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Trade Integration and the Polarisation of Eco-Labelling Strategies*

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Abstract

Growing ecological concerns give rise to salient discussions of green policy impact within different social sciences domains. This research studies the outcomes of voluntary environmental labelling in autarky and upon trade integration in the presence of two types of heterogeneity, across countries and across producers. It investigates the impact of the two main types of 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, lower-middle productive and the most efficient firms are incentivized to greenwash, and the upper-middle productive firms choose trustful programmes. It also shows that voluntary green restrictions lead to substantial productivity effects in the market upon opening to international trade, conditionally, depending on the type of the labelling and the relative degree of environmental awareness across trading countries. The model predicts average market productivity losses and within segments productivity gains for the relatively more eco-concerned country, while the effects for the relatively less eco-concerned country are the opposite.

Keywords: eco-labelling, firm heterogeneity, trade integration, voluntary environmental regulation, firms productivity

JEL code: F18 - Trade and Environment.

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1 Introduction

Environmental labelling belongs to a wide range of green policy instruments that fall under the umbrella of *voluntary environmental programmes* (VEPs). VEPs represent a relatively new tool that emerged in the 1980s. They are highly diversified: they include eco-standards, stewardship certificates, ranking and rating, green mutual funds, environmental management systems, environmental declarations, codes of conduct, reporting standards, green trademarks, and eco-labels (Boström and Klintman, 2008). VEPs reflect the shortcomings of the *direct*, or *command and control*, approach to green regulation, ongoing shift towards environmentally-friendly consumer behaviour, complexity of production processes, deepening international economic integration, and the redistribution of economic power towards producers and consumers.

Eco-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. Many of them are not country-specific but used worldwide. Voluntary eco-labels are supposed to push the producer beyond 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 development[1] which raised issues about their possible economic consequences.

The main goal of this paper is to discover the productivity effects of voluntary environmental labelling in autarky and upon trade integration. The framework is based on the three key elements: (1) two types of heterogeneity, across countries and across producers; (2) two types of eco-labels; and (3) one source of eco-concerns. (1) The heterogeneity of countries implies the difference in the attitude of the society towards environmental problems, and 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*,

[1] Gruère (2013) reports a fivefold increase in the number of environmental labelling and information schemes from 1970 to 2012.

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 VEPs 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.[2] Particularly, the model introduces *eco-quality* as an environmental characteristic of any product variety that is defined by country-specific 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 (*internal VEPs*). The only control within the present model is provided by NGOs who act as stakeholders of ISO Type I standards (*external VEPs*).

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 VEPs*), and the upper-middle productive firms opt for the green products of verified quality (*external VEPs*). Thus, the lack of public monitoring increases the attractiveness of false environmental labels for producers from different productivity sub-segments. Meanwhile, conditional to the particular characteristics of external VEPs 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 role of eco-concerns in autarky. 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

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

eco-friendly programmes. As a result, the non-labelled (brown) segment becomes narrower but on average less efficient due to the relatively stronger impact on existing brown firms who remain in the market and choose eco-friendly strategies. Accordingly, the labelled (green) segment also faces efficiency decline. Meanwhile, due to the redistribution of firms across market segments, the average market productivity increases.

Finally, the model illustrates the productivity effects of eco-labelling upon trade integration. Exposure to trade with a relatively less eco-concerned country affects the average productivity in green and brown market segments similarly. Trade integration opens the room for less efficient firms to enter the market with brown strategies. Additionally, it incentivises the least productive green firms to discontinue eco-friendly programmes. The latter effect dominates the former, and the average productivity within brown segment increases. It also determines the average productivity growth within the green segment. Meanwhile, due to the reallocation of firms across segments, the average market productivity in a more eco-concerned country declines - the opposite holds true with a less eco-concerned country. The model also illustrates the analogous but mirror-like effect in the case of the cross-country eco-heterogeneity growth assuming the aggregate green demand remains constant.

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[3]. 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 (2003)[4]. 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 about the environ-

[3]A recent comprehensive review of the theoretical research on labels is provided by Bonroy and Constantatos (2014).

[4]Cherniwchan et al. (2016) provide a comprehensive overview of the relevant studies, both theoretical and empirical.

[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).

mental 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 heterogeneity, across producers and countries, and two types of environmental labelling, in order to investigate the market sorting and market efficiency patterns.

The rest of the paper is organised as follows. Section 2 describes the development of eco-labelling. Section 3 overviews the environmental sociology findings related to the ecological concerns hypothesis. Section 4 introduces the eco-quality concept and corresponding types of VEPs. Sections 5, 6 and 7 outline the model and the results of comparative statics. Section 8 presents the quantitative analysis. And Section 9 discusses the results and 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 includes any type of environmental *"cradle-to-grave"* impact of products.

Eco-labelling is one of the most significant and influencing type of VEPs[6]. Whereas the labelling itself is not a new phenomenon[7], eco-labelling is a part 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

[6]For the purpose of this research let's follow the most broad approach to eco-labelling, referring to *eco-label* as a general term capturing all ways of environmentally-friendly goods and services symbolic differentiation.

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

[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.

first multinational eco-label the *Nordic Ecolabel (Nordic Swan)* was established in 1989 in Norway.[11]

In 2016 the Ecolabel Index, a global directory of eco-labelling, contained 465 eco-labels represented in 199 countries and 25 industry sectors[12]. Eco-labelling 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)[13]. The most significant ecolabelling systems serve from 5% to 20% of the market (Amacher et al., 2004).

VEPs are widely represented in the agenda of firms including B2B segments. The broad online survey of the perspectives on eco-labelling conducted by the Institute of Management and Development (IMD) and *École Polytechnique Fédérale de Lausanne* in Switzerland[14] reports the following reasons for producers to introduce green programmes: (1) to strengthen the brand and differentiate it in the market, (2) to fulfil the eco-biased preferences of consumers and investors, (3) to diminish the risk of being attacked by green NGOs, (4) to address investors demands, and (5) to contribute to overall environmental awareness in society (Comas Martí and Seifert, 2012).

At the same time, some practitioners report an excessive number of eco-identifiers which decreases their value and expected income leading to the establishment of *"a new industry of 'selling stickers'"*. They also show some scepticism concerning eco-labels including their credibility, lack of transparent and clear criteria, and their possible role as technical barriers to trade. Some arguments are based on the lack of evidence about the actual impact of eco-labelling which leads to a misunderstanding of their importance in industry development.

The significance of eco-labelling is non-negligible in light of the *credence* goods

[11] A deep investigation of the main trends supporting the implementation of eco-labels and sceptical and encouraging arguments of their use are provided by Boström and Klintman (2008), pp.19-26 and pp.67-82 respectively.

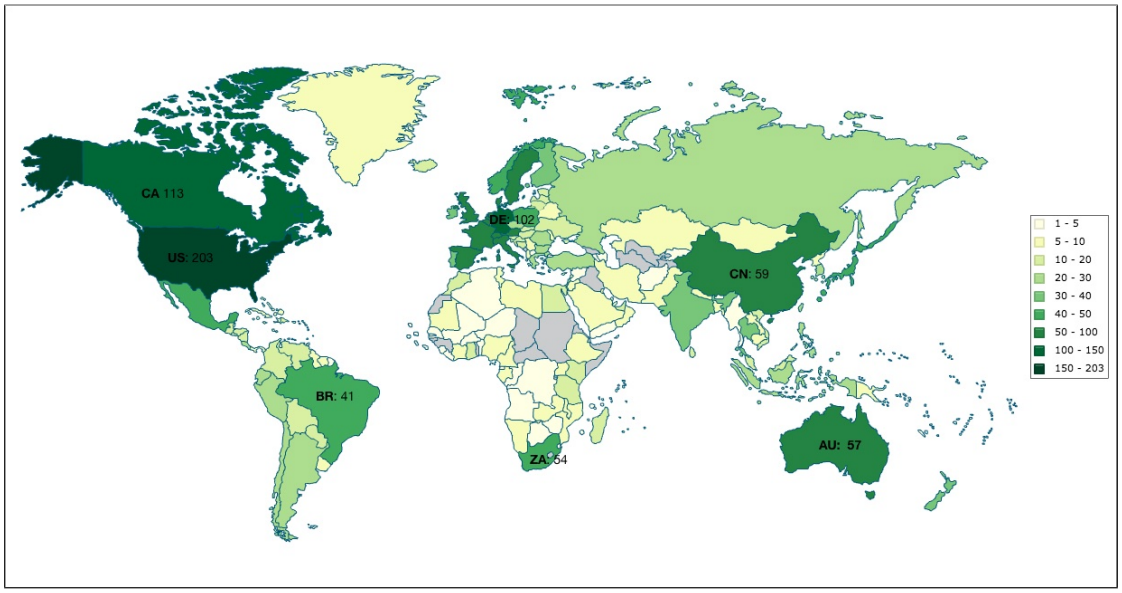
[12] Gruère (2013) and Gruère (2015) provide a comprehensive overview of environmental labelling and information schemes worldwide - its development and classification approaches.

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

[14] The survey is based on 1,052 responses of practitioners who have received training at IMD business school (the whole sample is 8,553 practitioners, 12% of which provided complete responses to the questionnaire). The target group was selected according to the criteria of the industry of activity and function (Comas Martí and Seifert, 2012).

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

(number of eco-labels available in the market)



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

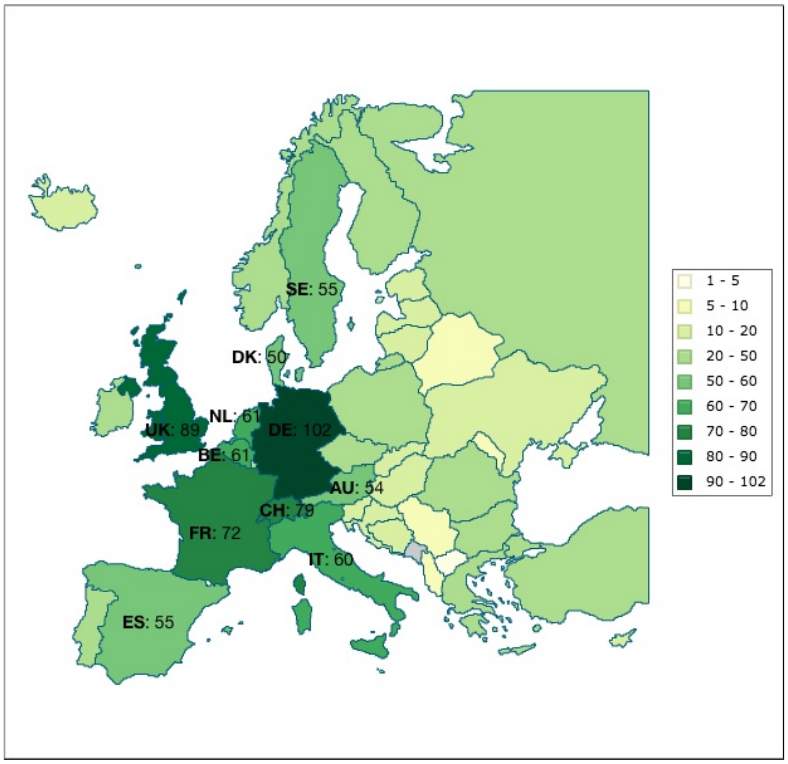
concept (Darby and Karni, 1973)[15] which applies to products in a relationship with their environmental footprint. Green quality of a particular variety cannot be discovered by consumers on the basis of their experience or knowledge forcing them to rely on additional information. Accordingly, eco-labels are often a subject of 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 behaviour patterns for consumers to translate their eco-concerns into eco-friendly behaviour (Young et al., 2010).

Empirical evidence of eco-labelling as a factor influencing consumer choice has

[15]Darby and Karni (1973) establish the background for two closely related concepts of credence goods. One strand of literature focuses on the case when a consumer is not able to specify the needs *ex ante* the purchase but observe the utility *ex post* (see, for example, Dulleck and Kerschbamer (2006) for an overview of the literature related to this concept of credence goods). Examples of this include medical or taxi services. The second strand of literature treats credence goods as a type of product consumers are willing to buy but unable to observe the utility even after the purchase. For example, non-GMO or environmentally-friendly goods whose pronounced characteristics are prohibitively expensive or even impossible to verify by individuals.

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

(number of eco-labels available in the market)



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

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.[16] 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

[16]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).

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.

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.

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.

3 Environmental Concerns

Franzen and Vogl (2013) state that *"individuals react in three distinct ways to environmental problems: having rational insight into the problem, being willing to act, and being emotionally affected by environmental degradation"*. Environmental sociology develops three basic hypotheses to explain the existence and variation of eco-appreciation across individuals and countries: *Ingelhart's post-materialism hypothesis*, *Dunlap and Van Liere's "New Environmental Paradigm" hypothesis* , and *prosperity or affluence hypothesis*.[17]

Inglehart (1995) considers a relationship between social development and environmental concerns: analogously to Maslow's hierarchy of needs (Maslow, 1943), more prosperous societies adopt post-materialistic values including ecological awareness. At the same time less developed countries can also demonstrate a high level of green concerns in response to a low quality of environment due to underdevelopment. This refers to the *objective problems and subjective values* hypothesis that allows for two independent effects on the green awareness growth: shift to post-material values and immediate response to the quality of environment. Dunlap and Van Liere's *"New Environmental Paradigm"* (Dunlap and Van Liere, 1978) states that green concerns are in line with global development despite the wealth in society. And *affluence, or prosperity, hypothesis* (Diekmann and Franzen, 1999) is related to the positive relationship between national wealth and ecological awareness.

Franzen and Meyer (2010) define these hypotheses stating *"that environmental concern depends on wealth, that it depends on post-material values, and that wealth should not matter"*. The latter is also supported by empirical studies[18] that explore other significant factors influencing eco-appreciation level, such as the distribution of wealth, quality of environment, population density, age and gender, educational level, and various sociodemographic characteristics[19].

[17] Franzen and Meyer (2010) provide a comprehensive overview of these hypotheses.

[18] See, for example, Van Liere and Dunlap (1980), Franzen and Meyer (2010), Meyer (2015).

[19] These findings are also in line with the concept of green consumerism as a part of the *political consumption* phenomenon implying the global responsibility-taking behaviour of individuals (Micheletti, 2003). Consumers can express their concerns through boycotting some products or by *buycotting* them (Boström and Klintman, 2008). The latter leads to choosing particular goods or products because of their "political" qualities even if it turns out to be more expensive.

4 Eco-Quality Within Different Types of VEPs

In order to link environmental concerns to green-biased preferences of consumers underpinning VEPs, 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, eco-quality indicates the 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 an environmental policy or the design of environmental regulation, eco-quality also refers to its actual environmental footprint.

Let's denote eco-quality as $\chi_i \geq 0$, a value assigned to each variety produced in the economy. The model defines *eco-quality* $\chi_i = \chi[pr^i, \varepsilon]$[20] as a differentiable strictly concave continuous function increasing in promotion activity of eco-label stakeholders[21] $pr \geq 0$ and in the level of environmental concerns (or eco-appreciation level) in the country $\varepsilon \geq 0$ such that $\chi[0, \varepsilon] = \chi[pr, 0] = 0$, $\chi''_{pr\,\varepsilon} > 0$.[22] 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, let's also assume the elasticity of the eco-quality with respect to each of the dependent variables to vary such that the efficiency of promotion decreases with its 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 ($\varepsilon > 0$)

The political consumption phenomenon finds its roots in the US-nonimportation movement of 1764-76. Though such movements emerged strongly in the mid-nineteenth century (Boström and Klintman, 2008), green consumerism entered the environmental agenda only in the 1980s.

[20] Throughout the paper square brackets are used to group the arguments of any function.

[21] 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 VEP.

[22] 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.

in all countries in the model 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 promotional programmes, the model assumes them to trust the information 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 classification 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 VEPs are summarised in the Table 2.

External voluntary environmental labelling (ISO 14024: 1999 Type I) can be supported by any institution, e.g. NGO, industry association, or government.

Table 2: *VEPs Parameters*

	technology	application/ licence fees	promotion expenditures	eco-quality
External VEPs ISO 14024 (Type I)	$T > 0$	$F_a > 0$ $0 < 1 - F_l < 1$	$A \gg F_a$	$\chi[A, \varepsilon]$
Internal VEPs ISO 14021 (Type II)	$t^i \geq 1$	-	$a^i > 0$	$\chi[a^i, \varepsilon]$

To join an external VEP firms need to meet the requirements of the programme[23]: they pay the application fee $F_a > 0$ as additional fixed costs and licence fee as a share of the turnover $0 < 1 - F_l < 1$; they also develop a production process that changes marginal input by a factor of $T > 0$.[24] Accordingly, the model allows for the "win-win" Porter hypothesis ($T < 1$) that considers the case when environmental regulation acts as an instrument of technological improvement (Porter and van der Linde, 1995).[25] Greening the technology is less costly for more productive firms.

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 ($A \gg F_a$). The eco-quality of any labelled variety is represented by the parameter $\chi = \chi[A, \varepsilon]$.

[23]The proposed structure of external VEP generally mirrors the selected eco-labelling programmes, 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.

[24]I assume the parameters of the external VEP to be constant over the time period of the model. 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.

[25]It is necessary to mention that the Porter hypothesis is still a doubtful concept due to the mixed empirical evidence of the relationship between environmental and financial performance of firms (see Horváthová (2010) for a brief overview and a meta-analysis of the relevant empirical studies published in 1980-2007).

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

5 General Assumptions of the Structural Model

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

Preferences are biased due to 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 $\sigma > 1$[26]:

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

where M represents the measure of varieties available in the market.

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.

[26]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, more efforts are needed to motivate them to choose green varieties persistently.

The design of the utility function also fits a wide strand of literature on quality in trade.[27] This research allows the quality parameter to be independent from the productivity of the 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 factor in the economy) that is homogeneous and perfectly mobile across industries but immobile internationally. Production in industry C does not cause any negative environmental effects[28]. Let's normalise wages $w = 1$. Then, by construction, if the output of the industry is positive, $P_C = 1$.

Industry D is 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 $f > 0$. They pay fixed costs $f_{entry} > 0$ 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 green technology or remain brown.

To reduce environmental damage, firms in industry D can introduce a voluntary environmental programme. Thus, the market is comprised of two segments: a *green segment* formed by firms changing the technology and joining any type of VEP, external or internal; and a *brown segment* formed by firms preserving the initial technology. Let's assume that only green firms implement promotion programmes to influence consumer choice.

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

[28] Industry C can also be considered environmental 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.

6 Autarky

Let's first investigate the closed economy where firms can choose between joining one of the VEP programmes, *external* or *internal*, or preserving the initial (brown) status.

6.1 Environmental Strategies

Brown strategy. Any firm opting for *brown* strategy in autarky faces the demand $d_b^i = \alpha L P^{\sigma-1}(p_b^i)^{-\sigma}$ and sets the price $p_b^i = \frac{\sigma}{\sigma-1}(\varphi^i)^{-1}$, where $P^{1-\sigma} = \int_{m\in M}(\chi^m + 1)(p^m)^{1-\sigma}dG[\varphi]$ is a CES type eco-quality adjusted price index that also accounts for the consumer green goods price perception. Then the optimal profit in increasing and convex in φ and represented as

$$\pi_b^{opt}[\varphi^i] = BP^{\sigma-1}(\varphi^i)^{\sigma-1} - f, \tag{2}$$

where $B \triangleq \alpha L(\sigma-1)^{\sigma-1}\sigma^{-\sigma}$.

Green external strategy. Any firm opting for a *green external* strategy faces the demand $d_{ext}^i = \alpha L P^{\sigma-1}(\chi[A,\varepsilon]+1)(p_{ext}^i)^{-\sigma}$. Maximising the profit $\pi_{ext}[p_{ext}^i] = (F_\ell p_{ext}^i - T(\varphi^i)^{-1})\, q[p_{ext}^i] - F_a - f$, they set the optimal price $p_{ext}^i = \frac{\sigma}{\sigma-1}\frac{T}{F_\ell}(\varphi^i)^{-1}$. The expectation of a positive green price premium implies $\frac{T}{F_\ell} > 1$ but for the present analysis this assumption can be relaxed. Thus, the model allows for cheaper green varieties due to two factors, high productivity of producers and more efficient green technology.

Then the optimal profit is increasing and convex in φ and represented as

$$\pi_{ext}^{opt}[\varphi^i] = BP^{\sigma-1}\mathcal{E}(\varphi^i)^{\sigma-1} - F_a - f, \tag{3}$$

where $\mathcal{E} \equiv F_\ell^\sigma T^{1-\sigma}(\chi[A,\varepsilon]+1)$.

Green internal strategy. The demand for goods labelled with self-declarations is represented by $d_{int}^i = \alpha L P^{\sigma-1}(\chi[a^i,\varepsilon]+1)(p_{int}^i)^{-\sigma}$. Firms make the decision on price p^i, technological t^i and promotional a^i activities maximising the profits $\pi_{int}[p_{int}^i, a^i, t^i] = (p_{int}^i - t^i(\varphi^i)^{-1})\, q[p_{int}^i] - a^i - f$ s.t. $t^i \geq 1$, $a^i > 0$.[29] Accordingly,

[29]The function $\pi_{int}[p_{int}^i, a^i, t^i]$ is concave due the assumption of the eco-quality function concavity.

green internal firms set the optimal price $p^i_{int} = \frac{\sigma}{\sigma-1}(\varphi^i)^{-1}$ and make no additional technological changes $t^i = 1$ that is related to the *greenwashing* phenomena as a result of the lack of public monitoring assumption. They also choose the promotion activity according to $BP^{\sigma-1}\chi'_a[a^i, \varepsilon](\varphi^i)^{\sigma-1} = 1$, $a[0, \varepsilon] = 0$. The latter defines the function $a[\varphi, \varepsilon]$ as increasing in $\varphi > 0$ (Appendix 10.1). Thus, more productive firms spend more on promotion.

Optimal profit that is increasing and convex (if $\sigma \geq 2$)[30] in φ is represented as

$$\pi^{opt}_{int}[\varphi^i] = BP^{\sigma-1}(\chi[a[\varphi^i, \varepsilon], \varepsilon] + 1)(\varphi^i)^{\sigma-1} - a[\varphi^i, \varepsilon] - f \tag{4}$$

6.2 Environmental Market Segmentation

The relative parameters of the VEPs determine the environmental structure of the market. Let's consider the environmentally-mixed case with non-empty sets of firms implementing each type of eco-strategy. Then the profit functions (2) - (4) yield the following productivity composition (Figure 3):

- the least productive firms with productivity $\varphi \in [\varphi^*_b, \varphi^*_{gm}]$ remain brown;[31]
- lower-middle productive firms with productivity $\varphi \in [\varphi^*_{gm}, \varphi^*_e]$ introduce green internal programmes;[32]
- upper-middle productive firms with productivity $\varphi \in [\varphi^*_e, \varphi^*_{gl}]$ join green external programmes;[33]
- the most productive firms with productivity $\varphi \in [\varphi^*_{gl}, \infty)$ ("greenwashing leaders") introduce green internal programmes.

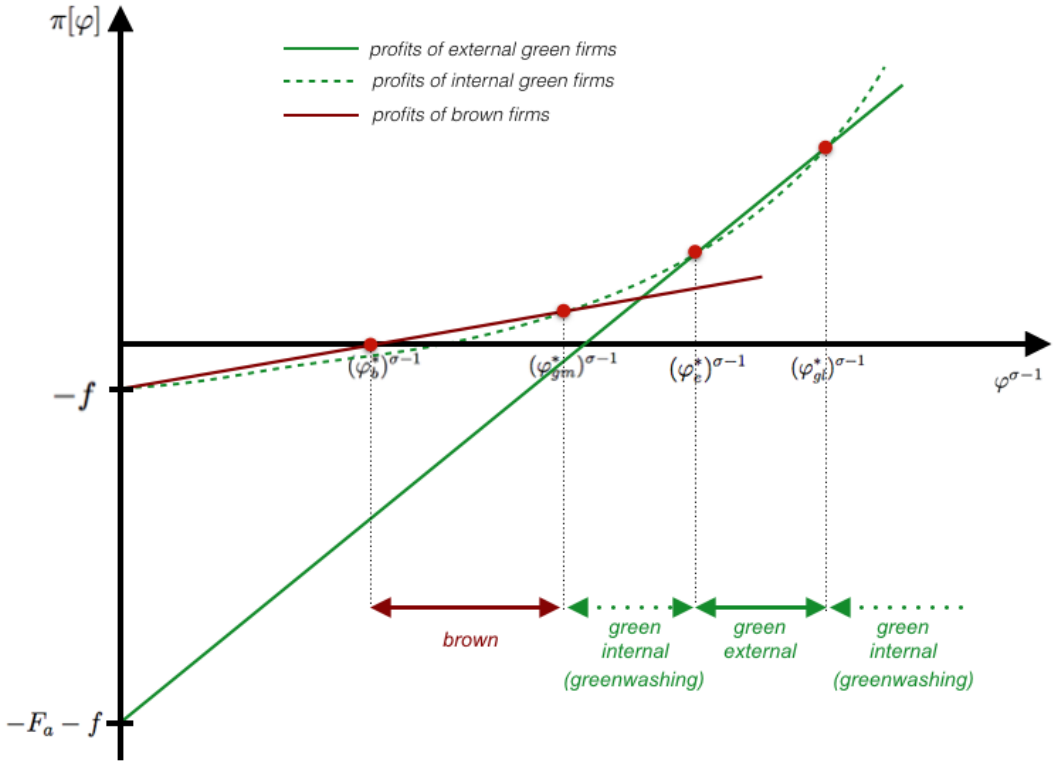
[30]The requirement that $\sigma \geq 2$ is an over-sufficient condition stems from the unique elasticity of substitution within and across green and brown sub-sectors assumption (see Appendix 10.2 for the details). It is also necessary to mention that regardless of the framework of this paper, empirical literature generally estimates the elasticity of substitution $\sigma > 2$ (see, for example, Disdier and Head (2008), Head and Mayer (2014)).

[31]The sub-sector exists if $\pi^{opt}_b[\varphi^*_b] > \pi^{opt}_{gm}[\varphi^*_b]$ which implies relatively low returns on promotion expenditures.

[32]The sub-segment exists if $\forall\varphi \in (\varphi^*_{gm}, \varphi^*_e)$, $\pi^{opt}_{int}[\varphi] > \pi^{opt}_b[\varphi]$, $\pi^{opt}_{int}[\varphi] > \pi^{opt}_{ext}[\varphi]$ which implies $f < \frac{a[\varphi,\varepsilon]}{\chi[a[\varphi,\varepsilon],\varepsilon]} < \frac{F_a}{\mathcal{E}[\varepsilon]-1}$. Thus, fixed expenditures on VEP correspond to higher returns of promotion expenditures within green internal relative to green external labelling.

[33]The sub-segment exists if $\forall\varphi \in (\varphi^*_e, \varphi^*_{gl})$, $\pi^{opt}_{ext}[\varphi] > \pi^{opt}_{int}[\varphi]$ which implies $\mathcal{E} \geq \chi[a[\varphi, \varepsilon], \varepsilon]+1$, $F_a \geq a[\varphi, \varepsilon]$, and returns of promotion expenditures within green internal relative to green external labelling are lower $\frac{a[\varphi,\varepsilon]}{\chi[a[\varphi,\varepsilon],\varepsilon]} > \frac{F_a}{\mathcal{E}[\varepsilon]-1}$.

Figure 3: *Environmental Market Segmentation in Autarky*



The cutoff productivities are determined by a brown segment zero profit condition (ZPC) and a set of indifference conditions (IC) for each green sub-segment such that

$$ZPC \qquad \pi_b^{opt}[\varphi_b^*] = 0 \tag{5}$$

$$IC_{gm} \qquad \pi_{int}^{opt}[\varphi_{gm}^*] = \pi_b^{opt}[\varphi_{gm}^*] \tag{6}$$

$$IC_e \qquad \pi_{ext}^{opt}[\varphi_e^*] = \pi_{int}^{opt}[\varphi_e^*] \tag{7}$$

$$IC_{gl} \qquad \pi_{int}^{opt}[\varphi_{gl}^*] = \pi_{ext}^{opt}[\varphi_{gl}^*] \tag{8}$$

The average productivity within each segment and sub-segment can be represented as a weighted average such that $\widetilde{\varphi}_{lr}^{\sigma-1} = \frac{1}{G(\varphi_r^*)-G(\varphi_l^*)} \int_{\varphi_l^*}^{\varphi_r^*} \varphi^{\sigma-1} dG[\varphi]$, where φ_l^* and φ_r^* denote the minimum and maximum productivity cutoffs within the sub-segment respectively.

The model assumes firms' free entry that drives ex-ante expected profits to the market entry costs:

$$\begin{aligned}\int_{\varphi_b^*}^{\varphi_{gm}^*} \pi_b^{opt}[\varphi] dG[\varphi] + \int_{\varphi_{gm}^*}^{\varphi_e^*} \pi_{int}^{opt}[\varphi] dG[\varphi] + \\ \int_{\varphi_e^*}^{\varphi_{gl}^*} \pi_{ext}^{opt}[\varphi] dG[\varphi] + \int_{\varphi_{gl}^*}^{\infty} \pi_{int}^{opt}[\varphi] dG[\varphi] = f_{entry}\end{aligned} \tag{9}$$

By plugging (5) into (6)-(9), I obtain four equations that allow to determine the cutoff and average productivities in all segments and sub-segments in the market (Appendix 10.3).

6.3 Stationary Equilibrium

Stationary equilibrium requires the labor market to be clear over time. Industry C spends on labor $(1-\alpha)L$ and the dirty industry D αL. Then the labor market clearing condition is represented as

$$\alpha L = L_b[M_b, \varphi_b^*, \varphi_{gm}^*] + L_{gm}[M_{gm}, \varphi_{gm}^*, \varphi_e^*] + L_e[M_e, \varphi_e^*, \varphi_{gl}^*] + L_{gl}[M_{gl}, \varphi_{gl}^*] + L_{entry}, \tag{10}$$

where $L_k[M_k, \varphi_l^*, \varphi_r^*]$ and M_k, $k = b, gm, e, gl$, represent aggregate labour input and mass of firms within the market sub-segment bounded by productivities φ_l^* and φ_r^*, $\varphi_l^* \leq \varphi_r^*$. Accordingly, the mass of producing firms is defined as

$$M = M_b[M] + M_{gm}[M] + M_e[M] + M_{gl}[M] \tag{11}$$

such that

$$M_k = \frac{G[\varphi_r^*] - G[\varphi_l^*]}{1 - G[\varphi_b^*]} M, \quad k = b, gm, e, gl \tag{12}$$

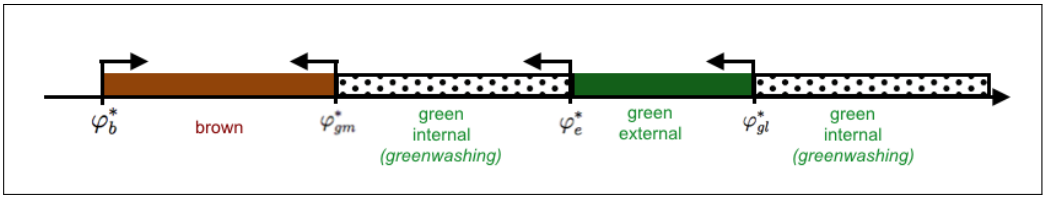
L_{entry} denotes the labor required to cover the sunk costs of entering firms such that $L_{entry} = f_{entry} M_{entry}$, where f_{entry} represents fixed entrance costs, and M_{entry} is a mass of entrants such that $M = (1 - G[\varphi_b^*]) M_{entry}$.

Accordingly, labor market clearing condition (10) allows to define the total mass of varieties available in the market.

6.4 Comparative Statics

A comparative statics analysis shows, first, that the eco-concerns growth increases a brown sub-segment cutoff productivity implying more productive firms serving the market. Meanwhile, the green cutoffs decrease in all sub-segments. Moreover, the model shows that the "productivity windows" for all environmentally-pronounced segments increase, leading to less productive firms supplying green varieties (Figure 4). The third result indicates the changes in average productivity across and within segments. Thus, eco-appreciation growth leads to lower average efficiency within brown and green segments. The impact within the green sub-segments depends on the productivity distribution. The only exception is the sub-segment of greenwashing leaders that faces the decline in average productivity. Meanwhile, the market becomes more productive overall (Appendix 10.4).

Figure 4: *Productivity Composition in Autarky*
(arrows indicate the direction of cutoff productivities' motion occurring with eco-appreciation growth)



7 Open Economy

Now let's consider trade integration of countries X and Y. The countries are identical in all parameters except eco-appreciation $\varepsilon_X \neq \varepsilon_Y$. Export implies symmetric iceberg transport costs $\tau_X = \tau_Y = \tau$, such that a fraction $\tau \in (0, 1]$ of a traded good arrives to its destination. The model also assumes zero fixed exporting costs, hence, within trade integration all firms export. Upon opening to trade, firms follow the same environmental strategy in both markets.

7.1 Environmental Strategies

Brown strategy. Any brown firm in country X trading with country Y sets the prices $p^i_{bXX} = \frac{\sigma}{\sigma-1}(\varphi^i)^{-1}$ and $p^i_{bXY} = \tau^{-1}p^i_{bXX}$ to sell at home and abroad respectively. Accordingly, the optimal profit is represented as

$$(\pi_X)^{opt}_b[\varphi^i] = B\left(P_X^{\sigma-1} + \omega P_Y^{\sigma-1}\right)(\varphi^i)^{\sigma-1} - f, \tag{13}$$

where P_X and P_Y denote eco-quality adjusted CES price indexes of varieties sold in the markets of country X and Y respectively and $\omega \equiv \tau^{\sigma-1}$ is a measure of trade openness.

Green external strategy. Upon opening to international trade any firm adopting a green external strategy in country X sets profit maximising prices at home $p^i_{extXX} = \frac{\sigma}{\sigma-1}\frac{T}{F_\ell}(\varphi^i)^{-1}$ and abroad $p^i_{extXY} = \tau^{-1}p^i_{extXX}$ and faces the optimal profit

$$(\pi_X)^{opt}_{ext}[\varphi^i] = B\left\{P_X^{\sigma-1}\mathcal{E}_X + \omega P_Y^{\sigma-1}\mathcal{E}_Y\right\}(\varphi^i)^{\sigma-1} - F_a - f \tag{14}$$

Green internal strategy. Any green internal firm in the open economy optimally sets the prices $p^i_{intXX} = \frac{\sigma}{\sigma-1}(\varphi^i)^{-1}$ and $p^i_{intXY} = \tau^{-1}p^i_{intXX}$, makes no technological efforts $t^i = 1$, and chooses the promotional activity in accordance with the promotion function $a_X[\varphi^i, \varepsilon_X, \varepsilon_Y, \omega]$ such that

$$B\left\{P_X^{\sigma-1}\chi_a^{'}[a, \varepsilon_X] + \omega P_Y^{\sigma-1}\chi_a^{'}[a, \varepsilon_Y]\right\}\varphi^{\sigma-1} = 1 \tag{15}$$

The promotion function increases in all its arguments including the openness to trade parameter (Appendix 10.5). The latter implies that promotion activity is also increasing with trade integration.

Then the optimal profit is represented as follows

$$(\pi_X)^{opt}_{int}[\varphi^i] = B\left\{P_X^{\sigma-1}(\chi[a^i_X, \varepsilon_X] + 1) + \omega P_Y^{\sigma-1}(\chi[a^i_X, \varepsilon_Y] + 1)\right\}(\varphi^i)^{\sigma-1} - a^i_X - f \tag{16}$$

Following the over-sufficient assumption $\sigma \geq 2$ as in autarky, the profit function is increasing and convex in φ (Appendix 10.6).

7.2 Environmental Market Segmentation

The relative parameters of the VEPs determine the same four segments in industry D, defined by the following set of indifference equations

$$IC_{gmX} \qquad (\pi_X)^{opt}_{int}[\varphi^*_{gmX}] = (\pi_X)^{opt}_{b}[\varphi^*_{gmX}] \tag{17}$$

$$IC_{eX} \qquad (\pi_X)^{opt}_{ext}[\varphi^*_{eX}] = (\pi_X)^{opt}_{int}[\varphi^*_{eX}] \tag{18}$$

$$IC_{glX} \qquad (\pi_X)^{opt}_{int}[\varphi^*_{glX}] = (\pi_X)^{opt}_{ext}[\varphi^*_{glX}] \tag{19}$$

and a free entry condition

$$\begin{aligned} &\int_{\varphi^*_{bX}}^{\varphi^*_{gmX}} (\pi_X)^{opt}_{b}[\varphi] dG[\varphi] + \int_{\varphi^*_{gmX}}^{\varphi^*_{eX}} (\pi_X)^{opt}_{int}[\varphi] dG[\varphi] \\ &+ \int_{\varphi^*_{eX}}^{\varphi^*_{glX}} (\pi_X)^{opt}_{ext}[\varphi] dG[\varphi] + \int_{\varphi^*_{glX}}^{\infty} (\pi_X)^{opt}_{int}[\varphi] dG[\varphi] = f_{entry} \end{aligned} \tag{20}$$

assuming the zero profit condition $(\pi_X)^{opt}_{b}[\varphi^*_{bX}] = 0$ to hold (Appendix 10.7).

7.3 Stationary Equilibrium

The labor market clearing condition is analogous to the autarky case and represented as

$$\begin{aligned} \alpha L = {} & L_b[M_{bX}, \varphi^*_{bX}, \varphi^*_{gmX}] + L_{gmX}[M_{gmX}, \varphi^*_{gmX}, \varphi^*_{eX}] \\ & + L_{eX}[M_{eX}, \varphi^*_{eX}, \varphi^*_{glX}] + L_{glX}[M_{glX}, \varphi^*_{glX}] + \frac{f_{entry} M_X}{1 - G[\varphi^*_{bX}]} \end{aligned} \tag{21}$$

Substituting the masses of firms within each sub-segment according to (12), the condition (21) allows me to define the aggregate number of varieties produced in each country.

7.4 Comparative Statics

To study the eco-labelling effects in open economy let's consider two countries, $\mathcal{G}$ and $\mathcal{B}$, such that $\varepsilon_{\mathcal{G}} > \varepsilon_{\mathcal{B}}$: consumers in country $\mathcal{G}$ are more environmentally concerned than in country $\mathcal{B}$. Accordingly, $\varphi^*_{b\mathcal{G}} > \varphi^*_{b\mathcal{B}}$, $\varphi^*_{gm\mathcal{G}} < \varphi^*_{gm\mathcal{B}}$, $\varphi^*_{e\mathcal{G}} <$

$\varphi^*_{e\mathcal{B}}$, $\varphi^*_{gl\mathcal{G}} < \varphi^*_{gl\mathcal{B}}$. Thus, the brown segment is wider in the less eco-concerned country while the overall green segment is wider in the more eco-concerned country. The composition of green sub-segments depends on the eco-appreciation difference across economies.

Table 3: *Comparative Statics in Open Economy: cutoff productivity*

	Brown segment cutoff productivity		**Green segment cutoff productivity***	
	Country $\mathcal{G}$	Country $\mathcal{B}$	Country $\mathcal{G}$	Country $\mathcal{B}$
(1) Countries with identical eco-preferences: trade effects	0		0	
(2) Countries with different eco-preferences: trade effects	$\Downarrow$	$\Uparrow$	$\Uparrow$	$\Downarrow$
(3) Trade integration: eco-difference growth effects	$\Uparrow$	$\Uparrow$	$\Downarrow$	$\Downarrow$

* The comparative statics is analogous for all green sub-segments. See Appendix 10.8 for the details.

Note: In the first two cases, country $\mathcal{G}$ is considered to be more eco-concerned than country $\mathcal{B}$. In the third case, country $\mathcal{G}$ experiences an increase in eco-bias while eco-concerns in country $\mathcal{B}$ remain unchanged.

The productivity effects are determined by two factors, trade integration and eco-heterogeneity across countries. To disentangle the impact of each factor let's consider the three following steps. First, let's investigate trade between eco-homogeneous countries - a case that is well-studied in the literature. Second, let's analyse the general effect of trade integration across eco-heterogeneous countries. And finally, let's focus on the influence of the eco-distance between countries to the dynamics of productivity changes in open economy (Tables 3 and 4, Appendix 10.8).

(1) Trade integration of countries with identical eco-preferences. In the departure case the model delivers the well-known result: when the countries are eco-homogeneous and the fixed exporting costs are zero, trade integration does not influence the cutoff and average productivity.

Table 4: *Comparative Statics in Open Economy: average productivity*

	Brown average productivity		**Green average productivity***		**Market average productivity**	
	Country $\mathcal{G}$	Country $\mathcal{B}$	Country $\mathcal{G}$	Country $\mathcal{B}$	Country $\mathcal{G}$	Country $\mathcal{B}$
(1) Countries with identical eco-preferences: trade effects	0		0		0	
(2) Countries with different eco-preferences: trade effects	$\Uparrow$	$\Downarrow$	$\Uparrow$	$\Downarrow$	$\Downarrow$	$\Uparrow$
(3) Trade integration: eco-difference growth effects	$\Downarrow$	$\Downarrow$	$\Downarrow$	$\Downarrow$	$\Uparrow$	$\Uparrow$

*The comparative statics is analogous for the greenwashing leaders sub-segment. The direction of average productivity changes within greenwashing lower-middle productive and green external sub-segments depend on the particular form of the eco-quality function and the productivity distribution. See Appendix 10.8 for the details.

Note. In the first two cases country $\mathcal{G}$ is considered to be more eco-concerned than country $\mathcal{B}$. In the third case country $\mathcal{G}$ experiences an increase in eco-bias while eco-concerns in country $\mathcal{B}$ remain unchanged.

(2) Trade integration of countries with different eco-preferences. The second case reflects the overall effect of international trade in the model investigating the productivity effects when the countries are identical in all dimensions except their eco-concerns.

Before opening to trade, the green market is relatively more efficient in country $\mathcal{B}$ while in country $\mathcal{G}$ green biased consumers attract more firms to introduce the VEP. At the same time, brown market productivity cutoff is lower in country $\mathcal{B}$. Trade integration causes opposite effects, conditionally, on the national eco-appreciation level. Upon opening to trade less efficient green producers of country $\mathcal{G}$ are forced to leave the green sector that is in line with the well-known effect of trade integration. On the contrary, the green sector in country $\mathcal{B}$ enlarges due to the new opportunities of the relatively more green-biased demand in country $\mathcal{G}$. As a result, the green sector in country $\mathcal{G}$ shrinks becoming more efficient while green sector in country $\mathcal{B}$ expands attracting new, less efficient firms.

The effects in the brown market are opposite. Brown firms in country $\mathcal{B}$ leave the market through two exits: the least efficient quit the market (well-studied

effect of trade integration), the most efficient join the green VEP to benefit from the expansion to county $\mathcal{G}$. As a result, the brown sector in country $\mathcal{B}$ shrinks. In country $\mathcal{G}$ due to trade integration producers get an access to the less eco-concerned market of country $\mathcal{B}$. Thus, it significantly increases the profits of brown firms in country $\mathcal{G}$ opening new opportunities for the least efficient firms to enter the market. As a result, the brown sector in country $\mathcal{G}$ expands.

The dynamics of average productivities is opposite across countries. Globalisation influences the average eco-appreciation level in the global economy. Thus, country $\mathcal{B}$ faces an increase in eco-concerns because of to trade integration with a more eco-concerned country $\mathcal{G}$. As a result, productivity effects coincide with the effects in autarky arising due to the growth of eco-concerns. The effects for the country $\mathcal{G}$ are the opposite.

(3) Eco-difference growth across trading countries. To explore the effects of increasing eco-heterogeneity across countries let's consider the case when the one trading country experiences a growth in eco-concerns while in the other they remains the same, such that $\varepsilon_{\mathcal{G}} = \varepsilon_{\mathcal{B}} + \Delta\varepsilon$, $\Delta\varepsilon > 0$.

Due to the overall increase in eco-concerns in the global economy, the results of the comparative statics analysis coincides with the analogous analysis in autarky with the growth of eco-concerns. Both countries face the increase of brown cutoff productivities and the decrease of green cutoff as well as average brown and green productivities. On average the market becomes more competitive and, hence, efficient due to the redistribution of firms across sub-segments.

8 Quantitative Analysis

The quantitative analysis of eco-labelling effects comprises two steps. First, let's focus on the productivity effects under the three cases analysed in the previous section. Second, I will extend the third stage of the comparative statics analysis in order to expose numerically the role of eco-heterogeneity in the open economy eliminating the impact of an overall increase in environmental concerns across trading countries.

8.1 Numerical Illustration of Qualitative Analysis

In order to illustrate the effects quantitatively, let's consider a reduced model with two environmental sub-sectors, brown and green, where the green sector is shaped by the external VEP. Then the structural model can be described by a set of four conditions: indifference and free entry, for each country, respectively (Appendix 10.9).

First, let's expose numerically the productivity effects under the three cases discussed in the previous section. To discover the impact I simulate the model allowing for elasticity of substitution between varieties $\sigma = [2, 6]$, Pareto productivity distribution with the shape $k = \sigma + 0.25$ and scale $\varphi_0 = 1$. All types of fixed costs of operation (f) and fixed entry costs (f_e) are normalised to 1. The country is populated by 1000 inhabitants (L).

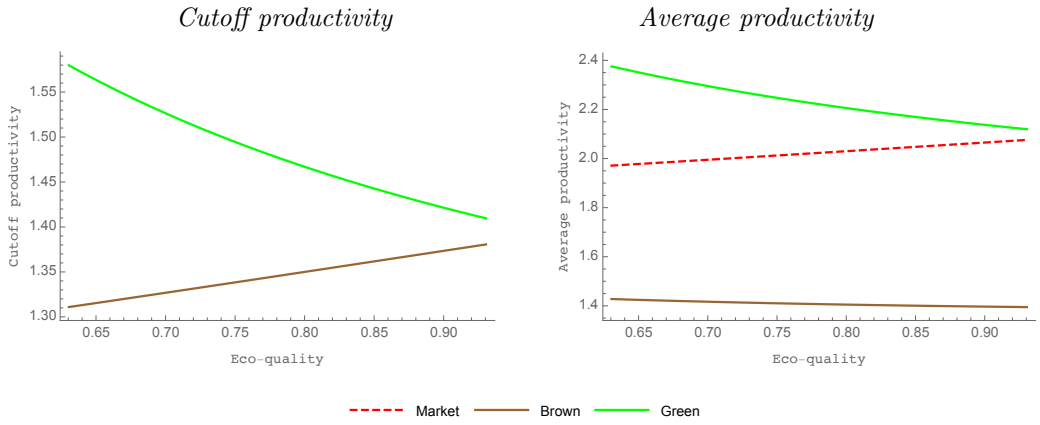
To determine the parameters of the external VEP I rely on the fee structure of the most significant European eco-labelling schemes such as *The Nordic Eco-Label* and *EU Ecolabel*, in which on average set the share of licence fees to $1 - F_\ell = 0.0015$. Annual fees F_a and the technological parameter T are determined by the assumption of the eco-heterogeneity of markets that requires $1 < \mathcal{E}_\mathcal{B} < \mathcal{E}_\mathcal{G} < F_a + 1$. The former also allows for $T < 1$ which is in line with the Porter hypothesis (Porter and van der Linde, 1995).

To illustrate the trade integration between countries with different eco-preferences, I assume the eco-appreciation parameter to be based on the results of Bjørner et al. (2004) who estimate the Danish consumers marginal willingness to pay for the *The Nordic Ecolabel* certified green products to be in the range of 13-18%[34]. Accordingly, $\chi_\mathcal{G} = 1.18^\sigma - 1$ and $\chi_\mathcal{B} = 1.13^\sigma - 1$.

The model simulated within the above determined ranges delivers similar outcomes for each set of parameters. Thus, I report the results for the case when $\sigma = 4$, $\mathcal{E}_\mathcal{B} = 1.15$, $\mathcal{E}_\mathcal{G} = 1.37$, $T = 1.05$, $F_a = 0.7$, $\tau = 0.5$. Figures (5) - (7) illustrate the quantitative analysis in the closed and open economy cases respectively. The results expose the comparative statics numerically. They additionally deliver the two following results. First, changes in eco-concerns yield a higher impact on

[34]Bjørner et al. (2004) base their estimations on the data of Danish market. Particularly, they estimate the consumers' willingness to pay for toilet paper, paper towels and detergents, certified by *The Nordic Ecolabel* in 1997-2001.

Figure 5: *Productivity Effects in the Market with Eco-labels in Autarky*



the green rather than on the brown productivity level, both cutoff and average. This finding adds one more explanation to the observed results. Second, they show the absolute differences in productivity changes due to the increase in eco-concerns across countries: the country with the growing environmental bias in preferences faces more significant effects in comparison with the country where the green bias remains on the same level.

8.2 Numerical Extension of Qualitative Analysis

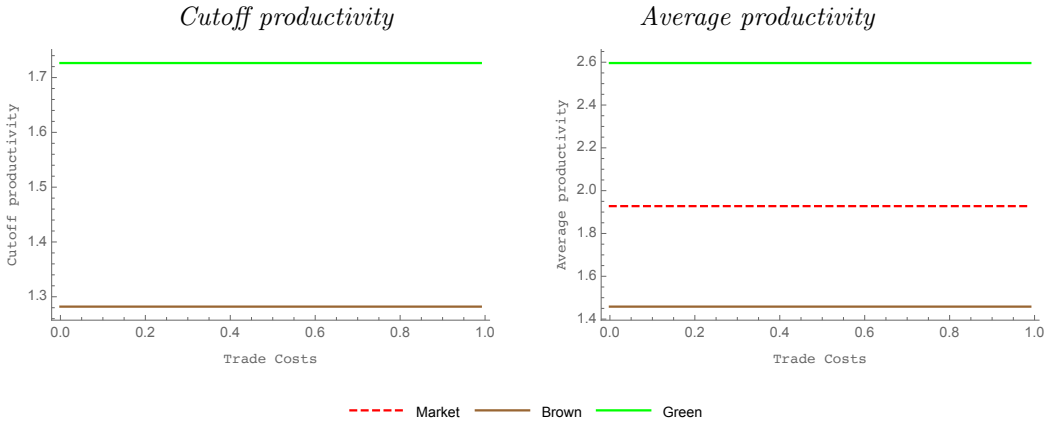
Let's extend the qualitative analysis results in order to isolate the effect of the global eco-heterogeneity growth. Comparative statics shows identical productivity effects across countries as a result of the increase in the overall eco-appreciation level. To eliminate this effect, let's investigate productivity effects when country-level green biases in consumers preferences change in a such a way that $\varepsilon_{\mathcal{G}} = \overline{\varepsilon}+\Delta\varepsilon_i$, $\varepsilon_{\mathcal{B}} = \overline{\varepsilon} - \Delta\varepsilon_j$, and

$$(D_{g\mathcal{G}}[\varepsilon_{\mathcal{G}}, \varepsilon_{\mathcal{B}}] + D_{g\mathcal{B}}[\varepsilon_{\mathcal{G}}, \varepsilon_{\mathcal{B}}])|_{\substack{\overline{\varepsilon}>0,\\ \Delta\varepsilon_i=0,\\ \Delta\varepsilon_j=0}} = (D_{g\mathcal{G}}[\varepsilon_{\mathcal{G}}, \varepsilon_{\mathcal{B}}] + D_{g\mathcal{B}}[\varepsilon_{\mathcal{G}}, \varepsilon_{\mathcal{B}}])|_{\substack{\overline{\varepsilon}>0,\\ \Delta\varepsilon_i>0,\\ \Delta\varepsilon_j>0}}, \qquad (22)$$

where $\overline{\varepsilon} > 0$ denotes the initial eco-concerns, and $D_{g\mathcal{G}}$ and $D_{g\mathcal{B}}$ are the aggregate spending on green varieties in countries $\mathcal{G}$ and $\mathcal{B}$ respectively. Accordingly, I assume the global green demand to remain constant despite changes in cross-country eco-concerns. Then the model can be described by a set of six conditions,

Figure 6: *Productivity Effects in the Market with Eco-labels Upon Trade Integration: Cases 1 and 2*

(1) Trade integration of eco-homogeneous countries.



(2) Trade integration of eco-heterogeneous countries

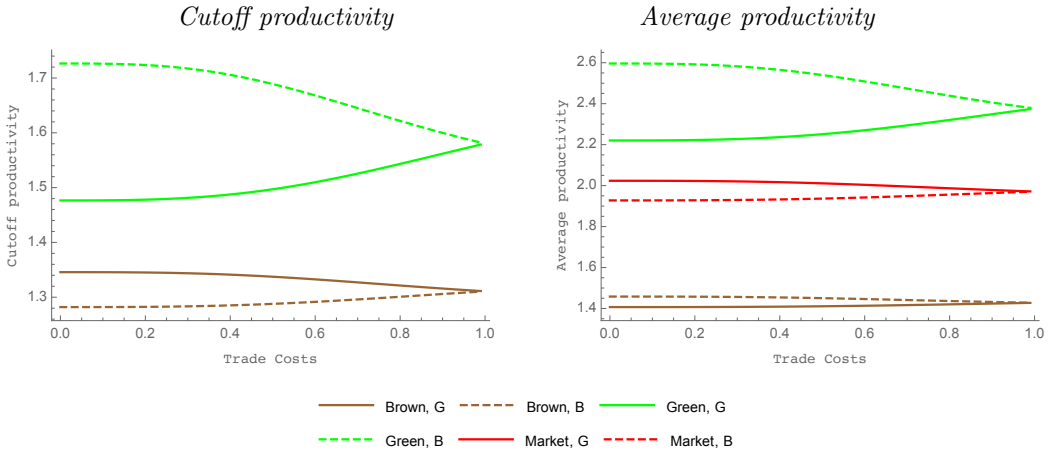
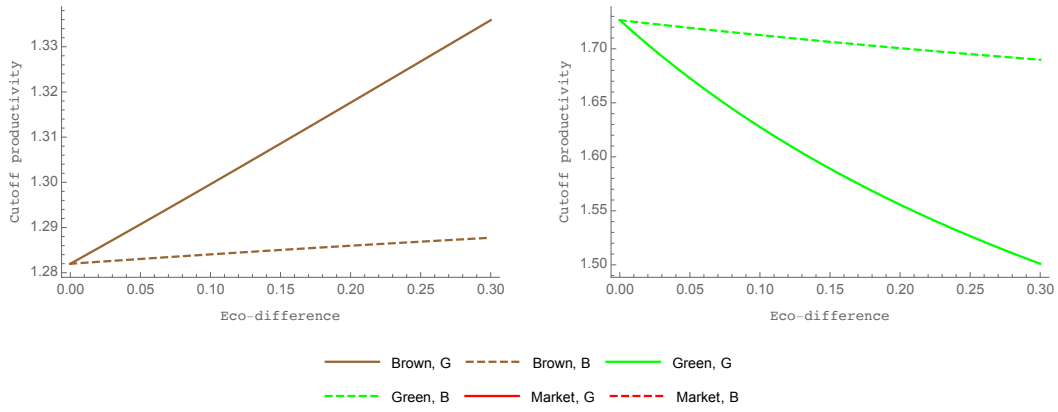


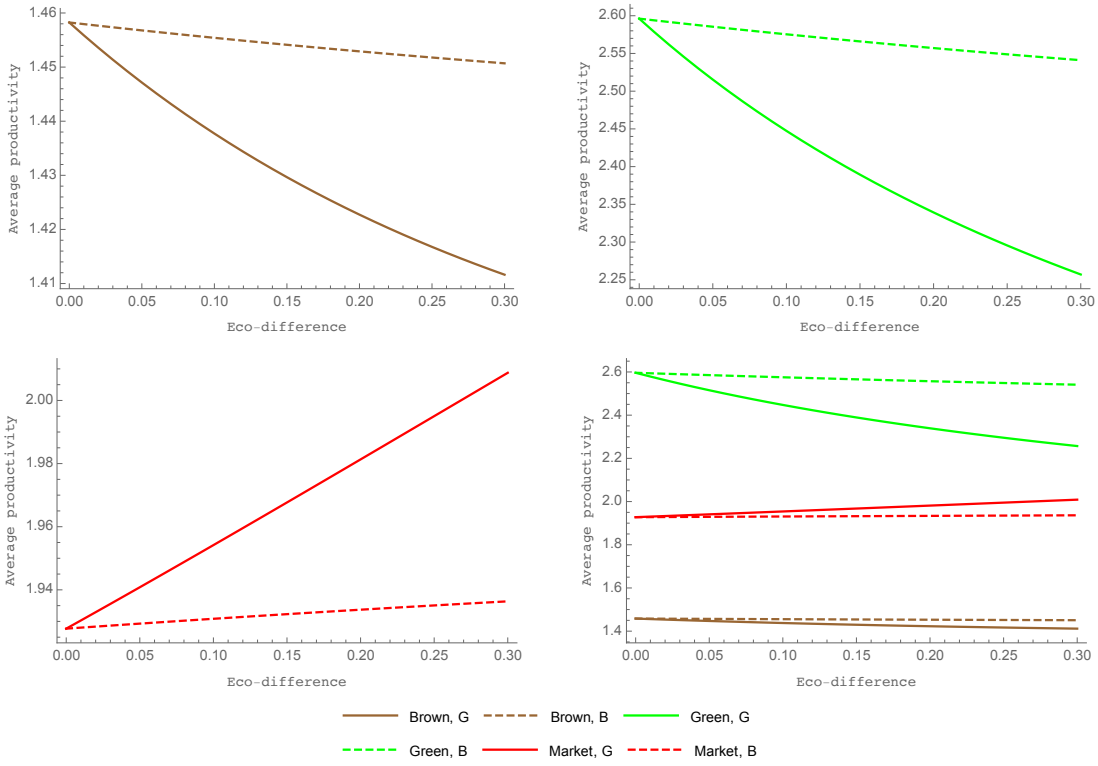
Figure 7: *Productivity Effects in the Market with Eco-labels Upon Trade Integration: Case 3*

(3) Eco-difference growth across trading countries

(3.A) Cutoff productivity

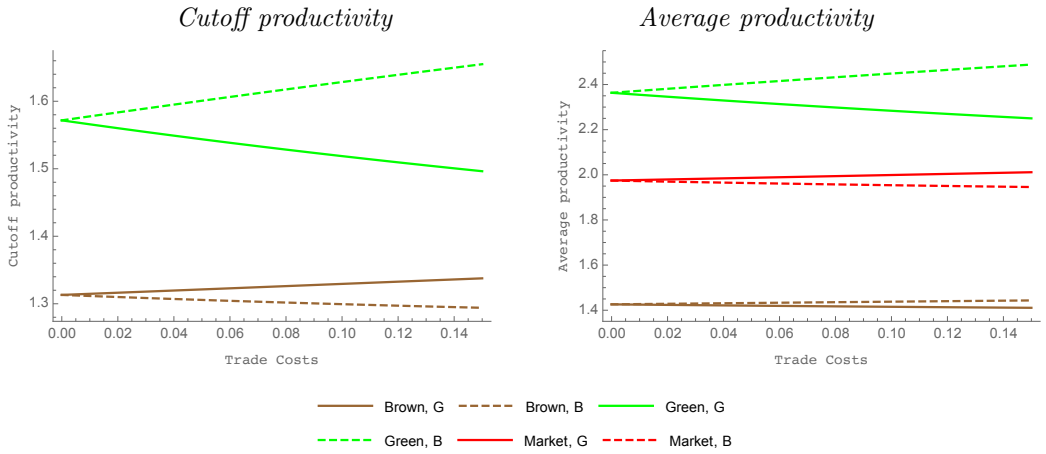


(3.B) Average productivity



Note. County $\mathcal{G}$ faces the increase in eco-appreciation while eco-concerns in country $\mathcal{B}$ remains the same.

Figure 8: *Productivity Effects in the Market with Eco-labels Upon Trade Integration: the effect of cross-country eco-heterogeneity growth while the global green demand remains constant*



indifference, free entry, and labor market clearance for each country respectively (Appendix 10.10).

A quantitative analysis demonstrates the positive relationship between eco-concerns and market efficiency in the open economy (Figure 8). The results are similar to the case of increasing eco-concerns in autarky.

9 Discussion and Conclusion

This research aims at bridging the gap between international economics and environmental sociology findings: it enriches a widely used framework of heterogeneous firms within trade integration by introducing the eco-quality concept. 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 study considers eco-labelling a tool of current importance to study for several reasons. First, this type of policy 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" and 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). It explores a range of productivity effects arising with VEPs in the market with autarky and upon opening to trade and discloses the impact of the eco-awareness level across countries. The results of the research can be generally aggregated into the three following parts.

First, 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 VEPs the research explores a polarisation of voluntary environmental programmes such that:

- the lower-middle productive firms introduce an internal VEP (Type II) while they still find it too expensive to join the external VEP (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 VEPs;

- the upper-middle segment of the market corresponds to more efficient firms who can afford to join an external VEP (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[35].

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

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

Firms choose VEPs 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 ExxonMobil who funded climate change deniers despite having received evidence of the causality between fossil fuels and climate change[36], or the Volkswagen group who used the software to provide false positive results of diesel engines environmental tests[37].

The second strand of obtained results shows that eco-labelling yields additional productivity effects in autarky. Eco-bias preferences toughen the market competition. As a result, industries in the countries with a higher eco-awareness level are relatively more productive in comparison with less eco-aware countries. Meanwhile, both sectors are served by, on average, less efficient producers. The effect is observed because of the mass of firms redistributed across segments as well as the relatively more significant changes to the green cutoff productivity levels in comparison with the brown.

Finally, the model illustrates the impact of globalisation that depends on relative eco-appreciation across countries. In general, trade integration across eco-heterogeneous countries boosts efficiency benefits for a relatively less eco-concerned country, while in a relatively more eco-concerned country, globalisation decreases average productivity in the market. Meanwhile, the effects within brown and green sectors are opposite reflecting the firms redistribution across segments.

Accordingly, the research emphasises the role of eco-concerns as a tool to influence market efficiency. The results show the importance of developing eco-awareness in society. But at the same time it shows that, combined with insufficient public monitoring, consumers eco-bias is capable of widening the niche for greenwashing programmes. As a result, greenwashing practices can disseminate quickly, discrediting the green product concept and diminishing the corresponding positive effects. Consequently, the growth of eco-concerns should be supported by a systematical monitoring of the quality of green products.

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

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

At 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.[38] 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 VEPs originating out with promotional activity. Thus, eco-labels of Type I supported by NGOs might be considered more credible in comparison with self-declarations.

Finally, the existence of greenwashing leaders can be questioned taking into high possible reputation risks facing by big companies in case of greenwashing as well as the potential harm for the careers of managers (Schwarcz, 2017). Accordingly, high probability of disclosure can prevent firms, especially the leaders, from environmental cheating.

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. Among the range of theoretical extensions, it may be also valuable to consider public monitoring that can deter firms from greenwashing. One can also introduce the damage function

[38]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.

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.

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10 Appendix

10.1 Green internal promotion function in autarky

The promotion function of a green internal firm in autarky $a[\varphi, \varepsilon]$ is represented as

$$BP^{\sigma-1}\chi_a^{'}[a^i, \varepsilon](\varphi^i)^{\sigma-1} = 1 \tag{23}$$

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

$$\frac{da^i}{d\varphi^i} = (1-\sigma)\frac{\chi_a'[a^i, \varepsilon]}{\varphi^i \chi_{aa}^{''}[a^i, \varepsilon]} > 0 \tag{24}$$

$$\frac{da^i}{d\varepsilon} = -\frac{\chi_{a\varepsilon}^{''}[a^i, \varepsilon]}{\chi_{aa}^{''}[a^i, \varepsilon]} > 0, \tag{25}$$

where $\chi[a, \varepsilon] \equiv \chi[a[\varphi, \varepsilon], \varepsilon]$.

10.2 Optimal profit of a green internal firm in autarky

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

$$\pi_{int}^{opt}[\varphi^i] = BP^{\sigma-1}(\chi[a^i, \varepsilon] + 1)(\varphi^i)^{\sigma-1} - a[\varphi^i, \varepsilon] - f \tag{26}$$

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

$$\frac{d\pi_{int}^{opt}[\varphi^i]}{d\varphi^i} = BP^{\sigma-1}(\sigma-1)(\chi[a^i, \varepsilon] + 1)(\varphi^i)^{\sigma-2} > 0 \tag{27}$$

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

$$\frac{d^2\pi_{int}^{opt}[\varphi^i]}{d(\varphi^i)^2} = BP^{\sigma-1}(\sigma-1)(\varphi^i)^{\sigma-3}(\chi[a^i, \varepsilon] + 1)\left\{(\sigma-2) - (\sigma-1)\frac{X_a}{\mathcal{X}_a}\right\}, \tag{28}$$

where $X_a \equiv \frac{a\chi_a'[a,\varepsilon]}{\chi[a,\varepsilon]+1}$ and $\mathcal{X}_a \equiv \frac{a\chi_{aa}^{''}[a,\varepsilon]}{\chi_a'[a,\varepsilon]}$ denote the elasticity of the eco-quality shifter and the elasticity of the slope of the eco-quality shifter respectively. Thus, if

$$\sigma > 1 + \frac{1}{1 - \frac{X_a}{\mathcal{X}_a}} \tag{29}$$

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 $\sigma < 1 + \frac{1}{1-\frac{\chi_a}{\chi_a'}}$ 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 programmes seem to be inefficient to influence the behaviour of consumers.

10.3 Productivity composition in autarky

Productivity composition in autarky is based on indifference (6)- (8), and free entry (9) conditions and the green internal segment relationship $f(\varphi_b^*)^{1-\sigma}\chi_a'[a^i,\varepsilon](\varphi^i)^{\sigma-1} = 1$:

$$(\chi_a'[a_{gm}^*,\varepsilon])^{-1} = \frac{a[\varphi_{gm}^*,\varepsilon]}{\chi[a_{gm}^*,\varepsilon]} \tag{30}$$

$$(\chi_a'[a_e^*,\varepsilon])^{-1} = \frac{F_a - a[\varphi_e^*,\varepsilon]}{\mathcal{E} - \chi[a_e^*,\varepsilon] - 1} \tag{31}$$

$$(\chi_a'[a_{gl}^*,\varepsilon])^{-1} = \frac{a[\varphi_{gl}^*,\varepsilon] - F_a}{\chi[a_{gl}^*,\varepsilon] + 1 - \mathcal{E}} \tag{32}$$

$$\begin{aligned} &f(\varphi_b^*)^{1-\sigma}\left\{\int_{BR}\varphi^{\sigma-1}dG[\varphi] + \int_{GW}(\chi[a,\varepsilon]+1)\varphi^{\sigma-1}dG[\varphi]\right. \\ &\left.+\mathcal{E}\int_{GE}\varphi^{\sigma-1}dG[\varphi]\right\} - \int_{GW}a[\varphi,\varepsilon]dG[\varphi] \\ &- f(1-G[\varphi_b^*]) - F_a(G[\varphi_{gl}^*] - G[\varphi_e^*]) = f_{entry}, \end{aligned} \tag{33}$$

where BR, GW, and GE stand for the brown, greenwashing, and green external segments respectively.

10.4 Comparative statics in autarky

Cutoff productivity. The eco-quality function $a[\varphi, \varepsilon]$ such that $f(\varphi_b^*)^{1-\sigma}\chi_a^{'}[a,\varepsilon]\varphi^{\sigma-1} = 1$, three indifference conditions (6)-(8), and free entry condition (9) allow for the comparative statics analysis.

- Brown segment

$$\frac{d\varphi_b^*}{d\varepsilon} = \varphi_b^* \frac{\int_{GW} \frac{\chi_\varepsilon^{'}[a,\varepsilon]}{\chi_a^{'}[a,\varepsilon]} dG[\varphi] + \mathcal{E}_\varepsilon^{'} \int_{GE} \varphi^{\sigma-1} dG[\varphi]}{(\sigma-1)I} > 0, \tag{34}$$

where $I \equiv \int_{BR} \varphi^{\sigma-1} dG[\varphi] + \int_{GW} (\chi[a,\varepsilon]+1)\varphi^{\sigma-1} dG[\varphi] + \mathcal{E} \int_{GE} \varphi^{\sigma-1} dG[\varphi]$.

- Greenwashing lower-middle productive firms sub-segment

$$\frac{d\varphi_{gm}^*}{d\varepsilon} = \frac{\varphi_{gm}^*}{(1-\sigma).\chi_a^{'}[a_{gm}^*,\varepsilon]} \frac{\chi_\varepsilon^{'}[a_{gm}^*,\varepsilon]}{a[\varphi_{gm}^*,\varepsilon]} < 0 \tag{35}$$

- Green external firms sub-segment

$$\frac{d\varphi_e^*}{d\varepsilon} = \frac{\varphi_e^*}{(1-\sigma).\chi_a^{'}[a_e^*,\varepsilon]} \frac{\mathcal{E}_\varepsilon^{'} - \chi_\varepsilon^{'}[a_e^*,\varepsilon]}{F_a - a[\varphi_e^*,\varepsilon]} < 0 \tag{36}$$

- Greenwashing leading firms sub-segment

$$\frac{d\varphi_{gl}^*}{d\varepsilon} = \frac{\varphi_{gl}^*}{(1-\sigma).\chi_a^{'}[a_{gl}^*,\varepsilon]} \frac{\chi_\varepsilon^{'}[a_{gl}^*,\varepsilon] - \mathcal{E}_\varepsilon^{'}}{a[\varphi_{gl}^*,\varepsilon] - F_a} < 0 \tag{37}$$

Due to the assumption of the eco-quality function $\chi[a,\varepsilon]$ concavity, one can obtain

$$\frac{\chi_\varepsilon^{'}[a_{gm}^*,\varepsilon]}{a[\varphi_{gm}^*,\varepsilon]} \geq \frac{\mathcal{E}_\varepsilon^{'} - \chi_\varepsilon^{'}[a_e^*,\varepsilon]}{F_a - a[\varphi_e^*,\varepsilon]} \geq \frac{\chi_\varepsilon^{'}[a_{gl}^*,\varepsilon] - \mathcal{E}_\varepsilon^{'}}{a[\varphi_{gl}^*,\varepsilon] - F_a} \tag{38}$$

Accordingly,

$$\left|\frac{d\varphi_{gm}^*}{d\varepsilon}\right| \geq \left|\frac{d\varphi_e^*}{d\varepsilon}\right| \geq \left|\frac{d\varphi_{gl}^*}{d\varepsilon}\right| \tag{39}$$

Average productivity.

- Brown segment

$$\begin{aligned}\frac{d\widetilde{\varphi}_b}{d\varepsilon} = \frac{\widetilde{\varphi}_b^{2-\sigma}}{\sigma-1}\frac{1}{G[\varphi^*_{gm}]-G[\varphi^*_b]}\Bigg(&g[\varphi^*_b]\frac{d\varphi^*_b}{d\varepsilon}\left\{(\varphi^*_b)^{\sigma-1}-(\widetilde{\varphi}_b)^{\sigma-1}\right\}\\ &+g[\varphi^*_{gm}]\frac{d\varphi^*_{gm}}{d\varepsilon}\left\{(\varphi^*_{gm})^{\sigma-1}-(\widetilde{\varphi}_b)^{\sigma-1}\right\}\Bigg)\\ <0\end{aligned} \tag{40}$$

- Greenwashing lower-middle productive firms sub-segment

$$\begin{aligned}\frac{d\widetilde{\varphi}_{gm}}{d\varepsilon} = \frac{\widetilde{\varphi}_{gm}^{2-\sigma}}{\sigma-1}\frac{1}{G[\varphi^*_e]-G[\varphi^*_{gm}]}\Bigg(&g[\varphi^*_{gm}]\frac{d\varphi^*_{gm}}{d\varepsilon}\left\{(\varphi^*_{gm})^{\sigma-1}-(\widetilde{\varphi}_{gm})^{\sigma-1}\right\}\\ &+g[\varphi^*_e]\frac{d\varphi^*_e}{d\varepsilon}\left\{(\varphi^*_e)^{\sigma-1}-(\widetilde{\varphi}_{gm})^{\sigma-1}\right\}\Bigg)\end{aligned} \tag{41}$$

Thus, the effect depends on the type of productivity distribution and the form of the eco-quality function.

- Green external firms sub-segment

$$\begin{aligned}\frac{d\widetilde{\varphi}_e}{d\varepsilon} = \frac{\widetilde{\varphi}_e^{2-\sigma}}{\sigma-1}\frac{1}{G[\varphi^*_{gl}]-G[\varphi^*_e]}\Bigg(&g[\varphi^*_e]\frac{d\varphi^*_e}{d\varepsilon}\left\{(\varphi^*_e)^{\sigma-1}-(\widetilde{\varphi}_e)^{\sigma-1}\right\}\\ &+g[\varphi^*_{gl}]\frac{d\varphi^*_{gl}}{d\varepsilon}\left\{(\varphi^*_{gl})^{\sigma-1}-(\widetilde{\varphi}_e)^{\sigma-1}\right\}\Bigg)\end{aligned} \tag{42}$$

As before, the effect depends on the type of productivity distribution and the form of the eco-quality function.

- Greenwashing leading firms sub-segment

$$\frac{d\widetilde{\varphi}_{gl}}{d\varepsilon} = \frac{\widetilde{\varphi}_{gl}^{2-\sigma}}{\sigma-1}\frac{1}{1-G[\varphi^*_{gl}]}g[\varphi^*_{gl}]\frac{d\varphi^*_{gl}}{d\varepsilon}\left\{(\widetilde{\varphi}_{gl})^{\sigma-1}-(\varphi^*_{gl})^{\sigma-1}\right\}<0 \tag{43}$$

- Green segment

$$\frac{d\widetilde{\varphi}_g}{d\varepsilon} = \frac{\widetilde{\varphi}_g^{2-\sigma}}{\sigma-1}\frac{1}{1-G[\varphi^*_{gm}]}g[\varphi^*_{gm}]\frac{d\varphi^*_{gm}}{d\varepsilon}\left\{(\widetilde{\varphi}_{gm})^{\sigma-1}-(\varphi^*_{gm})^{\sigma-1}\right\}<0 \tag{44}$$

- Market

$$\frac{d\widetilde{\varphi}}{d\varepsilon} = \frac{\widetilde{\varphi}_b^{2-\sigma}}{\sigma-1}\frac{1}{1-G[\varphi^*_b]}g[\varphi^*_b]\frac{d\varphi^*_b}{d\varepsilon}\left\{(\widetilde{\varphi}_b)^{\sigma-1}-(\varphi^*_b)^{\sigma-1}\right\}>0 \tag{45}$$

10.5 Green internal promotion function in open economy

The green internal promotion function in open economy $a[\varphi^i, \varepsilon_X, \varepsilon_Y, \omega]$ is represented as

$$B\left\{P_X^{\sigma-1}\chi_a^{'}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_a^{'}[a^i,\varepsilon_Y]\right\}(\varphi^i)^{\sigma-1}=1, \tag{46}$$

where $\chi[a^i,\varepsilon_X]\equiv\chi[a[\varphi^i,\varepsilon_X,\varepsilon_Y,\omega],\varepsilon_X]$, $a^i\equiv a[\varphi^i,\varepsilon_X,\varepsilon_Y,\omega]$.

Under the assumption that firms do not anticipate the changes in price indexes as a result of their decisions, the function is increasing in its arguments due to

$$\frac{da^i}{d\varphi^i}=-\frac{(\sigma-1)(P_X^{\sigma-1}\chi_a^{'}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_a^{'}[a^i,\varepsilon_Y])}{\varphi^i(P_X^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_Y])}>0 \tag{47}$$

$$\frac{d\varphi^i}{d\varepsilon_X}=-\frac{P_X^{\sigma-1}\chi_{a\varepsilon_X}^{''}[a^i,\varepsilon_X]}{P_X^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_Y]}>0 \tag{48}$$

$$\frac{da^i}{d\varepsilon_Y}=-\frac{\omega P_Y^{\sigma-1}\chi_{a\varepsilon_Y}^{''}[a^i,\varepsilon_Y]}{P_X^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_X]+\rho P_Y^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_Y]}>0 \tag{49}$$

$$\frac{da^i}{d\omega}=-\frac{P_Y^{\sigma-1}\chi_a^{'}[a^i,\varepsilon_Y]}{P_X^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_Y]}>0 \tag{50}$$

10.6 Green internal firm's profit function in open economy

Profit function of a green internal firm upon opening to international trade is represented as

$$(\pi_X)_{int}^{opt}\left[\varphi^i\right]=B\left\{P_X^{\sigma-1}(\chi[a^i,\varepsilon_X]+1)+\omega P_Y^{\sigma-1}(\chi[a^i,\varepsilon_Y]+1)\right\}(\varphi^i)^{\sigma-1}-a^i-f\,, \tag{51}$$

Under the assumption that firms do not anticipate the changes in price indexes as a consequence of their decisions, the function is increasing and convex (under the over-sufficient condition $\sigma\geq 2$ - see Appendix 10.2) in φ due to

$$\begin{aligned}\frac{d(\pi_X)_{int}^{opt}\left[\varphi^i\right]}{d\varphi^i}&=B(\sigma-1)(\varphi^i)^{\sigma-2}\left\{P_X^{\sigma-1}(\chi[a^i,\varepsilon_X]+1)+\omega P_Y^{\sigma-1}(\chi[a^i,\varepsilon_Y]+1)\right\}\\&>0\end{aligned} \tag{52}$$

$$\begin{aligned}\frac{d^2(\pi_X)_{int}^{opt}\left[\varphi^i\right]}{d(\varphi^i)^2}&=B(\sigma-1)(\varphi^i)^{\sigma-3}\left\{P_X^{\sigma-1}(\chi[a^i,\varepsilon_X]+1)+\omega P_Y^{\sigma-1}(\chi[a^i,\varepsilon_Y]+1)\right\}\\&\frac{(\sigma-2)(P_X^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_Y])-B^{-1}(\varphi^i)^{1-\sigma}}{P_X^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_X]+\omega P_Y^{\sigma-1}\chi_{aa}^{''}[a^i,\varepsilon_Y]}\\&>0\end{aligned} \tag{53}$$

10.7 Productivity composition in open economy: productivity

Zero profit conditions for trading countries imply

$$BP_X^{\sigma-1} = \frac{f\{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}\}}{1-\omega^2} \tag{54}$$

Then the productivity composition in the open economy is based on the promotion function $a_X[\varphi, \varepsilon_X, \varepsilon_Y, \omega]$ such that

$$\begin{aligned} &f\varphi^{\sigma-1}\left\{\chi_a^{'}[a,\varepsilon_X]\{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}\} + \omega\chi_a^{'}[a,\varepsilon_Y]\{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}\}\right\} \\ &= 1-\omega^2 \end{aligned} \tag{55}$$

and on indifference (17)-(19), and free entry (20) conditions:

$$\begin{aligned} &\left\{\chi[a_{gmX}^*, \varepsilon_X]\frac{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}}{1-\omega^2}\right. \\ &\left. + \omega\chi[a_{gmX}^*, \varepsilon_Y]\frac{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}}{1-\omega^2}\right\}(\varphi_{gmX}^*)^{\sigma-1} = f^{-1}a_{gmX}^* \end{aligned} \tag{56}$$

$$\begin{aligned} &\left\{\Delta\mathcal{E}_{eX,X}\frac{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}}{1-\omega^2} + \omega\Delta\mathcal{E}_{eX,Y}\frac{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}}{1-\omega^2}\right\}(\varphi_{eX}^*)^{\sigma-1} \\ &= f^{-1}(F_a - a_{eX}^*) \end{aligned} \tag{57}$$

$$\begin{aligned} &\left\{\Delta\mathcal{E}_{glX,X}\frac{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}}{1-\omega^2} + \omega\Delta\mathcal{E}_{glX,Y}\frac{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}}{1-\omega^2}\right\}(\varphi_{glX}^*)^{\sigma-1} \\ &= f^{-1}(a_{glX}^* - F_a) \end{aligned} \tag{58}$$

$$\begin{aligned} &f(\varphi_{bX}^*)^{1-\sigma}\int_{BRX}\varphi^{\sigma-1}dG[\varphi] + \\ &\int_{GWX}\left(\left\{(\chi[a_X,\varepsilon_X]+1)\frac{f\{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}\}}{1-\omega^2}\right.\right. \\ &\left.\left. + \omega(\chi[a_X,\varepsilon_Y]+1)\frac{f\{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}\}}{1-\omega^2}\right\}\varphi^{\sigma-1} - a_X\right)dG[\varphi] + \\ &\left\{\mathcal{E}_X\frac{f\{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}\}}{1-\omega^2} + \omega\mathcal{E}_Y\frac{f\{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}\}}{1-\omega^2}\right\} \\ &\int_{GRX}\varphi^{\sigma-1}dG[\varphi] - f(1-G[\varphi_{bX}^*]) - F_a(G[\varphi_{glX}^*] - G[\varphi_{eX}^*]) = \delta f_{entry}, \end{aligned} \tag{59}$$

where $\Delta\mathcal{E}_{eX,Y} \equiv \mathcal{E}_Y - \chi[a^*_{eX}, \varepsilon_Y] - 1$, $\Delta\mathcal{E}_{glX,Y} \equiv \chi[a^*_{glX}, \varepsilon_Y] + 1 - \mathcal{E}_Y$; $X = \mathcal{B}, \mathcal{G}; Y = \mathcal{G}, \mathcal{B}; X \neq Y$.

10.8 Comparative statics upon trade integration

Considering trade integration between two countries X and Y, such that $X = \mathcal{B}, \mathcal{G}, Y = \mathcal{G}, \mathcal{B}, X \neq Y$, from the promotion function $a_X[\varphi^i, \varepsilon_X, \varepsilon_Y, \omega]$ one can obtain:

$$\left.\frac{da_X}{d\varphi^*_{bX}}\right|_{\omega=0} = \frac{(\sigma-1)(\varphi^*_{bX})^{-\sigma}\chi'_a[a_X, \varepsilon_X]}{\chi''_{aa}[a_X, \varepsilon_X](\varphi^*_{bX})^{1-\sigma}}, \qquad \left.\frac{da_X}{d\varphi^*_{bY}}\right|_{\omega=0} = 0 \tag{60}$$

$$\left.\frac{da_X}{d\omega}\right|_{\omega=0} = \frac{(\varphi^*_{bY})^{1-\sigma}(\chi'_a[a_X, \varepsilon_X] - \chi'_a[a_X, \varepsilon_Y])}{\chi''_{aa}[a_X, \varepsilon_X](\varphi^*_{bX})^{1-\sigma}} \tag{61}$$

$$\left.\frac{da_X}{d\varepsilon_X}\right|_{\omega=0} = -\frac{\chi''_{a_X\varepsilon}[a_X, \varepsilon_X]}{\chi''_{aa}[a_X, \varepsilon_X]}, \qquad \left.\frac{da_X}{d\varepsilon_Y}\right|_{\omega=0} = 0 \tag{62}$$

$$\left.\frac{da_X}{d\varphi}\right|_{\omega=0} = -\frac{(\sigma-1)(\varphi^*_{bX})^{\sigma-1}}{f\varphi^\sigma\chi''_{aa}[a_X, \varepsilon_X]} \tag{63}$$

10.8.1 Trade integration of eco-homogeneous countries

Cutoff productivity

$$\left.\frac{d\varphi^*_b}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = \left.\frac{d\varphi^*_{gm}}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = \left.\frac{d\varphi^*_e}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = \left.\frac{d\varphi^*_{gl}}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = 0 \tag{64}$$

Average productivity

$$\left.\frac{d\widetilde{\varphi}^*_b}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = \left.\frac{d\widetilde{\varphi}^*_{gm}}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = \left.\frac{d\widetilde{\varphi}^*_e}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = \left.\frac{d\widetilde{\varphi}^*_{gl}}{d\omega}\right|_{\varepsilon_\mathcal{G}=\varepsilon_\mathcal{B}} = 0 \tag{65}$$

10.8.2 Trade integration of eco-heterogeneous countries

Cutoff productivity.

- Brown segment

$$\left.\frac{d\varphi^*_{b\mathcal{G}}}{d\omega}\right|_{\omega=0} = \frac{(\varphi^*_{b\mathcal{G}})^\sigma(I_{\mathcal{G}\mathcal{B}} - I_{\mathcal{G}\mathcal{G}})}{(\sigma-1)(\varphi^*_{b\mathcal{B}})^{\sigma-1}I_{\mathcal{G}\mathcal{G}}} < 0 \tag{66}$$

$$\left.\frac{d\varphi^*_{b\mathcal{B}}}{d\omega}\right|_{\omega=0} = \frac{(\varphi^*_{b\mathcal{B}})^{\sigma}(I_{\mathcal{BG}} - I_{\mathcal{BB}})}{(\sigma-1)(\varphi^*_{b\mathcal{G}})^{\sigma-1}I_{\mathcal{BB}}} > 0, \tag{67}$$

where
$I_{XX} \equiv \int_{BRX} \varphi^{\sigma-1} dG[\varphi] + \int_{GWX} (\chi[a_X, \varepsilon_X]+1)\varphi^{\sigma-1} dG[\varphi] + \mathcal{E}_X \int_{GRX} \varphi^{\sigma-1} dG[\varphi]$,
$I_{XY} \equiv \int_{BRX} \varphi^{\sigma-1} dG[\varphi] + \int_{GWX} (\chi[a_X, \varepsilon_Y]+1)\varphi^{\sigma-1} dG[\varphi] + \mathcal{E}_Y \int_{GRX} \varphi^{\sigma-1} dG[\varphi]$,
$X = \mathcal{B}, \mathcal{G}; Y = \mathcal{G}, \mathcal{B}; X \neq Y$.

- Green segment

The comparative statics is analogous for all green sub-segments, thus, I report the derivations for the *greenwashing lower-middle productive firms* sub-segment only.

$$\left.\frac{d\varphi^*_{gm\mathcal{G}}}{d\omega}\right|_{\omega=0} = \frac{(\varphi^*_{b\mathcal{G}})^{\sigma-1}\varphi^*_{gm\mathcal{G}}\left\{I_{\mathcal{GB}} - \frac{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{B}}]}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{G}}]} I_{\mathcal{GG}}\right\}}{(\sigma-1)(\varphi^*_{b\mathcal{B}})^{\sigma-1} I_{\mathcal{GG}}}, \tag{68}$$

where
$I_{\mathcal{GB}} - \frac{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{B}}]}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{G}}]} I_{\mathcal{GG}} = \left\{1 - \frac{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{B}}]}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{G}}]}\right\} \int_{BR\mathcal{G}} \varphi^{\sigma-1} dG[\varphi] + \chi[a^*_{gm\mathcal{G}}, \varepsilon_{\mathcal{B}}]$
$\left(\int_{GW\mathcal{G}} \left\{\frac{\chi[a_{\mathcal{G}},\varepsilon_{\mathcal{B}}]+1}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{B}}]} - \frac{\chi[a_{\mathcal{G}},\varepsilon_{\mathcal{G}}]+1}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{G}}]}\right\} \varphi^{\sigma-1} dG[\varphi] + \left\{\frac{\mathcal{E}_{\mathcal{B}}}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{B}}]} - \frac{\mathcal{E}_{\mathcal{G}}}{\chi[a^*_{gm\mathcal{G}},\varepsilon_{\mathcal{G}}]}\right\} \int_{GR\mathcal{G}} \varphi^{\sigma-1} dG[\varphi]\right)$.
Due to $\left(\frac{\chi[a,\varepsilon]+1}{\chi[a^*_{gm\mathcal{G}},\varepsilon]}\right)''_{a\varepsilon} < 0$,

$$\left.\frac{d\varphi^*_{gm\mathcal{G}}}{d\omega}\right|_{\omega=0} > 0 \tag{69}$$

$$\left.\frac{d\varphi^*_{gm\mathcal{B}}}{d\omega}\right|_{\omega=0} = \frac{(\varphi^*_{b\mathcal{B}})^{\sigma-1}\varphi^*_{gm\mathcal{B}}\left\{I_{\mathcal{BG}} - \frac{\chi[a^*_{gm\mathcal{B}},\varepsilon_{\mathcal{G}}]}{\chi[a^*_{gm\mathcal{B}},\varepsilon_{\mathcal{B}}]} I_{\mathcal{BB}}\right\}}{(\sigma-1)(\varphi^*_{b\mathcal{G}})^{\sigma-1} I_{\mathcal{BB}}} < 0 \tag{70}$$

Average productivity.

- Brown segment

$$\left.\frac{d\widetilde{\varphi}^*_{b\mathcal{G}}}{d\omega}\right|_{\omega=0} > 0, \quad \left.\frac{d\widetilde{\varphi}^*_{b\mathcal{B}}}{d\omega}\right|_{\omega=0} < 0$$

- Green segment

Analogous to the autarky case, the sign of $\left.\frac{d\widetilde{\varphi}^*_{gmX}}{d\omega}\right|_{\omega=0}$ and $\left.\frac{d\widetilde{\varphi}^*_{eX}}{d\omega}\right|_{\omega=0}$, $X = \mathcal{G}, \mathcal{B}$, depends on the eco-quality function and productivity distribution.

$$\left.\frac{d\widetilde{\varphi}^*_{gl\mathcal{G}}}{d\omega}\right|_{\omega=0} > 0, \quad \left.\frac{d\widetilde{\varphi}^*_{gl\mathcal{B}}}{d\omega}\right|_{\omega=0} < 0$$
$$\left.\frac{d\widetilde{\varphi}^*_{g\mathcal{G}}}{d\omega}\right|_{\omega=0} > 0, \quad \left.\frac{d\widetilde{\varphi}^*_{g\mathcal{B}}}{d\omega}\right|_{\omega=0} < 0$$

- Market

$$\left.\frac{d\widetilde{\varphi}^*_{\mathcal{G}}}{d\omega}\right|_{\omega=0} < 0, \quad \left.\frac{d\widetilde{\varphi}^*_{\mathcal{B}}}{d\omega}\right|_{\omega=0} > 0$$

10.8.3 Eco-difference growth across trading countries

To investigate the role of eco-concerns changes let's consider eco-appreciation level $\varepsilon_X \equiv \varepsilon_Y + \Delta\varepsilon$, where $\Delta\varepsilon$ represents the changes in eco-difference across countries.

Cutoff productivity

- Brown segment

$$\left.\frac{d\varphi^*_b}{d\Delta\varepsilon}\right|_{\Delta\varepsilon=0} = \frac{E'\varphi^*_b(1-\omega)}{(1+\omega)^2(\sigma-1)I} > 0, \tag{71}$$

where
$E' \equiv \int_{GW} \chi[a_X,\varepsilon]'_\varepsilon \varphi^{\sigma-1} dG[\varphi] + \mathcal{E}'_\varepsilon \int_{GR} \varphi^{\sigma-1} dG[\varphi]$,
$I \equiv \int_{BR} \varphi^{\sigma-1} dG[\varphi] + \int_{GW} \frac{\chi[a_X,\varepsilon]+1}{1+\omega} \varphi^{\sigma-1} dG[\varphi] + \frac{\mathcal{E}}{1+\omega} \int_{GR} \varphi^{\sigma-1} dG[\varphi]$.

- Green segment

As before, the comparative statics is analogous for all green sub-segments, thus, I report the derivations for the *greenwashing lower-middle productive firms* sub-segment only.

$$\left.\frac{d\varphi^*_{gm}}{d\Delta\varepsilon}\right|_{\Delta\varepsilon=0} = -\frac{\varphi^*_{gm}(1-\omega)}{(1+\omega)(\sigma-1)}\left(\frac{E'}{(1+\omega)I} + \frac{\chi'_\varepsilon[a,\varepsilon]}{\chi_\varepsilon[a,\varepsilon]}\right) < 0, \tag{72}$$

where $E' \equiv \int_{GW} \chi'_\varepsilon[a_X,\varepsilon]\varphi^{\sigma-1} dG[\varphi] + \mathcal{E}'_\varepsilon \int_{GR} \varphi^{\sigma-1} dG[\varphi]$.

Average productivity

- Brown segment

$$\left.\frac{d\widetilde{\varphi}_b^*}{d\Delta\varepsilon}\right|_{\Delta\varepsilon=0} < 0$$

- Green segment

Analogous to the previous cases, the sign of $\left.\frac{d\widetilde{\varphi}_{gm}^*}{d\Delta\varepsilon}\right|_{\Delta\varepsilon=0}$ and $\left.\frac{d\widetilde{\varphi}_e^*}{d\Delta\varepsilon}\right|_{\Delta\varepsilon=0}$ depends on the eco-quality function and productivity distribution.

$$\left.\frac{d\widetilde{\varphi}_{gl}^*}{d\Delta\varepsilon}\right|_{\omega=0} < 0$$

$$\left.\frac{d\widetilde{\varphi}_g^*}{d\Delta\varepsilon}\right|_{\omega=0} < 0$$

- Market

$$\left.\frac{d\widetilde{\varphi}^*}{d\Delta\varepsilon}\right|_{\Delta\varepsilon=0} > 0$$

10.9 Quantitative analysis: numerical illustration of qualitative analysis

Zero profit condition for trading countries implies

$$BP_X^{\sigma-1} = \frac{f\{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}\}}{1-\omega^2} \tag{73}$$

Then the productivity composition in the open economy with two sub-sectors, brown and green external, is based on the following indifference and free entry conditions:

$$\left\{(\mathcal{E}_X - 1)\frac{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}}{1-\omega^2} + \omega(\mathcal{E}_Y - 1)\frac{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}}{1-\omega^2}\right\}(\varphi_{eX}^*)^{\sigma-1} = F_a \tag{74}$$

$$\begin{aligned} & f(\varphi_{bX}^*)^{1-\sigma}\int_{BRX}\varphi^{\sigma-1}dG[\varphi] \\ & + \left\{\mathcal{E}_X\frac{f\{(\varphi_{bX}^*)^{1-\sigma} - \omega(\varphi_{bY}^*)^{1-\sigma}\}}{1-\omega^2} + \omega\mathcal{E}_Y\frac{f\{(\varphi_{bY}^*)^{1-\sigma} - \omega(\varphi_{bX}^*)^{1-\sigma}\}}{1-\omega^2}\right\} \\ & \int_{GRX}\varphi^{\sigma-1}dG[\varphi] - f(1-G[\varphi_{bX}^*]) - F_a(1-G[\varphi_{eX}^*]) = f_{entry}, \end{aligned} \tag{75}$$

$X = \mathcal{B}, \mathcal{G}; Y = \mathcal{G}, \mathcal{B}; X \neq Y$.

10.10 Quantitative analysis: numerical extension of qualitative analysis

Aggregate expenditures on green varieties in country X are represented as

$$D_X = \sigma B F_\ell^{-1} \left\{ M_{eX} \left[\mathcal{E}_X P_X^{\sigma-1} + \omega \mathcal{E}_Y P_Y^{\sigma-1} \right] \widetilde{\varphi}_{eX}^{\sigma-1} + M_{eY} \left[\mathcal{E}_Y P_Y^{\sigma-1} + \omega \mathcal{E}_X P_X^{\sigma-1} \right] \widetilde{\varphi}_{eY}^{\sigma-1} \right\} \tag{76}$$

Plugging zero profit condition (73) into (76), one can obtain

$$\begin{aligned} D_X = \frac{\sigma f}{F_\ell (1-\omega^2)} \Bigg\{ & M_X \frac{1 - G[\varphi_{eX}^*]}{1 - G[\varphi_{bX}^*]} \left[\mathcal{E}_X \{ (\varphi_{bX}^*)^{1-\sigma} - \omega (\varphi_{bY}^*)^{1-\sigma} \} \right. \\ & \left. + \omega \mathcal{E}_Y \{ (\varphi_{bY}^*)^{1-\sigma} - \omega (\varphi_{bX}^*)^{1-\sigma} \} \right] \widetilde{\varphi}_{eX}^{\sigma-1} \\ & + M_Y \frac{1 - G[\varphi_{eY}^*]}{1 - G[\varphi_{bY}^*]} \left[\mathcal{E}_Y \{ (\varphi_{bY}^*)^{1-\sigma} - \omega (\varphi_{bX}^*)^{1-\sigma} \} \right. \\ & \left. + \omega \mathcal{E}_X \{ (\varphi_{bX}^*)^{1-\sigma} - \omega (\varphi_{bY}^*)^{1-\sigma} \} \right] \widetilde{\varphi}_{eY}^{\sigma-1} \Bigg\} \end{aligned} \tag{77}$$

Labor market clearing condition for country X

$$\alpha L = L_{bX} + L_{eX} + \frac{f_{entry} M_X}{1 - G[\varphi_{bX}^*]}, \tag{78}$$

where

$$L_{bX} = f M_X \frac{G[\varphi_{eX}^*] - G[\varphi_{bX}^*]}{1 - G[\varphi_{bX}^*]} \left[1 + (\sigma - 1) B^{-1} \left(\frac{\widetilde{\varphi}_{bX}}{\varphi_{bX}^*} \right)^{\sigma-1} \right] \tag{79}$$

$$\begin{aligned} L_{eX} = M_X \frac{1 - G[\varphi_{eX}^*]}{1 - G[\varphi_{bX}^*]} \Bigg[& f + F_a + \frac{f(\sigma-1)}{TB} \left(\mathcal{E}_X \{ (\varphi_{bX}^*)^{1-\sigma} - \omega (\varphi_{bY}^*)^{1-\sigma} \} \right. \\ & \left. + \omega \mathcal{E}_Y \{ (\varphi_{bY}^*)^{1-\sigma} - \omega (\varphi_{bX}^*)^{1-\sigma} \} \right) \widetilde{\varphi}_{eX}^{\sigma-1} \Bigg] \end{aligned} \tag{80}$$

Accordingly, the equilibrium is described by six equations (74), (75), and (78) with six unknowns M_X, φ_{bX}^*, φ_{eX}^*, $X = \mathcal{G}, \mathcal{B}; Y = \mathcal{G}, \mathcal{B}; X \neq Y$.