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Do Sociodemographic Characteristics in Waste Management Matter? Case Study of Recyclable Generation in the Czech Republic

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Abstract: The generation of recyclables in the Czech Republic has long been under the European average, but the proportion from municipal waste as a whole has been growing over the past few years. Previous research in the Czech Republic mainly focused on organizational or situational factors explaining recycling performance in municipalities. This study focuses on individual characteristics that are connected, among other things, to ongoing demographic changes. Currently ongoing sociodemographic development in the Czech Republic, as well as other developed countries, influence a broad range of aspects of social life, including waste generation and its structure. This paper aims at quantifying the relation between the sociodemographic characteristics of municipality inhabitants and recyclable generation. For this purpose, 13 variables describing inhabitants, households, and housing in 4897 Czech municipalities were selected that could influence the generation of recyclables according to foreign studies. Data were analyzed using multidimensional linear regression. Even though the resulting model only explains 9%, it is statistically significant and implies that sociodemographic variables can help explain recyclable generation. From this point of view, important variables are average household size, share of tertiary educated people, share of family houses, purchasing power per person, percentage of people employed in agriculture, and sex ratio. To increase the explained variability and emphasize local differences in recyclable generation, we also used geographically weighted regression (GWR). GWR results show that, to understand waste generation (at least in the Czech Republic) on a municipal level, it is necessary to also consider spatial effects and regional specifics.

Keywords: recycling; Czech Republic; sociodemographic determinants; regression; spatial analysis

1. Introduction

The separated collection and recycling of waste fractions such as glass, paper, plastic, or metal from municipal waste represent a significant contribution to environmental protection because they save primary resources and reduce the amount of waste that has to be treated, which would otherwise mainly be landfilled. In January 2018, the European Union (EU) adopted a new set of measures as a part of a Circular Economy Package that aims to help make Europe's economy more sustainable. To implement this effort, the EU set clear targets for reducing waste generation and promoting recycling; key elements of the proposal include a common EU goal for recycling 65% of municipal waste by 2030. This target has to be implemented in Czech national legislation, but based on Eurostat data, it is quite clear that the Czech Republic is lagging behind in this matter and it could be quite difficult to reach the given target value. In 2016, the average recycling rate of municipal waste of all EU countries was 45.3%, whereas in the Czech Republic, it was more than 10% less (33.6%). With this value, the Czech Republic was ranked among the best Eastern and Central European countries, but was still far behind leaders from Western Europe [1]. To improve the situation, legislation changes would certainly be needed, but better understanding of who recycles could also be helpful. Based on foreign studies, it seems that there are significant differences in municipal waste generation and recycling performance between households and municipalities. To explain these distinctions, the description of the sociodemographic characteristics of producers could be used. Unfortunately, for the Czech Republic, as for the most of other foreign countries, there are no available data on waste production and waste producers on a household or individual level, and that is why the most commonly analyzed units are municipalities. The municipal level is still sufficiently homogeneous to capture differences and dispose of needed data.

There is broad range of studies explaining the production of recyclables in various countries. The selection of factors used for the explanation varies according to local conditions, data availability, units that are used in the analysis, as well as according to the consideration of particular researchers. In general, factors explaining the generation of recyclables are usually divided into two categories, individual and situational variables [2]. Among situational characteristics, waste management organization, logistics, and charging policy are included (e.g., References [3–6]). On the other hand, there is also a broad range of studies dealing with individual factors, such as socioeconomic or demographic factors (e.g., References [7–10]).

Based on foreign experience, it seems that the most important sociodemographic factors influencing or explaining the production of recyclables are average household size, age, gender, and attained education level. The goal of this paper is to contribute to this literature by empirically investigating the relations between selected sociodemographic determinants and waste recycling in the Czech Republic on a municipal level. This analysis covers the biggest possible sample of Czech municipalities with available data (more than 80% of all Czech municipalities), and is built on municipal data on recycling performance and on a number of possible sociodemographic influencing factors on a municipal level. To the best of the authors' knowledge, there is no similar study for the whole Czech Republic dealing with the recycling of municipal waste and its possible sociodemographic determinants. Much greater attention was focused so far on situational (especially organizational) characteristics. This analysis was further extended with spatial aspects of this relation. Data used for this analysis have a spatial character because they are connected with concrete spatial units, in this case, municipalities. That enables us to also consider geographical differences in the relation between sociodemographic factors and recycling rate because it seems possible that these relations are not spatially stable. This approach is new in analyzing municipal waste production in the Czech Republic.

There are several reasons why mainly focusing on sociodemographic variables can be particularly interesting for municipalities. First, data on sociodemographic characteristics are available for all municipalities with a maximum of ten years periodicity in the case of information from the population census (e.g., household size, dwellings characteristics, level of education). Basic data can be obtained for every year (e.g., age or gender), and municipalities can access and use them for planning. Considering the selected variables, new indicators reflecting the specificity of the consumer's decision-making process in the Czech Republic were used, e.g., purchasing power (presenting information on inhabitants' disposable income at the level of all territorial units), or heating methods in combination with energy origins used for heating. The second mentioned variable makes it possible to study dwellings that only rely on solid fuels. These variables not only influence the amount of generated municipal waste, but also its composition and, therefore, municipal waste treatment and management costs.

Second, the results can help municipal and national authorities to better aim policies and campaigns oriented to promote environmentally responsible behavior to particular population groups or regions that recycle less, and support the recycling performance of those who already have a higher recycling rate.

Third, finding a correlation between sociodemographic and recycling performance could also be useful for planning new infrastructure. If results are connected with population projections of particular municipalities or regions (infrastructure is better served mostly for bigger regions then just one municipality), the future production of various waste streams could be predicted.

The paper consists of four sections and is structured as follows. The first chapter describes the current state of knowledge in the research dealing with sociodemographic determinants and their influence on recyclable generation in developed countries, and shortly describes the waste management system in the Czech Republic. In the second chapter, the method and data used for this research are presented. The third chapter introduces the main results. In the last chapter, the research results are concluded, and possibilities for further research are presented.

1.1. Factors Influencing Recyclable Generation

In the case of municipal waste production as a whole, it seems that the most unambiguous characteristic is average household size. The average generation of municipal waste per person drops with a growing number of household members [11–14]. However, regarding recyclables, the situation does not seem that clear. Terry [15] and Martin, Williams, and Clark [16] discovered no statistically significant relation. Abbott, Nandeibam, and O'Shea [17] only found a significant relation between average household size and biowaste recycling. Jenkins et al. [18], D'Elia [19], and Gaeta, Ghinoi, and Silvestri [20] discovered a positive connection with recycling rate that could mean that bigger households, on average, recycle more than smaller ones.

Another regularly analyzed demographic characteristic is age or age distribution of municipalities' inhabitants. A problem of result comparability regarding this indicator arises because, in some cases, age is described as mean or median age, while in other cases, the percentage of people in particular age groups is taken into account, and age-group intervals differ among studies. Sidique, Joshi, and Lupi [21], and Tabernero et al. [22] found a positive correlation between recycling rate and age. Kipperberg [5] confirmed that age significantly influences the recycling of paper, glass, and metal. The explanation is ambiguous. On the one hand, older people are probably less used to recycling. On the other hand, they have lower opportunity costs than younger people [23]. Waste recycling can be quite time-consuming, and persons with high opportunity costs especially have to decide to which activities they dedicate their time. Sterner and Bartelings [9] also concluded that if waste sorting consumes a lot of time, people are less willing to do it, and they produce more residual municipal waste. Terry [15] discovered a higher recycling rate in the 25–44 age group. Gaeta, Ghinoi, and Silvestri [20] discovered a negative correlation between average age and waste recycling, which they explained as the complexity of waste recycling making it more likely to avoid among older people compared to younger people. Negative correlation with the percentage of the population over 64 years was also observed by Saladie [24]. D'Elia [19], Hage, and Söderholm [8], and Hage et al. [25] found no relation between recycling behavior and age.

Gender is another often-analyzed indicator. However, D'Elia [19], Hage, and Söderholm [8], Tabernero et al. [22], and Pikturnienė and Bäumle [26] discovered no significant correlation with recycling behavior. This was also supported by the meta-analysis results of Schultz et al. [2]. To explain recyclable production, the number of persons mostly staying at home may be more important than their gender. Usually, women stay at home. According to Bach et al. [3], municipalities with higher percentages of housewives statistically produce, on average, less waste paper. Housewives are defined as "a male or female person who does domestic work for their own family without pay" (Reference [3], p. 70). The authors did not assume any direct causality, as the percentage of household members staying at home could serve as an indicator for social structure of every particular municipality. Similarly, Sterner and Bartelings [9] found that the number of people staying at home during a part of the day has a positive effect on composting, and these households also produce less municipal waste.

The education of waste producers could also be an important indicator to explain recycling behavior. Sidique, Joshi, and Lupi [21] proved that the higher the proportion of people who studied at the university for at least four years is, the higher the municipal recycling rate is. Miller et al. [27] also supported this conclusion. If the percentage of people who are 25 years and older with a bachelor's degree or higher increases by 1%, then recyclable tons increase by 0.7%. On a household level, Jenkins et al. [18] found a weak but significant influence of a person with the highest attained education in the household on recycling rate. If this person's level of education increases from secondary to university, the probability of recycling 95% of produced aluminous waste would rise by 0.1%. In the case of paper, it would even be 1.5%. A similar conclusion was reached by Tabernero et al. [22], and by Pikturnienė and Bäumle [26]. Hage and Söderholm [8] presented contradictory results. According to their conclusions, plastic waste recycling rate decreases with attained education level. The authors explained this relation with higher opportunity costs of households with higher education. No statistically significant influence of education on waste sorting was detected Hage et al. [25], or by Šauer, Pařízková, and Hadrabová [28] for the Czech Republic.

Another possible explanatory variable according to the literature review could be the presence of children in the household. The relation to recycling rate is ambiguous here, too. Martin, Williams, and Clark [16] came to the conclusion that young childless occupants and families with children are more likely to be nonrecyclers. No relation was found by D'Elia [19].

The influence of population density on recycling was studied by Kipperberg [5], who found that its influence on sorting of metal, plastic, and biowaste was statistically significant and negative. His results were supported by Hage and Söderholm [8] in sorting plastics in Sweden. According to them, people living in densely populated areas accumulate, on average, 530 g less plastic packaging waste per person than people living in smaller and less densely populated localities. Hage and Söderholm [8] defined a densely populated city as a municipality with at least 800 residents per km^2. No significant relation between population density and recycling rate was found by Sidique, Joshi, and Lupi [21], or by Gaeta, Ghinoi, and Silvestri [20].

Income is another broadly considered variable that has to be often omitted because of data availability. A positive but nonsignificant relation between income and recycling rate was described by Terry [15]. Jenkins et al. [18] only discovered a significant positive relation in the case of sorting waste paper, and Gaeta, Ghinoi, and Silvestri [20] observed a highly significant positive correlation. According to Sidique, Joshi, and Lupi [21], the relation is entirely opposite. They estimated that a $1000 increase in income per person and year leads to a reduction of recycling rate by 0.2%. No or rather weak influence of income on generation of recyclables was observed by Abbott, Nandeibam and O'Shea [17], Mazzanti and Zoboli [23], Hockett, Lober and Pilgrim [29], Hage et al. [25], and Saladie [24].

The relation between sociodemographic (as well as other factors) and waste recycling was analyzed by various one- and multidimensional statistical methods, e.g., correlation analysis [12], simple linear regression (among other methods, Reference [7]), time-series analysis, and input–output analysis. However, the most commonly used method is multiple-regression analysis (e.g., References [7–9,13,14]). It is quite interesting that even though most of these studies are conducted on the municipal level, their authors do not consider the data's spatial dimension. Nevertheless, sociodemographic variables may be significantly correlated with spatial factors [30], and their influence on waste generation may differ in the space [31]. For example, education may be positively correlated with municipal waste generation in a spatial unit (e.g., municipality, region, or state) and negatively in another. In this case, the data show spatial nonstationarity that can misrepresent statistical method results that do not consider this aspect (e.g., multiple-regression analysis). The number of studies dealing with spatial variation in MSW data has been rather limited so far (e.g., References [31–33]).

1.2. Waste-Management System in the Czech Republic

In the Czech Republic, the development of waste-management legislation began in 1991. Since then, Czech legislation has been adapted to meet the standards and requirements of the European Union. Currently, the basic legal document in the field of waste management is Law no. 185/2001 Coll. on Waste. It was amended in 2014 [34].

Municipalities are the producers of municipal waste and have direct responsibility for the physical waste management in their territory. Each community creates a system of collection, removal, and other waste management that is usually embedded in a municipal ordinance. Financing the waste-management system is a mandatory expenditure of municipal budgets [35].

The municipal waste includes mixed municipal waste, its separated components (paper, plastic, glass, metal, and others), large-volume waste, and hazardous waste [36]. The per capita generation of municipal waste stagnated in the period of 2009–2015; since 2015, value has been increasing (Figure 1). The mixed municipal waste category is comprised of residual (unseparated) waste produced by households and nonmanufacturing business activities [36]. Its production has been declining since 2009, which can be regarded as a positive.

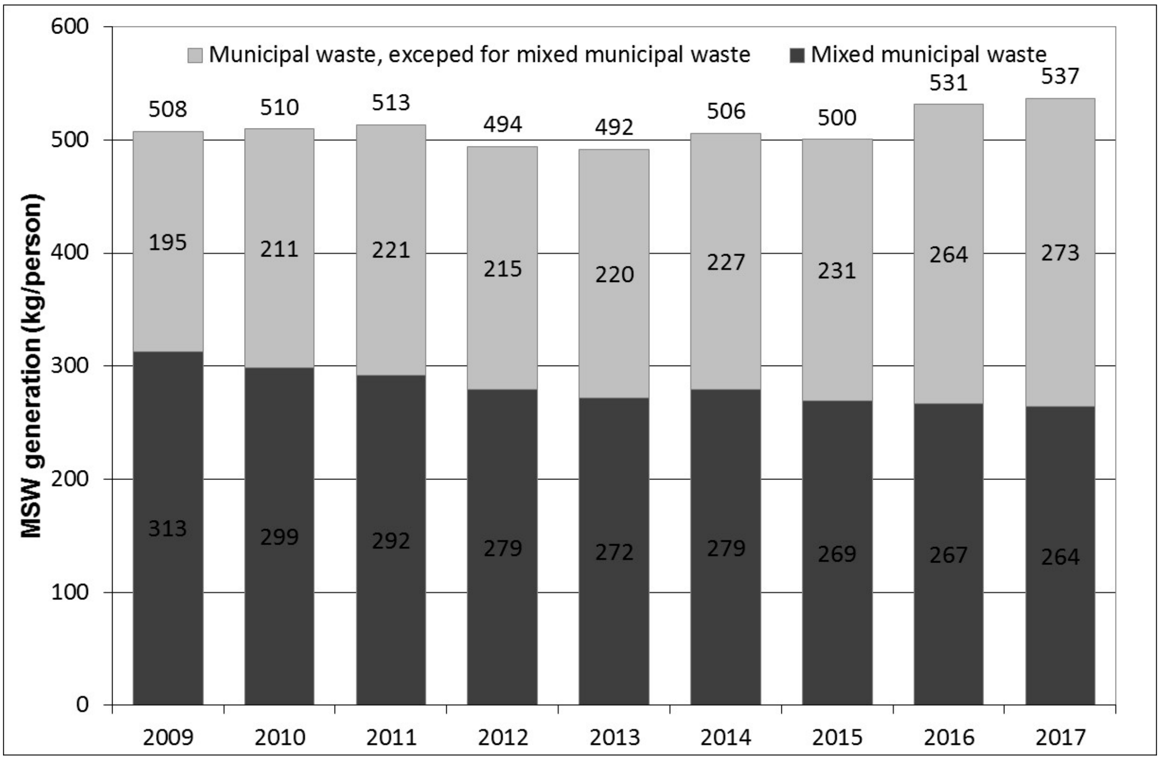

Figure 1. Production of municipal solid waste (kg per capita), Czech Republic (CR), 2009–2017. Source: ISOH (Waste Management Information System).

Czech municipalities have to separately collect hazardous waste, paper, glass, plastic, and, since 2015, metal and biowaste as well. It is up to each municipality to select a concrete collection method. It can choose between drop-off centers, large-volume containers, or curbside collection [37]. For recyclables, Czech municipalities mostly use drop-off collection [38].

To finance the waste-management system, most Czech municipalities use a local fee. The municipality is able to set a fee for individual taxpayers with regard to their waste production and the degree of sorting [35]. The law defines a maximal fee amount. Since 2013, this has been 1000 CZK per person and year (approximately €40). Before then, it was 500 CZK per person and year (approximately €20) [39]. In comparison with average monthly wages, the local fee is relatively low (see Figure 2).

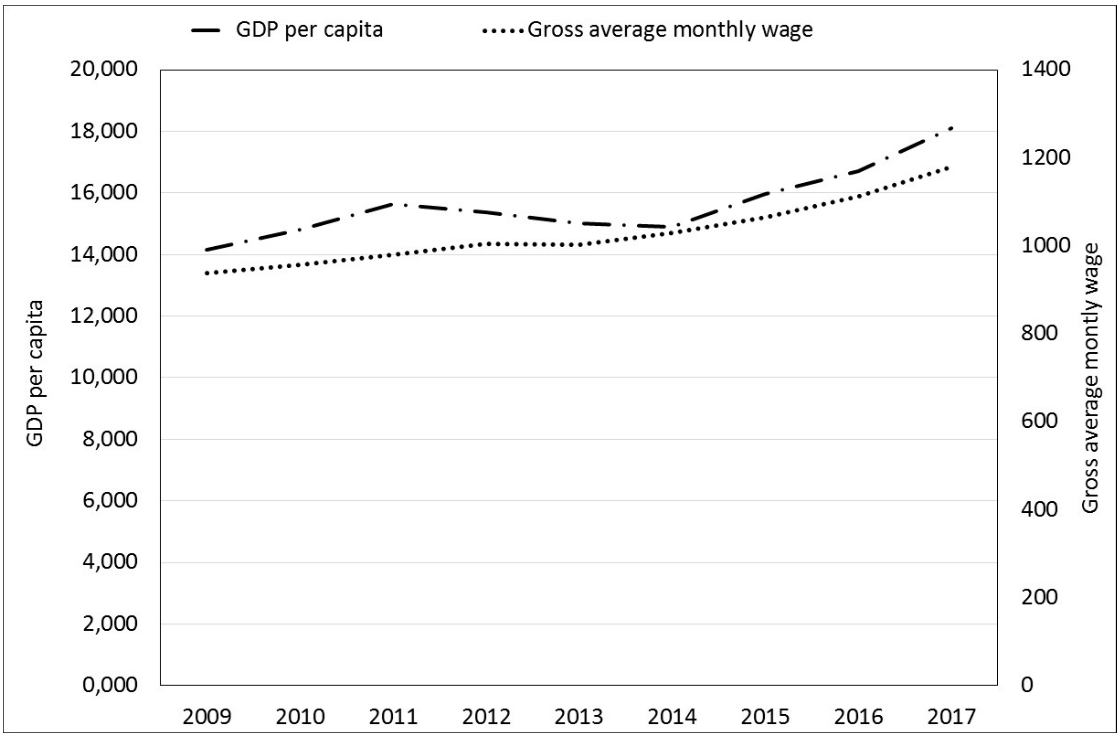

Figure 2. Gross Domestic Product (GDP) per capita and gross average monthly wage (in Euro), CR, 2009–2017. Source: Czech Statistical Office.

The most common method of municipal waste disposal in the Czech Republic is still landfilling, even though there has been a slight yearly decline in the proportion of landfilled municipal waste since 2009. Between 2009 and 2017, it fell from 64.0% to 45.5% [36]. However, this situation is still far from satisfactory. The aim of the state and the Ministry of the Environment is to decisively reduce the percentage of landfilled municipal waste and increase material and energy recovery in compliance with circular-economy principles and EU objectives [35].

2. Materials and Methods

Data preparation and analysis was done following the steps in the scheme below (Figure 3); particular working steps are further described in this section.

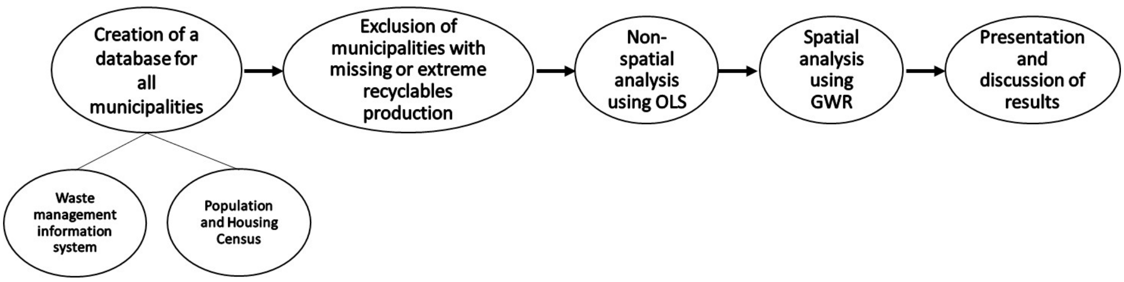

Figure 3. Working steps.

To create the needed database for analysis, two data sources were used, the Waste Management Information System, and the Population and Housing Census. We used the average production of recyclables per capita and year in kilograms as the dependent variable for nonspatial and spatial data analysis. Recyclable production was computed as the sum of separately collected paper, plastics, and glass. These three materials were selected because, in 2011, they were separately collected in all Czech municipalities, while other materials were not that widely separated, and that could lead to higher differences in recycling rates between municipalities with and without the separated collection of other materials, which could subsequently bias the presented research results. The total production of recyclables in each municipality was divided by the number of its inhabitants to eliminate different population sizes of particular municipalities. The data used for the construction of the dependent variable were obtained from the Waste Management Information System (ISOH) database, operated by the Czech Environmental Information Agency (CENIA). Every waste producer has to report their production every year to the system if they satisfy the condition that they produce more than 100 kg hazardous or 100 tons nonhazardous waste per year [40]. This includes municipalities that are responsible for the generation of municipal waste in their territory.

After excluding municipalities with no reported data about their production or with extreme values, the sample consisted of 4897 municipalities from all Czech regions. The sample represents more than 80% of all Czech municipalities. The average production of recyclables in 2011 was 35 kg per capita (see Table 1). The table shows that the production of sorted waste streams broadly differs between municipalities. We explain these differences with sociodemographic determinants.

Table 1. Basic statistical characteristics for production of recyclables (kg per capita); CR, 2011.

	Minimum	Maximum	Mean	Std. Deviation
Recyclables	2.0	124.7	35.1	17.9

Source: ISOH.

The following map (Figure 4) shows the distribution of recyclable production on a municipal level. It is obvious that the production presents a mosaic of varying values, and it is difficult to find any pattern. In general, we can state that waste-sorting activities are more prevalent in the western half of the Czech state; in the vicinity of Brno (second-biggest Czech city, situated in the southeast), separated waste collection is lower.

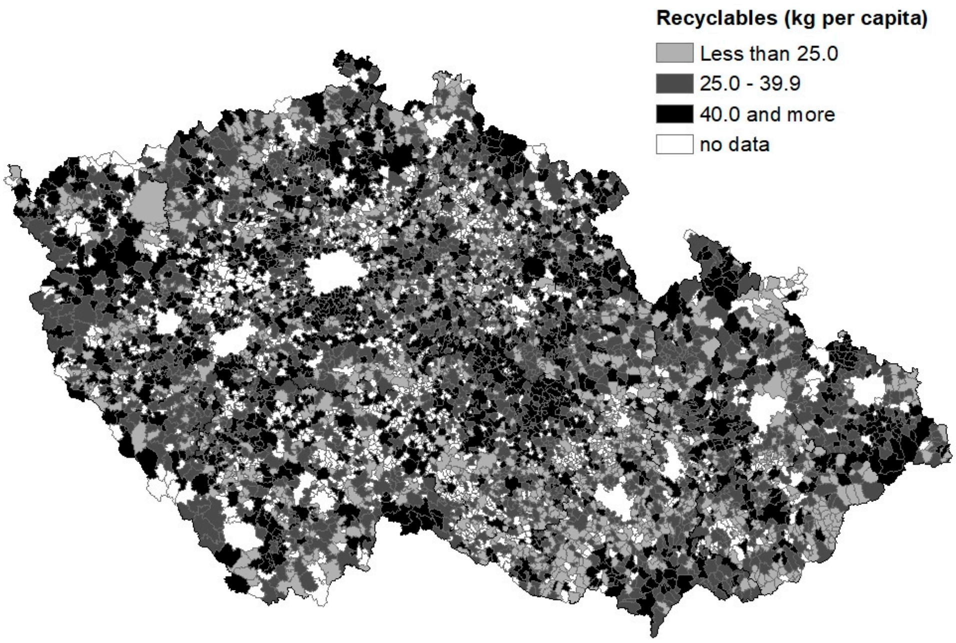

Figure 4. Production of recyclables in municipalities (kg per capita), CR, 2011. Source: ISOH.

To explain the production of recyclables, we selected 13 independent sociodemographic variables. Because some of these selected variables are not collected yearly by official statistics or any other institution, at least on the municipal level (e.g., household size or population structure according to attained level of education), we had to use the results from the Population and Housing census. In the

Czech Republic, the last census was organized by the Czech Statistical Office in 2011 [41]. That is why we could analyze the relationship between dependent and independent variables only for that year.

As explaining variables, we used the following indicators:

- average household size in the municipality (HHS),
- percentage of households with children from all households in the municipality (Child),
- percentage of population with secondary education from all inhabitants 15 years old and older in the municipality (Sec),
- percentage of population with tertiary education from all inhabitants 15 years old and older in the municipality (Ter),
- percentage of family houses in municipality from all dwellings in the municipality (Famh),
- percentage of flats with solid fuel heating system from all flats in the municipality (Heat),
- percentage of population aged 65 or more from all inhabitants in the municipality (Age65),
- median age,
- sex ratio as number of males per 100 females in the population of the municipality (IMA),
- percentage of unemployed in the 15–64-year age group in the municipality (Unempl),
- population density of the municipality (Popden),
- purchasing power per person in € in the municipality (PPP), and
- percentage of people employed in agriculture in the municipality (Agric).

Independent variables HHS, Child, Sec, Ter, Famh, Heat, Age65, IMA, and Agric were obtained from the population census carried out by the Czech Statistical Office in 2011. Unempl and Popden were added from official records, also compiled by the Czech Statistical Office. The PPP variable was obtained from company INCOMA GfK. For Czech municipalities, there are no data on average household income that could be used for analysis. The PPP indicator was used as an appropriate estimator for differences in income level among Czech municipalities [42]. Therefore, the missing data on average income should not bias the presented results. The following table (Table 2) presents basic statistical characteristics of used sociodemographic indicators.

Table 2. Basic statistical characteristics for selected sociodemographic indicators, CR, 2011.

	Minimum	Maximum	Mean	Std. Deviation
HHS	1.3	3.5	2.6	0.2
Child	0.0	54.0	28.5	5.5
Sec	38.0	85.0	68.7	4.5
Ter	0.0	35.0	8.9	4.4
Famh	0.0	100.0	83.0	17.7
Heat	0.0	100.0	43.4	26.8
Age65	2.0	43.0	15.7	3.9
Medage	30.0	56.0	40.4	2.5
IMA	52.1	781.8	101.2	17.3
Unempl	0.0	30.0	7.3	3.3
Popden	1.5	2447.4	99.6	143.3
PPP	4619.9	9154.2	6767.8	557.5
Agric	0.0	23.8	3.3	2.7

Source: Czech Statistical Office, INCOMA GfK.

2.1. Nonspatial Analysis

To analyze the influence of sociodemographic determinants on the production of recyclables in municipalities, multiple linear regression was used. This method represents the group of global methods that do not consider the spatial dimension of the analyzed data. The used model can be described with following form:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots + \beta_k X_{ki} + \varepsilon_i \quad (1)$$

where Y_i are observations of dependent variables, X_{1i}, X_{2i}, ... , X_{ki} are observations of independent variables, β_0, β_1, ... , β_k are underlying regression coefficients, and ε_i are random errors. Studied data using linear regression have to fulfill assumptions of independence from random errors, identically distributed normal random variables with zero expectations, and constant variance σ^2. Stability of error variability was tested with the Glejser test, and its normality via the Kolmogorov–Smirnov test. Linearity was examined using a scatterplot between standardized predicted values and standardized residuals [14].

To estimate regression parameters, we used the standard ordinary least-squares method (OLS) that was already used by other authors in reviewed studies (e.g., References [3,8,14]). To obtain a model with only statistically significant covariates, we used stepwise regression, and backward selection with alpha for removing variables equal to 0.1 (i.e., no independent variable with p-value greater than 0.1 remained in the model [43]). The model was computed using IBM SPSS 20 program package.

2.2. Spatial Analysis

To test if the data were spatially stationary, we used Koenker's studentized Breusch–Pagan statistics. A significant result of this test indicates that there is statistically significant heteroscedasticity and/or nonstationarity in the data. Based on the results from Koenker's statistics, we computed geographically weighted regression (GWR). In the case that there was a possibility that the relation between dependent and independent variables differed over geographical space, we could use GWR to explore local relations by moving the spatial kernel through study area. Kernel functions are used to calculate weights that represent spatial dependence between observations. So, unlike OLS, GWR gives us so-called local coefficients β that are specific for each areal unit [26]. For each model calibration location, $i = 1, \ldots, n$, the GWR model is:

$$Y_i = \beta_{i0} + \Sigma\beta_{ik} X_{ik} + \varepsilon_i \quad (2)$$

where

Y_i is the dependent variable value at location i,
X_{ik} is the value of the kth covariate at location i,
β_{i0} is the intercept,
β_{ik} is the regression coefficient for the kth covariate,
p is the number of regression terms, and
ε_i is the random error at location i [44].

The GWR model was computed using the ArcGIS program.

3. Results and Discussion

3.1. Results of Nonspatial Analysis

The resulting regression model computed with OLS consists of only six from the original 13 variables (Table 3). The other seven variables do not help significantly increase the explained variability, and were therefore not included in the resulting model. These are: percentage of households with children, percentage of population with secondary education, percentage of flats with solid fuel heating system, percentage of population aged 65 or more, percentage of unemployed, and population density.

From the significant variables, five were significant on a 1% significance level: average household size, proportion of tertiary-educated inhabitants, proportion of family houses, purchasing power, and proportion of inhabitants employed in agriculture. Sex ratio was significant on a 5% level. Overall, the model is statistically significant, but only explains 9% of the intermunicipal data variability.

Table 3. Ordinary least-squares (OLS) results for production of recyclables, CR, 2011.

	Beta
Constant	46.900
HHS	−10.801 ***
TER	0.456 ***
Famh	−0.130 ***
PPP	0.004 ***
Agric	0.313 ***
IMA	−0.030 **
N	4897
R^2	0.087

, *: statistical significance at 5%, respectively, 1%. Source: own computations.

The most important variable influencing the production of recyclables is average household size. A one-person increase in household size leads to a reduction in the average production of separated waste by 11 kg. Bigger households produce, on average, less recyclable waste per person than smaller ones. This could be caused by fewer sorting activities, but this relation is also obvious regarding the production of all municipal waste (e.g., Reference [7]). Households use products regardless of size, e.g., food, newspaper, packaging, or other kinds of consumer goods [12–14]. Information on the relation between household size and recyclable production is important to municipal governments because of the management of container sizes. Over the last few decades, the average household size in the Czech Republic has been steadily decreasing, and this development will probably continue into the future. It is, therefore, justified to expect that smaller households produce more waste.

Lower production of recyclables is also connected with municipalities with a higher percentage of family houses and a higher share of men in the population. The relation between recycling performance and the proportion of family houses in the municipality is unclear because it could be assumed that in family houses, there is more space for recycling. On the other hand, it is possible that its inhabitants are able to otherwise dispose of some portion of waste (composting or waste-paper burning).

Regarding differences in recycling rates between genders, the results observed by Schultz et al. [2] supported that recycling activities are more typical in women than men. This means, in this case, that municipalities with a lower sex ratio collect higher amounts of recyclables. Proenvironmental behavior is more often connected with women.

On the contrary, a higher production of sorted waste streams is connected with a higher share of tertiary-educated inhabitants, with higher proportion of inhabitants employed in agriculture and also with higher purchasing power. Results presented here support the conclusions of Sidique, Joshi, and Lupi [21], Miller et al. [27], and Jenkins et al. [18] on the relationship between education and waste separation. A 1% increase of the proportion of tertiary-educated inhabitants in the municipality leads to an increase in recycling of 0.5 kg per person. This relationship was only confirmed for tertiary education, while secondary education has no significant impact on recycling. It could be assumed that more-educated people have better access to information, are more aware of environmental problems, and are therefore also more likely to be more concerned of the negative impact of their own behavior on the environment [45].

Purchasing power was in this case considered an estimator of household income, and the presented results therefore support the conclusions of Terry [15], Jenkins et al. [18], and Gaeta, Ghinoi, and Silvestri [20] that people with higher income recycle more. In the Czech Republic, income is also correlated with education, so the results are in agreement with the above-mentioned relationship between level of education and recycling.

In accordance with the results of studies by D'Elia [19], and Hage and Söderholm [8], age has no significant effect on waste sorting. Using the variable percentage of the population aged 65 or more and the median age, it was not possible to prove that younger people recycle more than older people or vice versa. No influence was also found in the case of household percentage with children, even though it could be expected that children could bring home the learned behavior they obtain at school, as a lot of proenvironmental campaigns focus on schools [38].

Population density also does not influence the recycling rate, which means that, in general, there is no difference in recycling performance between bigger cities, mostly with higher population density, and smaller municipalities with lower values of this indicator. There is also no impact of unemployment that could imply that employed and unemployed people differ in their recycling activities.

The last nonsignificant characteristic was the percentage of flats with a solid fuel heating system. These results could be seen as a positive, because it could have been expected that people inhabiting flats with solid fuel heating systems could burn part of their waste (especially paper and plastics) at home, but the presented results do not show such a trend.

3.2. Results of Spatial Analysis

Further, in order to analyze if the influence of the three most important sociodemographic variables (average household size, percentage of population with tertiary education, and percentage of family houses) is spatially stable, Koenker's studentized Breusch–Pagan statistics were computed. The result of this test was statistically significant, which indicates heteroscedasticity and/or nonstationarity. Therefore, GWR application is justified.

The GWR model explains 33% of intermunicipal variation in the production of recyclables. Local R^2 distribution for the analyzed municipalities varied from 0% to 86%, as is depicted in the following map (Figure 5). Significant spatial nonstationarity regarding the influence of the three selected independent variables on waste sorting was detected. Such a result means that the relation to recyclable production spatially differs, but it is also possible to detect regions with similar patterns of sorting behavior. It is interesting that the local R^2 does not correlate with municipality population size. Demographic variables, therefore, do not better explain the situation in smaller cities than in bigger cities, or vice versa.

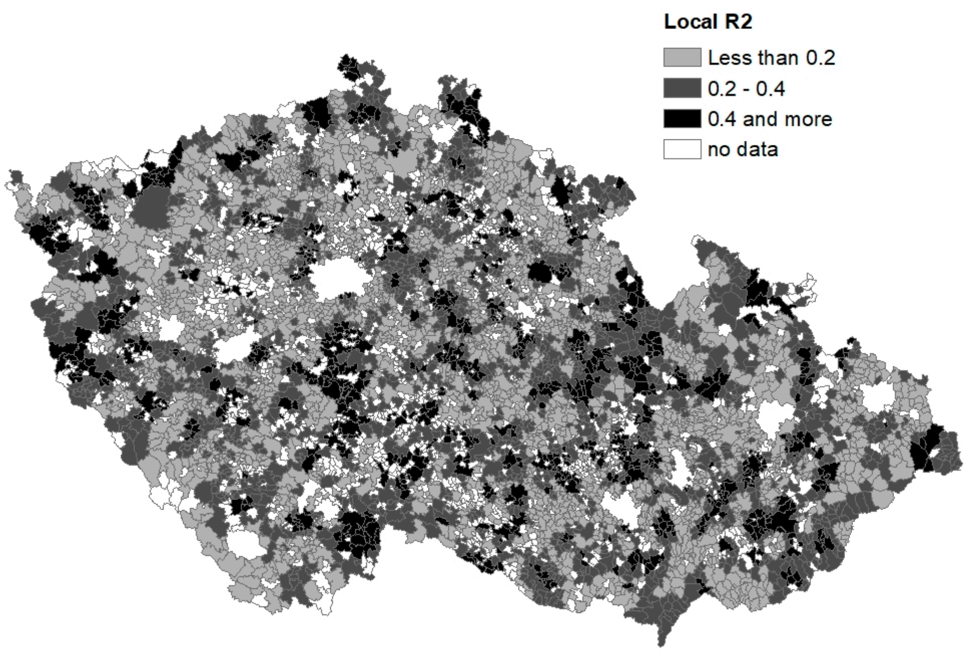

Figure 5. Local R^2 distribution for geographically weighted regression (GWR) model, CR, 2011. Source: own computations.

Regarding all three variables on the global level, the author came to the conclusion that their relation to production of recyclables is explicitly positive or negative. However, in all three cases, on the local level the relation is ambiguous. On the local level, 55% of analyzed municipalities show negative coefficient estimates for household size, on the contrary, in 45% of municipalities the coefficient is positive. In the case of tertiary education, on the local level 65% of all coefficient estimates are positive and 35% negative. Regarding the family houses, there are 73% of municipalities with negative coefficients and 27% with positive.

4. Conclusions

The aim of this article was to evaluate the impact of sociodemographic characteristics on the production of recyclables, and what trends can be expected due to further demographic development. In the Czech Republic, there are no available data on the level of individuals or households, so analysis was carried out on the municipality level. This approach, of course, leads to some simplifications in assessing population behavior regarding environmental behavior, but in this case, it was the only option for statistical analysis, and has already been used in a number of other studies (e.g., References [7,8,14]).

Based on the reviewed studies, 13 sociodemographic variables were created that could help explain the intermunicipal variability of produced recyclables. For analysis, the multiple linear-regression method was first used. The resulting model explains less than 9% of the variability in the production of separated waste. This means that there are still other factors that have a greater influence on the production of analyzed types of waste (e.g., economic and political instruments, internal convictions). Nevertheless, it was proven that the impact of sociodemographic characteristics is statistically significant and cannot be neglected.

From the 13 selected independent variables analyzed, only six were statistically significant: average household size, proportion of tertiary educated inhabitants, proportion of family houses, purchasing power, proportion of inhabitants employed in agriculture, and sex ratio. It was not confirmed whether age has any impact on waste recycling. In accordance with foreign studies, the most important sociodemographic variable was average household size; as household size increases, the average production of recyclables decreases. Over the last few decades, it has been possible to see a decrease in average household size and an increase in the number of households in the Czech society. This trend can be expected to continue into the future. For waste management, including recyclable production, this long-term trend may mean an increase in average waste production per person, and there may be an overall increase in the volume of waste production because the Czech Republic still has a stable or even slightly growing number of inhabitants.

The presented results can help municipalities understand who recycles more, and which groups so far have mostly been nonrecyclers and should be targeted by campaigns promoting proenvironmental behavior, including municipal waste recycling.

Further, the three most important significant sociodemographic variables (average household size, percentage of population with tertiary education, and percentage of family houses) according to the linear-regression analysis results were selected, and used for analysis with geographically weighted regression. This method helped increase the explained variability, but showed that the influence of selected variables is not spatially stable, and the coefficients for a particular variable could have negative as well as positive values in different municipalities. This situation could diminish the detected variability explained by OLS and lead to neglecting the sociodemographic aspect in decision-making. This conclusion about spatial nonstationarity is important for waste-management planning as well, because it supports the application of the subsidiarity principle in the practice. Even though the objectives of waste-management policy are given at the national level, many decisions are made at the local level by local representatives who know the particular situation in their municipality or region best. The results of our study show that this approach is appropriate, and that there is no simple way of predicting municipal recycling performance based on results and experiences from other administrative units.

Even though this paper considered a broad range of sociodemographic variables, further study of the factors influencing recycling performance in the Czech Republic is needed. Several selected indicators were found significant in explaining differences between municipalities, which is why the next step should be focusing on underlying psychological drivers, such as social norms, environmental attitudes, and other behavioral factors. To obtain such information, it is necessary to carry out research among inhabitants as waste producers and recyclers. A deeper understanding of spatial variability would also demand further research. It is possible that spatial nonstationarity is also caused by organizational factors of waste collection, but the data on this topic are also currently unavailable. It is also interesting to see the connection of the presented results with population projection. This approach would make sense for particular regions that are planning to build new waste management facilities and can estimate their future recyclable production.

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