Journal of Cleaner Production 92 (2015) 216–222

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Regulation of waste management under spatial competition

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ARTICLE INFO

Article history:
Received 16 May 2014
Received in revised form
29 October 2014
Accepted 15 December 2014
Available online 30 December 2014

JEL classification:
D43
L13
Q53

Keywords:
Waste management
Spatial competition
Firms' locations
Collection point

ABSTRACT

We consider a regulator with different sensibilities with regard to consumers and producers. This regulator has a say in (i) the location of a waste collection point; (ii) who pays the waste transportation costs to the collection point; and (iii) whether firms locate simultaneously or sequentially. We find that these decisions depend on the regulator's profile and on the relationship between waste and product transportation costs. They also have an impact on competition between firms and on welfare. When the regulator requires firms to pay waste transportation costs the optimal location of the collection point is in the middle of the city, regardless of whether firms' locations are chosen simultaneously or sequentially. When the regulator decides that the cost is to be paid by consumers and that firms locate sequentially the collection point is located outside the middle of the city.

1. Introduction

The production and distribution of goods causes waste and rubbish that firms must get rid of. Disposing of waste is expensive as waste materials must be transported to a collection point. This is usually done in batches and not unit by unit as waste is continuously generated, because the latter system would be very costly. The location of the collection point is thus crucial in determining the cost to firms of transporting their waste.

In this paper we study a duopoly in a linear city. We consider that firms and consumers share the same cost structure: firms use it to get rid of their waste and consumers to transport goods home. These costs are quadratic with the distance traveled, as suggested by d'Aspremont et al. (1979) to avoid the problem of there being no price equilibrium for some locations of the two firms. The difference between consumers and firms is that each consumer transports home one unit of the good, while all waste is transported at the same time to the collection point. We consider a collection point alone rather than a landfill, because a landfill generates negative externalities which would lead it to be located outside the residential area. Thus, we do not assume that the collection point has any negative externalities, so it can be located within the city limits when it is of interest to do so from a social welfare point of view.

Plants for processing and classifying waste are commonly located within residential areas when their negative effects can be considered negligible. One example of collection points located in the residential areas of the cities can be found in municipal garbage processing plants. For example in Vitoria–Gasteiz, a city located in northern Spain, one of the plants that process the garbage is located close to the city's medieval Old Town, a core city center district. Recently 79 small apartments for young people have been built adjacent to the garbage processing plant near the city center. Our paper does not refer to urban garbage but waste produced by firms, but the same arguments can be used to justify the central location of the collection point for a broad variety of non-dangerous waste materials.

Literature on the location of firms begins with the seminal paper by Hotelling (1929), who states the principle of minimum differentiation in a linear city. In this paper consumers have linear transportation costs but this assumption causes problems in obtaining an equilibrium in prices when firms are close enough

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http://dx.doi.org/10.1016/j.jclepro.2014.12.052
0959-6526/

together. This problem is analyzed by d'Aspremont et al. (1979), who suggest a different approach to get price equilibria in all subgames by considering quadratic transportation costs. Under this cost structure firms locate at the endpoints of the city (the so-called principle of maximum differentiation). Later Lambertini (1994) and Tabuchi and Thisse (1995) extend this model by allowing firms to locate outside city boundaries given that they have incentives to locate where there are no consumers. In this setting, in the simultaneous case firms locate symmetrically outside the city boundaries at a distance from their rivals equivalent to 1.5 times the size of the city. In the sequential case the leader locates in the middle of the market and the follower locates at a distance from the leader equivalent to the size of the city. There are several different extensions of these models but to our knowledge literature on the location of firms has never before addressed the economic consequences of the location of a collection point.

Another branch of literature analyzes related issues. Thisse and Wildasin (1992) consider a single public facility whose location is fixed and two firms that choose their locations. They also assume that the location of households and land rent are endogenously determined, but in their model the price of the good sold by the two firms is exogenously given. Chen and Sheu (2013) employ a reverse Hotelling model to characterize the eco-design motivation in an eco industrial park. Morrissey and Browne (2004) review the types of model that are currently used in the area of municipal waste management. ReVelle and Eiselt (2005) review papers that analyze the location of facilities, focusing on models that consider discrete and continuous optimization.

To analyze social welfare effects we use a weighted welfare function which can be interpreted as a special case for private duopolies of the generalized social welfare function proposed by White (2002). That function gives different weights to consumer and producer surpluses and has been used before in location models (see e.g. Hamoudi and Risueño, 2012; Bárcena-Ruiz and Casado-Izaga, 2014; Bárcena-Ruiz et al., 2014). The function allows to analyze the behavior of a regulator who may have different sensitivities with respect to firms' profits and the consumer surplus.

We focus on two alternative settings: first we consider that firms pay waste transportation costs; second we assume that consumers equally share those costs regardless of the location of the collection point. In the first case the price set by the firms comprises the cost of transporting the waste. In the second setting the public authorities impose a uniform tax that finances all the costs of collecting certain spent goods. For example within the EU countries such as France, Italy and Spain have ruled that collecting used tires is the responsibility of producers, but in other countries, e.g. Denmark and the Slovak Republic, the state takes this responsibility and finances the relevant operations through a tax (see European Tyre and Rubber, 2011).[2] From the point of view of our analysis what is relevant is not who is responsible but whether firms are allowed to finance operations through a tax or must pay the relevant expenses themselves.[3]

We find that when firms pay the waste transportation costs the optimal location of the collection point is in the middle of the city, regardless of whether firms decide their locations simultaneously or sequentially. The collection point acts as a centripetal force for the location of both firms because there is a cost reduction effect that pushes them both to locate near the collection point. Thus, firms locate closer together when there is a collection point than when disposing of waste is free. As a result competition between firms increases, which results in lower prices. Moreover, a regulator who has a say in the timing of the location game can influence the decisions of firms. The regulator can force a simultaneous choice of locations when it is very concerned about firms' profits and a sequential choice of locations when it is very concerned about the consumer surplus. For example, when the regulator must approve the location of firms by granting an operating certificate, both locations could be approved at the same time or on different days. In the first case firms locate symmetrically around the collection point, but in the second case the leader locates at the location of the collection point and the follower locates far from it.

When consumers pay the waste transportation cost through a tax the optimal location for the collection point is outside the middle of the city only when firms decide their locations sequentially. As when firms pay the cost, if the regulator is concerned about firms' profits a simultaneous choice of locations is preferred. In this setting the location decisions of firms (be they simultaneous or sequential) do not depend on waste transportation costs.

Finally, we analyze the decisions made by the regulator regarding who pays waste transportation costs and whether firms locate simultaneously or sequentially, and find that they depend on how sensitive the regulator is towards consumers and producers, and on the relationship between waste and product transportation costs. A regulator who is very concerned about firms' profits chooses the tax system and thus consumers pay waste transportation costs.[4] Otherwise, weighted welfare is greater when firms pay these costs, so the regulator decides accordingly. In the latter case, when the regulator is highly concerned about the consumer surplus a sequential choice of locations is better.

The rest of the paper is organized as follows. Section 2 presents the basic model. Section 3 considers that firms pay waste transportation costs. Section 4 studies the locations of firms when this cost is borne by consumers. Section 5 compares the results, and Section 6 draws conclusions.

2. The basic model

Consumers are distributed uniformly and with unitary density along a linear city, in the interval [0,1]. Consumers' locations are denoted by x. They transport their purchases home at a cost td^2, where t is a positive constant and d is the distance traveled from the firm's location to the consumer's home. Each consumer buys one unit of the good at the lowest delivered price, considered as the mill price plus transportation cost.[5] Each consumer derives a surplus from consumption, gross of price and transportation costs, denoted by s. We assume that s is large enough for each consumer to buy one unit of the product.

There are two private firms indexed by i ($i = 1,2$) competing in the market. Let $l_i \in R$ denote the location of firm i. Firms may therefore locate outside the linear city where consumers are

[2] Milanez and Bührs (2009) analyze the development and implementation of a regulation based on the extended producer responsibility concept towards tyre waste in Brazil.

[3] In those countries where the tax system is used the recovery and recycling of end of life tires is financed by a tax levied on tire production and subsequently passed on to consumers. When the responsibility lies with producers it is commonly financed through an environmental fee generally applied to the producer's price, regardless of the location of the collection point.

[4] Depending on the relationship between the parameters sometimes simultaneous location is better and at other times a sequential choice of locations is preferable.

[5] The assumption that each consumer buys exactly one unit of the product is quite standard in the literature on spatial competition since the seminal work by Hotelling (1929). The use of this assumption is suitable for analyzing many consumption goods with an environmental impact, as for example, electrical and electronic equipment. For these goods the government may find very difficult to justify the restriction of the market in order to reduce waste.