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Research article

# Population age structure and the cost of municipal waste collection. A case study from the Czech Republic

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ABSTRACT

Waste management is a common public service whose provision is the responsibility of local governments. As is usual with public services, the question of its efficiency naturally arises. The majority of studies focus on such efficiency from the perspective of the provider. This is based on the assumption that waste collection expenditure is a function of available equipment and municipal characteristics. In our opinion this approach has its limitations, and therefore we have used a novel approach based on the demand from municipal citizens for waste collection services. We build on previous results obtained from data concerning social and demographic characteristics, and focus on the relationship between age and expenditure on municipal solid waste, concentrating specifically on the ageing of the population. The ageing of societies in general is a very topical issue, but there is rather little focus in research on the effects of ageing on the demand for various public services. The research that does exist in the area of waste management that takes the age factor into account typically only makes a very rough division of the population into age categories such as *children*, *people of working age* and *elderly people*. Such wide groups naturally contain people with a large variety of needs, and therefore often lead to ambiguous results. The goal of our paper is to examine this topic in more detail, and to estimate the effects of various age categories of municipal citizens on municipal waste expenditure. We use models with age categories differentiated by decades, an approach which provides significantly more detailed information than the age variables used in other studies in this area. We use population age and waste management expenditure data collected from more than 6100 municipalities in the Czech Republic in 2011 and 2014. The results of our investigation have shown that senior citizens of a certain age (approximately at the onset of retirement) have a surprisingly strong influence on waste management expenditure.



## 1. Introduction

Municipal solid waste (MSW) generation and treatment represents an important socioeconomic issue for the Czech Republic and becomes even more important when the cost-effectiveness of municipal solid waste management (MSWM) expenditure is considered. Local municipal governments are the most important public authorities responsible for the prevention, collection, sorting and treatment of MSW.

MSWM in the Czech Republic is a kind of public service that today is often perceived as something which is taken care of automatically with little to no participation by the municipal population. However, just as with any other kind of public service, there is expenditure connected with it that needs to be raised (usually from taxes or fees), or subsidized from other municipal revenues, before it can be provided. It is important to have a clear idea of the amount of funds that should be raised in order to cover the cost of MSWM. The issue is then how to determine how high this expenditure will be, as well as how local municipal authorities can improve the cost-effectiveness of such expenditure. In our research we focus on municipal waste management services, which from our perspective include municipal solid waste collection and treatment.

A lot of research has been conducted regarding factors influencing the cost-effectiveness of MSWM expenditure (MSWME). These studies, which are oriented towards demand and production functions, have not provided clear-cut results (see Section 2 of the paper). At the same time, a lot of research focuses on the generation of waste in municipalities, and variables influencing this generation. These variables are dominated by socio-demographic characteristics, particularly the age structure of the population. We have combined both approaches and focused on age structure as a factor influencing municipal waste management expenditure.

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As a result, and also with regard to our previous research that examines the population as a key factor influencing MSWME (Soukopová et al., 2013), we have chosen a completely new approach which is not derived from the function of supply and the production function of the collection company, but instead is based on the function of demand. We do not focus on the municipality as the source of demand, but rather on the end users of the given service, i.e. the citizens of the municipality.

We have indirectly worked with the waste generation function for the inhabitants of municipalities, who are waste collection service consumers on the one hand while generating the waste which their municipalities produce on the other. They are thus a key variable when determining MSWME. Here it is obvious that an understanding of society and also the determinants that drive societal development can help predict future waste generation. Society is affected by demographic change. As a result, demographic characteristics represent significant determinants that can influence waste generation and subsequently MSWME.

Our aim is to evaluate the impact of demographic variables (mainly the age structure of the population) on waste generation and MSWME in Czech municipalities, and to discuss how future MSWM practices at the local level should be adapted to take the influence of such variables into account. The added value of our paper lies in the novel and innovative approach to the evaluation of MSWME taken by the research it describes, which gives consideration to new factors affecting such expenditure. We have also utilized research related to waste generation. This approach could fill the gap left by current studies, which focus only on the supply side. Moreover, the use of a different approach to MSWME evaluation offers new opportunities to gain savings in the area of public expenses and provides new options for managing municipal waste management services in accordance with circular economy goals.

The paper is structured as follows. Section 2 describes the current state of knowledge with regard to research dealing with age structure and its influence on MSW generation, and potentially on MSWM expenditure; Section 3 describes the methodology and 3 OLS models for MSWM expenditure; Section 4 lays out the results obtained from econometric analysis and discusses them. Finally, Section 5 includes our conclusions and the practical implications of our study.

## 2. Theoretical framework

### 2.1. Factors influencing municipal solid waste management expenditure

A lot of research has been conducted regarding factors influencing the cost-effectiveness of the provision of waste management services (e.g. Hirsch, 1965; Savas, 1977; Stevens, 1977; McDavid, 1985; Reeves and Barrow, 2000; Callan and Thomas, 2001; Dijkgraaf and Gradus, 2003; Bel and Fageda, 2011; Simões and Marques, 2012; Bel et al., 2014; Gradus et al., 2014). One of the first research papers on the factors influencing the cost of MSWM to municipalities was published by Hirsch in 1965. He chose to estimate the relevant cost function using regression analysis and summarized five basic variables affecting the cost of waste management: the quantity of services, service quality, service conditions affecting input requirements, the price level, and the state of technology and productivity. This approach is based on the assumption that the production function for waste collection can be represented by Cobb-Douglas technology in such a manner that its output is a function of drivers and loaders, trucks and authority-specific characteristics.

A lot of researchers (Stevens, 1977; Domberger et al., 1986; Reeves and Barrow, 2000; Dijkgraaf and Gradus, 2003, 2007; Ohlsson, 2003; Bel and Fageda, 2011; Bel et al., 2014; etc. (see Appendix 1)) have utilized the above approach, and have also added other factors affecting MSWM expenditure (i.e. economies of scale, mode of production, inter-municipal cooperation, market structure, etc.). Appendix 1 contains a table with the results of studies from 1965 to 2015 and divided according to the examined factors. Although these studies are mainly focused on the aforementioned five factors affecting the cost-effectiveness of MSWME (Appendix 1), they provide ambiguous results. Most of them (Stevens, 1977; Domberger et al., 1986; Reeves and Barrow, 2000; Ohlsson, 2003; Dijkgraaf and Gradus, 2007; Bel and Fageda, 2011; Bel et al., 2014) confirm the impact of the amount of waste (number of pick up points). This is nothing unexpected, of course, as from the viewpoint of the production function this variable depends on the quantity of services, which unambiguously affects the supply function. In the case of the other factors (connected with service quality, service conditions affecting input requirements and the state of technology and productivity), the results differ.

At the same time, some studies deal with the influence of population, and not only in terms of population density (Dubin and Navarro, 1988) but also with regard to population size as an alternative to the output (produced by MSWM services) (Bel and Mur, 2009; Bel et al., 2014). For example, Dubin and Navarro (1988) draw attention to the fact that "the density effect is actually quite significant" and Bel and Mur (2009) assume that the total population of the municipality allows the calculation of the possible effect that the demand for a local service can have on the decision regarding the provision of that service. Our research (Soukopová et al., 2013, Struk, 2015) shows that the number of inhabitants has a stronger correlation with municipal solid waste expenditure than with the amount of waste produced in tons. We have therefore concentrated on the number of inhabitants and especially population (age) structure as factors influencing MSWME.

### 2.2. Population (age) structure and models of municipal solid waste generation

The impact of demographic characteristics on waste generation has been analysed in many case studies in many countries (Hockett et al., 1995; Dennison et al., 1996; Sterner and Bartelings, 1999; Dyson and Chang, 2005; Martin et al., 2006; Bandara et al., 2007; Beigl et al., 2008; Hage and Söderholm, 2008; Gellynck et al., 2011; Lebersorger and Beigl, 2011; Brown, 2015; and Talalaj and Walery, 2015).

MSWM expenditure is determined primarily by the population and the amount of generated MSW (see above). The available literature offers a variety of approaches for estimating MSW generation. These approaches are mainly based on identifying important factors affecting MSW generation and their correlation with the amount of generated MSW (Daskalopoulos et al., 1998), regression models (Hockett et al., 1995), various other econometric approaches (Beigl et al., 2004; Johnstone and Labonne, 2004), mathematical modelling (Benítez et al., 2008), or methods such as system dynamics (Dyson and Chang, 2005) that are able to overcome the data scarcity that often becomes apparent when predicting future MSW generation. In the case of the Czech Republic, a prediction model for MSW generation and treatment has also been created (Soukopová and Kalina, 2012; Hřebíček et al., 2013).

If we only focus on demographic variables as the dominant factor, then from our literature review it is clear that the age structure of the population may have a significant impact on waste generation. Age is one of the most frequently analysed demographic characteristics (Sterner and Bartelings, 1999; Beigl et al., 2004, 2008; Lebersorger and Beigl, 2011; Pickerin and Shaw, 2015; Talalaj and Walery, 2015). Some of the above research studies have discovered that elderly people generate less municipal solid waste than younger people. We found this fact extremely interesting, and have therefore examined it in greater detail, at least partly due to the fact that the phenomenon of demographic ageing is highly