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Towards the estimation of demand for recycling in Chile: The case of Santiago

Óscar C. Vásquez[a,b], Adolfo Álvarez[c], Julio Silva[d], Alicia Pincheira Muga[e]

[a] University of Santiago, Industrial Engineering Department, Chile
[b] Pierre and Marie Curie University, Computer Science Laboratory (LIP6), France
[c] Universidad Carlos III de Madrid, Statistics Department, Spain
[d] Municipality of Santiago, Environmental Management Department, Chile
[e] University of Arts, Sciences and Communication, Psychology Department, Chile

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ABSTRACT

In developing countries, the recycling of municipal solid waste (MSW) as an alternative to the traditional MSW management requires an economic sustainability valuation. From this perspective, the estimation of demand for recycling is crucial. In this paper, we study the case of recycling MSW in Santiago, Chile. We estimate the relation between the monthly amount of MSW separated voluntarily from apartments located in Santiago and the monthly price required to participate in a municipal recycling program. We consider the transference of the municipal cost savings to the owners of the apartments due to the amount of MSW separated for recycling, which is not collected and deposited in the current MSW system. For the estimation, we use concepts from environmental economics and psychology, analyzing the operation and municipal costs incurred by current MSW management and designing and applying a survey based on a contingent valuation method (CVM) approach. The results indicate that the percentage of MSW separated for recycling varies between a 27.98% and 33.18%, that only four MSW types are affected by a variation of the monthly price, and that a reduction of monthly collection trips in the current MSW system from 24 to 18 can be obtained. Additionally, we discuss a number of methodological aspects to be considered in a similar study of valuation of recycling in developing countries. Our conclusion is that Santiago has favorable conditions for the implementation of a recycling program as an alternative to the current MSW system.

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1. Introduction

Nowadays, municipal solid waste (MSW) management represents a complex problem for developing countries (Marmolejo et al., 2013; Abarca Guerrero et al., 2013). In their most populous districts, explosive increases of urban population density are accompanied by increasing and heterogeneous consumption patterns (UN, 2001), which involve a double dilemma: the large increase in demand for cleaning services and the lack of public sector resources to address it in order to avoid pollution, inequality (some areas are better served than others), and direct or indirect public health problems (Ahmed and Ali, 2006; Konteh, 2009; Coffey and Coad, 2010; Marshall and Khosrow, 2013).

A good example for this is Santiago, which is the most important municipal district in Chile. This district is located at the center of the city of Gran Santiago, housing the country's principal government activities, services, finances, trade and cultural institutions. Santiago's resident population has incremented increased by 43.8% between the years 2002 and 2012, reaching a population density greater than many cities of developed countries (Galetovic and Jordán, 2006).

Currently, Santiago leads the urban expansion phenomenon in the country, with the number of building in the area increasing due to a special government subsidy for urban renovation (Arriagada et al., 2007; Greene et al., 2012; Contrucci Lira, 2011). In 2011, the supply of apartments located in Santiago reached 23.4% of total and an increasing trend is expected (MINVIU, 2012).

In this scenario, MSW generation has increased from 137,540 tons in 2001 to 154,684 tons in 2010 (SEREMI RM, 2012), introducing a new problem for the municipal district government, which is legally responsible for the cleanliness and beautification of the city, defined as the collection, transportation, and disposal systems of MSW management (Government of Chile, 1994, 1996, 2000, 2006, 2008, 2010).

Hence, an efficient municipal system of MSW management is important, not only because the direct benefits quality of life in the area, but also for indirect benefits due to the redirection of

E-mail addresses: oscar.vasquez@usach.cl (Ó.C. Vásquez), aaapinto@est-econ.uc3m.es (A. Álvarez), mambiente@munistgo.cl (J. Silva), alicia.pincheira@uniacc.edu (A.P. Muga).

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municipal resources to other government responsibilities, such as primary health, primary and secondary public education and subsidies for water and electricity consumption (Vásquez and Alfaro, 2011).

Vásquez (2011) indicates that 10% of the budget of the municipal districts in Gran Santiago is used for MSW management and reveals that the municipal cost for MSW compared to the municipal cost incurred by an alternative use (e.g., subsidies on water and electricity consumption) within the same municipal budget item reaches 40%. In practice, efficient MSW management should be focused on two areas: a short-term perspective, where such operations as collection and transport are improved or ideally optimized, and a middle- and long-term perspective, where the generation of MSW is minimized by changing consumption patterns and recycling awareness (Kinnaman, 2009; Wilson and Scheinberg, 2010).

The case of Santiago, Chile has the potential to improve efficiency of MSW management in the middle and long term: CONAMA RM (2005) shows that over 50% of the population has a positive attitude towards the separation of MSW, and 90% of the population identified recycling as the solution to the MSW management system. Ruiz et al. (2010) show the social and economic benefits of recycling activities. Additionally, the demographic density of Santiago yields a positive element for minimization of recycling operation costs, due to several highly concentrated zones from which a large amount of MSW can be collected.

In addition to the environmental, political, and social points of view, an economic analysis of MSW management is crucial because recycling programs might not be economically viable from a municipal perspective (Vásquez, 2011). Laws 19,300 (Government of Chile, 1994) and 20,417 (Government of Chile, 2010) are good attempts in this direction, as they establish a new institutional framework by defining regulatory agencies and the use of economic analysis in environmental regulations, although these efforts are still not sufficient (Katz et al., 2010).

To reach this goal, three factors are important: estimating the demand for recycling services, understanding inhabitants' willingness to pay for recycling, and optimizing the municipality's expenditure in the current MSW management system (Bolaan, 2006; Suttibak and Nitivattananon, 2008; Omran et al., 2009; Weng and Fijiwara, 2011).

In this paper, we seek to contribute to the economic discussion of this topic by studying the valuation of recycling from inhabitants of Santiago. Our goal is to estimate the demand curve, considering the willingness of apartment-dwellers to pay and the transference of municipal costs savings due to recycled MSW. To conduct this analysis, we assume a recycling program in which the separation of MSW from apartments is voluntary, and a monthly price is required of the participants for the collection service.

2. Materials and methods

2.1. Models for prices

To model recycling demand we consider two function prices: one defined by the current MSW management system and the other defined by the willingness to pay for a separated collection service. To the best of our knowledge, this report describes a novel approach that has not been followed in previous research.

Formally, we define WR as the monthly separated amount of MSW for an apartment with two associated prices: direct and indirect. The *indirect price* $IP(WR)$ is the monthly municipal savings per apartment in a collection area due to WR not collected, whereas the *direct price* $DP(WR)$ is the monthly willingness of an apartment to pay for the collection service of WR. Note that if the monthly price is negative, then the value will be the monthly charge demanded from the apartment to separate the WR to be collected by the recycling program.

To estimate the indirect price, we study the amount of MSW collected per round trip in a collection area, and we compute the municipal savings due to a decrease in the deposed MSW, or if one or more round trips of the garbage truck are eliminated. We state the indirect price IP as shown in Eq. (1).

$$IP(WR) = \frac{P_l WR + ((P_m + P_f R)K + OC) \cdot \lfloor WR/W_t \rfloor}{A} \quad (1)$$

where A is the average number of apartments located at a collection area; P_l the landfills sanitary and transfers station price for kilogram of MSW deposited in USD; P_m the maintenance cost of the truck for kilometers traveled in USD; P_f the fuel cost per liter in USD; R the performance of truck in kilometers per liter of fuel; K the kilometers traveled in a round trip on a collection area; OC the cost of truck workers in a round trip in USD and W_t is the amount of MSW collected and deposited in a round trip, in kilograms.

Note that the above function defines a constant indirect price for a given round trip, but is incremented when a round trip is removed.

In the case of direct price DP, we compute the inverse value $DP^{-1} = WR(DP)$ based on the probability of recycling for each MSW, given a fixed DP. Our model is in contrast to other similar models in the literature (Basili et al., 2006; Danso et al., 2006; Sarkhel and Banerjee, 2010; Afroz and Musad, 2011), where factors such as sex, age, income, education level among others are considered as variables.

Formally, we fix a DP and express the amount of recycled MSW from an apartment WR as the weighted sum over the probabilities p_i's, the monthly average of MSW generated by an apartment in a collection area $W = W_t T$ in kilograms, where T is the number of monthly round trips on a collection area, and the ratio r_i of each MSW type i. The WR is given by Eq. (2).

$$WR(DP) = W \sum_i r_i p_i(DP) \quad (2)$$

The probability of recycling for each MSW type is estimated by a logistic regression model to ensure the response variable will fall into the [0, 1] interval (Hosmer and Lemeshow, 2000). The estimated model for each type of MSW is given by Eq. (3).

$$\text{logit}(p_i) = \log\left(\frac{p_i}{1 - p_i}\right) = \beta_{0i} - \beta_{1i} DP \quad (3)$$

Notice from this model that the probability $p_i(DP)$ of recycling WR type i as a function of direct price is given by $\exp(\beta_{0i} + \beta_{1i} DP)/(1 + \exp(\beta_{0i} + \beta_{1i} DP))$. Therefore, when the parameter associated with DP is not significant, i.e., $\beta_{1i} = 0$, then $\text{logit}(p_i) = \beta_{0i}$. This is equivalent to estimating the proportion directly by the sample proportion and setting the confidence intervals for the estimator as the usual $p_i \pm z_{\alpha/2}\sqrt{p_i(1-p_i)/n}$.

2.2. Scenarios

We consider two scenarios where the recycling program was applied. More formally, we state as the independent variable the monthly price P_k to pay for the collection service of WR in USD by an apartment located in a collection area on a scenario $k = \{1, 2\}$, whereas the dependent variable is the direct price DP. This definition aims to analyze the impact of a fixed DP over the expected savings of municipal cost due to WR that is not collected and deposited, and the potential round trips to be reduced in the collection area. We consider in both scenarios $DP \in [-9; 9]$ USD.

In the first scenario $k = 1$, we consider the monthly transference from municipal savings to the inhabitants due to the WR not

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