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Can demographic characteristics explain intermunicipal differences in production of municipal waste?

Rybová, Kristýna
Slavík, Jan

Abstract

Ongoing demographic changes have been influencing many aspects of society and its functioning, infrastructure including waste management is not any exception. This paper aims at quantifying how demographic variables influence the municipal waste generation in the Czech Republic. For this purpose similar variables as in studies from abroad are constructed and reviewed methods are applied on the data for municipalities from the Czech Republic in year 2011. 8 indicators for 5 887 municipalities were investigated. For the analysis correlation and multidimensional linear regression were used. The resulting regression model included average household size, percentage of population with tertiary education and sex ratio. The model assumptions for linear regression analysis were met and resulting model was significant but regardless, only small part of municipal solid waste variation was explained.

Keywords: Municipal solid waste; Demographic change; Influencing factors; Regression.

JEL Classification: J11, Q53

1 Introduction

Demographic change as a social phenomenon is constituted mainly by the population ageing that is associated with a growing number and proportion of the elderly in the population, a falling number and proportion of children and an increasing burden on economically active people. At the same time, there is a selective migration of certain population groups from the countryside and peripheral areas to the centres/their hinterland and, conversely, suburbanisation processes. Simultaneously, the average household size decreases, while the proportion of one-person households and, subsequently, of one-member households of the elderly rises. All the changes then have an impact on diverse ways of life and the functioning of society. This may relate to the offer of the manpower, public budgets, health and social services and also infrastructure [10].

Current demographic trends have also a significant impact on environmental service provision at the local level. Especially municipal waste management seems to be affected by the development of demographic characteristics enormously, because households and their behaviour influence the municipal waste production, treatment (incl. recycling), and the effectiveness of charging policy. The environmental (or recycling) behaviour is influenced also by other intrinsic, and extrinsic factors with different significance and for better understanding of this issue, it is important to analyze and if possible to quantify the effects of various factors.

The relationship between demographic characteristics of the population and households on the one hand, and waste management on the other has been examined by a number of studies that often arrived to different conclusions if and how important is the role of demography in explaining of various aspects of waste management and production. From the literature review it seems that average household size, age, gender and attained education are the most frequently analyzed demographic variables.

Unambiguous are the conclusions regarding household size, in several studies [3], [9], [15], [17] for different populations it has been proved that average generation of municipal waste per person falls with the growing number of household members.

The second most frequently analyzed demographic characteristic is age or age distribution of inhabitants. In case of this indicator a problem of comparability of results arises because in some cases age is described with mean or median age, while in other cases percentage of people in age groups is taken into account, the age group intervals differ among studies. Sterner and Bartelings [21], or Hoffmeister and Gellenbeck [12] found out that elderly people generate less solid waste. According to [21], it may result from a rather modest way of life of older people. Beigl et al. [2] analyzed the above mentioned relationship from the viewpoint of the representation of three in demographical studies often used age groups (0-14, 15-59 and 60+ years). They found positive influence of the proportion of the persons aged 15-59 on the total generation of municipal waste only in the European cities with medium incomes. Similarly, Lebersorger and Beigl [17] tried to quantify the influence of representation of the persons from four age groups (0-4, 5-14, 15-59 and over 60 years) on the generation of solid municipal waste using a regression model but on the municipality level, it has not turned out that the representation of the persons in any of the age groups is significantly correlated with waste generation. This is why the authors (e.g. [13]) have suggested that age structure has only weak, if any influence on waste generation.

In some cases, gender is another analyzed demographic characteristic. This variable was examined by D'Elia [8] on the household level, by Hage, Söderholm [11] on the municipal level and Talalaj, Walery [15] on the county level. The first two studies did not find any significant relationship between gender and the quantity of generated municipal waste that is consistent with a broad review of older studies [19]. According to [15], in communities with higher share of women there is also higher waste production.

Last more frequently analyzed demographic characteristic is the level of attained education but the results are ambiguous. [4] stated that persons with elementary education generate on average more municipal waste than those with a higher level of education. However, [13] did not find any significant relationship between education and waste generation.

In order to analyze the relationship between demographic development and waste management, a use is made of both one-dimensional and multidimensional methods such as the correlation analysis [9], the one-dimensional regression analysis (as one of the methods employed by [2]), an analysis of time series or the input-output analysis. However, the multidimensional regression analysis is the most frequently used, e.g. [2], [11], [15], [17] and [21].

The main goal of this paper is to evaluate how demographic variables influence the municipal waste generation in the Czech Republic. For this purpose similar variables as in studies from abroad are constructed and reviewed methods are applied on the data for the Czech Republic.

The paper consists of four chapters and is structured as follows. The first chapter describes the current state of knowledge in the research dealing with the demographic change and its influence on waste generation. In the second chapter, the method and data used for the purpose of the research in the Czech Republic are presented. The third chapter introduces then the main results of the research. In the last chapter the research results realized in the Czech Republic are concluded.

2 Material and Methods

Based on the literature review and available data a dataset for municipalities in the Czech Republic was created. For the description two sources were needed – the first for the demographic indicators and the second for the information about waste production. These two sources have to cover the same units (municipalities) and have to be available for the same year.

The intention was to use similar information that was used in above mentioned studies. Because demographic indicators such as household size or level of education are not a part of routine statistics of the Czech statistical office (or any other public institution), it was necessary to use the data obtained within the Population and Housing Census. Data from the last Census in 2011 were used.

As for the data about waste production, waste management information system (ISOH) was used. ISOH is a statewide database collecting data about waste production and treatment since 2001. Every waste producer who produces yearly more than 100 kg of hazardous or 100 tons of nonhazardous waste has to report his yearly production into the system [22]. In the case of municipal waste municipalities are seen as waste producers and they are bound to report into the system. But not all the municipalities surpass the given limit for produced waste amount. In 2011 about 4 % of all Czech municipalities did not report its waste production because these units are mostly rather small, only 1 % of state population was living there.

Based on these two sources, the database contained following indicators at municipal level:

- Average household size (HHS),
- Mean age (MAGE),
- Percentage of population aged 0–14 years (AGE0014),
- Percentage of population aged 15–64 years (AGE1564),
- Percentage of population aged 65 and more years (AGE65),
- Sex ratio (IMA),
- Percentage of population with secondary education (SEC),
- Percentage of population with tertiary education (TER),
- Production of municipal solid waste in kg per capita (MSW).

Sex ratio was computed as number of men per 100 women in the municipal population. For assessment of variables SEC and TER the number of people with secondary, resp. tertiary education was related to number of inhabitants aged 15 and more years.

The analysis itself comprised an explorative data analysis, correlation and multiple regression analysis of data at the municipal level in the year 2011. All computations were made by applying IBM SPSS Statistics 20.

The purpose of explorative analysis was the basic description of the data and control of assumptions for linear regression. In the first step basic descriptive statistics was computed and extreme values were tested and corrected if necessary. In general every entry that differs significantly from the mean was controlled. Afterwards, normality of distribution was tested. As most of the data were normally distributed, Pearson correlation coefficient was used. Based on the correlation among the independent variables and between the independent variables and the dependent variable municipal solid waste, the selection of variables for regression analysis was made. Selected were indicators with higher significant correlation with municipal solid waste.

The assumptions of linear regression (linear relationship between dependent and independent variables, homoscedascity, multicollinearity and normality of the error distribution) were tested [17].

3 Results and Discussion

After exclusion of municipalities with no reported data production or with extreme values the sample consisted of 5 887 municipalities from all regions. The average municipal solid waste production in 2011 was 268 kg per capita (see Table 1).

Table 1. Values of descriptive statistics for municipal solid waste, CR, 2011

	Minimum	Maximum	Mean	Std. Deviation
Municipal solid waste	0,02	651,13	268,58	144,73

Source: ISOH

To assess the relationship between municipal solid waste production and selected demographic characteristics, correlation analysis was performed. Table 2 shows values of Pearson correlation coefficients between all variables. We can see significant correlation between municipal solid waste and average household size, percentage of population with tertiary education and sex ratio.

Our results confirmed negative (but rather weak) correlation between waste production and average household size (thus bigger households produce in average less municipal waste per person than smaller households). This result is not surprising when household members share the consumption goods such as food, packaging, newspapers etc. [3], [9],[15], or [17] also came to this result and found the relationship significant. Only [21] found the correlation as not statistically significant. The knowledge of the relationship between the waste production and average household size helps the municipal representatives to accommodate the container policy (not only for household mixed waste, but also for separate collection).

Weak but significant negative correlation was found between waste production and sex ratio. Talalaj and Walery [24] also confirmed the positive relationship between gender and waste production and concluded that higher share of women on the municipal level (not the number on men and women, or the total population) predicts the higher waste production. The reason lies in the higher attention to their appearance [24], or more frequent acquisition of products through catalogue shopping or home delivery services [7]. On the other hand other studies did not find any significant relationship between gender and the quantity of generated municipal waste [19], [8], [11]

Last significant correlation but positive was indicated between waste and percentage of population with tertiary education - in municipalities with higher share of tertiary educated people the waste production was higher. But there is no relation with secondary education. These results are in the contradiction with Benitez et al. [4] that came to the result that the higher level of education the less municipal waste production should be expected. Other studies did not find any significant relationship between education and waste production [13], or studied the relationship between the level of education and recycling rate. While Jenkins et al. [14] found the positive relationship between the educational level by a person with the highest education in a household and the recycling rate, Hage and Söderholm [11] concluded that because of the higher costs of sacrificed opportunity of higher educated households the recycling rate of plastics goes down when the educational level increases.

All characteristics connected with age were insignificant which was a little bit surprising, when [3], [12] or [21] confirmed the relationship and found that older people generate less municipal waste. On the other hand [17] found out that the age structure has weak, if any influence on waste generation and [13] rejected the influence of age on the municipal waste generation.

These three significant variables (average households size, sex, and education) will be inserted into the regression model.

As one of the assumptions for the linear regression is absence of multicolinearity between independent variables, the correlations between household size, tertiary education and sex ratio are also important (Table 2). Both the household size and tertiary education has weak but significant relationship with sex ratio. To test the assumption that selected explaining variables

are not highly correlated, the variance inflation factor (VIF) will be examined within the regression analysis.

Table 2. Values of Pearson correlation coefficients between variables, CR, 2011

	HHS	MAGE	AGE0014	AGE1564	AGE65	SEC	TER	IMA	MSW
HHS	1	-0,456**	0,382**	0,021	-0,296**	0,050**	0,025	-0,056**	-0,104**
MAGE	-0,456**	1	-0,754**	-0,350**	0,857**	-0,038**	-0,195**	-0,056**	0,005
AGE0014	0,382**	-0,754**	1	-0,241**	-0,502**	0,045**	0,195**	-0,139**	-0,011
AGE1564	0,021	-0,350**	-0,241**	1	-0,710**	0,031*	0,025	0,248**	0,020
AGE65	-0,296**	0,857**	-0,502**	-0,710**	1	-0,057**	-0,161**	-0,121**	-0,009
SEC	0,050**	-0,038**	0,045**	0,031*	-0,057**	1	-0,154**	-0,099**	0,004
TER	0,025	-0,195**	0,195**	0,025	-0,161**	-0,154**	1	-0,075**	0,094**
IMA	-0,056**	-0,056**	-0,139**	0,248**	-0,121**	-0,099**	-0,075**	1	-0,068**
MSW	-0,104**	0,005	-0,011	0,020	-0,009	0,004	0,094**	-0,068**	1

Source: Authors

Regression equation for model with three significant variables follows:

$$MSW = 466{,}224 - 72{,}256\ HHS + 3{,}057\ TER - 0{,}379\ IMA \quad (1)$$

This model explains only 2,5 % of the variation of municipal solid waste between municipalities, which is really low compared to regression models from other studies. Reported R^2 achieve usually at least 50 % (e.g. [17], [4] or [21]), but the results depend also on sample size and number of independent variables. Nevertheless, this model is statistically significant. The standardized coefficients (Table 3) indicate that household size has the highest relative impact, followed by the share of tertiary educated inhabitants and sex ratio. The model assumptions are met. Between dependent and independent variables there is a linear relationship and all of them showed normal distribution. The results of multicollinearity measurements do not indicate that there is multicollinearity between independent variables because all values of tolerance are higher than 0,2 and variance inflation factors are smaller than 5, these two values indicate the acceptable limits.

Table 3. Regression model for municipal solid waste (coefficients, significant and multicollinearity measurements), CR, 2011

	Coefficients	Standardized Coefficients	t Value	Significance	Tolerance	VIF
Constant	466,224		19,603	0,000		
HHS	-72,256	-0,110	-8,515	0,000	0,996	1,004
TER	3,057	0,092	7,125	0,000	0,994	1,006
IMA	-,379	-0,068	-5,228	0,000	0,991	1,009

Source: Authors

When demographic characteristics explain only 2.5 of the variation, other factors influencing the municipal waste generation seems to have higher significance in the Czech Republic. Because the functioning of waste management system and its performance are supported by the educational and informational campaigns in the long term the role of the environmental behaviour should stay in the centre of interest (e.g. [6], [16], [25]). Another important factor represents the

recycling rate of the municipal waste – the higher recycling rate the less municipal waste is generated ([1]). Environmental policy and the implementation of broad scale of instruments (e.g. unit-based fees) also influences the municipal waste generation ([5], [20], [23]). All these factors should be included in the model that aims to explain the amount of municipal waste generation.

4 Conclusion

The purpose of the paper was to evaluate the influence of demographic characteristics on municipal solid waste production. Because in the Czech Republic there are no waste management data on individual or household level we decided to use the data for municipalities. This leads to some simplifications regarding conclusions about individual behaviour in waste production but this is the only method enabling in this case the statistical analysis and was used in several previous studies, e. g. [2], [11], [17].

Based on reviewed studies, we constructed 8 demographic variables that can explain the intermunicipal differences in waste production. We used the same computing method, the linear regression analysis, as was used in other reviewed studies ([2], [4], [11], [15], [17], [21]). By contrast to these studies, our model explained only 2,5 % of intermunicipal variation in solid waste production. That means that there are other factors that have much greater influence on municipal waste production than demographic characteristics (e.g. environmental behaviour, recycling rate, or policy instruments) However it is important to state that the impact of demography is also significant.

Only three of the selected demographic characteristics were found statistically significant – average household size, percentage of people with tertiary education and sex ratio. We did not find any evidence that support the assumption that the waste production vary between different age groups. In agreement with studies from abroad ([2], [9], [15], [17]), the most important demographic characteristics was average household size, with growing household size the average waste production per person is decreasing.

In general, we can conclude that there is significant relationship between demographic characteristics and waste production, but in comparison with other studies and on the municipal level for the whole Czech Republic this relation is rather weak. Greater impact can be attributed to other factors, such as waste management organisation and logistics. The obtained results confirmed the desirability of further research of other factors and possibly other waste streams.

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Changes in the document based on reviews

First review:

1. Methodology and Methods
    a. We left out the Stepwise method, so the last sentence in Section 2 was also left out.
2. Discussion and conclusion
    a. We broaden the discussion and conclucions, we stated that the used method was the same as in other studies and try to explain the results in more detail, adding also more references.
3. Conclusion Notes for Authors
    a. There is broader comparison with other studies and implications for our results

Second review

1. Methodology and Methods
    a. As suggested, we left the Stepwise method out, because there was not higher added value in this case, because we could use only some explaining variables for the computation