Are We Reversing the Trend in Waste Generation: Panel Data Analyses of Municipal Waste Generation in Regard to the Socio-Economic Factors in European Countries

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ABSTRACT: *The purpose of this research is to investigate whether there is a decline in the amounts of generated municipal waste that is influenced by the changes which cannot be attributed to the changes in the socio-economic variables and can therefore be ascribed to a changing behaviour and the effectiveness of the policies implemented with the aim of preventing generation of waste. The analyses in this paper cover the data of 30 European countries in the period 2002–2015. The method applied is the panel data analysis of the data on seven socio-economic variables by using both the fixed-effect and the random-effects models. The results of our research show that if we control the model for the socio-economic variables, a decline in the amounts of generated municipal waste can be observed in the period 2011–2015, indicating certain effectiveness of the implemented policies on waste prevention in Europe.*

Key words: *municipal waste generation, waste prevention policy, socio-economic factors*

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1 INTRODUCTION

The sustainability of Europe's growth in prosperity is challenged by an increase in the consumption of goods and services which generates large amounts of waste and drains the Earth's resources. Municipal solid waste management has emerged as one of the biggest challenges in many parts of the world in recent times (Kumar & Samadder, 2017). Human

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activities generate waste and the generated waste amount can reflect the socio-economic development, industrialization and urbanization, as it is a symptom of raw material and energy losses that lead to additional costs for society regarding waste collection, treatment and disposal (Ghinea et al., 2016).

The circular economy (CE) represents the main concept for the sustainability of the EU economy which tries to create minimum or no environmental negative impacts, thus respecting the triple bottom line, namely people, planet and profit (Tantau, Maassen & Fratila, 2018). CE preserves physical stocks by making things last. It results from concerns over resource security, ethics and safety as well as greenhouse gas reductions which are shifting our approach to perceiving materials as assets to be preserved rather than continually consumed (Stahel, 2016).

However, there is still no clear understanding what circular economy actually is. In their study, Kirchherr, Reike and Hekkert (2017) gathered 114 CE definitions which indicate that this term is most frequently depicted as a combination of reduce, reuse and recycle activities, whereas it is oftentimes not highlighted that circular economy necessitates a systemic shift. The authors state that the main aim of CE is considered to be economic prosperity, followed by environmental quality, while its impact on social equity and future generations is barely mentioned. Furthermore, the authors found that only one out of five definitions considers the consumer as a second enabler of CE and outlines consumption as a research gap for the CE community (Kirchherr, Reike & Hekkert, 2017).

Two of the main subjects of debate for the political, economic and social fields are the recovery efficiency concerns (especially for the municipal waste) and the circular material usage (Tantau, Maassen & Fratila, 2018). By making waste prevention the main priority, the policymakers in Europe have steered the waste management directive and policy making in the direction to break the link between population, affluence and the amounts of generated waste.

Research and management of processes that are as complex as the waste management system is are challenging tasks. On one hand, lacking and questionable reliability of the data available on waste is often a challenge in not only planning, but also in implementing the sorting technology and deploying the information systems that support waste management. Namely, waste is not measured on a detailed basis (at the level of every single generator of waste or at disaggregate levels) and is managed by different channels involving several stakeholders, making the necessary data collection and compilation difficult (Beigl et al., 2008; Kannangara et al., 2018). On the other hand, waste management involves sophisticated interactions and multiple feedbacks associated with environmental effects, economic development patterns, population, etc. (Chen, Giannis & Wang, 2012; Kollikkathara, Huan & Danlin, 2010). In order to be able to plan and efficiently manage urban environments, it is essential to determine the factors that affect the generation of municipal waste (Liu & Yu, 2007). Waste projections are an important part of waste management as their results are often used to provide justification for a specific waste policy measure formulation and the planning of waste treatment and recycling facilities, including waste collection service. With them in hand, policymakers are able to better understand the dimension and scale of the problem and consequently make informed decisions (Shan, 2010).

The purpose of this research is to investigate whether there is a decline in the generated amounts of municipal waste influenced by the changes that cannot be contributed to the changes in the socio-economic variables, but rather to the influence of other factors such as improvements in the technology or pro-environmental behaviour stemming from the change in the environmental awareness of the European population. These factors are hard to define and quantify over time, however, they may have a considerable influence on the amounts of generated waste. As being distinct from most of the papers dedicated predominantly to finding the evidence of the Environmental Kuznets Curve or constructing predictive models, this study focuses on determining whether other factors affect the generation of municipal waste. The present paper contains a literature review of the field, a description of the definition and preparation of the data used in the study, an explanation of the methodology applied and closes with a discussion of the results.

2 LITERATURE REVIEW

Traditional models for the analyses of waste generation usually use socio-economic and demographic variables which typically include economic conditions, population growth, weather conditions, geographical situation, people hobbies and household size (Abdoli et al., 2011; Bach et al., 2004; Chang & Lin, 1997; Medina, 1997). While the existing household and community-level data allow for the examination of a number of important relationships in the area of solid waste, it is the use of macroeconomic data that can be applied to cast further light on a number of potentially significant factors, as are for instance the relative importance of economic growth and population density, as well as the demographic characteristics of households (Johnstone & Labonne, 2004). Indicators of decoupling are increasingly popular in detecting and measuring improvements in environmental and resource efficiency with respect to economic activity (Mazzanti & Zoboli, 2008). The traditionally used variables in the models analysing waste generation include GDP, consumption, population density, age, income, household size, education and employment, however, there are other variables, such as the pro-environmental behaviour and technology advances in favour of less waste, that can be leveraged through different policy measures. These variables are not part of the official statistics and are not easily incorporated in the analyses of waste generation.

The Environmental Kuznets Curve (EKC), named after Simon Kuznets (1955), hypothesizes that as a country becomes wealthier, at the beginning, its emissions to the environment increase, however, after a certain period, the emissions of the same country start to decrease as the country's economic prosperity continues (Kuznets, 1955; Stern, 2004). This indicates that certain pollutions follow the inverted U-curve in relation to the income per capita. Bruvoll, Fæhn and Strøm (2003) argue that even if this was true since the growth of income can ensure further progress in environmental protection, there are many other factors in play and there is therefore no guarantee that this trend will continue also in the future. In his paper, Stern (2004) concludes that the empirical analysis of EKC is not robust enough and should be tested with more rigorous time-series or panel data methods.

In respect to the aforementioned decoupling and the formation and implementation of environmental policies, the social aspects of waste management such as environmental attitudes become very important. Nevertheless, this aspect is poorly studied. Raising awareness on the understanding, protecting, and solving environmental problems through education has been universally recognized since 1970 (Shobeiri, Omidvar & Prahallada, 2006; Uzunboylu, Cavus & Ercag, 2009). The environmental awareness as such can be divided into two aspects, namely the perception of environmental problems that involves people's objective knowledge, perception and environmental realities on one hand, and on the other hand, the behavioural inclination to protect the environment (Desa, Kadir & Yusooff, 2011). The environmental awareness regarding the issue of waste is usually studied by surveying the opinions and attitudes of population (Follows & Jobber, 1999; De Feo & De Gisi, 2011; De Feo, De Gisi & Williams, 2013; Wassermann, et al., 2004; Salhofer, et al., 2008; Parfitt, Barthel & Macnaughton, 2010; MDNR, 2000; Ferrara & Missios, 2011; Taylor & Webster, 2004; Greenberg, et al., 2007). However, as most of these studies are cross-sectional, there is lack of research that would track the impact of the changing environmental attitudes on waste generation in a time perspective. Du et al. (2018) conducted a survey on the environmental behaviour, environmental perception and attitude towards environmental improvement in Beijing, China in the years 2006 and 2015. In case of attitudes towards the issue of waste, the results of Du et al. showed a decrease in the variable index by 33% caused by the local mismanagement of waste. In the study by Wray-Lake, Flanagan & Osgood (2010) conducted on high school seniors in the period from 1976 to 2005, the results showed not only an increase in the awareness on the resource scarcity in the period 1995-2005, but also a considerable decline in youth indicating that they mostly agreed or agreed with the resource scarcity from 81% in 1980 to only 46% of youth in 2004 (Wray-Lake et al., 2010). In their study of environmental attitudes, values and behaviour in Ireland, Motherway et al. (2003) compared the surveys from the years 1993 and 2002. The results showed that the reported recycling behaviour has increased significantly, reflecting increased accessibility of facilities. Hellevik's (2002) series of surveys on the environmental beliefs, attitudes and behaviour in the Norwegian population showed a decrease in the people choosing the option "very much worried" concerning the household waste from 10% in 1991 to 2% in 2001. However, attitude is something more but simple facts that may be judged against other data, as it also has an evaluation component (Heberlein, 1981).

Similar to the environmental awareness, the changes in processes caused by the technological advancements, especially in the field of waste prevention, are also hard to measure directly and through time. The usual method of linking the amounts of waste to material inputs in the production as constants excludes the technological changes, as the material inputs needed for the production of a certain product change over time (e.g. the amount of input material or the type of input materials changes) (Alfsen, Bye & Holmøj, 1996; Bruvoll & Ibenholt, 1997).

The data on awareness changes in production and consumption and technological progress are therefore hard to define and measure. This creates a challenge for acquiring an insight on how changes in awareness and technological progress affect the changes in the generation of waste. Both effects are usually treated as an unexplained residual in traditional models rather than an economic production function (Ayres, 1998).

In traditional models, the data on the household and non-profit institutions serving households (NPISH) final consumption expenditure and income are often used in waste generation as explanatory variables by many authors (Mazzanti & Zoboli, 2008; Gawande, Berrens & Bohara, 2001; Dinda, 2004; Johnstone & Labonne, 2004; Abrate & Ferraris, 2010; Ichinose, Yamamoto & Yoshi, 2011). This is understandable since the level of consumption reflects the levels of generated municipal waste, and as income grows, consumption can grow too, while people can at the same time invest in higher levels of environmental protection.

Higher population density requires a lower cost of service for municipal waste collection, while higher unemployment can lower waste generation as it lowers the household income (Chen, 2010; Mazzanti & Zoboli, 2008; Beigl et al., 2004; Alvarez et al., 2008). Certain authors have linked waste generation to the level of education and age, since more highly educated people are expected to have higher environmental awareness as opposed to younger people who are expected to litter more (Abrate & Ferraris, 2010; Kinnaman & Fullerton, 1999; Ghinea et al., 2016; Sterner & Bartelings, 1999; Johnson et al., 2017; Beigl et al., 2004). Various authors provide evidence that the amount of municipal waste generated by a country is influenced by its population size, household income levels and other socio-economic factors like for example the number of persons per dwelling, cultural patterns and personal attitudes (Bandara et al., 2007). Nevertheless, the effects of the income level, household size and education status can differ in significance within countries, cities and regions. For example, income may have a positive impact on the waste generation rate in one location, while it may exhibit a negative or an insignificant impact in another location (Keser, Duzgun & Aksoy, 2012). The adaptation of the waste addressing policies, such as the environmental and taxation recycling policies, is something rarely included in the studies (Mazzanti & Zoboli, 2008). The extensive overview of studies analysing the socio-economic variables in regard to waste generation is listed in Table 1.

Table 1: *Overview of the studies analysing the socio-economic and policy variables in regard to the amounts of generated waste*

Variable	Considerable as an explanatory variable	Non considerable as an explanatory variable
GDP	Liu & Yu, 2007; Shan, 2010; Dai, Li & Huang, 2011; Chen, Giannis & Wang, 2012; Beigl et al., 2004.	Mazzanti, 2008; Sun & Zhang, 2015; Daskalopoulos, Badr & Probert, 1998.
Consumption	Mazzanti & Zoboli, 2008; Mazzanti & Zoboli, 2008; Sun & Zhang, 2015; Dai, Li & Huang, 2011.	Johnstone & Labonne, 2004.
Population/ Population density	Mazzanti & Zoboli, 2008; Johnstone & Labonne, 2004; Liu & Yu, 2007; Shan, 2010; Thanh, Matsui & Fujiwara, 2010; Abdoli et al., 2011; Dai, Li & Huang, 2011; Chen, Giannis & Wang, 2012; Daskalopoulos, Badr & Probert, 1998; Alvarez et al., 2008; Abrate & Ferraris, 2010; Dyson & Chang, 2005.	Ghinea et al., 2016; Hockett, Lober & Pilgri, 1995; Sun & Zhang, 2015; Keser, Duzgun & Aksoy, 2012; Azadi & Karimi-Jashni, 2016; Daskalopoulos, Badr & Probert, 1998; Johnson et al., 2017; Abrate & Ferraris, 2010; Liu & Yu, 2007.
Age	Mazzanti & Zoboli, 2008; Johnstone & Labonne, 2004; Ghinea et al., 2016; Kannangara et al., 2018; Sterner & Bartelings, 1999; Johnson et al., 2017; Chen, 2010; Beigl et al., 2004.	Johnstone & Labonne, 2004; Lebersorger & Beigl, 2011.
Income	Thanh, Matsui & Fujiwara, 2010; Abdoli et al., 2011; Kannangara et al., 2018; Kumar & Samadder, 2017; Bandara et al., 2007; Johnson et al., 2017; Chen, 2010; Alvarez et al., 2008; Abrate & Ferraris, 2010; Dyson & Chang, 2005.	Hockett, Lober & Pilgri, 1995; Liu & Yu, 2007; Sterner & Bartelings, 1999.
Household size	Thanh, Matsui & Fujiwara, 2010; Lebersorger & Beigl, 2011; Beigl et al., 2004; Abrate & Ferraris, 2010.	
Taxation	Mazzanti & Zoboli, 2008; Lebersorger & Beigl, 2011; Bandara et al., 2007.	
Education	Keser, Duzgun & Aksoy, 2012; Sterner & Bartelings, 1999; Chen, 2010; Alvarez et al., 2008; Abrate & Ferraris, 2010.	Kannangara et al., 2018; Kumar & Samadder, 2017; Johnson et al., 2017.
Employment/ Unemployment	Bach et al., 2004; Keser, Duzgun & Aksoy, 2012; Kannangara et al., 2018; Bandara et al., 2007; Chen, 2010; Alvarez et al., 2008.	Johnstone & Labonne, 2004.

3 METHODOLOGY

3.1 Data collection and preparation

As the first step in the analysis, we conducted a thorough investigation of the availability of the statistical data needed for the panel data analyses models in order to make solid conclusions. As the main dependent variable, the generated amounts of waste were used while the decision on what variables to use as explanatory variables was made based on the extensive literature review (Table 1) and the availability of the statistical data. The data on the household and NPISH final consumption expenditure and income were chosen as the main explanatory variables. In order to better explain the differences between the analysed countries, we selected four structural and socio-economic variables: unemployment rates, population density, tertiary education graduates and the ratio of young people in the total population. In order to incorporate a certain measure of policy and having in mind the availability of the data and the fact that most of the analysed countries are the EU member states with a similar EU waste management legislative, the data on environmental taxes were chosen as a proxy for the policy variable. The above stated data were available for the period 2002-2015 for the following 30 European countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the UK, all of which were thus included in the analyses of this paper.

The data were collected from the Eurostat database, from the "Economy and the finance" and "Environment and energy" data sets and cover the variables on the municipal waste generation (in kg per capita), the total environmental taxes (in millions of euro per capita with applied implicit deflator—year 2010 = 100), the household and NPISH final consumption expenditure (in real prices in euro per capita with applied implicit deflator—year 2010 = 100), the household and NPISH income (in real prices in euro per capita with applied implicit deflator—year 2010 = 100), the unemployment rates (in percentages), the population density (in inhabitants per km2), the tertiary education graduates (per 1000 of population), and the ratio of young people in the total population (in percentages) (Eurostat, 2019). Although the 30 European countries were chosen as having the most complete available data, certain parts of the data were still missing and had to be assessed. This was done by using the averages for the years for which the data were available. The data which were missing were the following: the data on the municipal waste generation for certain years for Croatia, Denmark, Ireland and Portugal; the data on the household and NPISH final consumption expenditure and income for certain years for Croatia, Iceland, Luxembourg, Malta and Romania; the data on tertiary education graduates for certain years for Croatia, Denmark, Estonia, France, Greece, Luxembourg, Iceland, Italy, Malta and Slovakia; and the data on the ratio of young people in the total population for certain years for Hungary, Iceland and Norway.

The total values of the municipal waste generation, household and NPISH final consumption expenditure and income, population density, tertiary education graduates, unemployment rates, ratio of young people in the total population, and the total environmental taxes for the selected 30 European countries in the period 2002-2015 are presented in Table 2.

Table 2: *Descriptive statistics of the total values of municipal waste generation, household and NPISH final consumption expenditure and income, population density, tertiary education graduates, unemployment rates, ratio of young people in the total population and total environmental taxes for 30 European countries in the period 2002-2015*

Variable	Mean	Minimum	Maximum	Standard Deviation	Kurtosis	Skewness	Unit of measurement
Municipal waste	14740.43	14036.00	15747.00	548.56	-0.66	0.49	Kg per capita
Consumption	384757.13	288344.56	448651.76	49999.33	-0.37	-0.88	Euro per capita
Income	392251.34	300043.94	452268.38	48278.64	-0.46	-0.89	Euro per capita
Environmental taxation	19756.96	14590.88	23896.16	2656.86	-0.15	-0.64	Mill. euro per capita
Education	1855.63	1303.46	2148.82	288.42	-0.90	-0.55	Total graduates per 1000 of population aged 20-29
Unemployment	18.43	13.03	22.91	3.23	-0.81	-0.36	Average %
Ratio of young people	42.64	39.57	44.84	1.72	-0.96	-0.49	Average % (from 15 to 29 years)
Density	4780.90	4640.70	4929.00	91.27	-1.18	0.03	Inhabitants per km²

The development of a reliable model for the analyses of the economic trends and socio-demographic changes on solid waste generation is a useful progress in the practice of solid waste management (Dyson & Chang, 2005). The dependencies of the amounts of generated municipal waste to socio-economic variables are often analysed through the econometric models which combine economic modelling and data with mathematical statistics (Bruvoll, Fæhn & Strøm, 2003; Östblom, Söderman & Sjöström, 2010; Greyson, 2007; Hansen, 2014). There are two mostly used statistical models for this kind of analysis: the fixed-effect model and the random-effects model. In the former, we assume that there is one true effect size that underlies all the studies in the analysis, and that all differences in the observed effects are due to a sampling error (Borensteina et al., 2010). In the latter, i.e. the random-effects model, the effect sizes in the studies that actually were performed are assumed to represent a random sample from a particular distribution of these effect sizes (hence the term random effects) (Borensteina et al., 2010).

Having in mind possible correlation, in order to develop the panel data analyses models, all independent variables were tested for the variance inflation factor (VIF). We applied a benchmark of high correlation of VIF ≥ 5 (Marquardt, 1970; Neter, Wasserman & Kutner, 1989; Hair et al., 1995) and the results show very high VIF values for the variables of the household and NPISH final consumption expenditure and the household and NPISH income (> 20) meaning high correlation, while the rest of the variables scored much lower. Based on these results, two competing models were build:

1. The model with the data on the household and NPISH final consumption expenditure as the main independent variable and

2. The model with the data on the household and NPISH income as the main independent variable.

Both of these two models were analysed by using both the fixed-effects and the random-effects approaches by applying the following equations:

1. For the fixed-effects estimation model:

$$W_{Mcy} = \beta_0 + \beta_1 x_{1cy} + \beta_2 x_{2cy} + \beta_3 x_{3cy} + F_c + T_y + \varepsilon_{cy} \quad (1)$$

2. For the random-effects estimation model:

$$W_{Mcy} = \beta + \beta_1 x_{1cy} + \beta_2 x_{2cy} + \beta_3 x_{3cy} + T_y + \mu_c + \varepsilon_c \quad (2)$$

Where W_{Mcy} is an amount of municipal waste generated in a country c in a year y in tonnes. The variable x_1 represents the household and NPISH final consumption expenditure in a country c in a year y in millions of euro per capita—or in alternative represents the household and NPISH income in a country c in a year y in millions of euro per capita. The secondary explanatory variables are marked with x_{2cy} (the unemployment rates in %, the population density measured as inhabitants per km^2, the tertiary education graduates measured as total graduates per 1 000 of population aged 20-29, and the ratio of young people in % of the total population) and x_{3cy} the environmental taxation in million euro per capita. The two variables included in vectors x_{1cy} were tested in separate models. The variables F_c and T_y represent the dummy variables for the countries and year-specific effects, while ε_{cy} represents country and time-varying error term in fixed effects, while ε_c is a within-country error and μ_c is a between-country error.

4 RESULTS AND DISCUSSION

Having in mind that the variables are in different measures, the analyses were conducted on both standardised and not standardised coefficients. The fixed effect analyses were conducted by applying Equation (1). Both fixed-effects models (Model 1 with household and NPISH final consumption expenditure as the main independent variable, and Model 2 with household and NPISH income as the main independent variable) show very high R Square (0.93), implying a very high level of variance explained by the models (Table 3). If we look at the coefficients, all of the variables in Model 1 have significant coefficients except for the population density and the environmental taxation, while in Model 2 the variables education, unemployment and the ratio of young people prove significant at

5% and the other three not (Table 5). Model 2 shows that the income variable and the population density variable are significant only at a 10% significance level. For the dummy variables (countries and years) in both models, the 26 coefficients of a total number of 42 are significant, indicating a relatively good model, out of which the years dummy variables coefficients are negative and significant at 5% for the years 2011-2015 (Table 5).

The random-effect analyses were conducted by applying Equation (2). The results of Model 3 with household and NPISH final consumption expenditure as the independent variable show R Square within, R Square between and R Square overall with the values of 0.31, 0.34 and 0.33, respectively. The results of Model 4 with household and NPISH income as the independent variable show R Square within, R Square between and R Square overall with the values of 0.31, 0.34 and 0.33, respectively (Table 4). The Wald Chi-Square statistic tests for the 19 degrees of freedom (high because of the year dummy variables) for Model 3 and Model 4 had the values of 180.81 and 175.74 with the probability higher than 0.00, which indicate that at least one of the predictor variables in the models is significantly different from zero (Table 3). If we look at the coefficients in Model 3, three independent variables have significant coefficients at 5%—consumption, education and the ratio of young people, and three of the independent variables have insignificant coefficients at 5%—unemployment, population density and environmental taxation (Table 5). In Model 4, three independent variables have significant coefficients at 5%—income, education and the ratio of young people, and three independent variables have insignificant coefficients at 5%—unemployment, population density and environmental taxation (Table 5).

Table 3: *Results of the level of variance explained by the two fixed-effects models*

	Model 1	**Model 2**
R Square	0.9319	0.9310
p-value	1.8E-187	1.8E-186
Significance	yes	Yes

Table 4: *Results of the level of variance explained by the two random-effects models*

	Model 3			**Model 4**		
	Within	Between	Overall	Within	Between	Overall
R Square	0.3122	0.3450	0.3335	0.3034	0.3773	0.3608
Wald Chi-Square statistic 19 degrees of freedom		180.81			175.74	
Probability > chi2		0.0000			0.0000	
Significance		yes			Yes	

Table 5: *Results of the models analysing the data on household and NPISH final consumption expenditure and income, tertiary education graduates, unemployment rates, ratio of young people in the total population, population density and environmental taxation in regard to the data on generation of municipal waste*

	Model 1			*Model 2*			*Model 3*			*Model 4*		
	Stand. Coeff.	*Unstand. Coeff.*	*p-value*	*Stand. Coeff.*	*Unstand. Coeff.*	*p-value*	*Stand. Coeff.*	*Unstand. Coeff.*	*p-value*	*Stand. Coeff.*	*Unstand. Coeff.*	*p-value*
Intercept ***Standardized***	0.11	--	0.11	0.11	--	0.15	0.18	--	0.25	0.17	--	0.26
Intercept ***Unstandardized***	--	320.29***	0.00	--	321.74***	0.00	--	274.92***	0.00	--	269.58***	0.00
Consumption	0.22***	0.00***	0.00	--	--	--	0.27***	0.00***	0.00	--	--	--
Income	--	--	--	0.15*	0.00*	0.06	--	--	--	0.23***	0.00***	0.00
Education	0.16***	0.94***	0.00	0.16***	0.97***	0.00	0.14***	0.84***	0.00	0.14***	0.87***	0.00
Unemployment	-0.05**	-1.41**	0.05	-0.06**	-1.59**	0.03	-0.05*	-1.31*	0.07	-0.05*	-1.38*	0.06
Ratio of young people	0.13***	7.71***	0.00	0.14***	8.03***	0.00	0.10***	5.62***	0.00	0.10***	5.82***	0.00
Density	-0.77	-0.41	0.13	-0.85*	-0.45*	0.1	0.19	0.10	0.16	0.18	0.10	0.17
Environmental taxation	0.01	0.00	0.93	0.10	0.03	0.31	0.06	0.02	0.53	0.12	0.03	0.17
2003	-0.04	-4.48	0.62	-0.04	-4.48	0.62	-0.04	-5.30	0.56	-0.04	-5.35	0.56
2004	-0.03	-4.21	0.65	-0.03	-4.33	0.65	-0.05	-6.51	0.49	-0.05	-6.60	0.49
2005	-0.02	-2.85	0.77	-0.02	-2.42	0.81	-0.06	-7.16	0.47	-0.05	-6.73	0.50
2006	0.03	3.94	0.70	0.04	4.77	0.65	-0.01	-1.86	0.86	-0.01	-1.06	0.92
2007	0.04	4.81	0.67	0.05	5.84	0.60	-0.02	-3.04	0.78	-0.02	-2.11	0.85
2008	0.07	8.17	0.47	0.07	9.03	0.43	0.00	0.37	0.97	0.00	0.51	0.96
2009	-0.05	-6.7	0.54	-0.05	-5.87	0.6	-0.11	-13.56	0.21	-0.11	-14.02	0.2
2010	-0.16*	-19.72*	0.1	-0.15	-18.43	0.13	-0.23**	-28.43**	0.02	-0.23**	-28.3**	0.02
2011	-0.23**	-28.21**	0.03	-0.22**	-26.94**	0.04	-0.31***	-38.28***	0.00	-0.3***	-38.1***	0.00
2012	-0.3***	-37.76***	0.01	-0.29***	-35.74***	0.01	-0.39***	-49.08***	0.00	-0.39***	-48.29***	0.00
2013	-0.32***	-39.7***	0.00	-0.3***	-37.74***	0.01	-0.42***	-52.08***	0.00	-0.41***	-51.39***	0.00
2014	-0.31***	-38.5***	0.01	-0.29***	-36.72***	0.01	-0.42***	-52.46***	0.00	-0.41***	-51.85***	0.00
2015	-0.28**	-35.27**	0.02	-0.27**	-33.63**	0.02	-0.41***	-51.27***	0.00	-0.41***	-50.69***	0.00

*Stand. – standardized; Unstand. – unstandardized; Coeff. – coefficients; *significant at 0.1; ** significant at 0.05; *** significant at 0.01*

The results of the Hausman test and the robust Hausman test by using the Mundlak Device and in general a cluster-robust Wald statistic test (Mundlak, 1978; Wooldridge, 2010) show in Table 6 that only the results of the fixed-effects models are relevant for interpretation (Model 1 and Model 2).

Table 6: *Results of the Hausman tests on the random-effects models*

TEST	MODEL	Chi-square	p-value
Hausman	**Model 3**	17.19	0.0086
Hausman	**Model 4**	14.87	0.0213
Robust Hausman	**Model 3**	13.39	0.0372
Robust Hausman	**Model 4**	11.03	0.0795

Since we used models which have different main independent variables, namely Model 1 with the household and NPISH final consumption or Model 2 with the household and NPISH income, we compared the fixed-effects models through the Akaike Information Criterion (AIC) and Schwarz Criterion (SBC) (Akaike, 1973; Fabozi et al., 2014). The results of both of these criterions show that Model 1 is better fit than Model 2 (Table 7).

Table 7: *Results of the Akaike Information Criterion (AIC) and Schwarz Criterion (SBC)*

MODEL	CRITERION	VALUES Standardized	VALUES Unstandardized
Model 1	Akaike Information Criterion (AIC)	102.57	4159.12
Model 2	Akaike Information Criterion (AIC)	107.92	4164.48
Model 1	Schwarz Criterion (SBC)	183.37	4239.93
Model 2	Schwarz Criterion (SBC)	188.72	4245.23

If we look at the coefficients, for Model 1 the most significant variable at 5% is the household and NPISH final consumption expenditure with the standardised coefficient of 0.2227. The considerable and positive effect of this variable on the increase in the amounts of generated municipal waste is in line with the previous studies (Mazzanti & Zoboli, 2008; Mazzanti, 2008; Johnstone & Labonne, 2004; Sun & Zhang, 2015; Dai, Li & Huang, 2011). The results showed the tertiary education graduates as the second significant variable with a standardised coefficient of 0.1551, thus confirming the findings of some authors that this variable representing the educational level of the population has a significant positive influence on the amounts of generated municipal waste due to improved life standards of the population with higher education (Keser, Duzgun & Aksoy, 2012). However, this contradicts the conclusions of other authors (e.g. Kumar & Samadder, 2017; Johnson et al., 2017; Kinnaman & Fullerton, 1999) who find that higher education is related to higher environmental awareness, resulting therefore in lower amounts of generated waste.

Our results correspond to the findings of previous studies on the population age distribution as a significant explanatory variable in the case of waste generation. The statistically significant standardised coefficient of 0.1307 for the ratio of young people in the total population indicates that the younger is the population, the more waste is generated (Ghinea et al., 2016; Sterner & Bartelings, 1999; Johnson et al., 2017; Beigl et al., 2004). The unemployment rate variable has a negative and significant impact with the coefficient of -0.0491, meaning the higher the unemployment rate in economy, less waste is being generated possibly through changes in the structure of consumption. This is consistent with authors Keser, Duzgun & Aksoy (2012), Kannangara et al. (2018), Bandara et al. (2007), and Alvarez et al. (2008). Population density is one of the most frequently analysed variables in the literature, however, often with conflicting results. Namely, certain authors find this variable significant (i.e. Johnstone & Labonne, 2004; Alvarez et al., 2008; Thanh, Matsui & Fujiwara, 2010), while other authors find it insignificant, although the outcomes of certain analyses also depend on the method and type of waste analysed (i.e. Keser, Duzgun & Aksoy, 2012; Abrate & Ferraris, 2010). In any case, the results in this paper show that the variable population density is not significant at 5%. The few authors who used the environmental policy variable in their models found this variable to be significant which is contrary to the results of this paper (Mazzanti & Zoboli, 2008; Lebersorger & Beigl, 2011).

The results of Model 2 were similar to those of Model 1, with one big difference, namely the independent variable for household income does not seem to be statistically significant. This is in line with authors like Sterner & Bartelings (1999), however, Thanh, Matsui, & Fujiwara (2010) provide mixed results, while some researchers found this variable to be significant (Abdoli et al., 2011; Kannangara et al., 2018; Kumar & Samadder, 2017; Bandara et al., 2007; Johnson et al., 2017; Chen, 2010; Alvarez et al., 2008; Abrate & Ferraris, 2010; Dyson & Chang, 2005).

Regarding the possible evidence of the EKC forming, we expanded our models by incorporating the square of the income. The results show that in the fixed-effect Model 2 and the random-effect Model 4 the income coefficient has a negative value and the square of the income coefficient has a positive value which indicates that a regular U curve is formed (and not the inverted one) and thus no evidence of EKC can be established.

Especially interesting for the purpose of this paper are the coefficients of the year dummy variables which can imply whether the decline in the amounts of generated municipal waste occurred in a certain year independent from the changes in the explanatory variables used in the models. This would mean that this decline could be ascribed to other factors, like for example improving technologies, raising awareness and stricter policies. For the analysed European countries, the coefficients of the year dummy variables in the period 2011-2015 are negative (linked to the decrease in waste generation) and significant at 5% in both models which can be considered as a relatively robust evidence on the decline in the amounts of generated municipal waste independent of the socio-economic variables used in the model.

5 CONCLUSIONS

This paper demonstrates the possibility of the analyses of the statistical data on waste with the socio-economic variables. Departing from the majority of other papers centred on finding the evidence of the Environmental Kuznets Curve or on building the predictive models, the analyses in this paper were centred more on finding the evidence of the causes of the generation of municipal waste which cannot be attributed to the available explanatory socio-economic variables.

The panel data analyses were applied in order to investigate the causes of the possible decline in the amounts of generated waste in the 30 European countries. In the analyses, both the fixed-effect model and the random-effects model were used as a control of the robustness of the findings. Although the analysis covered the period 2002-2015, the results consistently show a statistically significant decline in waste generation for the period 2011-2015 which is independent of the socio-economic variables used in the model.

According to our results, three significant variables influence the increase in the amounts of waste—consumption, level of education and the age structure of the population, while only the unemployment level has a significant negative impact on the amounts of waste. Including more variables in combination with the ones suggested in this paper would certainly improve the results. As waste generation and management is a topical issue nowadays, the research in micro and macro aspects of it should be intensified in order to better understand the processes, as well as to monitor the effectiveness of the different policies on waste generation. In this paper, only one policy variable is used, thus the development of models which will include more variables which represent the effects of the implementation of different directives, national policies, and funds spent on implementing certain policies could be done to gain better insight. One of the ways that this can be done is to develop policy indicators which can be measured through time. This research was conducted on the amounts of municipal waste, however, the study can be deepened by analysing different waste materials within the municipal waste, for example paper, plastics, glass etc. In addition, an analysis of different countries grouped based on their similar characteristics (e.g. based on the level of their GDP) could provide interesting results.

The findings of this paper have importance for the national and international level policymakers as the findings enable quantification of the level of changes in the socio-economic fluctuations which influence the desired change in the municipal waste generation. This feedback allows decision makers to learn from past experience and evaluate the implemented measures. Political decisions and policies without a doubt influence the changes in the socio-economic conditions, namely the conditions which are used as explanatory variables for waste generation in panel data analyses models. Environmental policies should not distort markets, but rather increase the competitiveness and improve the environmental protection. Policymakers have to balance between the immediate benefits for companies gained from cutting their environmental costs and the positive results of implementing environmental policies which generally take longer to be observed. Thus, not determining the time frame for obtaining the results or deeming them to be too far in the future can shift the policies towards being short-termed with easily observable results instead of being more profound and far reaching ones bringing the benefits in a more distant future. The panel data analysis provides a better understanding of the drivers of municipal waste generation and assesses the potential for its reduction by adopting and efficiently implementing waste prevention measures. Certainly, obtaining data of higher quality and quantity would allow for better analyses of the effects which environmental policies have on waste generation. However, certain influences as are the pro-environmental behaviour and technology advances prove hard to quantify, although they are a strong driving force behind the waste prevention processes.

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