within the k-segment respectively.

In the case of a two-segment market, productivity structure can be targeted only by eco-concerns ϵ changes while within the framework of a three-segment and a four-segment markets the productivity composition can be also influenced by changes in the parameters of the external eco-labelling programme such that

Figure 6: *Productivity Composition in the Two-Segment Market*

(horizontal/ vertical arrows indicate the direction of cutoff/ average productivities' motion occurring with eco-appreciation growth respectively; question marks indicate cases with no clear results)

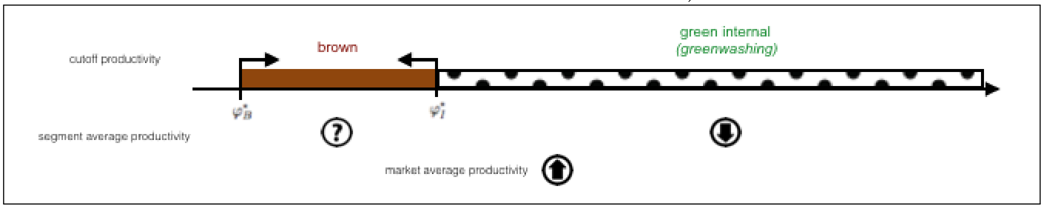
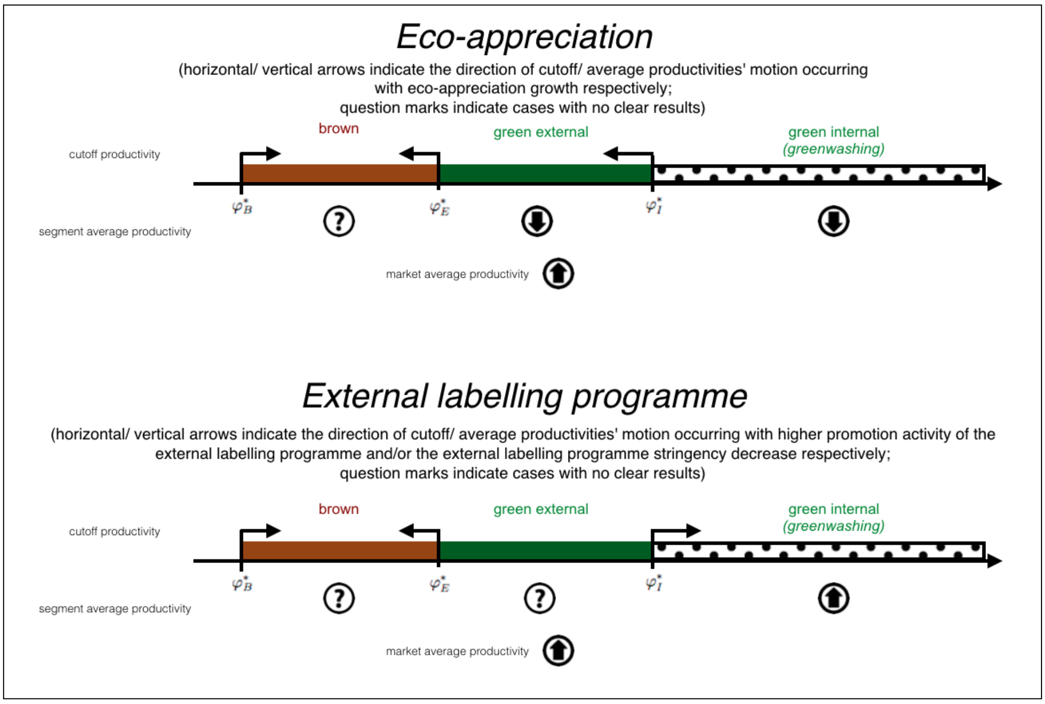


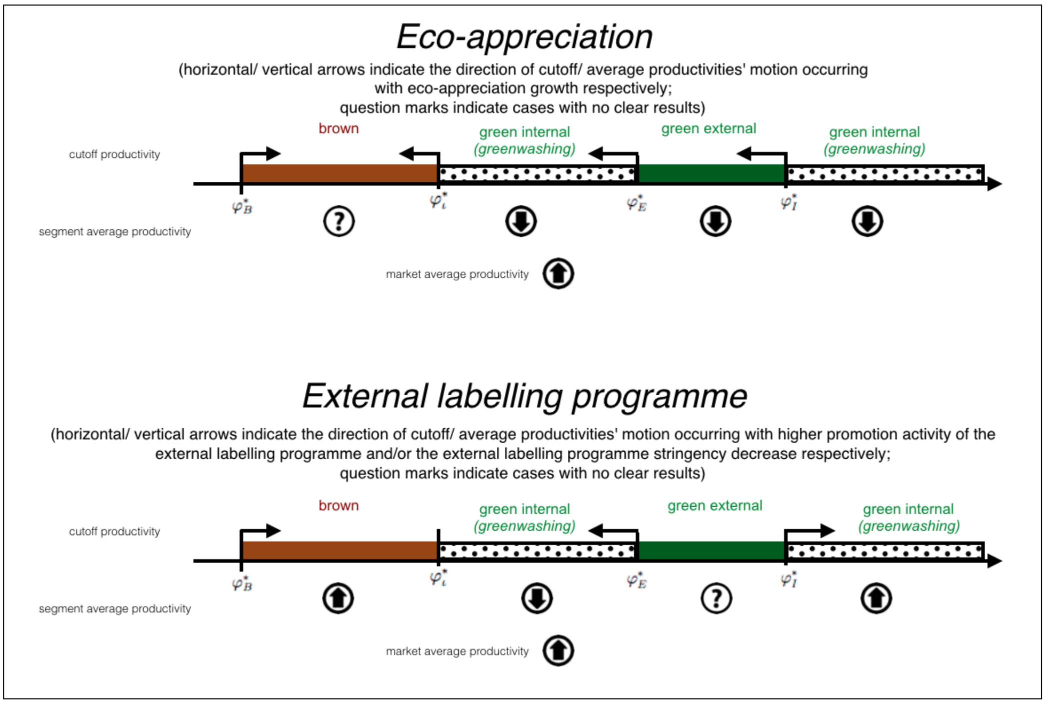
Figure 7: *Productivity Composition in the Three-Segment Market*



advertising activity A, technological requirements T, application Φ_a and licence R fees (see Appendices G, H, and I).

Changes in **eco-appreciation** induce identical effects within all possible market segmentations (Figures 6-8). If the society becomes more concerned about environmental problems, competition gets tougher for brown firms while green firms gain more market power. As a result, the least productive firms leave the market while the most productive brown firms introduce eco-friendly technologies.

Figure 8: *Productivity Composition in the Four-Segment Market*



Accordingly, the effect on the average productivity in the brown segment remains unclear: it depends on the particular form of the eco-quality function and the productivity distribution. Meanwhile, average productivities in all green segments decreases: regardless of the market segmentation eco-concerns growth is more significant for relatively more productive firms inducing them to change the strategy climbing up the "segmentation ladder".

Changes in the parameters of the **external labelling programme** influences the productivity composition in the three- and four-segment markets (Figures 7 and 8). As in case of growing environmental concerns, the market competitiveness increases with the less stringent external labelling programme and/or higher promotion activity of the external label stakeholder benefiting green firms. Analogously, it forces the least productive brown firms to leave the market and increases the overall market productivity. The same changes in the design and the activity of the green external programme makes it more attractive for firms widening the corresponding segment at the expenses of brown and/or green internal segments. While the external programme is represented by a wider range of productivities, the changes in its average segment productivity remains unclear depending on the forms of the eco-quality function and productivity distribution.

The external programme expansion leads to the increase in average and cutoff productivities of the upper green internal segment, meanwhile, the effects within brown and lower-middle green internal segments depend on the particular market segmentation. Thus, in the three-segment market the average productivity in the brown segment can increase or decrease conditionally on the parameters of the eco-quality function and productivity distribution while in the four-segment market brown average productivity increases. This is due to the fact that the green internal productivity cutoff remains unchanged as far as it does not depend on the design of the external labelling programme. And the lower-middle greenwashing sector in the the four-segment market gets less productive on average due to the external green segment expansion.

6 Numerical Example

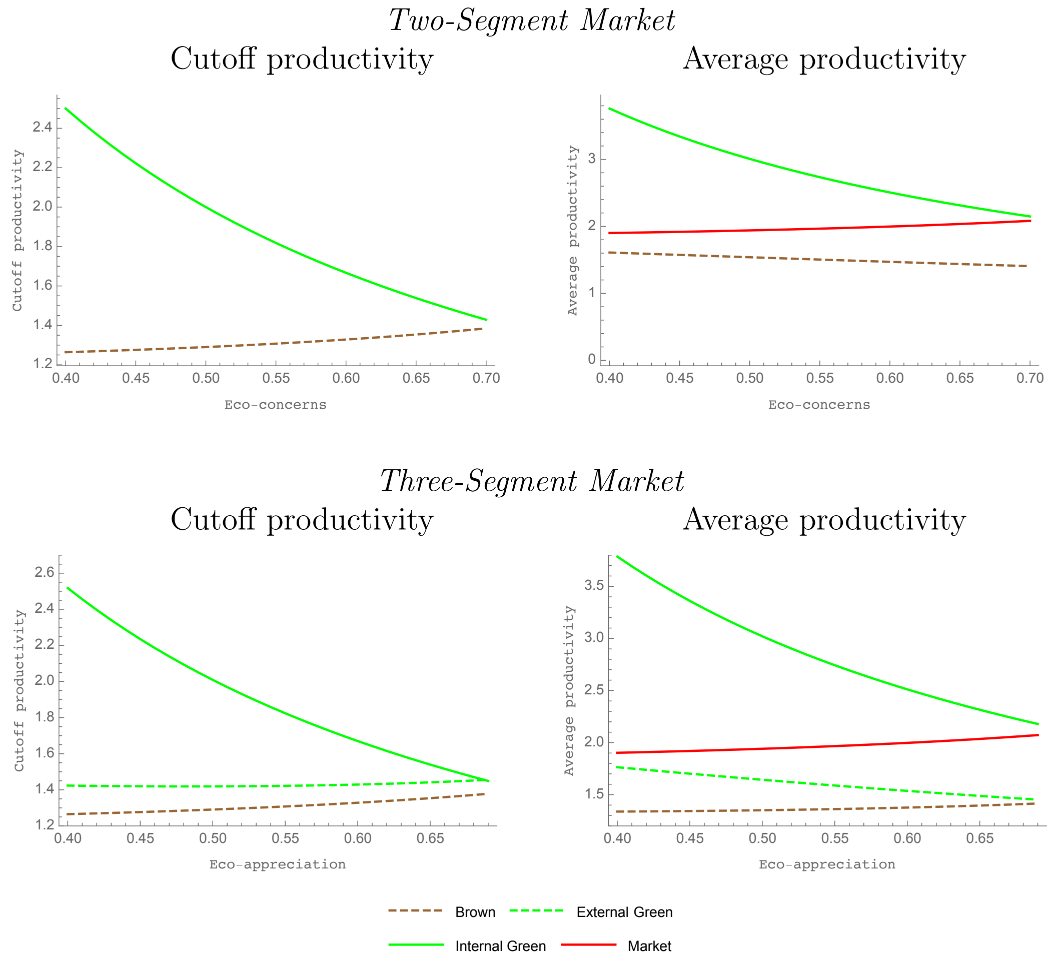
In this subsection I illustrate the theoretical comparative statics with a numerical example for the case of two- and three-segment markets. The four-segment case is ruled out due to the following reasoning. In the market with four segments middle-productive firms with productivity $\varphi \in [\varphi_\iota^*, \varphi_E^*]$ choose green internal labelling when their advertising expenditures are lower than the annual fee of the external programme $a_\iota^* < a_E^* < \Phi_a$. Meanwhile, annual fees are more plausible to assume to be lower than the sufficient level of promotion activity that yields sufficient corresponding consumer response.

To specify the eco-quality $\chi = \chi(a, \epsilon)$ I introduce a function

$$\xi(\varphi, \epsilon) = \frac{\chi(a(\varphi, \epsilon), \epsilon)}{\chi_a'(a(\varphi, \epsilon), \epsilon)} - a(\varphi, \epsilon) \tag{19}$$

that is determined by the properties of the eco-quality function (see Section 3) such that $\xi_\varphi' > 0$, $\xi_\epsilon' > 0$, $\xi_{\varphi\varphi}'' > 0$, $\xi_{\varphi\epsilon}'' \geq 0$ (see Appendix J for the analysis of the function $\xi(\varphi, \epsilon)$ and Appendices K and L for the corresponding sets of conditions determined the productivity composition in the two- and three-segment markets respectively). For the purpose of the numerical illustration I set $\xi(\varphi, \epsilon) \triangleq \varphi^2 - \epsilon^{-2}$.

Figure 9: *Productivity Effects Induced by Eco-Concerns Growth*



Following Melitz and Redding (2015) I assume productivity to be Pareto-distributed with the shape $k = 4.25$ and scale $\varphi_0 = 1$ and set the elasticity of substitution between varieties $\sigma = 4$, fixed overhead costs $\Phi = 1$, and fixed entry costs $\Phi_e = 1$.

Numerical example illustrates the results of the comparative statics analysis showing the productivity changes with eco-concerns growth (Figure 9) and with the external labelling programme stringency decrease (Figure 10). Under the both cases I assume eco-concerns $\epsilon \in [0.4, 0.7]$. In the three-segment case I also set annual fee $\Phi_a = 0.02\Phi$, eco-quality shifter $\mathcal{E} = (1 + 0.01\epsilon)1.01$, and investigate the directions of productivity changes within the ranges $\Phi_a \in [0.015, 0.1]$, $\mathcal{E} \in$

$[1.001, 1.015]$ when $\epsilon = 0.4$. Numerical example is consistent with the results of the comparative statics.

7 Policy Implication

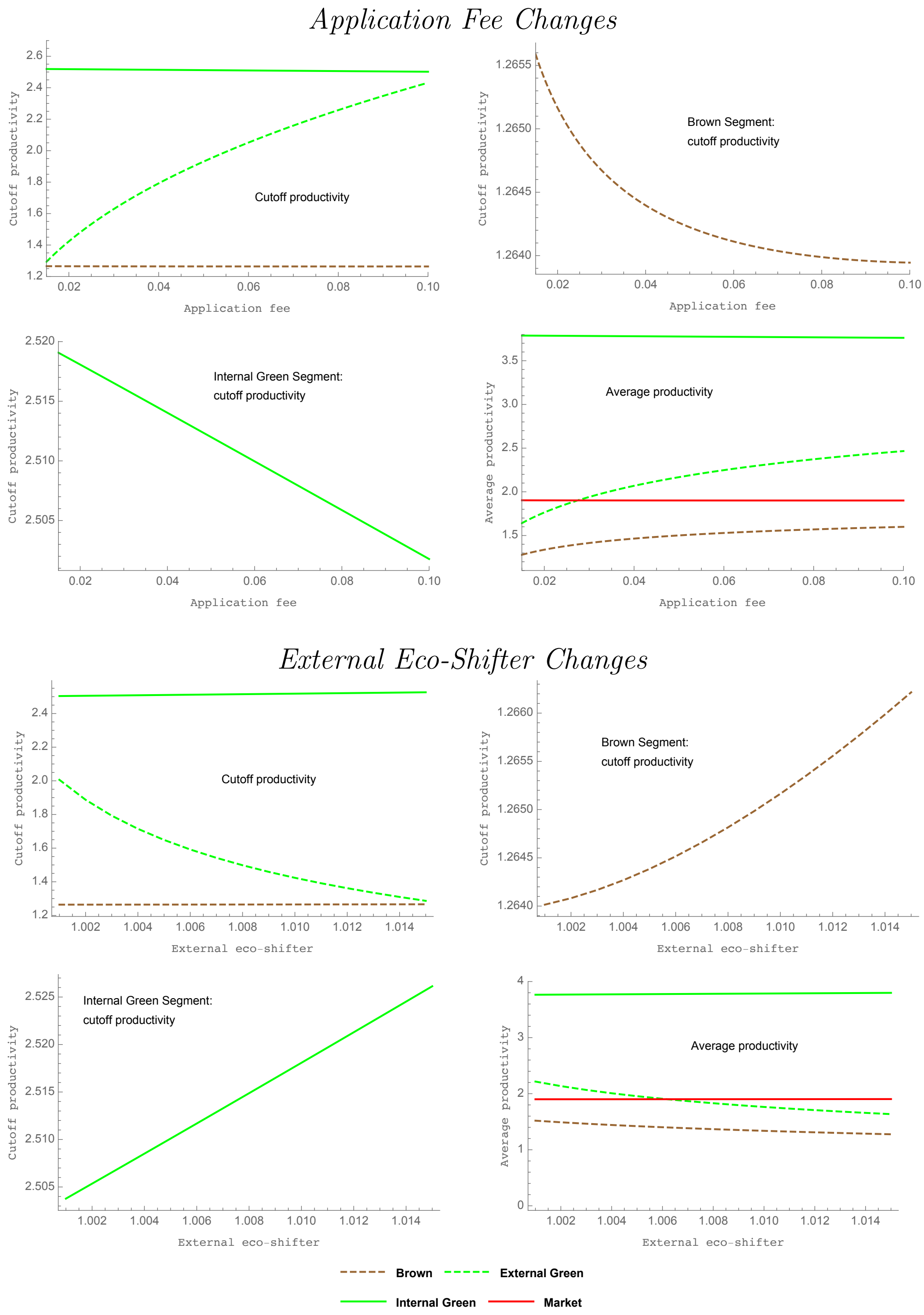
The study considers eco-labelling as an environmental policy tool of current importance to study for several reasons. First, it is widespread and growing steadily. Second, emerging from common society concerns it provides an important channel for the two-way influence: environmentally-biased consumers push firms to "go green" while widely promoted corporate eco-strategies increase the perceived value of green products. Third, eco-labels are differentiated in their forms yielding a range of possible consequences for the markets.

The present research contributes to the analysis of voluntary environmental policies by proposing a framework for the joint investigation of two main types of eco-labels, Type I (ISO 14024) and Type II (ISO 14021), where the latter can correspond to greenwashing in the case of no control for eco-labelling quality. The lack of this monitoring is due to its difficulty coming from the tailored nature of the internal labelling. Programmes of Type II generally serves as technology- and firm-specific while Type I programmes are based on the more general criteria. Accordingly, the direct control of the internal labelling is prohibitively-costly and, moreover, it contradicts the basic principles of the instrument. This research points out the alternative policy channels to influence the market that can be introduced in the environmental policy design.

The government can use two possible channels to influence the market segmentation aiming at narrowing the greenwashing segments, through the eco-appreciation level or the design of the external labelling programme.

First channel targets the general level of eco-concerns in the society forcing the consumers to behave more environmentally-friendly. This type of strategy increases the level of market competition and positively influences the average market as well as the cutoff productivity levels. It also enlarges the green segments of the market. Meanwhile, greenwashing strategies become more attractive to firms as well. Accordingly, the overall effect of this general policy remain unclear depending on the particular parameters of the market.

Figure 10: *Productivity Effects Induced by Changes in External Labelling Restrictions in a Three-Segment Market: promotion activity increase or stringency decrease*



Second channel corresponds to the design of the external labelling programme. By raising its attractiveness for the firms, the government is also able to positively influence the market productivity. At the same time, such policy targets directly the green external segment, forcing firms to choose the external label over the brown or the internal strategy. As a result, the greenwashing segment is getting narrower. The external labelling programme can become more attractive by relaxing its technological requirements, decreasing the fees, or increasing the promotion activity. The last two channels should be considered as dominant as far as the former one corresponds to the less environmentally-friendly technologies that lead to negative ecological impact increase. It also can discredit the overall programme eroding the consumer trust in eco-labelling.

The government can also focus on the reputation risks facing by companies in case of greenwashing as well as potential harm for the careers of managers. Particularly, it can be efficient in the case of leading companies whose losses in case of disclosure can be high enough to prevent them from environmental cheating (Schwarcz, 2017).

8 Conclusion

This research enriches a widely used framework of heterogeneous firms by introducing the eco-quality concept to capture the market effects of eco-labelling. The designed eco-quality parameter is based on producer activity and environmental concerns in the society. It introduces eco-biased consumers preferences which incentivise producers to implement green strategies corresponding to eco-labels.

The model shows that more productive firms tend to self-select for eco-friendly instruments. Accordingly, the least productive firms do not consider environmentally-friendly strategies due to the lack of resources to launch their own programme or join an existing one. However, within the group of green labels the research explores a polarisation of voluntary environmental programmes such that:

- the lower-middle productive firms introduce an internal label (Type II) while they still find it too expensive to join the external label (Type I), even when it is related to a higher promotion effect. In the absence of public monitoring one can expect to find in the market a group of *greenwashing lower-middle productive firms* introducing internal labels;

- the upper-middle segment of the market corresponds to more efficient firms who can afford to join an external label (Type I) that guarantees a subsequent demand shift due to the programme holder's promotional activity. This group tends to produce with truly eco-friendly technologies[20].

- the most efficient and, accordingly, the largest producers prefer internal to external labels forming a *greenwashing leaders* group. In the absence of public control or inefficient regulations, these firms can find it profitable to avoid external labels when they have enough resources to launch a wide promotional programme saving on the corresponding production technology improvement.

Firms choose a type of eco-labelling depending on their parameters and the size of eco-bias in consumer demand. Meanwhile, regardless of the particular design of voluntary regulation and the degree of environmental concerns, the most productive firms always find greenwashing programmes profitable. These findings refer to such anecdotal evidence as, for example, the emission scandals with Exxon-Mobil who funded climate change deniers despite having received evidence of the causality between fossil fuels and climate change[21], or the Volkswagen group who used the software to provide false positive results of diesel engines environmental tests[22].

The considered framework allows for a range of policy recommendations. Thus, it shows that higher eco-concerns or more attractive and/or affordable external labelling programme increase the overall market efficiency. Meanwhile, the increase in promotion of the eco-labelling rather then targeting the general level of eco-concerns in the society is expected to bring better outcomes narrowing the greenwashing segments. The same result can be reached by decreasing the application and licence fees of the Type I labelling programme.

[20] I assume that external labels do not provide greenwashing policies due to the reputation risk.

[21] Goldenberg, Suzanne (2015, July 8) "Exxon knew of climate change in 1981, email says - but it funded deniers for 27 more years", *The Guardian*.

[22] Mathiesen, Karl, and Neslen, Arthur (2015, September 23) "VW scandal caused nearly 1m tonnes of extra pollution, analysis shows", *The Guardian*.

At the same time, the application of the obtained results is limited by a number of shortcomings. First, it considers consumers as the only source of green incentives for producers. However, a recent survey by International Institute Management and Development (IMD) reports that environmental policy, employees and internal management can be even more influential than customers, civil society and NGOs in implementing eco-friendly solutions (Comas Martí and Seifert, 2012). The power of these agents lies beyond the borders of this research.

One more shortcoming of the model addresses the "one firm - one variety" assumption, whereas there is an empirical evidence that in some cases green products represent only a part of a produced varieties range corresponding to a relatively low share of revenues (Comas Martí and Seifert, 2012).

The obtained results are also highly dependent on the behaviour of the average consumer who is often not well-informed about the particular content of each eco-label and may not be able to distinguish between them.[23] Meanwhile, Carlsson et al. (2010) report a sharp increase in the demand for environmentally friendly products over the last 15 years.

Also the model does not allow for the heterogeneous quality of eco-labels originating out with promotional activity. Thus, eco-labels of Type I supported by NGOs might be considered more credible in comparison with self-declarations.

Nevertheless, the developed framework provides a background for subsequent theoretical and empirical research. Particularly, it can be useful to model different types of environmental policies in the presence of eco-labelling. One can also introduce the damage function that takes into account the corresponding improvement of the technological process and the decrease of environmental degradation. Finally, the results of the analysis can be used for empirical studies of particular industries.

[23]For example, Chan and Muran (2009) cite a survey conducted in December 2007 by a USA-based market research group, Leisure Trends, which discovered the fact that around one-third of consumers are unable to verify the green claims of firms. Thus, 10% of consumers just trust them. Moreover, only less than 50% consumers study the real content of eco-labels by doing online research or carefully reading the labels on the packaging.

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Appendices

A Green Internal Advertising Function

The advertising function of a green internal firm $a(\varphi, \epsilon)$ is represented as

$$\Lambda P^{\sigma-1}\chi_a^{'}(a,\epsilon)\varphi^{\sigma-1} = 1 \tag{20}$$

Due to the assumption that firms take the price index as given, the function is increasing in its arguments due to

$$\frac{da}{d\varphi} = (1-\sigma)\frac{\chi_a^{'}(a,\epsilon)}{\varphi\chi_{aa}^{''}(a,\epsilon)} > 0 \tag{21}$$

$$\frac{da}{d\epsilon} = -\frac{\chi_{a\epsilon}^{''}(a,\epsilon)}{\chi_{aa}^{''}(a,\epsilon)} > 0, \tag{22}$$

where $\chi(a,\epsilon) \triangleq \chi(a(\varphi,\epsilon),\epsilon)$.

B Optimal Profit of a Green Internal Firm

Optimal profit of a firm implementing a green internal strategy in autarky is represented as

$$\pi_I^*(\varphi) = \Lambda P^{\sigma-1}(\chi(a,\epsilon)+1)\varphi^{\sigma-1} - a(\varphi,\epsilon) - \Phi \tag{23}$$

Due to the assumption that the eco-quality $\chi(a,\epsilon)$ is increasing and concave in φ, firms do not anticipate the changes in price indexes due to their decisions, the relationship $\Lambda P^{\sigma-1}\chi_a^{'}(a,\epsilon)(\varphi)^{\sigma-1} = 1$, and the envelope theorem the profit function is increasing in φ:

$$\frac{d\pi_I^*(\varphi)}{d\varphi} = \Lambda P^{\sigma-1}(\sigma-1)(\chi(a,\epsilon)+1)(\varphi)^{\sigma-2} > 0 \tag{24}$$

The curvature of the profit function is determined by the sign of the expression

$$\frac{d^2\pi_I^*(\varphi)}{d(\varphi)^2} = \Lambda P^{\sigma-1}(\sigma-1)(\varphi)^{\sigma-3}(\chi(a,\epsilon)+1)\left\{(\sigma-2)-(\sigma-1)\frac{X_a}{\mathcal{X}_a}\right\}, \tag{25}$$

where $X_a \triangleq \frac{a\chi_a'(a,\epsilon)}{\chi(a,\epsilon)+1}$ and $\mathcal{X}_a \triangleq \frac{a\chi_{aa}''(a,\epsilon)}{\chi_a'(a,\epsilon)}$ denote the elasticity of the eco-quality shifter and the elasticity of the slope of the eco-quality shifter respectively. Thus, if

$$\sigma > 1 + \frac{1}{1-\frac{X_a}{\mathcal{X}_a}} \tag{26}$$

the profit function is convex. Accordingly, one can rely on the over-sufficient condition of the profit convexity $\sigma \geq 2$.

The concavity of the function requires $\sigma < 1 + \frac{1}{1-\frac{X_a}{\mathcal{X}_a}}$ that implies $1 < \sigma < 2$. I rule out this case from the analysis due to the following reasoning. Under this assumption, to overcome the demand rigidness related to highly heterogeneous varieties, the deceleration of eco-quality with the promotion growth should be much lower in comparison with the eco-quality changes speed rate to force eco-friendly consumption. Particularly, the eco-quality function should be nearly linearly increasing. That requires consumers to be sharply eco-biased (high ε) to maintain nearly the same high return to green promotion. This outcome is unlikely to be plausible. Accordingly, if the elasticity of substitution is relatively low and identical across green and brown varieties, eco-promotion within internal eco-labelling programmes is inefficient to influence the behaviour of consumers.

C Proof of the Proposition 1

Equations (3) and (6) imply

$$\Delta\pi_{BI}^*(\varphi) \triangleq \pi_B^*(\varphi) - \pi_I^*(\varphi) = -\Lambda P^{\sigma-1}\chi(a(\varphi),\varphi)\varphi^{\sigma-1} + a(\varphi) \tag{27}$$

Then due to (22)

$$\frac{\partial\Delta\pi_{BI}^*(\varphi)}{\partial\varphi} = -\Lambda P^{\sigma-1}\chi(a(\varphi),\varphi)(\sigma-1)\varphi^{\sigma-2} < 0 \tag{28}$$

Accordingly, the least productive firms remain brown, and the more productive firms choose a green internal strategy.

Equations (3) and (4) imply

$$\Delta\pi^*_{BE}(\varphi) \triangleq \pi^*_B(\varphi) - \pi^*_E(\varphi) = (1-\mathcal{E})\Lambda P^{\sigma-1}\varphi^{\sigma-1} + \Phi_a \tag{29}$$

Then

$$\frac{\partial\Delta\pi^*_{BE}(\varphi)}{\partial\varphi} = (1-\mathcal{E})\Lambda P^{\sigma-1}(\sigma-1)\varphi^{\sigma-2} \tag{30}$$

If $\mathcal{E} \leq 1$, no firms find profitable to choose green external strategy. If $\mathcal{E} > 1$, $\frac{\partial\Delta\pi^*_{BE}(\varphi)}{\partial\varphi} < 0$, the least productive firms remain brown, and the the more productive firms choose a green external strategy.

D Proof of the Proposition 2

Equations (6) and (3) imply

$$\Delta\pi^*_{IB}(\varphi) \triangleq \pi^*_I(\varphi) - \pi^*_B(\varphi) = \Lambda P^{\sigma-1}\chi(a,\varphi)\varphi^{\sigma-1} - a(\varphi) \tag{31}$$

Then due to (22)

$$\frac{\partial\Delta\pi^*_{IB}(\varphi)}{\partial\varphi} = \Lambda P^{\sigma-1}\chi(a,\varphi)(\sigma-1)\varphi^{\sigma-2} > 0 \tag{32}$$

Accordingly, the most productive firms prefer a green internal strategy over a brown strategy.

Equations (6) and (4) imply

$$\Delta\pi^*_{IE}(\varphi) \triangleq \pi^*_I(\varphi) - \pi^*_E(\varphi) = (\chi(a,\varphi) + 1 - \mathcal{E})\Lambda P^{\sigma-1}\varphi^{\sigma-1} - a(\varphi) + \Phi_a \tag{33}$$

Then due to (22)

$$\frac{\partial\Delta\pi^*_{IE}(\varphi)}{\partial\varphi} = \Lambda P^{\sigma-1}(\chi(a,\varphi) + 1 - \mathcal{E})(\sigma-1)\varphi^{\sigma-2} \tag{34}$$

Since $a'_\varphi > 0$ (see Appendix A) and $\chi'_a > 0$ by definition, $\chi'_\varphi > 0$ that implies $\frac{\partial\Delta\pi^*_{IE}(\varphi)}{\partial\varphi} > 0$ when φ is sufficiently high. Accordingly, the most productive firms prefer a green internal strategy over a green external strategy.

E Two-Segment Market Equilibrium

Zero profit condition

$$\pi^*_B(\varphi^*_B) = 0 \tag{35}$$

Indifference condition

$$\pi_B^*(\varphi_I^*) = \pi_I^*(\varphi_I^*) \tag{36}$$

Free entry condition

$$\int_{\varphi_B^*}^{\varphi_I^*} \pi_B^*(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \pi_I^*(\varphi) dG(\varphi) = \Phi_e \tag{37}$$

Mass of producing firms

$$\Omega = \Omega_B + \Omega_I \tag{38}$$

Labor market clearing condition

$$\alpha L = L_B + L_I + L_e, \tag{39}$$

where

$$\begin{aligned} L_B &= \Omega_B \Phi + \int_{\varphi_B^*}^{\varphi_I^*} \varphi^{-1} q_B(\varphi) dG(\varphi) \\ L_I &= \Omega_I \Phi + \int_{\varphi_I^*}^{\infty} a(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \varphi^{-1} q_I(\varphi) dG(\varphi), \end{aligned} \tag{40}$$

F Three-Segment Market Equilibrium

Zero profit condition

$$\pi_B^*(\varphi_B^*) = 0 \tag{41}$$

Indifference conditions

$$\pi_B^*(\varphi_E^*) = \pi_E^*(\varphi_E^*) \tag{42}$$

$$\pi_E^*(\varphi_I^*) = \pi_I^*(\varphi_I^*) \tag{43}$$

Free entry condition

$$\int_{\varphi_B^*}^{\varphi_E^*} \pi_B^*(\varphi) dG(\varphi) + \int_{\varphi_E^*}^{\varphi_I^*} \pi_E^*(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \pi_I^*(\varphi) dG(\varphi) = \Phi_e \tag{44}$$

Mass of producing firms

$$\Omega = \Omega_B + \Omega_E + \Omega_I \tag{45}$$

Labor market clearing condition

$$\alpha L = L_B + L_E + L_I + L_e, \tag{46}$$

where

$$
\begin{aligned}
L_B &= \Omega_B \Phi + \int_{\varphi_B^*}^{\varphi_E^*} \varphi^{-1} q_B(\varphi) dG(\varphi) \\
L_E &= \Omega_E(\Phi + \Phi_a) + T \int_{\varphi_E^*}^{\varphi_I^*} \varphi^{-1} q_E(\varphi) dG(\varphi) \\
L_I &= \Omega_I \Phi + \int_{\varphi_I^*}^{\infty} a(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\infty} \varphi^{-1} q_I(\varphi) dG(\varphi),
\end{aligned}
\tag{47}
$$

G Two-Segment Market: productivity composition and comparative statics

Productivity composition in a two-segment market is based on zero profit (35), indifference (36), and free entry (37) conditions, and the green internal segment relationship $\Phi(\varphi_B^*)^{1-\sigma} \chi_a'(a^\omega, \epsilon)(\varphi^\omega)^{\sigma-1} = 1$ that imply:

$$
(\chi_a'(a_I^*, \epsilon))^{-1} = \frac{a(\varphi_I^*, \epsilon)}{\chi(a_I^*, \epsilon)} \tag{48}
$$

$$
\begin{aligned}
&\Phi(\varphi_B^*)^{1-\sigma} \left\{ \int_{\varphi_B^*}^{\varphi_I^*} \varphi^{\sigma-1} dG(\varphi) + \int_{\varphi_I^*}^{\infty} (\chi(a, \epsilon) + 1) \varphi^{\sigma-1} dG(\varphi) \right\} \\
&- \int_{\varphi_I^*}^{\infty} a(\varphi, \epsilon) dG(\varphi) - \Phi(1 - G(\varphi_B^*)) = \Phi_e
\end{aligned}
\tag{49}
$$

Then by the envelope theorem one can obtain

$$
\frac{d\varphi_B^*}{d\epsilon} = \frac{\varphi_B^* \int_{\varphi_I^*}^{\infty} \varphi^{\sigma-1} \chi_\epsilon' dG(\varphi)}{(\sigma - 1) \left\{ \int_{\varphi_B^*}^{\varphi_I^*} \varphi^{\sigma-1} dG(\varphi) + \int_{\varphi_I^*}^{\infty} (\chi(a, \epsilon) + 1) \varphi^{\sigma-1} dG(\varphi) \right\}} > 0 \tag{50}
$$

$$
\frac{d\varphi_I^*}{d\epsilon} = -\frac{\varphi_I^* a_I^* \chi_\epsilon'(a_I^*, \varphi_I^*) \chi_a'(a_I^*, \varphi_I^*)}{(\sigma - 1) \chi^2(a_I^*, \varphi_I^*)} < 0, \tag{51}
$$

where $a_I^* \triangleq a(\varphi_I^*, \epsilon)$, $\chi_\epsilon' \triangleq \frac{\partial \chi(a, \epsilon)}{\partial \epsilon} > 0$.

$$
\begin{aligned}
\frac{d\widetilde{\varphi}_B}{d\epsilon} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma - 1} \left(\frac{1}{G(\varphi_I^*) - G(\varphi_B^*)} \right) \Bigg(& g(\varphi_B^*) \frac{d\varphi_B^*}{d\epsilon} \left\{ \widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} \\
& + g(\varphi_I^*) \frac{d\varphi_I^*}{d\epsilon} \left\{ (\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_B^{\sigma-1} \right\} \Bigg)
\end{aligned}
\tag{52}
$$

$$\frac{d\widetilde{\varphi}_I}{d\epsilon} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{d\epsilon}\left\{\widetilde{\varphi}_I^{\sigma-1}-(\varphi_I^*)^{\sigma-1}\right\} < 0 \tag{53}$$

$$\frac{d\widetilde{\varphi}}{d\epsilon} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{d\epsilon}\left\{\widetilde{\varphi}^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\} > 0 \tag{54}$$

H Three-Segment Market: productivity composition and comparative statics

Productivity composition in a three-segment market is based on zero profit (41), indifference (42) - (43), and free entry (44) conditions, and the green internal segment relationship $\Phi(\varphi_B^*)^{1-\sigma}\chi_a^{'}(a^\omega,\epsilon)(\varphi^\omega)^{\sigma-1} = 1$ that imply:

$$(\varphi_E^*)^{\sigma-1}\Phi(\mathcal{E}-1) = \Phi_a(\varphi_B^*)^{\sigma-1} \tag{55}$$

$$(\chi_a^{'}(a_I^*,\varepsilon))^{-1} = \frac{\Phi_a - a_I^*}{\mathcal{E}-\chi(a_I^*,\epsilon)-1} \tag{56}$$

$$\Phi(\varphi_B^*)^{1-\sigma}\mathcal{I} - \int_{\varphi_I^*}^{\infty} a(\varphi,\epsilon)dG(\varphi) - \Phi(1-G(\varphi_B^*)) - \Phi_a(G(\varphi_I^*)-G(\varphi_E^*)) = \Phi_e, \tag{57}$$

where $\mathcal{I} \triangleq \left\{\int_{\varphi_B^*}^{\varphi_E^*}\varphi^{\sigma-1}dG(\varphi) + \mathcal{E}\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}dG(\varphi) + \int_{\varphi_I^*}^{\infty}(\chi(a,\epsilon)+1)\varphi^{\sigma-1}dG(\varphi)\right\}$, $\Phi_a < a_I^*$, $\mathcal{E} < \chi(a_I^*,\epsilon)+1$. Then by the envelope theorem one can obtain

- Eco-concerns ϵ

$$\frac{d\varphi_B^*}{d\epsilon} = \frac{\varphi_B^*\left(\mathcal{E}_\epsilon'\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}dG(\varphi) + \int_{\varphi_I^*}^{\infty}\chi_\epsilon'\varphi^{\sigma-1}dG(\varphi)\right)}{(\sigma-1)\mathcal{I}} > 0 \tag{58}$$

$$\frac{d\varphi_E^*}{d\epsilon} = -\frac{\varphi_E^*\left(\mathcal{E}_\epsilon'\int_{\varphi_B^*}^{\infty}\varphi^{\sigma-1}dG(\varphi) + \int_{\varphi_I^*}^{\infty}\left[\chi(a,\epsilon)\mathcal{E}_\epsilon' - (\mathcal{E}-1)\chi_\epsilon'(a,\epsilon)\right]dG(\varphi)\right)}{\Phi\mathcal{I}(\sigma-1)(\mathcal{E}-1)^2} < 0 \tag{59}$$

$$\frac{d\varphi_I^*}{d\epsilon} = -\frac{\varphi_I^*(\mathcal{E}_\epsilon' - \chi_\epsilon'(a_I^*,\epsilon))}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)} < 0 \tag{60}$$

$$\frac{d\widetilde{\varphi}_B}{d\epsilon} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*)-G(\varphi_B^*)}\right)\left(g(\varphi_B^*)\frac{d\varphi_B^*}{d\epsilon}\left\{\widetilde{\varphi}_B^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\}\right.$$
$$\left.+\,g(\varphi_E^*)\frac{d\varphi_E^*}{d\epsilon}\left\{(\varphi_E^*)^{\sigma-1}-\widetilde{\varphi}_B^{\sigma-1}\right\}\right) \tag{61}$$

$$\frac{d\widetilde{\varphi}_E}{d\epsilon} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*)-G(\varphi_E^*)}\right)\left(g(\varphi_E^*)\frac{d\varphi_E^*}{d\epsilon}\left\{\widetilde{\varphi}_E^{\sigma-1}-(\varphi_E^*)^{\sigma-1}\right\}\right.$$
$$\left.+\,g(\varphi_I^*)\frac{d\varphi_I^*}{d\epsilon}\left\{(\varphi_I^*)^{\sigma-1}-\widetilde{\varphi}_E^{\sigma-1}\right\}\right) \tag{62}$$
$$< 0$$

$$\frac{d\widetilde{\varphi}_I}{d\epsilon} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{d\epsilon}\left\{\widetilde{\varphi}_I^{\sigma-1}-(\varphi_I^*)^{\sigma-1}\right\} < 0 \tag{63}$$

$$\frac{d\widetilde{\varphi}}{d\epsilon} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{d\epsilon}\left\{\widetilde{\varphi}^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\} > 0, \tag{64}$$

where $\mathcal{E}'_\epsilon = \frac{\partial\chi(A,\epsilon)}{\partial\epsilon}R^\sigma T^{1-\sigma} > 0$.

- Advertising activity of the external labelling programme A

$$\frac{d\varphi_B^*}{dA} = \frac{\varphi_B^*\mathcal{E}'_A\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}G(\varphi)}{(\sigma-1)\mathcal{I}} > 0 \tag{65}$$

$$\frac{d\varphi_E^*}{dA} = -\frac{\varphi_E^*\mathcal{E}'_A\left(\int_{\varphi_B^*}^{\infty}\varphi^{\sigma-1}dG(\varphi)+\int_{\varphi_I^*}^{\infty}\chi(a,\varphi)\varphi^{\sigma-1}dG(\varphi)\right)}{\mathcal{I}(\sigma-1)(\mathcal{E}-1)} < 0 \tag{66}$$

$$\frac{d\varphi_I^*}{dA} = -\frac{\varphi_I^*\mathcal{E}'_A}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)} > 0 \tag{67}$$

$$\frac{d\widetilde{\varphi}_B}{dA} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*)-G(\varphi_B^*)}\right)\left(g(\varphi_B^*)\frac{d\varphi_B^*}{dA}\left\{\widetilde{\varphi}_B^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\}\right.$$
$$\left.+\,g(\varphi_E^*)\frac{d\varphi_E^*}{dA}\left\{(\varphi_E^*)^{\sigma-1}-\widetilde{\varphi}_B^{\sigma-1}\right\}\right) \tag{68}$$

$$\frac{d\widetilde{\varphi}_E}{dA} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*)-G(\varphi_E^*)}\right)\left(g(\varphi_E^*)\frac{d\varphi_E^*}{dA}\left\{\widetilde{\varphi}_E^{\sigma-1}-(\varphi_E^*)^{\sigma-1}\right\}\right.$$
$$\left.+\,g(\varphi_I^*)\frac{d\varphi_I^*}{dA}\left\{(\varphi_I^*)^{\sigma-1}-\widetilde{\varphi}_E^{\sigma-1}\right\}\right) \tag{69}$$

$$\frac{d\widetilde{\varphi}_I}{dA} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma - 1}\left(\frac{g(\varphi_I^*)}{1 - G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{dA}\left\{\widetilde{\varphi}_I^{\sigma-1} - (\varphi_I^*)^{\sigma-1}\right\} > 0 \tag{70}$$

$$\frac{d\widetilde{\varphi}}{dA} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma - 1}\left(\frac{g(\varphi_B^*)}{1 - G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{dA}\left\{\widetilde{\varphi}^{\sigma-1} - (\varphi_B^*)^{\sigma-1}\right\} > 0, \tag{71}$$

where $\mathcal{E}'_A = \frac{\partial\chi(A,\epsilon)}{\partial A}R^\sigma T^{1-\sigma} > 0$.

- Technological requirements of the external labelling programme T

$$\frac{d\varphi_B^*}{dT} = \frac{\varphi_B^*\mathcal{E}'_T\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}G(\varphi)}{(\sigma-1)\mathcal{I}} < 0 \tag{72}$$

$$\frac{d\varphi_E^*}{dT} = -\frac{\varphi_E^*\mathcal{E}'_T\left(\int_{\varphi_B^*}^{\infty}\varphi^{\sigma-1}dG(\varphi) + \int_{\varphi_I^*}^{\infty}\chi(a,\varphi)\varphi^{\sigma-1}dG(\varphi)\right)}{\mathcal{I}(\sigma-1)(\mathcal{E}-1)} > 0 \tag{73}$$

$$\frac{d\varphi_I^*}{dT} = -\frac{\varphi_I^*\mathcal{E}'_T}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)} < 0 \tag{74}$$

$$\begin{aligned}\frac{d\widetilde{\varphi}_B}{dT} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*) - G(\varphi_B^*)}\right)\bigg(& g(\varphi_B^*)\frac{d\varphi_B^*}{dT}\left\{\widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1}\right\} \\ &+ g(\varphi_E^*)\frac{d\varphi_E^*}{dT}\left\{(\varphi_E^*)^{\sigma-1} - \widetilde{\varphi}_B^{\sigma-1}\right\}\bigg)\end{aligned} \tag{75}$$

$$\begin{aligned}\frac{d\widetilde{\varphi}_E}{dT} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*) - G(\varphi_E^*)}\right)\bigg(& g(\varphi_E^*)\frac{d\varphi_E^*}{dT}\left\{\widetilde{\varphi}_E^{\sigma-1} - (\varphi_E^*)^{\sigma-1}\right\} \\ &+ g(\varphi_I^*)\frac{d\varphi_I^*}{dT}\left\{(\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_E^{\sigma-1}\right\}\bigg)\end{aligned} \tag{76}$$

$$\frac{d\widetilde{\varphi}_I}{dT} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma - 1}\left(\frac{g(\varphi_I^*)}{1 - G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{dT}\left\{\widetilde{\varphi}_I^{\sigma-1} - (\varphi_I^*)^{\sigma-1}\right\} < 0 \tag{77}$$

$$\frac{d\widetilde{\varphi}}{dT} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma - 1}\left(\frac{g(\varphi_B^*)}{1 - G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{dT}\left\{\widetilde{\varphi}^{\sigma-1} - (\varphi_B^*)^{\sigma-1}\right\} < 0, \tag{78}$$

where $\mathcal{E}'_T = (1-\sigma)R^\sigma T^{-\sigma}(\chi(A,\epsilon)+1) < 0$.

- Licence fee of the external labelling programme Φ_a

$$\frac{d\varphi_B^*}{d\Phi_a} = -\frac{(\varphi_B^*)^\sigma[G(\varphi_I^*) - G(\varphi_E^*)]}{\Phi(\sigma-1)\mathcal{I}} < 0 \tag{79}$$

$$\frac{d\varphi_E^*}{d\Phi_a} = \frac{\varphi_E^*(\varphi_B^*)^{\sigma-1}\left(\int_{\varphi_I^*}^{\infty} a(\varphi,\epsilon)dG(\varphi) + \Phi[1-G(\varphi_B^*)] + \Phi_e\right)}{\Phi\mathcal{I}(\sigma-1)\Phi_a} > 0 \tag{80}$$

$$\frac{d\varphi_I^*}{d\Phi_a} = \frac{\varphi_I^*\chi_a'(a_I^*,\epsilon)}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)} < 0 \tag{81}$$

$$\begin{aligned}\frac{d\widetilde{\varphi}_B}{d\Phi_a} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*)-G(\varphi_B^*)}\right)\Bigg(&g(\varphi_B^*)\frac{d\varphi_B^*}{d\Phi_a}\left\{\widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1}\right\}\\ &+ g(\varphi_E^*)\frac{d\varphi_E^*}{d\Phi_a}\left\{(\varphi_E^*)^{\sigma-1} - \widetilde{\varphi}_B^{\sigma-1}\right\}\Bigg)\end{aligned} \tag{82}$$

$$\begin{aligned}\frac{d\widetilde{\varphi}_E}{d\Phi_a} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*)-G(\varphi_E^*)}\right)\Bigg(&g(\varphi_E^*)\frac{d\varphi_E^*}{d\Phi_a}\left\{\widetilde{\varphi}_E^{\sigma-1} - (\varphi_E^*)^{\sigma-1}\right\}\\ &+ g(\varphi_I^*)\frac{d\varphi_I^*}{d\Phi_a}\left\{(\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_E^{\sigma-1}\right\}\Bigg)\end{aligned} \tag{83}$$

$$\frac{d\widetilde{\varphi}_I}{d\Phi_a} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{d\Phi_a}\left\{\widetilde{\varphi}_I^{\sigma-1} - (\varphi_I^*)^{\sigma-1}\right\} < 0 \tag{84}$$

$$\frac{d\widetilde{\varphi}}{d\Phi_a} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{d\Phi_a}\left\{\widetilde{\varphi}^{\sigma-1} - (\varphi_B^*)^{\sigma-1}\right\} < 0 \tag{85}$$

- Licence fee of the external labelling programme R

$$\frac{d\varphi_B^*}{dR} = \frac{\varphi_B^*\mathcal{E}_R'\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}G(\varphi)}{(\sigma-1)\mathcal{I}} > 0 \tag{86}$$

$$\frac{d\varphi_E^*}{dR} = -\frac{\varphi_E^*\mathcal{E}_R'\left(\int_{\varphi_B^*}^{\infty}\varphi^{\sigma-1}dG(\varphi) + \int_{\varphi_I^*}^{\infty}\chi(a,\varphi)\varphi^{\sigma-1}dG(\varphi)\right)}{\mathcal{I}(\sigma-1)(\mathcal{E}-1)} < 0 \tag{87}$$

$$\frac{d\varphi_I^*}{dR} = -\frac{\varphi_I^*\mathcal{E}_R'}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)} > 0 \tag{88}$$

$$\frac{d\widetilde{\varphi}_B}{dR} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*)-G(\varphi_B^*)}\right)\Bigg(g(\varphi_B^*)\frac{d\varphi_B^*}{dR}\left\{\widetilde{\varphi}_B^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\} \\ + g(\varphi_E^*)\frac{d\varphi_E^*}{dR}\left\{(\varphi_E^*)^{\sigma-1}-\widetilde{\varphi}_B^{\sigma-1}\right\}\Bigg) \tag{89}$$

$$\frac{d\widetilde{\varphi}_E}{dR} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*)-G(\varphi_E^*)}\right)\Bigg(g(\varphi_E^*)\frac{d\varphi_E^*}{dR}\left\{\widetilde{\varphi}_E^{\sigma-1}-(\varphi_E^*)^{\sigma-1}\right\} \\ + g(\varphi_I^*)\frac{d\varphi_I^*}{dR}\left\{(\varphi_I^*)^{\sigma-1}-\widetilde{\varphi}_E^{\sigma-1}\right\}\Bigg) \tag{90}$$

$$\frac{d\widetilde{\varphi}_I}{dR} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{dR}\left\{\widetilde{\varphi}_I^{\sigma-1}-(\varphi_I^*)^{\sigma-1}\right\} > 0 \tag{91}$$

$$\frac{d\widetilde{\varphi}}{dR} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{dR}\left\{\widetilde{\varphi}^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\} > 0, \tag{92}$$

where $\mathcal{E}'_R = \sigma R^{\sigma-1}T^{1-\sigma}(\chi(A,\epsilon)+1) > 0$.

I Four-Segment Market: productivity composition and comparative statics

Productivity composition in a four-segment market is based on zero profit (8), indifference (13), and free entry (14) conditions, and the green internal segment relationship $\Phi(\varphi_B^*)^{1-\sigma}\chi_a'(a^\omega,\epsilon)(\varphi^\omega)^{\sigma-1} = 1$ that imply:

$$(\chi_a'(a_\iota^*,\epsilon))^{-1} = \frac{a(\varphi_\iota^*,\epsilon)}{\chi(a_I^*,\epsilon)} \tag{93}$$

$$\left(\chi_a'(a_E^*,\epsilon)\right)^{-1} = \frac{\Phi_a - a_E^*}{\mathcal{E}-\chi(a_E^*,\epsilon)-1} \tag{94}$$

$$\left(\chi_a'(a_I^*,\epsilon)\right)^{-1} = \frac{\Phi_a - a_I^*}{\mathcal{E}-\chi(a_I^*,\epsilon)-1} \tag{95}$$

$$\Phi(\varphi_B^*)^{1-\sigma}\mathcal{J} - \int_{\varphi_\iota^*}^{\varphi_E^*} a(\varphi,\epsilon)dG(\varphi) - \int_{\varphi_I^*}^{\infty} a(\varphi,\epsilon)dG(\varphi) \\ - \Phi(1-G(\varphi_B^*)) - \Phi_a(G(\varphi_I^*)-G(\varphi_E^*)) = \Phi_e, \tag{96}$$

where $\mathcal{J} \triangleq \int_{\varphi_B^*}^{\varphi_\iota^*} \varphi^{\sigma-1} dG(\varphi) + \int_{\varphi_\iota^*}^{\varphi_E^*} (\chi(a,\epsilon)+1)\varphi^{\sigma-1} dG(\varphi) + \mathcal{E}\int_{\varphi_E^*}^{\varphi_I^*} \varphi^{\sigma-1} dG(\varphi) + \int_{\varphi_I^*}^{\infty} (\chi(a,\epsilon)+1)\varphi^{\sigma-1} dG(\varphi)$, $a_E^* < \Phi_a < a_I^*$, $\chi(a_E^*,\epsilon)+1 < \mathcal{E} < \chi(a_I^*,\epsilon)+1$. Then by the envelope theorem one can obtain

- Eco-concerns ϵ

$$\frac{d\varphi_B^*}{d\epsilon} = \frac{\varphi_B^* \left(\int_{\varphi_\iota^*}^{\varphi_E^*} \chi'_\epsilon \varphi^{\sigma-1} dG(\varphi) + \mathcal{E}'_\epsilon \int_{\varphi_E^*}^{\varphi_I^*} \varphi^{\sigma-1} dG(\varphi) + \int_{\varphi_I^*}^{\infty} \chi'_\epsilon \varphi^{\sigma-1} dG(\varphi) \right)}{(\sigma-1)\mathcal{J}} > 0 \tag{97}$$

$$\frac{d\varphi_\iota^*}{d\epsilon} = -\frac{\varphi_\iota^* a_\iota^* \chi'_\epsilon(a_\iota^*,\varphi_\iota^*)\chi'_a(a_\iota^*,\varphi_\iota^*)}{(\sigma-1)\chi^2(a_\iota^*,\varphi_\iota^*)} < 0 \tag{98}$$

$$\frac{d\varphi_E^*}{d\epsilon} = -\frac{\varphi_E^*(\mathcal{E}'_\epsilon - \chi'_\epsilon(a_E^*,\epsilon))}{(\sigma-1)(\mathcal{E}-\chi(a_E^*,\epsilon)-1)} < 0 \tag{99}$$

$$\frac{d\varphi_I^*}{d\epsilon} = -\frac{\varphi_I^*(\mathcal{E}'_\epsilon - \chi'_\epsilon(a_I^*,\epsilon))}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)} < 0 \tag{100}$$

$$\begin{aligned} \frac{d\widetilde{\varphi}_B}{d\epsilon} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_\iota^*) - G(\varphi_B^*)} \right) \Bigg(& g(\varphi_B^*) \frac{d\varphi_B^*}{d\epsilon} \left\{ \widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} \\ & + g(\varphi_\iota^*) \frac{d\varphi_\iota^*}{d\epsilon} \left\{ (\varphi_\iota^*)^{\sigma-1} - \widetilde{\varphi}_B^{\sigma-1} \right\} \Bigg) \end{aligned} \tag{101}$$

$$\begin{aligned} \frac{d\widetilde{\varphi}_\iota}{d\epsilon} = \frac{\widetilde{\varphi}_\iota^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_E^*) - G(\varphi_\iota^*)} \right) \Bigg(& g(\varphi_\iota^*) \frac{d\varphi_\iota^*}{d\epsilon} \left\{ \widetilde{\varphi}_\iota^{\sigma-1} - (\varphi_\iota^*)^{\sigma-1} \right\} \\ & + g(\varphi_E^*) \frac{d\varphi_E^*}{d\epsilon} \left\{ (\varphi_E^*)^{\sigma-1} - \widetilde{\varphi}_\iota^{\sigma-1} \right\} \Bigg) \\ < 0 & \end{aligned} \tag{102}$$

$$\begin{aligned} \frac{d\widetilde{\varphi}_E}{d\epsilon} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_I^*) - G(\varphi_E^*)} \right) \Bigg(& g(\varphi_E^*) \frac{d\varphi_E^*}{d\epsilon} \left\{ \widetilde{\varphi}_E^{\sigma-1} - (\varphi_E^*)^{\sigma-1} \right\} \\ & + g(\varphi_I^*) \frac{d\varphi_I^*}{d\epsilon} \left\{ (\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_E^{\sigma-1} \right\} \Bigg) \\ < 0 & \end{aligned} \tag{103}$$

$$\frac{d\widetilde{\varphi}_I}{d\epsilon} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{d\epsilon}\left\{\widetilde{\varphi}_I^{\sigma-1}-(\varphi_I^*)^{\sigma-1}\right\}<0 \tag{104}$$

$$\frac{d\widetilde{\varphi}}{d\epsilon} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{d\epsilon}\left\{\widetilde{\varphi}^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\}>0 \tag{105}$$

- Advertising activity of the external labelling programme A

$$\frac{d\varphi_B^*}{dA} = \frac{\varphi_B^*\mathcal{E}'_A\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}G(\varphi)}{(\sigma-1)\mathcal{J}}>0 \tag{106}$$

$$\frac{d\varphi_\iota^*}{dA}=0 \tag{107}$$

$$\frac{d\varphi_E^*}{dA} = -\frac{\varphi_E^*\mathcal{E}'_A}{(\sigma-1)(\mathcal{E}-\chi(a_E^*,\epsilon)-1)}<0 \tag{108}$$

$$\frac{d\varphi_I^*}{dA} = -\frac{\varphi_I^*\mathcal{E}'_A}{(\sigma-1)(\mathcal{E}-\chi(a_I^*,\epsilon)-1)}>0 \tag{109}$$

$$\frac{d\widetilde{\varphi}_B}{dA} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_\iota^*)-G(\varphi_B^*)}\right)g(\varphi_B^*)\frac{d\varphi_B^*}{dA}\left\{\widetilde{\varphi}_B^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\}>0 \tag{110}$$

$$\frac{d\widetilde{\varphi}_\iota}{dA} = \frac{\widetilde{\varphi}_\iota^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*)-G(\varphi_\iota^*)}\right)g(\varphi_E^*)\frac{d\varphi_E^*}{dA}\left\{(\varphi_E^*)^{\sigma-1}-\widetilde{\varphi}_\iota^{\sigma-1}\right\}<0 \tag{111}$$

$$\begin{aligned}\frac{d\widetilde{\varphi}_E}{dA} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*)-G(\varphi_E^*)}\right)\Bigg(&g(\varphi_E^*)\frac{d\varphi_E^*}{dA}\left\{\widetilde{\varphi}_E^{\sigma-1}-(\varphi_E^*)^{\sigma-1}\right\}\\ &+g(\varphi_I^*)\frac{d\varphi_I^*}{dA}\left\{(\varphi_I^*)^{\sigma-1}-\widetilde{\varphi}_E^{\sigma-1}\right\}\Bigg)\end{aligned} \tag{112}$$

$$\frac{d\widetilde{\varphi}_I}{dA} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{dA}\left\{\widetilde{\varphi}_I^{\sigma-1}-(\varphi_I^*)^{\sigma-1}\right\}>0 \tag{113}$$

$$\frac{d\widetilde{\varphi}}{dA} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{dA}\left\{\widetilde{\varphi}^{\sigma-1}-(\varphi_B^*)^{\sigma-1}\right\}>0 \tag{114}$$

- Technological requirements of the external labelling programme T

$$\frac{d\varphi_B^*}{dT} = \frac{\varphi_B^* \mathcal{E}'_T \int_{\varphi_E^*}^{\varphi_I^*} \varphi^{\sigma-1} G(\varphi)}{(\sigma-1)\mathcal{J}} < 0 \tag{115}$$

$$\frac{d\varphi_\iota^*}{dT} = 0 \tag{116}$$

$$\frac{d\varphi_E^*}{dT} = -\frac{\varphi_E^* \mathcal{E}'_T}{(\sigma-1)(\mathcal{E} - \chi(a_E^*, \epsilon) - 1)} > 0 \tag{117}$$

$$\frac{d\varphi_I^*}{dT} = -\frac{\varphi_I^* \mathcal{E}'_T}{(\sigma-1)(\mathcal{E} - \chi(a_I^*, \epsilon) - 1)} < 0 \tag{118}$$

$$\frac{d\widetilde{\varphi}_B}{dT} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_\iota^*) - G(\varphi_B^*)} \right) g(\varphi_B^*) \frac{d\varphi_B^*}{dT} \left\{ \widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} < 0 \tag{119}$$

$$\frac{d\widetilde{\varphi}_\iota}{dT} = \frac{\widetilde{\varphi}_\iota^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_E^*) - G(\varphi_\iota^*)} \right) g(\varphi_E^*) \frac{d\varphi_E^*}{dT} \left\{ (\varphi_E^*)^{\sigma-1} - \widetilde{\varphi}_\iota^{\sigma-1} \right\} > 0 \tag{120}$$

$$\begin{aligned} \frac{d\widetilde{\varphi}_E}{dT} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_I^*) - G(\varphi_E^*)} \right) \Bigg(& g(\varphi_E^*) \frac{d\varphi_E^*}{dT} \left\{ \widetilde{\varphi}_E^{\sigma-1} - (\varphi_E^*)^{\sigma-1} \right\} \\ & + g(\varphi_I^*) \frac{d\varphi_I^*}{dT} \left\{ (\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_E^{\sigma-1} \right\} \Bigg) \end{aligned} \tag{121}$$

$$\frac{d\widetilde{\varphi}_I}{dT} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1} \left(\frac{g(\varphi_I^*)}{1 - G(\varphi_I^*)} \right) \frac{d\varphi_I^*}{dT} \left\{ \widetilde{\varphi}_I^{\sigma-1} - (\varphi_I^*)^{\sigma-1} \right\} < 0 \tag{122}$$

$$\frac{d\widetilde{\varphi}}{dT} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1} \left(\frac{g(\varphi_B^*)}{1 - G(\varphi_B^*)} \right) \frac{d\varphi_B^*}{dT} \left\{ \widetilde{\varphi}^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} < 0 \tag{123}$$

- Licence fee of the external labelling programme Φ_a

$$\frac{d\varphi_B^*}{d\Phi_a} = -\frac{(\varphi_B^*)^\sigma [G(\varphi_I^*) - G(\varphi_E^*)]}{\Phi(\sigma-1)\mathcal{J}} < 0 \tag{124}$$

$$\frac{d\varphi_\iota^*}{d\Phi_a} = 0 \tag{125}$$

$$\frac{d\varphi_E^*}{d\Phi_a} = \frac{\varphi_E^* \chi'_a(\varphi_E^*, \epsilon)}{(\sigma-1)(\mathcal{E} - \chi(a_E^*, \epsilon) - 1)} > 0 \tag{126}$$

$$\frac{d\varphi_I^*}{d\Phi_a} = \frac{\varphi_I^* \chi_a'(\varphi_I^*, \epsilon)}{(\sigma-1)(\mathcal{E} - \chi(a_I^*, \epsilon) - 1)} < 0 \tag{127}$$

$$\frac{d\widetilde{\varphi}_B}{d\Phi_a} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_\iota^*) - G(\varphi_B^*)} \right) g(\varphi_B^*) \frac{d\varphi_B^*}{d\Phi_a} \left\{ \widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} < 0 \tag{128}$$

$$\frac{d\widetilde{\varphi}_\iota}{d\Phi_a} = \frac{\widetilde{\varphi}_\iota^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_E^*) - G(\varphi_\iota^*)} \right) g(\varphi_E^*) \frac{d\varphi_E^*}{d\Phi_a} \left\{ (\varphi_E^*)^{\sigma-1} - \widetilde{\varphi}_\iota^{\sigma-1} \right\} > 0 \tag{129}$$

$$\begin{aligned} \frac{d\widetilde{\varphi}_E}{d\Phi_a} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_I^*) - G(\varphi_E^*)} \right) \Bigg(& g(\varphi_E^*) \frac{d\varphi_E^*}{d\Phi_a} \left\{ \widetilde{\varphi}_E^{\sigma-1} - (\varphi_E^*)^{\sigma-1} \right\} \\ & + g(\varphi_I^*) \frac{d\varphi_I^*}{d\Phi_a} \left\{ (\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_E^{\sigma-1} \right\} \Bigg) \end{aligned} \tag{130}$$

$$\frac{d\widetilde{\varphi}_I}{d\Phi_a} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1} \left(\frac{g(\varphi_I^*)}{1 - G(\varphi_I^*)} \right) \frac{d\varphi_I^*}{d\Phi_a} \left\{ \widetilde{\varphi}_I^{\sigma-1} - (\varphi_I^*)^{\sigma-1} \right\} < 0 \tag{131}$$

$$\frac{d\widetilde{\varphi}}{d\Phi_a} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1} \left(\frac{g(\varphi_B^*)}{1 - G(\varphi_B^*)} \right) \frac{d\varphi_B^*}{d\Phi_a} \left\{ \widetilde{\varphi}^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} < 0 \tag{132}$$

- Licence fee of the external labelling programme R

$$\frac{d\varphi_B^*}{dR} = \frac{\varphi_B^* \mathcal{E}_R' \int_{\varphi_E^*}^{\varphi_I^*} \varphi^{\sigma-1} G(\varphi)}{(\sigma-1)\mathcal{J}} > 0 \tag{133}$$

$$\frac{d\varphi_\iota^*}{dR} = 0 \tag{134}$$

$$\frac{d\varphi_E^*}{dR} = -\frac{\varphi_E^* \mathcal{E}_R'}{(\sigma-1)(\mathcal{E} - \chi(a_E^*, \epsilon) - 1)} < 0 \tag{135}$$

$$\frac{d\varphi_I^*}{dR} = -\frac{\varphi_I^* \mathcal{E}_R'}{(\sigma-1)(\mathcal{E} - \chi(a_I^*, \epsilon) - 1)} > 0 \tag{136}$$

$$\frac{d\widetilde{\varphi}_B}{dR} = \frac{\widetilde{\varphi}_B^{2-\sigma}}{\sigma-1} \left(\frac{1}{G(\varphi_\iota^*) - G(\varphi_B^*)} \right) g(\varphi_B^*) \frac{d\varphi_B^*}{dR} \left\{ \widetilde{\varphi}_B^{\sigma-1} - (\varphi_B^*)^{\sigma-1} \right\} > 0 \tag{137}$$

$$\frac{d\widetilde{\varphi}_\iota}{dR} = \frac{\widetilde{\varphi}_\iota^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_E^*)-G(\varphi_\iota^*)}\right) g(\varphi_E^*)\frac{d\varphi_E^*}{dR}\left\{(\varphi_E^*)^{\sigma-1} - \widetilde{\varphi}_\iota^{\sigma-1}\right\} \tag{138}$$

$$\begin{aligned}\frac{d\widetilde{\varphi}_E}{dR} = \frac{\widetilde{\varphi}_E^{2-\sigma}}{\sigma-1}\left(\frac{1}{G(\varphi_I^*)-G(\varphi_E^*)}\right)\Bigg(& g(\varphi_E^*)\frac{d\varphi_E^*}{dR}\left\{\widetilde{\varphi}_E^{\sigma-1} - (\varphi_E^*)^{\sigma-1}\right\} \\ & + g(\varphi_I^*)\frac{d\varphi_I^*}{dR}\left\{(\varphi_I^*)^{\sigma-1} - \widetilde{\varphi}_E^{\sigma-1}\right\}\Bigg)\end{aligned} \tag{139}$$

$$\frac{d\widetilde{\varphi}_I}{dR} = \frac{\widetilde{\varphi}_I^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_I^*)}{1-G(\varphi_I^*)}\right)\frac{d\varphi_I^*}{dR}\left\{\widetilde{\varphi}_I^{\sigma-1} - (\varphi_I^*)^{\sigma-1}\right\} > 0 \tag{140}$$

$$\frac{d\widetilde{\varphi}}{dR} = \frac{\widetilde{\varphi}^{2-\sigma}}{\sigma-1}\left(\frac{g(\varphi_B^*)}{1-G(\varphi_B^*)}\right)\frac{d\varphi_B^*}{dR}\left\{\widetilde{\varphi}^{\sigma-1} - (\varphi_B^*)^{\sigma-1}\right\} > 0 \tag{141}$$

J Quantitative Analysis: eco-quality function

In order to provide a numerical example I introduce a function

$$\xi(\varphi,\epsilon) = \frac{\chi(a,\epsilon)}{\chi'_a(a,\epsilon)} - a, \tag{142}$$

where $a \triangleq a(\varphi,\epsilon)$. Then

$$\frac{\partial\xi(\varphi,\epsilon)}{\partial\varphi} = (\sigma-1)\varphi^{-1}\frac{\chi(a,\epsilon)}{\chi'_a(a,\epsilon)} > 0 \tag{143}$$

$$\frac{\partial^2\xi(\varphi,\epsilon)}{\partial\varphi^2} = (\sigma-1)\varphi^{-2}\left[(1-\sigma)\frac{\chi'_a(a,\epsilon)}{\chi''_{aa}(a,\epsilon)} + (\sigma-2)\frac{\chi(a,\epsilon)}{\chi'_a(a,\epsilon)}\right] > 0, \tag{144}$$

when the condition of the optimal green internal profit convexity (26) holds.

$$\frac{\partial\xi(\varphi,\epsilon)}{\partial\epsilon} = \frac{\chi'_\epsilon(a,\epsilon)}{\chi'_a(a,\epsilon)} > 0 \tag{145}$$

$$\frac{\partial^2\xi(\varphi,\epsilon)}{\partial\epsilon^2} = \frac{\chi''_{\epsilon\epsilon}(a,\epsilon)\chi''_{aa}(a,\epsilon) - (\chi''_{\epsilon a}(a,\epsilon))^2}{\chi'_a(a,\epsilon)\chi''_{aa}(a,\epsilon)} < 0 \tag{146}$$

$$\frac{\partial^2\xi(\varphi,\epsilon)}{\partial\epsilon\partial\varphi} = (\sigma-1)\varphi^{-1}\left(\frac{\chi'_\epsilon(a,\epsilon)}{\chi'_a(a,\epsilon)} - \frac{\chi''_{a\epsilon}(a,\epsilon)}{\chi''_{aa}(a,\epsilon)}\right) \geq 0 \tag{147}$$

For the numerical example I assume

$$\xi(\varphi,\epsilon) \triangleq \varphi^2 - \epsilon^{-2} \tag{148}$$

that satisfies conditions (143)-(147).

K Quantitative analysis: a two-segment market

The productivity composition in a two-segment market is determined by two conditions with two unknowns φ_B^* and φ_I^*:

$$\xi(\varphi_I^*,\epsilon) = 0 \tag{149}$$

$$\Phi(\varphi_B^*)^{1-\sigma}\int_{\varphi_B^*}^{\infty}\varphi^{\sigma-1}dG(\varphi) + \int_{\varphi_I^*}^{\infty}\xi(\varphi,\epsilon)dG(\varphi) - \Phi(1-G(\varphi_B^*)) = \Phi_e \tag{150}$$

Assuming productivity to be Pareto-distributed $G(\varphi) = 1 - \left(\frac{\varphi_0}{\varphi}\right)^k$ and the equation (148) to hold the productivity composition is determined by a set of the two following equations:

$$\varphi_I^* = \epsilon^{-1} \tag{151}$$

$$(\varphi_B^*)^{-k} = \left(\varphi_0^{-k}\Phi_e + \frac{2\epsilon^{k-2}}{2-k}\right)\frac{\sigma-k-1}{1-\sigma}\Phi^{-1} \tag{152}$$

L Quantitative analysis: a three-segment market

The productivity composition in a three-segment market is determined by three conditions with three unknowns φ_B^*, φ_E^*, and φ_I^*:

$$(\varphi_E^*)^{\sigma-1}\Phi(\mathcal{E}-1) = \Phi_a(\varphi_B^*)^{\sigma-1} \tag{153}$$

$$(\varphi_I^*)^{\sigma-1}\Phi(\mathcal{E}-1) = (\varphi_B^*)^{\sigma-1}(\xi(\varphi_I^*,\epsilon)+\Phi_a) \tag{154}$$

$$\begin{aligned}\Phi(\varphi_B^*)^{1-\sigma}\int_{\varphi_B^*}^{\infty}\varphi^{\sigma-1}dG(\varphi) + \Phi_a(\varphi_E^*)^{1-\sigma}\int_{\varphi_E^*}^{\varphi_I^*}\varphi^{\sigma-1}dG(\varphi) \\ + \int_{\varphi_I^*}^{\infty}\xi(\varphi,\epsilon)dG(\varphi) - \Phi(1-G(\varphi_B^*)) - \Phi_a(G(\varphi_I^*)-G(\varphi_E^*)) = \Phi_e,\end{aligned} \tag{155}$$

where $\Phi_a < a_I^*$, $\mathcal{E} < \chi(a_I^*, \epsilon) + 1$.

Assuming Pareto productivity distribution $G(\varphi) = 1 - \left(\frac{\varphi_0}{\varphi}\right)^k$, and the equations (148) to hold, the productivity composition in a three-segment market is determined by the three following conditions:

$$(\varphi_E^*)^{\sigma-1}\Phi(\mathcal{E}-1) = \Phi_a(\varphi_B^*)^{\sigma-1} \tag{156}$$

$$(\varphi_I^*)^{\sigma-1}\Phi(\mathcal{E}-1) = (\varphi_B^*)^{\sigma-1}[(\varphi_I^*)^2 - \epsilon^{-2} + \Phi_a] \tag{157}$$

$$\begin{aligned}(\varphi_I^*)^{2-k}\frac{k(3-\sigma)}{2-k} + (\varphi_I^*)^{-k}(\sigma-1)(\Phi_a - \epsilon^{-2})\\ - (\varphi_E^*)^{-k}\Phi_a(\sigma-1) - (\varphi_B^*)^{-k}\Phi(\sigma-1) = \Phi_e\varphi_0^{-k}(\sigma-k-1)\end{aligned} \tag{158}$$