Groupe de Recherche en
Économie Théorique et Appliquée

Extended Producer Responsibility and Green Marketing: an Application to Packaging

Brice ARNAUD

GREThA, CNRS, UMR 5113
Université de Bordeaux

Cahiers du GREThA
n° 2014-04
February

GRETHA UMR CNRS 5113
Université Montesquieu Bordeaux IV
Avenue Léon Duguit - 33608 PESSAC - FRANCE
Tel : +33 (0)5.56.84.25.75 - Fax : +33 (0)5.56.84.86.47 - www.gretha.fr

Responsabilité élargie des Producteurs et marketing vert : le cas des emballages ménagers

Résumé

Ce papier analyse l'efficacité de la Responsabilité Elargie des Producteurs (REP) pour gérer les déchets d'emballages ménagers. Pour cela, nous utilisons un modèle de différenciation verticale inspiré de celui de Mussa & Rosen (1978). Dans notre modèle, deux firmes produisent un bien identique et elles utilisent l'emballage pour créer une différenciation verticale subjective. A partir de ce modèle, nous vérifions qu'une REP caractérisée par une taxe pigouvienne (chaque producteur supporte le coût social de gestion des déchets) n'est pas une politique optimale. Nous démontrons ensuite qu'une politique optimale implique d'ajuster la taxe pigouvienne en fonction du coût de gestion des déchets.

Mots-clés : différenciation verticale, duopole, emballage, responsabilité élargie des producteurs, taxe pigouvienne.

Extended Producer Responsibility and Green Marketing: an Application to Packaging

Abstract

This paper analyses the efficiency of Extended Producer Responsibility (EPR) to manage household packaging wastes. We use a Mussa-Rosen type model of vertical product differentiation: two firms produce a homogeneous good and use packaging to create a subjective vertical differentiation. We verify that an ERP characterised by a Pigouvian tax – producers bear the social cost of waste management – is not an optimal policy. We show then that an optimal policy is an adjusted Pigouvian tax, accounting for waste management costs.

Keywords: Automotive; Europe; Deindustrialisation; Delocalization; Offshoring; Geography of industry.

JEL: L13, Q53

Reference to this paper: ARNAUD Brice (2014) **Extended Producer Responsibility and Green Marketing: an Application to Packaging**, *Cahiers du GREThA*, n°2014-04.

http://ideas.repec.org/p/grt/wpegrt/2014-04.html.

GRETHA UMR CNRS 5113
Université Montesquieu Bordeaux IV
Avenue Léon Duguit - 33608 PESSAC - FRANCE
Tel : +33 (0)5.56.84.25.75 - Fax : +33 (0)5.56.84.86.47 - www.gretha.fr

1. Introduction

This paper analyses the efficiency of Extended Producer Responsibility (EPR) to manage household packaging wastes. An EPR switches physical and/or financial responsibilities for household waste management from municipalities to producers. So, each producer has to bear the cost of waste resulting from households' consumption of their product.

In the case of household packaging wastes, is common that the producers bear this cost collectively. They create a producer responsibility organisation, which collects producers' contributions and in exchange finances the cost of household packaging waste management. In order to lower this cost, and so their contributions, producers are induced to modify the design of their packaging by using more recyclable materials and/or reducing their weight.

This paper tries to characterise the optimal policy, tariffs that producers should bear to guarantee that they choose the optimal design of packaging. The economic literature has already proposed optimal schemes in several settings.

Under competitive market for product, an optimal policy implies that producers bear the social cost of waste management (Fullerton & Wu, 1998)[1]. This optimal policy can be viewed as a Pigouvian tax. From this, in the rest of the paper, we will refer to the benchmark policy where the producers face an EPR characterised by a pricing according to the social cost of waste management.

Under homogeneous oligopoly and Cournot competition, a Pigouvian tax is too stringent. This is because its introduction lowers quantities put on the market which are already too low

[1] In this paper, we focus on product market and we assume that all others markets – recycling and waste management services – are competitive.

(Runkel, 2003; Ino, 2007). An optimal policy supposes that producers bear a waste management cost which decreases according to their markup in product market (Ino, 2007)[2].

In this paper, the market of packaged product is supposed oligopolistic but also differentiated. Firms produce a perfect homogenous product, but use packaging to create a subjective differentiation (Tremblay & Polasky, 2002). This assumption is justified because packaging choice of consumers expresses an environmental consciousness (Bech-Larsen, 1996; Rokka & Uusitalo, 2008) which involves a willingness to pay for environmentally friendly packaging (van Birgelen, Semeijn, & Keicher, 2008; Yue, Hall, Behe, Campbell, Dennis, & Lopez, 2010; Barnes, Chan-Halbrendt, Quanguo, & Abejon, 2011). So, a vertically differentiated oligopoly seems to be the most relevant benchmark to analyse the efficiency of an ERP for household packaging wastes.

Fleckinger & Glachant (2010) assume a vertically differentiated duopoly and a Bertrand competition. Each producer sells a different quality of a product, and quality determines waste management costs. They show that a Pigouvian tax is an optimal policy when its introduction eliminates differentiation, while it is not an optimal policy in others cases[3].

Our paper pursues Fleckinger & Glachant's analysis focusing on situations where differentiation remains after the introduction of a Pigouvian tax. Our main contribution is to propose a more realistic representation of the management cost of household packaging wastes, which allows us to determine a new optimal policy.

---

[2] Ino (2007) assume that producers can also have a market power in recycling market. In that case, an optimal policy supposes that the cost of waste management born by producers could be higher or lower than a Pigouvian tax. This cost increases in the markup in the product market, and decreases in the markdown in the recycling market.

[3] Fleckinger & Glachant (2010) also assume that the introduction of an ERP induce producer to adopt a collusive behaviour. They call this situation a collective ERP. In that case, a Pigouvian tax is not an optimal policy even if it eliminates differentiation.

We modify two assumptions from Fleckinger & Glachant's model. First, we assume inelastic demand rather than elastic demand. This assumption is more restrictive than Fleckinger & Glachant's assumption, but not too unrealistic for our problematic. Indeed, household packaging wastes are mainly due to current consumer goods such food products. For this kind of product, it is reasonable to assume that all consumers buy it. So their purchasing decision can be resumed as a choice between different qualities. Second, we represent quality as a continuous variable rather than a binary variable. In the case of a differentiated duopoly, a binary variable implies that producers' choice of quality are given. A continuous variable allows us to endogenize producers' choice of quality in a differentiated market.

Consequently, our model is similar to those of Lombardini-Riipinen (2005) and Bansal (2008)[4]. However, Lombardini-Riipinen (2005) and Bansal (2008) assume that better quality implies less emissions, while we assume that quality affects waste management cost.

Packaging quality is determined by its material composition. In a schematic way, we can divided materials in two groups : recyclable and not recyclable. Since consumers have an environmental consciousness, higher is the part of recyclable materials in packaging higher is its quality. Each kind of material has a different treatment: recyclable is recycled, the other is dumped. In that case, there is a need to sorting operations for packaging made up of these two materials. As Fleckinger & Glachant (2010), we assume that recycling is socially less costly than dumping, but, contrary to them, we take into account the sorting cost that we represent by an inverted "U-shaped". So, a better quality does not always lower the cost of waste management.

[4] Our model is also similar to those of Cremer & Thisse et Crampes & Hollander, but these authors consider that consumers' preferences fall on a product characteristic which has no impact on environment.

This original representation of waste management cost allows us to determine a new optimal policy. To the best of our knowledge, only Lombardini-Riipinen (2005) determines an optimal policy in a vertically differentiated duopoly. This policy couples an uniform *ad valorem* tax to a product tax on the quantity of emissions whose the rate is higher than the cost of environmental damage from emissions[5]. Our optimal policy does not need an *ad valorem* tax, it is only based on EPR principle. We demonstrate that an optimal policy implies to modulate Pigouvian tax according to waste management cost: when waste management cost is high (respectively low), Pigouvian tax is too lax (respectively stringent) to implement the social optimum.

The rest of the paper is organized as follow. In section 2, we introduce the model. Section 3 characterizes the social optimum. In section 4, we solve for equilibrium prices and qualities. In section 5, we demonstrate that a Pigouvian tax is not an optimal policy, then we determine the optimal policy. Section 6 concludes about the implications of these optimal policy for household packaging waste management.

2. The Model

In this paper, we consider a Mussa-Rosen type model of vertical product differentiation which represents a duopoly market. The two firms will be denoted L and H. Both firms produce a perfect homogenous product. However, they use packaging to create a subjective vertical differentiation. We assume that each firm produces one variant of packaging, denoted ρ_i, with $i = L, H$. Without loss of generality, we assume that $\rho_H > \rho_L$.

---

[5] Assuming that an *ad valorem* tax and a product tax cannot be apply together, Bansal (2008) compares the efficiency of these taxes: a product tax is better than an *ad valorem* when environmental damage is high, it is the opposite when environmental damage is low.

To focus our attention on packaging only, we assume that the product itself involves no production cost and generates no waste. Consequently, the difference in cost between products is only due to packaging.

We assume that producers can use at most two materials to produce packaging: one material is recyclable, whereas the other is not. As, by assumption, consumers only pay attention to material composition to evaluate packaging quality, we assume that both packaging have the same weight and we normalize it to one. So, one unit of the recyclable material has the same weight than one unit of the non-recyclable material, and ρ_i represents the quantity of the recyclable material in packaging. We have $\rho_i \in [0,1]$. We call ρ_i as the packaging recyclability.

We assume that packaging production involves variable costs[6] which are convex in quality[7] and linear in quantity. The production cost of packaging is represented by the expression $C(\rho_i) = c\rho_i^2 q_i$ where c indicates the unit production cost, ρ_i the packaging recyclability, and q_i the output level[8].

Let us turn now to our assumptions on waste management cost. Packaging waste management can be divided in three steps: collection, sorting and treatment.

Collection is the transport of waste from households to recyclers. Its cost depends on packaging weight. In our model, by assumption both packaging are equally costly to collect

[6] We consider that fixed costs required to develop new packaging are sufficiently low to be neglected.

[7] A rise of recyclability can increases production cost for different reasons: recyclable materials such glass are more expansive than non-recyclable material such plastic; for food products, plastic is most cost effective than recyclable materials to produce packaging (Barnes, Chan-Halbrendt, Quanguo, & Abejon, 2011).

[8] The shape of production cost implies that a packaging only made up of the non-recyclable material $(\rho_i = 0)$ involves no production cost. The production cost could be represented by $C(\rho_i) = a + c\rho_i^2$ without alter conclusions. The production cost of a packaging only made up of the non-recyclable material will be equal to a.

since they have the same weight. We consider this cost equals to zero. After collection step, wastes are subjected to sorting and treatment operations.

We define sorting step as the operations necessary to produce homogeneous flows (operations to separate plastic and aluminum mixed in one packaging for example). Therefore, a packaging made up of one material $(\rho_i = 0, \rho_i = 1)$ involves no separation cost. In others cases $(\rho_i \in]0,1[)$, separation cost is positive. We assume that sorting operations extract minority material in packaging: the recyclable material for $0 < \rho_i \leq 0.5$, and the non-recyclable material for $0.5 < \rho_i < 1$. The separation cost is given by $S(\rho_i) = s\rho_i(1 - \rho_i)$ with s the unit separation cost[9]. This cost can be represented as in figure 1.

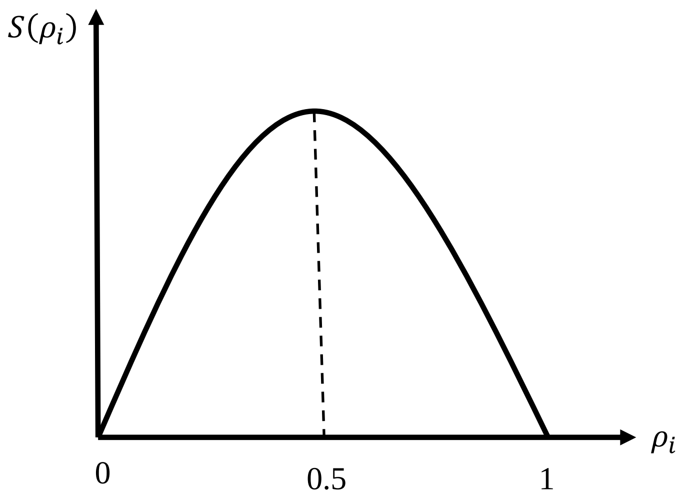

Figure 1 : Example of separation cost shape

The figure 1 implies two assumptions on sorting cost. On the one hand, sorting cost increases in the quantity of the minority material: to extract two units of the minority material is more costly than to extract one unit. On the other hand, sorting is unaffected by the nature of the minority material: to extract one unit of the recyclable or non-recyclable material involves an identical cost. As a result, sorting cost is maximal for packaging equally made up of the two

[9] We cannot obtain a general solution with a more general form such $S(\rho_i) = s\rho_i^{\alpha}(1 - \rho_i)^{\beta}$ with $\alpha > 0$ and $\beta > 0$

materials. Sorting operations are necessary because each material is differently treated: the recyclable material is recycled, while the non-recyclable material is dumped. Both materials would be dumped without sorting operations. In our model, sorting is perfect: no unit of the recyclable material is dumped.

Regarding to treatment step, we assume that recycling involves no cost[10] and that the social cost of dumping is linearly decreasing in packaging recyclability. The dumping cost is represented by $E(\rho_i) = e(1 - \rho_i)$ with e the unit dumping cost.

The social cost of waste management, denoted $W(\rho_i)$, includes sorting and dumping costs and it is represented by :

$$W(\rho_i) = s\rho_i(1 - \rho_i) + e(1 - \rho_i) \quad (1)$$

The equation (1) implies that a rise of packaging recyclability does not necessary decrease the social cost of waste management $(\partial W(\rho_i)/\partial\rho_i \lesseqgtr 0)$. Indeed, we have $(\partial W(\rho_i)/\partial\rho_i > 0)$ if $(\rho_i < 1/2 - e/2s)$. So, when packaging recyclability is low, improve it could increase the waste management cost. The equation (1) can explain why in reality producers are reticent to develop the recyclability of their packaging. This is because it is costly in terms of production but also in terms of waste management.

In our model, a rise of packaging recyclability increases the waste management cost if the packaging is mainly made up of the non-recyclable material $(\rho_i < 1/2)$, except if the dumping cost (e) is high compared to the sorting cost (s). In practice, the dumping cost is constant whatever the nature of the non-recyclable material. Contrary to the dumping cost, the sorting cost is very sensitive to the nature of materials.

[10] Integrate a positive recycling cost does not alter our conclusions about the optimal policy.

As a result, according to separation cost, a rise of packaging recyclability can increase or decrease the waste management cost. For example, when a mechanic sorting is available such that the sorting cost becomes negligible, a rise of packaging recyclability decreases the waste management cost. But, when the sorting technology involves more complicated treatment (man-made, chemical) a rise of packaging recyclability can involve an increase of the waste management cost.

Before characterising the social optimum, we make two assumptions to insure that all packaging qualities are feasible. On the one hand, we assume that the unit production cost (c) is higher than the unit dumping cost (e), so $c > e$. These assumption guarantees that a packaging characterised by $\rho_i = 1$ is more costly than one characterised by $\rho_i = 0$[11]. On the other hand, we assume that the unit production cost (c) is higher than the unit sorting cost (s), so $c > s$. This assumption guarantees that the producers have an incentive to mix materials to produce packaging. These two assumptions imply that waste management cost is not too high. Fleckinger & Glachant (2010) make a similar assumption.

3. The First Best Allocation

The social optimum is the situation that maximises social surplus. The social surplus is the sum of consumer and producer surplus.

The surplus of one consumer is given by the following expression:

$$U(\theta, p_i, \rho_i) = v + \theta\rho_i - p_i \tag{2}$$

In this expression (2), v is the intrinsic utility derived from the consumption one unit of the product. As Cremer & Thisse (1994), we make the assumption that v large enough for all

[11] We have $C(\rho_i = 0) + W(\rho_i = 0) = e$ and $C(\rho_i = 1) + W(\rho_i = 1) = c$

consumers to buy in equilibrium[12]. Consumers obtain an additional utility which depends on packaging recyclability ρ_i. This additional utility increases in consumers' environmental consciousness θ which is uniformly distributed over $[a, a+1]$. Consumers' environmental consciousness can be view as a willingness to pay for packaging recyclability. The global utility $(v + \theta\rho_i)$ is reduced by the price of the good p_i.

As Cremer & Thisse (1994) and Lombardini-Riipinen (2005), we use a utilitarian social welfare function to express the social surplus. Assuming that the number of quality is given and equal to two and that all consumers buy one unit of the good, the social surplus is given by:

$$SS(\theta, \rho_L, \rho_H) = \int_a^{\tilde{\theta}} v + \theta\rho_L - C(\rho_L) - W(\rho_L) d\theta + \int_{\tilde{\theta}}^{a+1} v + \theta\rho_H - C(\rho_H) - W(\rho_H)\, d\theta \quad (3)$$

In the expression (3), $\tilde{\theta}$ represents the consumer indifferent between consuming the good from producer L or from producer H.

From this expression (3), it is easy to obtain the conditions characterizing the socially optimal levels of quality and the social optimal allocation of consumers across qualities:

$$\rho_L^{\circ} = \frac{4a + 1 + 4(e - s)}{8(c - s)} \quad \rho_H^{\circ} = \frac{4a + 3 + 4(e - s)}{8(c - s)} \quad \tilde{\theta}^{\circ} = a + \frac{1}{2} \quad (4)$$

with an optimal quality dispersion $\rho_H^{\circ} - \rho_L^{\circ} = 1/4(c - s)$. The superscript ° denotes the optimal value.

---

[12] To guarantee that market is fully covered, others papers (Lombardini-Riipinen, 2005; Bansal, 2008) assume that θ is distributed over an interval which is not too large. This assumption does not modify our result.

4. The Market Equilibrium

A Pigouvian tax is applied, so the producers face an EPR characterised by a pricing according to the social cost of waste management. However, two taxes affecting this cost can be implemented: one tax affecting the separation cost, denoted t_s, and one tax affecting the dumping cost, denoted t_e.

From this, the waste management cost born by producers, denoted $G(\rho_i)$, is represented by:

$$G(\rho_i) = (t_s + s)\rho_i(1 - \rho_i) + (t_e + e)(1 - \rho_i) \tag{5}$$

As a result, there is settings of taxes where the producers bear a cost equals to the social cost of waste management ($G(\rho_i) = W(\rho_i)$), and others settings where the producers bear a cost higher or lower than the social cost of waste management ($G(\rho_i) \gtrless W(\rho_i)$).

These taxes are similar to the bonus/penalty system applied by *Eco-Emballages*. *Eco-Emballages* is a French producer responsibility organisation which collects producers' fees, and transfers it to municipalities which provide household packaging waste management. Producers' fees have to cover the social cost of waste management. However, fees can be affected by two penalties and one bonus: a penalty on packaging made up of materials difficult to separate; a penalty on packaging made up of non-recyclable materials; and a bonus to producers who improve the recyclability of their packaging. In a schematic way, t_s can be viewed as the penalty on packaging made up of materials difficult to separate, $t_e > 0$ as the penalty on packaging made up of non-recyclable materials and $t_e < 0$ as the bonus to producers who improve the recyclability of their packaging. So, according to the bonus/penalty system, producers can bear a cost higher or lower than the social cost of waste management.

The profit function of a producer i is represented by:

$$\pi_i(p_i, \rho_i, q_i) = \big(p_i - C(\rho_i) - G(\rho_i)\big)q_i \tag{6}$$

In these profit function (6), q_i represents the demand addressed to the producer i. Demands functions are:

$$q_L = \bar{\theta} - a \tag{7}$$

$$q_H = a + 1 - \bar{\theta} \tag{8}$$

In these conditions (7 and 8), $\bar{\theta}$ represents the type of consumer who is indifferent between purchasing the good from producer L or from producer H. From the expression of consumer surplus (2), we obtain the expression of $\bar{\theta}$ which is:

$$\overline{\theta} = \frac{p_H - p_L}{\rho_H - \rho_L} \tag{9}$$

The market equilibrium is characterised by a subgame perfect equilibrium. The duopolists' game takes place in two stages. In the first stage, firms choose simultaneously their packaging recyclability. In the second stage, they compete in price. As usual, the game is solved by backward induction. Assuming an interior solution, it is routine to obtain:

$$\rho_L^* = \frac{4a - 1 + 4(e + t_e - s - t_s)}{8(c - s - t_s)} \qquad \rho_H^* = \frac{4a + 5 + 4(e + t_e - s - t_s)}{8(c - s - t_s)} \tag{10}$$

with an equilibrium quality dispersion $\rho_H^* - \rho_L^* = 3/4(c - s)$. The superscript $*$ denotes the market equilibrium. From (9), it is easy to determine the equilibrium value of $\bar{\theta}$,

$$\overline{\theta}^* = a + \frac{1}{2} \tag{11}$$

implying the equilibrium profits:

$$\pi_L^* = \pi_H^* = \frac{3}{16(c - s - t_s)} \qquad (12)$$

Producers have identical demands and profits. This fact is due to the quadratic cost function (Bansal, 2008).

5. EPR and Optimal Pricing Policy

We start by demonstrating that a Pigouvian tax is not an optimal policy.

- **The Pigouvian Tax**

We assume that no tax is applied $(t_s = t_e = 0)$, other than the Pigouvian tax. So, we have $(W(\rho_i) = G(\rho_i))$. In that case, the allocation of consumers is optimal $(\overline{\theta}^* = \tilde{\theta}^\circ)$, but the producers differentiate too much: quality L is too low $(\rho_L^* < \mathring{\rho}_L)$ and quality H is too high $(\rho_H^* > \mathring{\rho}_H)$. This confirms the conclusion of Fleckinger & Glachant that Pigouvian tax is not an optimal policy in a vertically differentiated market.

Before to characterise the optimal policy, we analyse separately the impact of taxes (t_s, t_e) on packaging recyclability and quality dispersion[13]. The condition (11) implies that both taxes do not modify the allocation of consumers.

The tax t_e increases the dumping cost born by the producers. A rise of this cost induces both producers to increase the quality of their packaging. However, this does not modify quality dispersion, as:

$$\frac{\partial \rho_L^*}{\partial e} = \frac{\partial \rho_H^*}{\partial e} = \frac{1}{4(c - s)} > 0 \qquad (13)$$

[13] We analyse impacts of one tax assuming the other is equal to 0.

The tax t_s increases the sorting cost born by the producers. A rise of this cost induces both producers to modify the quality of their packaging according to the difference between the unit production cost (c) and the unit dumping cost (e). We denote this gap cost α, with $\alpha = c - e$.

$$\frac{\partial \rho_L^*}{\partial s} = \frac{4a - 1 - 4\alpha}{8(c-s)^2} \lesseqgtr 0 \qquad \frac{\partial \rho_H^*}{\partial s} = \frac{4a + 5 - 4\alpha}{8(c-s)^2} \lesseqgtr 0 \tag{14}$$

We have :

- $(\partial \rho_L^*/\partial s > 0)$ and $(\partial \rho_H^*/\partial s > 0)$ if $(a - 1/4 > \alpha)$;
- $(\partial \rho_L^*/\partial s < 0)$ and $(\partial \rho_H^*/\partial s > 0)$ if $(a - 1/4 < \alpha < a + 5/4)$;
- $(\partial \rho_L^*/\partial s < 0)$ and $(\partial \rho_H^*/\partial s < 0)$ if $(a + 5/4 < \alpha)$.

A rise of sorting cost induces both producers to decrease (respectively increases) the quality of their packaging if α is high (respectively low), i.e when the unit production cost is high (respectively low) compared to the unit dumping cost.

This result can be explained as follow. Let us first show that α determines the packaging composition. To do so, compare ρ_L^* and ρ_H^* with the value of the packaging equally made up of the two materials $(\rho = 1/2)$:

$$\rho_L^* - \frac{1}{2} = \frac{4a - 1 - 4\alpha}{8(c-s)} \qquad \rho_H^* - \frac{1}{2} = \frac{4a + 5 - 4\alpha}{8(c-s)} \tag{15}$$

- $(\rho_L^* > 1/2)$ and $(\rho_H^* > 1/2)$ if $(a - 1/4 > \alpha)$;
- $(\rho_L^* < 1/2)$ and $(\rho_H^* > 1/2)$ if $(a - 1/4 < \alpha < a + 5/4)$;
- $(\rho_L^* < 1/2)$ and $(\rho_H^* < 1/2)$ if $(a + 5/4 < \alpha)$.

When α is high (respectively low) both packaging are majority made up of the non-recyclable material (respectively the recyclable material) and a rise of separation cost, due to its form (figure 1), involves a decrease (an increase) of both packaging qualities. In all cases, a rise of sorting cost increases quality dispersion:

$$\frac{\partial(\rho_H^* - \rho_L^*)}{\partial s} = \frac{3}{4(c-s)^2} > 0 \tag{16}$$

Producers' reaction to a rise of sorting cost always involves a rise of the quality dispersion which increases their profit:

$$\frac{\partial \pi_L^*}{\partial s} = \frac{\partial \pi_H^*}{\partial s} = \frac{1}{4(c-s)^2} > 0 \tag{17}$$

- **The Optimal Policy**

The optimal policy has to induce producers to choose the right set of quality. The optimal policy is identified by solving the system of equations given by $\rho_i^* - \rho_i^\circ = 0$ with $i = L, H$, ρ_i^* as in (10) and ρ_i° as in (4). This yields the following optimal policy:

$$t_s^* = 2(s-c) \quad t_e^* = 2(a + \frac{1}{2} - \alpha) \tag{18}$$

The tax t_s^* is negative since $c > s$. Consequently, the regulator applies a subsidy which lowers the sorting cost born by producers. This subsidy reduces the quality dispersion, and so the producers' profit. The subsidy rate decreases in sorting cost. In others terms, the amount of the subsidy is higher when producers use materials which are costless to separate.

The tax t_e^* is positive for $a + 1/2 > \alpha$ and negative for $a + 1/2 < \alpha$, whith $\alpha = c - e$. So when the unit cost of dumping (e) is high (respectively low), the regulator applies a tax

$(t_e^* > 0)$ (respectively a subsidy $(t_e^* < 0)$) which increases (respectively decreases) the dumping cost born by producers.

As we know that $(\partial W(\rho_i)/\partial \rho_i > 0)$ if $(\rho_i < 1/2 - e/2s)$, the optimal policy increases the probability that a rise of packaging recyclability decreases the waste management cost. So, this optimal policy stimulates producers to increase the recyclability of their packaging, and especially the producer L.

Now, we determine conditions such that the optimal policy implies that producers bear a cost higher or lower than the social cost of waste management.

Producer L bears a cost equal or higher than the social cost of waste management when $e + s \geq a + 3/4 - 2c$, while producer H bears a cost equal or higher than the social cost of waste management when $e + s \geq a + 1/4 - 2c$ [14]. These results are summarized in table 1.

$\boldsymbol{e+s}$	$\cdot < a + \frac{1}{4} - 2c$	$\boldsymbol{a + \frac{1}{4} - 2c \leq \cdot \leq a + \frac{3}{4} - 2c}$	$\boldsymbol{a + \frac{3}{4} - 2c < \cdot}$
Producer *L*	$W(\rho_L) > G(\rho_L)$	$W(\rho_L) \geq G(\rho_L)$	$W(\rho_L) < G(\rho_L)$
Producer *H*	$W(\rho_H) > G(\rho_H)$	$W(\rho_H) \leq G(\rho_H)$	$W(\rho_H) < G(\rho_H)$

Table 1 : Comparison between social cost of waste management and the cost born by producers under the optimal policy.

The cost born by producers depends on separation cost (s) and dumping cost (e): the cost born by producers has to tend toward the social cost of waste management, even exceeds it, when waste management is costly ($s + e$ is high). The optimal policy implies that the producer H bears a cost higher than the social cost much faster than producer L. This result

[14] Proofs are presented in appendix.

may be perceived as counterintuitive: one could think that the producer L will be punished first. The optimal policy takes into account that consumers buying from firm L are looking for a costless packaging, while consumers buying from firm H are likely to pay an extra price for "green" packaging.

It is also interesting to note that even when $W(\rho_i) = G(\rho_i)$ our optimal policy is different from a Pigouvian tax since a producer i bears a separation cost and a dumping cost different from their true value. This is because our optimal policy corrects not only for externalities but also for market power.

6. Concluding Remarks

This paper analyses the efficiency of an EPR to insure optimal choices of packaging. Our model represents a vertically differentiated duopoly. Firms use packaging recyclability to create a vertical subjective differentiation. From this model, we confirm first that an EPR characterised by a Pigouvian tax is not an optimal policy: producers differentiate too much. Second, we determine an optimal policy which couples a subsidy reducing the sorting cost born by the producers to a tax or a subsidy affecting the dumping cost born by the producers. Depending to the sorting and dumping costs, this optimal policy implies that the producers bear a cost lower or higher than the social cost of waste management: if sorting and dumping costs are high (respectively low), producers have to bear a cost higher (respectively lower) than the social cost of waste management.

This optimal policy legitimates the application of a bonus/penalty system which affects the cost of waste management born by producers. However, our model seems to indicate that the bonus/penalty system applied by *Eco-Emballages* and described before is not optimal. In our model, t_s is negative. So, the penalty on packaging made up of materials difficult to separate applied by *Eco-Emballages* should be replaced by a subsidy whose its rate decreases in difficulty to separate materials.

For futures research, the efficiency of an EPR could be analysed assuming a differentiation on two packaging attributes: recyclability and functionality. As consumers prefer packaging which are more recyclables and functional, a model of two vertical differentiation seems to be relevant to extend research about the efficiency of an EPR.

Reference

Bansal, S. (2008). Choice and design of regulatory instruments in the presence of green consumers. *Resource and Energy Economics* , pp. 345-368.

Barnes, M., Chan-Halbrendt, C., Quanguo, Z., & Abejon, N. (2011). Consumers Preference and Willingness to Pay for Non-Plastique Food Containers in Honolulu, USA. *Journal of Environmental Protection* , pp. 1264 - 1273.

Bech-Larsen, T. (1996). Danish Consumers' Attitudes to the Functional and Environmental Characteristics of Food Packaging . *Journal of Consumer Policy* , pp. 339-363.

Crampes, C., & Hollander, A. (1995). Duopoly and quality standards. *European Economic Review* , pp. 71-82.

Cremer, H., & Thisse, J.-F. (1994). Commodity Taxation in a Differentiated Oligopoly. *International Economic Review* , pp. 613-633.

European Environment Agency. (2005). *Effectiveness of packaging waste management systems in selected countries: an EEA pilot study*.

Fleckinger, P., & Glachant, M. (2010). The Organization of Extended Producer Responsibility in Waste Policy with Product Differentiation. *Journal of Environmental Economics and Management* , pp. 57-66.

Fullerton, D., & Wu, W. (1998). Policies for Green Design. *Journal of Environmental Economics and Management* , pp. 131-148.

Ino, H. (2007). Extended producer responsibility in oligopoly. *Economics Bulletin* , pp. 1-9.

Lombardini-Riipinen. (2005). Optimal Tax Policy under Environmental Quality Competition. *Environmental & Resource Economics* , pp. 317-336.

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

Pro Europe. (2013). *Participation Costs Overview 2013.*

Rokka, J., & Uusitalo, L. (2008). Preference for green packaging in consumer product choices – Do consumers care? *International Journal of Consumer Studies* , pp. 516-525.

Runkel, M. (2003). Product Durability and Extended Producer Responsibility in Solid Waste Management. *Environmental and Resource Economics* , pp. 161-182.

Thogersen, J. (1999). The Ethical Consumer, Moral Norms and Packaging Choice. *Journal of Consumer Policy* , pp. 439-460.

Tremblay, V. J., & Polasky, S. (2002). Advertising with Subjective Horizontal and Vertical Product Differentiation. *Review of Industrial Organization* , pp. 253-265.

van Birgelen, M., Semeijn, J., & Keicher, M. (2008). Packaging and Proenvironmental Consumption Behavior: Investigating Purchase and Disposal Decisions for Beverages. *Environment and Behavior* , pp. 1-22.

Yue, C., Hall, C. R., Behe, B. K., Campbell, B. L., Dennis, J. H., & Lopez, R. G. (2010). Are Consumers Willing to Pay More for Biodegradable Containers Than for Plastic Ones? Evidence from Hypothetical Conjoint Analysis and Nonhypothetical Experimental Auctions. *Journal of Agricultural and Applied Economics* , pp. 757-772.

Appendix

The social cost of waste management from a packaging of quality i is represented by:

$$W(\rho_i) = e(1-\rho_i) + s\rho_i(1-\rho_i) \qquad \text{(A.1)}$$

Whereas, the waste management cost born by a producer i is represented by:

$$G(\rho_i) = (e+t_e)(1-\rho_i) + (s+t_s)\rho_i(1-\rho_i) \qquad \text{(A.2)}$$

The optimal policy is characterised by:

$$t_s^* = 2(s - c) \quad t_e^* = 2(a + \frac{1}{2} - \alpha) \tag{A.3}$$

Substituting in (A.2) t_s and t_e by their optimal value expressed in (A.3), we have now:

$$G(\rho_L) = (e + 2(\ a + \tfrac{1}{2} - \alpha))(1 - \rho_L) + \big(s + 2(s - c)\big)\rho_L(1 - \rho_L) \tag{A.4}$$

$$G(\rho_H) = (e + 2(\ a + \tfrac{1}{2} - \alpha))(1 - \rho_H) + \big(s + 2(s - c)\big)\rho_H(1 - \rho_H) \tag{A.5}$$

Compare (D.4) and (D.5) to (D.1), we have:

$$G(\rho_L) - W(\rho_L) = (2a + 1 - 2\alpha + 2(s - c)\rho_L)(1 - \rho_L) \tag{A.6}$$

$$G(\rho_H) - W(\rho_H) = (2a + 1 - 2\alpha + 2(s - c)\rho_H)(1 - \rho_H) \tag{A.7}$$

We know that $(1 - \rho_i > 0)$, so (D.6) and (D.7) are positives if respectively:

$$(2a + 1 - 2\alpha + 2(s - c)\rho_L) > 0 \tag{A.8}$$

$$(2a + 1 - 2\alpha + 2(s - c)\rho_H) > 0 \tag{A.9}$$

Substituting in (D.8) and (D.9) ρ_L and ρ_H by their optimal value expressed in (4), then rearranging terms and remember that $\alpha = c - e$, we have:

$$G\big(\rho_L^{\circ}\big) - W\big(\rho_L^{\circ}\big) > 0 \iff e + s > a + \frac{3}{4} - 2c \tag{A.10}$$

$$G\big(\rho_H^{\circ}\big) - W\big(\rho_H^{\circ}\big) > 0 \iff e + s \geq a + \frac{1}{4} - 2c \tag{A.11}$$

Cahiers du GREThA
Working papers of GREThA

GREThA UMR CNRS 5113

Université Montesquieu Bordeaux IV
Avenue Léon Duguit
33608 PESSAC - FRANCE
Tel : +33 (0)5.56.84.25.75
Fax : +33 (0)5.56.84.86.47

http://gretha.u-bordeaux4.fr/

Cahiers du GREThA (derniers numéros – last issues)

2013-17 : BECUWE Stéphane, BLANCHETON Bertrand, CHARLES Léo*, First globalization: why did France miss the boat?*

2013-18 : HARDY P.H., BENE C., DOYEN L., PEREAU J. C., MILLS D., *Viability and resilience of small-scale fisheries through cooperative arrangements*

2013-19 : BONNEFOND Céline, CLEMENT Matthieu, COMBARNOUS François*, In search of the elusive Chinese urban middle class: An exploratory analysis*

2013-20 : PASTUREAU Guillaume, JOURDHEUIL Romain, *Le prêt sur gages au Crédit municipal : vers une analyse exploratoire des relations entre banquier social et emprunteur*

2013-21 : BLANCHETON Bertrand, *L'autonomie de la Banque de France au XXe siècle*

2013-22 : MAVEYRAUD Samuel, *La structure du réseau de commerce international en 1850*

2013-23 : BONNEFOND Céline, *Growth dynamics and conditional convergence among Chinese provinces: a panel data investigation using system GMM estimator*

2013-24 : SALLE Isabelle, SENEGAS Marc-Alexandre, YILDIZOGLU Murat, *How Transparent About Its Inflation Target Should a Central Bank be? An Agent-Based Model Assessment*

2013-25 : LUSTOSA J. Maria Cecilia, FAURE Yves-André, *Changements institutionnels et politiques publiques au Brésil. Aux sources de la réduction des inégalités sociales, de la pauvreté et des disparités régionales*

2014-01 : BLANCHETON Bertrand, PASTUREAU Guillaume*, Le Mont-de-Piété à Bordeaux, les raisons d'un succès (1802-1913)*

2014-02 : FRIGANT Vincent, MIOLLAN Stéphane, *La restructuration de la géographie de l'industrie automobile en Europe durant les années 2000*

2014-03 : BLANCHETON Bertrand*, Les improvisations financière de la guerre de 1914-1918 en France. Les enjeux de la liquidité.*

2014-04 : ARNAUD Brice, *Extended Producer Responsibility and Green Marketing: an Application to Packaging*

La coordination scientifique des Cahiers du GREThA est assurée par Emmanuel PETIT. La mise en page est assurée par Anne-Laure MERLETTE.