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Summary

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JEL Classification: Q53, L13, L44

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Municipal waste collection: market competition and the EU policy

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August 2015

Abstract

Two of the main pillars of the EU waste collection policy are the Proximity Principle and Self-Sufficiency Principle. According to those, waste should be disposed as close as possible to where it has been produced. The effect of such provision is to increase the market power of local disposers, with possible undesirable consequences for other firms in the vertical chain. We show through a simple spatial model that one effect of the Proximity Principle and Self-Sufficiency Principle is to provide an incentive to collectors and waste producers to increase the amount of separated waste.

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1. Introduction

Municipal Solid Waste (MSW) is the waste generated by households. In the European Union (EU), local bodies at the municipality level are legally obliged to provide a collection system for MSW, in agreement with the regulations and guidelines set by EU directives, national laws, and regional plans.

The EU directives set the minimum targets to be reached and the environmental standards to be met; on top of that, the EU also requires that MSW should be handled and disposed close to the location where it is generated. This policy is rooted in the two pillars of Self-Sufficiency Principle (SSP) and Proximity Principle (PP) and it is aimed to reach two main goals: the first is to prevent the creation of pollution havens in regions with low environmental standards; the second is to enhance local communities' awareness of their environmental responsibilities.[1] From an economic viewpoint, however, the policy also has the effect of creating market power for the waste disposers operating in the district.

The MSW industry has a vertical structure, reflecting the three main phases of MSW processing. In the first phase households and, ultimately, local councils, generate MSW. The second phase is the collection of MSW: a municipality based collector picks up waste from the households. In this phase households/local councils do exert some effort to separate recyclable from undifferentiated waste. This is an important activity and it is rooted in another EU principle, the Extended Producer Responsibility (EPR). According to it, all subjects acting along the goods production and retail chains are responsible for the final diversion of those goods when transformed into waste. As a consequence, the EPR and its reuse-recover targets potentially reduce the amount of waste that reaches disposal facilities. In the third and last phase, the collector brings the waste to a disposer that processes MSW: separated waste can be recycled, while undifferentiated waste is either processed in a landfill or by an incinerator. Mainly due to scale and density economies, the collection phase can be considered a legal monopoly; moreover, the public/merit good nature of MSW advocates for the implementation of a compulsory public service.[2] The disposal segment instead could in principle operate in a competitive regime. The provisions of the SSP and PP, however, force local councils and collectors to find a disposing facility inside a defined district and

[1] European Parliament and Council Directive 2008/98/EC; please refer to Silvestri (2014) for further discussion of these principles.

[2] An inappropriate or inefficient collection causes significant negative externalities to the local community; see, for example, D'Alisa *et al.*, (2010).

among a restricted number of disposers, allowing the latter to potentially exploit a scarcity rent. It is also noticeable that such principles only apply to the MSW segment: industrial and commercial waste can be disposed outside the producing municipality, effectively allowing competition between disposers.

In this paper, we set up a simple spatial model of MSW production, collection and disposal. The model allows analysing the major economic effects of the EU policy and, in particular, the costs and benefits of the SSP and PP provisions. The analysis provides relevant policy implications. First of all, we confirm that the SSP and PP principles on waste collection, limiting competition between disposers, increase the cost of MSW collection to the local community; however, we also highlight a subtler consequence of such principles: the higher cost of disposing MSW leads households and local councils to exert more effort and, in turn, increase the amount of separated collection, decreasing instead the waste sent for disposal. The latter substitution effect may be a more or less intended consequence of the current EU regulation and it constitutes, perhaps, a further rationale behind the imposition of the SSP and PP principles. Aggregate level evidence from the 27 EU countries suggests indeed a negative correlation between the percentage of unselected MSW processed by a disposer (landfill or incinerator) and the average disposing costs (-0.65) and a positive correlation between the percentage of separated waste and the average disposing costs (0.73). The latter is illustrated in Figure 1. As liberalization in other regulated sectors (e.g. gas, electricity) has led to a decrease in the final price to users, we may conjecture that a similar process in the MSW segment would increase the percentage of disposed waste and reduce households' and councils' effort for separated collection.

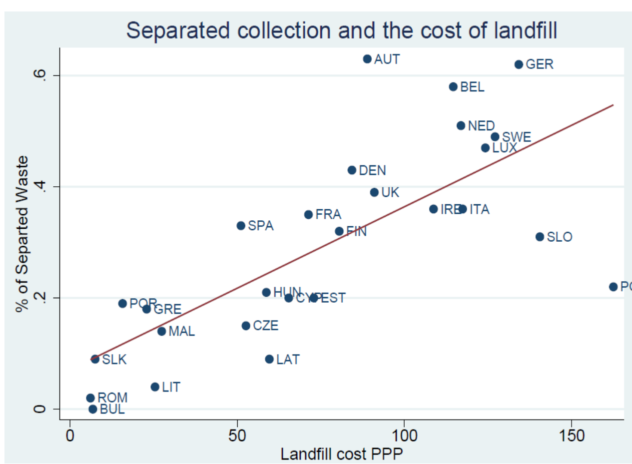

Fig.1 Source: Eurostat (2010).

To the best of our knowledge, this is one of the first papers to model the MSW industry in all its phases and participating agents. Most of the existing literature on MSW and its management has focused on either: (i) the environmental implications of waste and policies to correct welfare distortions (Davies and Doble, 2004; Jenkins *et al.*, 2004; Caplan *et al.*, 2006) or (ii) competition *for* the market (Demsetz, 1968), according to which natural monopolies can be managed by private firms whose right to operate is entrusted by the government via competitive tendering (Williamson, 1976; Laffont and Tirole, 1994, Ch.7). We focus instead on competition *in* the MSW market (Porter and van der Linde, 1995; Crocker and Masten, 1996; Massarutto, 2007). The closest contribution to ours is Choe and Fraser (1999). They also model the market for MSW but they focus on the environmental effects of dumping and illegal disposal and on welfare enhancing policy intervention in the sector.[3] Finally, the model in this paper can be adapted to address a number of other relevant and related issues. For example, Silvestri (2014) provides an in depth analysis of the EU MSW market and focuses on related issues like: (a) the welfare effects of the SSP and PP principles and compares the current regulation with other possible regulatory instruments; (b) the analysis of the implications of the sector's structure for entrance of new disposers.

The rest of the paper is structured as follows. In Section 2, we introduce the model. In Section 3 we solve the model and compare the "status quo", in which the SSP and PP are enforced, and with a scenario in which the SSP and PP are relaxed and the disposal sector is exposed to more competition. In Section 4 we briefly discuss our results and conclude. All proofs are in the Appendix.

2. A spatial model of MSW

Consider two bordering geographical areas ($i = A, B$); consistently with the previous discussion, in each area there is a Local Council (LC), a monopolistic Collector (C) and a disposing facility (D).

Local councils. LCs are representative of a municipal community that produces an amount of MSW Q_i, that, for analytical convenience, we shall normalise to 1. According to the current legislation, all the MSW must be removed. A fraction $q_i \leq 1$ is unseparated waste. As a consequence of the EPR principle, the removal of separated MSW is free for households and, hence, LCs: this provides

[3] A stream of literature has carefully modelled the MSW sector to analyze the optimal design of solid waste management programs: competition, however, is usually not addressed. See Di Corato and Montinari (2014) for a recent contribution.

an incentive to put costly effort e_i in separating waste. The previous discussion can be summarized by the following utility function of a given LC:

$$U_i^{LC} = \overline{u}_i - p_i q_i - e_i, \tag{2.1}$$

where p_i is the unit price paid by the LC for the collection of unseparated MSW. The quantity of separated collection d_i depends on the effort but also on the available selection capacity k_i, provided by the local collector. We shall assume that waste separation takes place according to the following Cobb-Douglas technology:

$$d_i = e_i^{\frac{1}{2}} k_i^{\frac{1}{2}}, \quad d_i \leq 1. \tag{2.2}$$

In other words, separated waste is the output originating from three inputs: the raw material, Q_i, that we normalised to 1, the LCs effort, e_i, and the installed capacity for separated collection, k_i.

Collectors. The monopolist collectors operate exclusively in their area; however, where waste is disposed depends on the regulatory regime. Under the current EU regime, unseparated waste must be disposed in the local area; on the contrary, if the provisions of the SSP and PP are relaxed, collectors have no obligation in disposing the picked unseparated waste in the local or the external landfill. The collector is chosen as a franchised or natural monopolist to operate in the collection segment. The collector also provides the facilities for LCs to separate waste: in particular, they install a selection capacity k_i and investment in capacity has a quadratic cost.[4] The (exogenous) unit price p_i for unseparated waste is set by the regulator; similarly, the unit price for separated waste collection $\widetilde{p}_i$ is also exogenously set according to the EPR system.

We capture the geographical aspects, a defining characteristic of this sector, through a simple model *à la* Hotelling (1929). Area A and B are represented as unit length lines, so that the overall market has a total length of 2 (see Figure 2). Households pertaining to a LC are uniformly distributed along the line in both areas, with $x_i \in [0, 2]$ denoting the location of a specific household. Disposal facilities are located at the extremes of each line, i.e. disposer A is located at $x = 0$ and disposer B at $x = 2$. Collectors face linear transportation costs in picking-up unseparated waste and bringing it to the location of the facilities.[5] We denote the

[4] Quadratic costs are assumed for analytical convenience but any convex function would not affect our results.

[5] For simplicity, we do not consider any intermediate recollection, such as transitional places where to accumulate and treat the unselected waste that come from households.

total transport costs of gathering the waste and bringing it to the disposal facility as T_i.

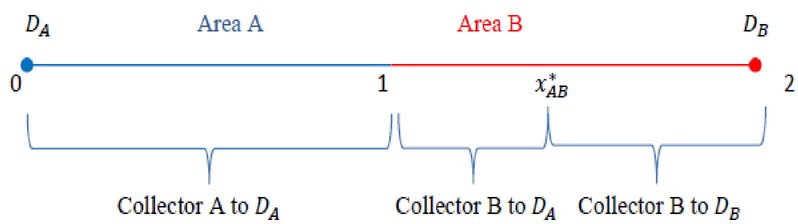

Fig. 2 An example of deregulated spatial waste market.

Taking for reference the collector operating in area A, collector A's profit can be written as:

$$\pi_A^C = \begin{cases} (p_A - a_A)q_A x^*_{AB} + (p_A - a_B)q_A(1 - x^*_{AB}) + \widetilde{p}_A d_A - k_A^2 - T_A(x^*_{AB}) & \text{if } x^*_{AB} < 1 \\ (p_A - a_A)q_A + \widetilde{p}_A d_A - k_A^2 - T_A(x^*_{AB}) & \text{if } x^*_{AB} > 1 \end{cases} \tag{2.3}$$

where $x^*_{AB} < 1$ is the fraction of unseparated waste taken to the local disposer, whereas the rest is brought for disposal at the external facility; if $x^*_{AB} > 1$ the collector brings all unseparated waste to the local disposer. Clearly, under the current EU regulation, $x^*_{AB} = 1$ is enforced and it is not a variable of choice of the collector. As it will become clear, if regulation is lifted, x^*_{AB} will depend on the disposal prices at the two facilities and on the transport costs. The total transport costs depend on x_i and can be explicitly expressed as:

$$T_A(x^*_{AB}) = \begin{cases} tq\left[\int_0^{x^*_{AB}} u du + \int_{x^*_{AB}}^{1} (2-u)\, du\right] & \text{if } x^*_{AB} < 1 \\ tq\int_0^1 u du & \text{if } x^*_{AB} > 1 \end{cases} \tag{2.4}$$

and similar expressions hold for both the profits and transport costs of collector B.

Disposers. The disposing facility D_i receives the unseparated MSW and charges a_i for each unit to be disposed. Notice that a_i is the same, no matter what is the origin of the waste. If the SSP and PP are relaxed, in fact, the facility may receive waste from both the local and the outside collectors: the disposers are not allowed to discriminate waste according to its origin. The profits of disposer A are, then:

$$\pi_A^D(a_A, a_B) = \begin{cases} a_A\left[q_A + q_B(x_{AB}^* - 1)\right] & \text{if } a_A < a_B \\ a_A q_A & \text{if } a_A = a_B \\ a_A q_A x_{AB}^* & \text{if } a_A > a_B \end{cases} \tag{2.5}$$

and the profits of disposer B can be written in a similar way.

The timing of the game is as follows:

1. Disposers decide the amount charged, a_i, for the disposal of unserparated waste;

2. Collectors choose the selection capacity k_i for separated collection and is obliged to collect any unseparated waste;

3. Local councils exert effort e_i for separated collection and produce unseparated waste q_i.

3. Analysis

3.1. The choice of effort

Proceeding by backward induction, we start by solving for the LCs choices on the effort to be put into separated collection and the amount of unseparated waste. These choices hold for any level of the installed selection capacity by collectors and prices chosen by the disposers. Given (2.2) and the fact that $q_i = 1 - d_i$, the LC i maximises utility (2.1). The optimal effort choice of LC i is obtained for:

$$e_i^* = \frac{k_i p_i^2}{4}, \tag{3.1}$$

which, in turn, implies that the unseparated collection is:

$$q_i^* = 1 - \frac{k_i p_i}{2}. \tag{3.2}$$

According to (3.1) and rather intuitively, the effort exerted by households and LCs in separated collection is positively related to the selection capacity installed by the collector, k_i and by the price of unseparated collection, p_i. A high collection price encourages the substitution of unseparated waste with separated one, as confirmed by (3.2). As the LCs never interact, their choices are not directly affected by the regulation regime, so these results apply to both the regimes that we analyse.

3.2. Collectors' choices

Whereas the EU regulation constitutes the current *status quo*, it arises a special case in our model: hence, we shall first analyze the case of no regulation. If no regulation is imposed, from (2.3), it is immediate to find that:

$$x_{AB}^{*} = 1 + \frac{a_B - a_A}{2t}, \tag{3.3}$$

i.e. whether it is collector A or collector B to bring unseparated waste to the disposer in a different area depends on the price differential, $a_B - a_A$. If the latter is non-negative, then $x_{AB}^{*} \geq 1$. We can then start by assuming, without loss of generality, that $x_{AB}^{*} \geq 1$. Given (3.1) and (3.2), collectors maximize profits π_A^C and π_B^C with respect to k_A and k_B respectively. The first order conditions are:

$$\begin{aligned} \frac{\partial \pi_A^C}{\partial k_A} &= \frac{-8k_A p_A \sqrt{k_A} + p_A^2 \sqrt{k_A}\left[2\left(a_A - p_A + \widetilde{p}_A\right) + t\right]}{4p_A\sqrt{k_A}} = 0 \\ \frac{\partial \pi_B^C}{\partial k_B} &= \frac{-16tk_B p_B \sqrt{k_B} - p_B^2 \sqrt{k_B}\left[\left(a_B - a_A\right)^2 - 4t\left(a_B - p_B + \widetilde{p}_B\right) - 2t^2\right]}{8tp_B\sqrt{k_B}} = 0 \end{aligned}$$

Solving these simultaneously allows finding the optimal selection capacity to be installed for separated collection:[6]

$$\begin{aligned} k_A^{*} &= \frac{p_A}{8}\left[2\left(a_A - p_A + \widetilde{p}_A\right) + t\right], & (3.4) \\ k_B^{*} &= \frac{p_B}{8}\left[2\left(a_B - p_B + \widetilde{p}_B\right) + t\right] - \frac{p_B}{16t}\left(a_B - a_A\right)^2, & (3.5) \end{aligned}$$

and, consequently, the resulting unseparated collection:

$$\begin{aligned} q_A^{*} &= 1 - \frac{p_A^2}{16}\left[2\left(a_A - p_A + \widetilde{p}_A\right) + t\right], & (3.6) \\ q_B^{*} &= 1 - \frac{p_B^2}{32}\left[4\left(a_B - p_B + \widetilde{p}_B\right) + 2t - \frac{\left(a_B - a_A\right)^2}{t}\right]. & (3.7) \end{aligned}$$

Under the assumption $x_{AB}^{*} \geq 1$, collector A brings all of the waste generated in area A to the local disposer. Hence, his selection capacity choice is not directly affected by the price of disposing in area B. If the latter inequality is strictly satisfied, this is not the case for collector B. In absence of regulation and as the

[6] It is immediate to verify that the second order conditions for a maximum hold.

price of disposing in area A is lower than in B ($a_A < a_B$), then the waste of households located between 1 and x^*_{AB} is brought for disposal to area A. The rest of the waste, gathered between x^*_{AB} and 2, is disposed in area B. Clearly, then, the disposal price differential $a_B - a_A$ affects the choices of collector B, as it can be seen in (3.5) and (3.7). In particular, (3.5) shows that the higher the price of disposal in both areas, the higher is the incentive for the collector B to install selection capacity.

If the EU regulation is imposed and $x^*_{AB} = 1$, the optimal selection capacity and unseparated collection are, respectively:

$$k_i^{EU} = \frac{p_i}{8}\left[2\left(a_i - p_i + \widetilde{p}_i\right) + t\right], \tag{3.8}$$

$$q_i^{EU} = 1 - \frac{p_i^2}{16}\left[2\left(a_i - p_i + \widetilde{p}_i\right) + t\right]. \tag{3.9}$$

Comparing (3.4) and (3.8) it is clear that, for a given price of disposal a_A, the choice of collector A is not affected by the regulatory regime.

3.3. Disposers' choices

In absence of EU regulation, the disposers maximize their profits given the choices of the LCs, (3.1), and the collectors, (3.4)-(3.7). As we focus on the case $x^*_{AB} \geq 1$, the profits functions of the disposers are, respectively:

$$\pi_A^D(a_A, a_B) = a_A\left[q_A^* + q_B^*(x^*_{AB} - 1)\right] \tag{3.10}$$

$$\pi_B^D(a_A, a_B) = a_B q_B^*\left(2 - x^*_{AB}\right) \tag{3.11}$$

According to the previous assumption on x^*_{AB}, disposer A receives the unseparated waste from both areas, whereas disposer B focuses on the remaining local waste.

In case EU regulation is holding and $x^*_{AB} = 1$ is enforced, no waste can be transferred from one area to the other; as a consequence, the profit functions are:

$$\pi_i^D = a_i q_i^{EU} \tag{3.12}$$

First, we can fully characterize the equilibrium if the SSP and PP principles hold. The following lemma highlights the disposers' price choices.

Lemma 1. *The disposers' price choices in presence of the EU regulation are:*

$$a_i^{EU} = \frac{1}{4}\left[\frac{16}{p_i^2} + 2p_i - 2\widetilde{p}_i - t\right]. \tag{3.13}$$

Lemma 1 shows that under regulation the disposers' price choices in each area are completely independent. In other words, EU regulation isolates local disposers from the competition of disposers from other areas. The equilibrium price of disposal is affected by the parameters of the model in a complex way. First, a_i^{EU} depends negatively on the price of separated collection, $\widetilde{p}_i$, and on the transport cost, t. The price of disposal also depends non-monotonically on the price of unseparated collection: a_i^{EU} increases if the collection price is sufficiently high. These effects depend on the way the parameters influence the collector's choice for selection capacity and how this, in turn, impacts on the demand for unseparated collection, q_i^{EU} and, consequently, disposal.

We can then turn our attention to the effects of abandoning regulation and the SSP and PP principles. In this case we cannot fully characterize the equilibrium and provide the equilibrium expressions for the prices of disposal. However, the following results can be stated.

Proposition 2. *(a) If in presence of the EU regulation the equilibrium prices were identical, $a_A^{EU} = a_B^{EU}$, abandoning regulation leads to a decrease in the disposal prices a_i^* in both areas, $i = A, B$;*

(b) if $a_A^{EU} < a_B^{EU}$, a sufficient condition for the disposal price of A to decrease if regulation is abandoned is: $a_A^{EU} > a_B^{EU}/2$. The disposal price of B decreases.

(c) If abandoning EU regulation leads to lower disposal prices, then the incentives to build capacity for separated collection, k_i^*, to exert effort e_i^* and, ultimately, the overall amount of separated collection as a whole, d_i^* are reduced.

Proposition 2 states the main results of the paper. In particular, part (a) and (b) identify the effects of relaxing the prescriptions of the current EU regulation on waste collection and disposal.

Part (a) establishes that if two areas, regions or countries have very similar prices of disposal in the current status-quo, opening the market for disposal and giving the possibility to collectors to transport waste to other neighbouring areas would lead to a reduction in the prices of disposal. The intuition is very simple: a small unilateral decrease in the price of disposal from a_i^{EU} would increase profits as it allows to extend the market size. In other words, the collector from the neighbouring area would consider bringing a small share of the waste, produced by households located near the border, to the disposal facility that reduced the price. As both disposers face this pressure to reduce prices, the resulting unregulated equilibrium features lower prices in both areas. Allowing disposal in other areas has a "pro-competitive effect" that decreases the cost of the disposal of unseparated waste in both areas.

Part (b) extends the result to the case in which areas are heterogeneous, which is reflected in a different price of disposal, a_i^{EU}, in the regulated status quo. In particular, the result establishes that the "pro-competitive effect" of abandoning regulation is very likely to take place also in this case. A sufficient, but not necessary, condition for the price of disposal to decrease is that areas are not too heterogeneous and, more precisely, that the status-quo disposal prices are not too different. If, as we assumed, area A is characterized by a lower disposal price, the pro-competitive effect of abandoning EU regulation prevails if the price is more than half of the price in area B, i.e. $a_A^{EU} > a_B^{EU}/2$. Moreover, the higher price disposer, D_B, is surely going to decrease its price in response to deregulation. Hence, unless areas are particularly heterogeneous, part (b) shows that it is very likely that the prices of disposing unseparated waste decrease when waste can travel across areas.

The intuition for this second result is more intricate. In particular, according to (A.3), the effect of unilaterally decreasing the disposal price in area A following a lift of the EU regulation can now be written as:

$$\frac{\partial \pi_A^D}{\partial a_A}|_{a_A=a_A^{EU}} = \underbrace{FOC_A^{EU}(a_A^{EU})}_{=0} + \underbrace{a_A^{EU} q_B^{EU} \frac{\partial x_{AB}^*}{\partial a_A}}_{\text{Pro-competitive effect}} + \underbrace{a_A^{EU} \frac{\partial q_B}{\partial a_A} (x_{AB}^* - 1)}_{\text{Indirect effect on } q_B} + \underbrace{q_B^{EU} (x_{AB}^* - 1)}_{\text{Infra-marginal gain}}. \tag{3.14}$$

In (3.14) there are three new terms than in case EU regulation still holds. The usual "pro-competitive effect", identified in part (a), is now captured by the second term and it pushes down the disposal price of A. However, there are now two extra terms. The third term captures the negative relation between the unseparated waste in B, q_B, and the price of disposal a_A: as a share of waste is "exported" from B to A, a higher disposal price of A increases the average disposal cost in area B and that acts to decrease the household production of unseparated waste. This effect, that we shall call "indirect effect" on q_B, clearly goes in the same direction of the "pro-competitive effect". The fourth term of (3.14), instead, captures the "infra-marginal gain" in profits due to abandoning regulation. This is related to the new market share obtained, as with no regulation $x_{AB}^* > 1$, and clearly encourages disposer A to increase its price. The complex balance of these three effects determines whether the price of disposal will decrease or not in area A: the condition provided on the prices of disposal establishes when the "pro-competitive" and "indirect" effects are surely dominating the "infra-marginal gain". Matters are much simpler when looking at disposer B: in that case all the effects univocally point in the direction of a price decrease.

Finally, part (c) establishes the effects of a possible decrease in the price of disposing unseparated waste. Given the comparative statics obtained in the previous stages of the game it is simple to see that the "pro-competitive effect" identified at the disposal layer of the waste market has an important consequence: higher competition in disposal can reduce and hinder the amount of resources dedicated to separated waste (selection capacity and household effort), leading to an overall decrease of the separation achieved by the local communities.

3.3.1. A special case: symmetric areas

We now focus on the special case of symmetric areas. This case may be of particular interest when considering regions with similar characteristics and it has the further advantage that equilibria in both scenarios can be characterized, which may be appealing for possible empirical applications of the model.[7]

If areas A and B are symmetric we have: $p_A = p_B = p$ and $\widetilde{p}_A = \widetilde{p}_B = \widetilde{p}$. The disposal equilibrium price under EU regulation is still:

$$a^{EU} = \frac{1}{4}\left[\frac{16}{p^2} + 2p - 2\widetilde{p} - t\right].$$

If regulation is lifted, instead, the disposers choose the equilibrium price:

$$a^* = \frac{1}{4}\left(\frac{16}{p^2} + 2p - 2\widetilde{p} + 7t\right) - \frac{\sqrt{4\left(p^3 - p^2\widetilde{p} + 8\right)^2 - 4p^2 + 65p^4t^2}}{4p^2}.$$

As a corollary of Proposition 2, the next result follows:

Corollary 3. *If areas A and B are symmetric, abandoning EU regulation leads to a decrease in the prices of disposal: $a^* < a^{EU}$. The latter implies a reduction in the incentives to build capacity for separated collection, k^*, to exert effort e^* and, ultimately, the overall amount of separated collection, d^*.*

The corollary reinforces the message of Proposition 2. Relaxing the current EU regulation on waste management would make the disposer's segment of the market

[7]Silvestri and Ghinoi (2015) apply an adapted version of this model to waste management in the region of Lombardy in Italy.

more competitive, with a decrease in the prices paid for disposal. However, the substitution between unseparated and separated collection lowers the collectors' incentives to invest in selection capacity. This, in turn, has a negative effect on the effort exerted by local councils and households, resulting in a lower and undesirable level of unseparated collection.

4. Discussion

This paper provides two main contributions. The first it is to formalise in a simple spatial model the economics of waste collection in the EU. The second is to highlight the main economic effects of EU regulation of the waste sector on market outcomes. In particular, our model confirms that the SSP and PP principles, on which the current EU regulation on waste collection is based, have the effect of limiting competition between disposers. Our main result suggests that an intuitive, "pro-competitive" effect may operate if regulation is abandoned: this is likely to be the case not only when areas are very similar but also when they are rather heterogeneous. Only if areas are very heterogeneous the "pro-competitive effect" of opening to disposers' competition may not reduce the prices. This intuitive effect, however, has another possible consequence: more competitive disposal markets, reduce the costs of collection and that, in turn, leads to lower incentives to build selection capacity and reduced incentives for households and local councils to engage in separated collection. Regulation, then, may be better suited to encourage recycling and separated collection.

The latter effect on separated collection incentives may be one more possible rationale behind the current EU regulation. One view, popularized by Hotelling (1931) and Buchanan (1969), asserts that less competitive market structures may be desirable, in some cases, to limit negative environmental externalities.[8] We highlight a similar effect within a model that captures the complicated structure of the waste collection and disposal sector. The EU policy, in this context, seems to have one more advantage, beyond its usually declared objectives (preventing the creation of pollution havens, above all): increasing the local communities' incentives to engage in recycling and separated collection.

Whereas our model has attempted to capture the main features of the MSW sector, our results were obtained under a number of simplifying assumptions. For example, one implication of our model is that the regime does not influence

[8] "It has been argued that market imperfection especially the polar case of monopoly, is the conservationists' best friend" (Hotelling, 1931).

the regulated price of collection of both the separated, $\widetilde{p}$, and the unseparated waste, p. The price of unseparated collection at least is likely to be related to the price of disposal. One way of capturing such a feature in our model is, for example, by assuming that the regulator applies a fixed mark-up to set the price of unseparated collection, e.g. $p_i = \mu_i a_i$ with $\mu_i > 1$. Such a case is tractable and it is easy to verify that the equilibrium expressions, substituting the relations above, are unaffected up to stage 2, i.e. up to the collectors' choices. However, as the solution of the first stage, in which prices of the disposers are chosen, is less straightforward and the expressions are rather complicated, in the paper we choose to focus on the basic case. Our results, however, turn out to be even sharper in the extended model. The reason is rather intuitive: abandoning the current regulatory regime, in fact, leads also to an adjustment in the relative price of unseparated collection. The "pro-competitive effect", then, implies a lower disposal price but also, proportionally, even less separated waste. A similar effect is likely to operate also in case the total amount of waste produced by the local council, that we normalised to one in our model, is allowed to vary between regimes: relaxing the current regulation would lead to the lower prices in the unseparated section of the market and this is likely to increase the size of the overall waste produce by councils.

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A. Appendix

A.1. Proof of Lemma 1

If EU regulation is in place, the first order conditions are symmetric for the two areas and can be written as:

$$FOC_i^{EU}(a_i) = q_i^{EU} + a_i \frac{\partial q_i^{EU}}{\partial a_i} = 0. \tag{A.1}$$

Importantly, the first order condition is unaffected by the variables and parameters relating to area j. As $\partial q_i^{EU}/\partial a_i = -p_i^2/8 < 0$, then $FOC_i^{EU}(a_i)$ is decreasing in a_i and a unique equilibrium exists. Substituting the relevant expressions, the equilibrium can also be characterized as (3.13).

Q.E.D.

A.2. Proof of Proposition 2

The effect of abandoning the current EU regulation is considered. Given our assumption on x^*_{AB}, there are two possible cases, depending on the "fundamentals" (i.e. p_i and $\widetilde{p}_i$): (a) the equilibrium is such that $a_A^{EU} = a_B^{EU}$; (b) the equilibrium is such that $a_A^{EU} < a_B^{EU}$.[9] We shall consider each in turn, corresponding to parts (a) and (b) of the Proposition.

(a) If $a_A^{EU} = a_B^{EU}$ and regulation stops being enforced, according to (3.3) we shall still have $x^*_{AB} = 1$. Suppose disposer A considers decreasing the price from a_A^{EU}; in that case the relevant profit function is (3.10), as $x^*_{AB} > 1$ following the considered price decrease. The impact of the change in the price, evaluated at $a_A^{EU} = a_B^{EU}$, can be written as:

$$\frac{\partial \pi_A^D}{\partial a_A}|_{a_A = a_A^{EU}} = \underbrace{FOC_A^{EU}(a_A^{EU}) + q_B^{EU}(x^*_{AB} - 1) + a_A^{EU}\frac{\partial q_B}{\partial a_A}(x^*_{AB} - 1)}_{=0} + \underbrace{a_A^{EU} q_B^{EU} \frac{\partial x^*_{AB}}{\partial a_A}}_{-} < 0, \tag{A.2}$$

where the first three terms are zero as a consequence of $\partial \pi_A^D/\partial a_A$ being evaluated at the EU equilibrium. Hence, (A.2) implies that a unilateral price decrease, increases disposer A profits. A similar argument applies to disposer B. These imply that $a_i^* < a_i^{EU}$.

[9] Notice that if the equilibrium is such that $a_A^{EU} > a_B^{EU}$ and $x^*_{AB} < 1$, the proof follows from case (b) inverting the roles of A and B.

(b) If $a_A^{EU} < a_B^{EU}$ then abandoning regulation would imply $x_{AB}^* > 1$ even if no price adjustment is made. From the perspective of disposer A, (3.10) is still the relevant profit function and the impact of a change in price is still:

$$\frac{\partial \pi_A^D}{\partial a_A}|_{a_A=a_A^{EU}} = \underbrace{FOC_A^{EU}(a_A^{EU})}_{=0} + \underbrace{q_B^{EU}(x_{AB}^* - 1)}_{+} + \underbrace{a_A^{EU}\frac{\partial q_B}{\partial a_A}(x_{AB}^* - 1) + a_A^{EU} q_B^{EU} \frac{\partial x_{AB}^*}{\partial a_A}}_{-}. \tag{A.3}$$

In this case, however, the second term is positive as $x_{AB}^* > 1$, whereas the last two terms are negative. The sign of (A.3) then depends on:

$$\Phi = q_B^{EU}\left[x_{AB}^* - 1 + a_A^{EU}\frac{\partial x_{AB}^*}{\partial a_A}\right] + a_A^{EU}\frac{\partial q_B}{\partial a_A}(x_{AB}^* - 1),$$

and although the expression is hard to sign in general, after substitution it can be re-written as:

$$\Phi = q_B^{EU}\left[\frac{1}{2t}\left(a_B^{EU} - 2a_A^{EU}\right)\right] - \frac{a_A^{EU} p_B^2}{32t^2}\left(a_A^{EU} - a_B^{EU}\right)^2,$$

implying that $a_A^{EU} > a_B^{EU}/2$ is sufficient for $\Phi < 0$ and, as a consequence, for $a_A^* < a_A^{EU}$.

From the point of view of disposer B abandoning regulation would imply a decrease in the demand ($2 - x_{AB}^* < 1$) even if no price adjustment is made. The relevant profits are then (3.11) and the impact of a change in price, evaluated at the EU regulation equilibrium, can be written as:

$$\frac{\partial \pi_B^D}{\partial a_B}|_{a_B=a_B^{EU}} = \underbrace{q_B^{EU}(2 - x_{AB}^*) + a_B^{EU}\frac{\partial q_B}{\partial a_B}(2 - x_{AB}^*)}_{<FOC_B^{EU}(a_B)} - \underbrace{a_B^{EU} q_B^{EU}\frac{\partial x_{AB}^*}{\partial a_B}}_{-} < 0 \tag{A.4}$$

The latter inequality holds as the first two terms are lower than the equivalent terms in (A.1) as $2 - x_{AB}^* < 1$, whereas the last term is negative. As such, disposer B always reduces his price if regulation is lifted: $a_B^* < a_B^{EU}$.

(c) If abandoning regulation leads to a decrease in disposal prices a_i^*, then the results on selection capacity, effort and overall amount of separated collection follow directly from the results obtained at Stage 2 and 3. In particular, as $\frac{\partial k_i^*}{\partial a_i^*} > 0$ a lower disposal price implies a lower selection capacity; this, in turn, implies:

$$\frac{\partial e_i^*}{\partial k_i^*}\frac{\partial k_i^*}{\partial a_i^*} > 0 \text{ and } \frac{\partial d_i^*}{\partial k_i^*}\frac{\partial k_i^*}{\partial a_i^*} > 0.$$

Q.E.D.

A.3. Proof of Corollary 3

The claim follows directly from part (a) of Proposition 2. However, as the equilibrium is fully characterized, it is sufficient to compute the disposal price differential:

$$\Delta a = a^* - a^{EU} = 2t - \frac{\sqrt{4\left(p^3 - p^2\widetilde{p} + 8\right)^2 - 4p^2 + 65p^4t^2}}{4p^2}.$$

The only zero of Δa_i is:

$$\widehat{t} = \frac{2}{p^2}\left(p^3 - p^2\widetilde{p} + 8\right),$$

hence Δa_i is either always positive or always negative for all other values of t. As $\partial^2 \Delta a / \partial t^2 \leq 0$ then Δa is always negative, implying $a^* < a^{EU}$. The implications of the result on selection capacity follow directly from part (c) of Proposition 2.

Q.E.D.

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