The amount of household waste disposed of in Poland, compared with other European Union countries

Anna Turczak
The West Pomeranian Business School in Szczecin, Poland
ORCID: 0000-0003-2965-4254, e-mail: anna.turczak@wp.pl

DOI: 10.14595/CP/01/006

Abstract: The purpose of this article is to answer the question how individual European Union countries differ from Poland with regard to the amount of household waste disposed of per capita. Two factors affecting the variable have been analysed in the paper: 1) the amount of household refuse generated per inhabitant and 2) the part of waste destined for disposal in the total quantity collected from households. Those two explanatory variables are directly proportional to the response variable. Thus, the smaller the mean volume of waste produced by one person and the lower the disposal rate, the smaller the quantity of waste disposed of per capita in a given country. Causal analysis enables us to answer the question of how the two factors affect the variable considered, namely, the direction and strength of their influence. The logarithmic method was applied to carry out the causal analysis. Data for 2010, 2012, and 2014 have been used for calculations.

Keywords: household waste, disposal, the European Union, Poland

JEL: C65, Q53, Q56

Introduction

The 'economics of waste' is a field of environmental economics which is of growing interest in theoretical analyses dealing with the design of optimal policy packages. The increasing scarcity of natural resources and the consequent changes in policy – focused first on reducing waste production, and then on decreasing the proportion of refuse destined for disposal to refuse destined for recovery – have also generated a need for empirical analyses providing evidence on the effectiveness of taxation and incentives, the relevance of specific regional features and the impact of a comprehensive set of socio-economic drivers [D'Amato et al., 2013]. Such sustainability drivers – in a gross simplification – are as follows [Kramer, 2012, p. 18]:

- **Consumer demand for sustainable products and services:** People today are making purchases not only as consumers, but also as responsible world citizens. By rejecting the indiscriminate consumption patterns of the past and becoming more selective in their choices, they are signalling a shift in consumer attitudes and behaviours that may significantly affect business profitability and growth.

- **Stakeholder influence:** Globalisation and technology give customers and citizens a powerful voice. Businesses and public sector organisations need to extend their reach to a new breed of stakeholders that includes non-government organisations, media, academics and the community at large.
- **Resource depletion:** Economic growth in developing markets, combined with high consumption in Western economies, has depleted natural resources.
- **Employee engagement:** Employees' commitment and enthusiasm for sustainability are shaping the way of working and living. As the sustainability mandate expands, organisations committed to social and environmental problems are likely to attract the top talent.
- **Capital market scrutiny:** Investors now look at sustainability performance when evaluating a company's potential for future returns.
- **Regulatory requirements:** Government and industry regulations are forcing companies in nearly every industry to take sustainability seriously.

Many studies have been conducted around the world to investigate and measure the effect of different factors on citizens' behaviour regarding waste production [Kinnaman, 2006]. For instance, social awareness [Evison and Read, 2001], intrinsic motivation [Halvorsen, 2004], social norms [Viscusi et al., 2011] and peer pressure [Shaw, 2008] can all have an impact on the effectiveness of a waste management system.

Among the variables for demographic factors, there is a consensus that population density and degree of urbanisation are positively correlated to solid waste generation [Gellynck and Verhelst, 2007; Mazzanti et al., 2008; Mazzanti and Zoboli, 2009; Mazzanti et al., 2009]. Karousakis [2006] notes that, though urbanisation is associated with higher levels of refuse generation, it has a negative impact on the amount of refuse sent to disposal.

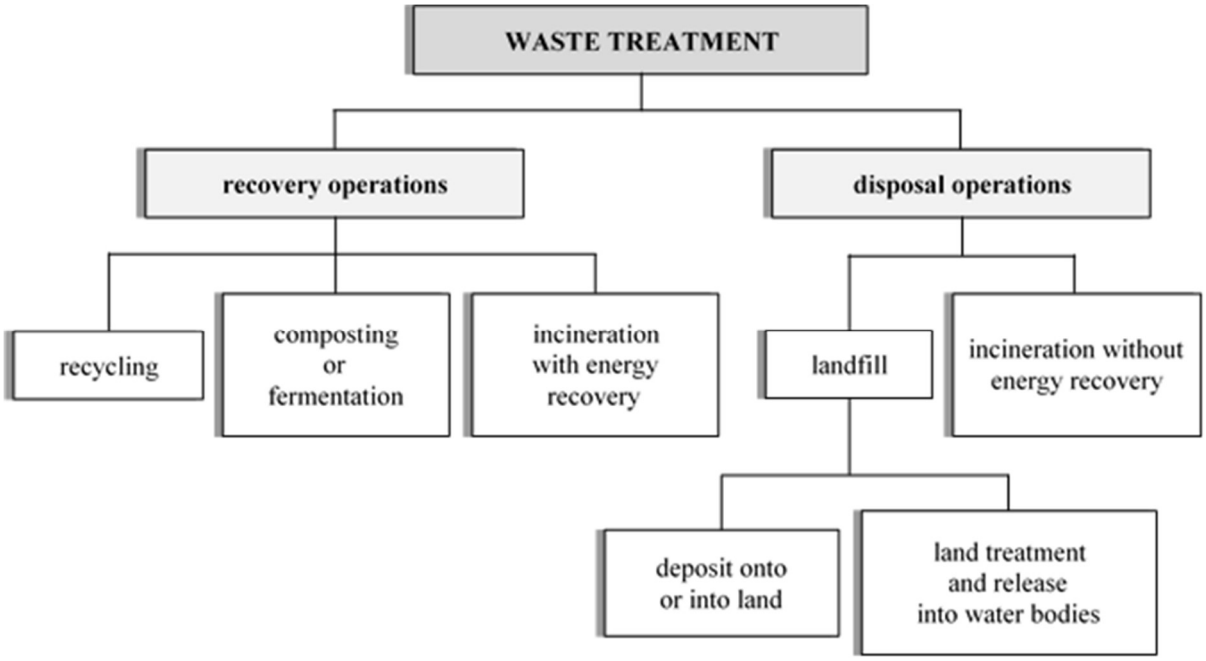
In considering the impact of socio-economic variables, some authors focus on the relationship between education and household waste production. Intuition would suggest that better educated people would be more likely to sort their waste and have a higher awareness of environmental and health issues. Indeed, Podolsky and Spiegel [1998] and Fullerton and Kinnaman [1999] estimate that higher education levels tend to reduce, respectively, the total amount of refuse produced and the amounts of non-separated refuse. Furthermore, Johnstone and Labonne [2004] find evidence that the number of children in the population has a negative and significant effect on waste generation.

Two strategies for managing solid waste are prevention and treatment. Waste prevention is the most desirable form of control because it poses the fewest risks to human health and the

environment. Prevention includes reduction of refuse generated. For example, manufacturers can use less packaging or use recycled materials in their products and packaging. Consumers can throw away less food, paper, shopping bags, and other items [Resnik, 2012, p. 150].

Generally speaking, the waste produced can be recovered or disposed of (see Fig. 1).

Fig. 1. Waste treatment



Source: own elaboration.

However, it should be strongly emphasised that solid waste disposal can have a number of different, adverse impacts on human health and the environment. Some of the health impacts include exposure to infectious diseases from landfills and medical waste; exposure to disease vectors, such as rats, flies, and mosquitoes; contamination of drinking water; gas discharge from landfills; air pollution from incineration; food and water contamination from chemicals that enter the environment; and exposure to radiation from radioactive waste. Depending on the nature of the waste product and the level of exposure, solid waste disposal can increase the risk of infectious diseases, such as cholera; parasites, such as malaria; various types of cancer; kidney disease; poisoning from heavy metals, such as lead, mercury, and cadmium; respiratory ailments; cardiovascular problems; and severe burns, trauma, or death from the ignition of gases emitted from landfills. Environmental impacts include the destruction of habitats when land is cleared to make room for waste disposal, and loss or extinction of species due to water contamination from landfills or hazardous waste sites [Rodenbeck et al., 2010].

Interestingly, Fullerton and Kinnaman [1995a, 1995b] describe the possibilities for substitution between waste disposal and recycling as part of household refuse management.

They develop models where households maximise utility subject to a budget constraint, which incorporates a unit price for refuse collection. These models underpin a series of solid waste disposal and recycling demand equations which are very helpful in understanding the behaviour of households [Abrate and Ferraris, 2013, p. 45].

There is no doubt that to manage something in the right way entails first getting to know it in depth. Moreover, it is necessary to quantify it and to identify the factors affecting it. Waste learning is an important element of waste management.

The 'waste revolution' in Poland

Since 1 May 2004, Poland has been a member of the European Union. This fact has forced the adjustment of Polish legislation to EU requirements. A number of legal regulations aligned with international standards have been introduced in this country. The term 'waste revolution' is commonly used in Poland to describe institutional changes resulting from the adjustment of domestic law to the European Union requirements.

In Poland, up to 2013, households directly contracted service providers for waste collection services. Due to insufficient policy enforcement by the local authorities, however, many households failed to do so, which resulted in illegal waste dumps or improper utilisation of refuse in households (for example waste burning). In this way, some households were able to avoid the cost of waste management.

The firms collecting municipal refuse received money directly from their customers, i.e. owners of real properties, in exchange for their services, and no money went to municipalities. This created situations where different companies collected waste from households on the same street, making the system inefficient.

Waste collectors did not have an incentive to invest in infrastructure, and the cheapest way of managing the waste was to send it to landfill. In addition, as many landfills lacked sufficient weighing equipment, service providers in some cases under-reported the amounts collected, in order to reduce landfill fees [EEA, 2016, p. 14].

It should be mentioned that the first time reform was attempted in Poland was in 2005, on the occasion of amending the law about municipal waste management, but legislative work was conducted in an atmosphere of a sharp dispute about the system's key assumptions [Radecki, 2012]. There were two main interest groups. One, represented by the Polish Waste Management Chamber, incorporating private enterprises engaged in waste transport, which favoured leaving the solutions in force that assumed competition among firms, with no major interference on the part of public authorities and no responsibility for reducing the waste mass stored. The other group, represented by the National Waste Management Chamber associating

communal companies involved in waste transport and management, which favoured municipalities taking over all duties and full responsibility in this field. Ultimately, the Parliament took the side of the first lobby, thus postponing the introduction of unavoidable systemic changes [Kołsut, 2016, pp. 97-98].

Vital reforms in this sector were constantly being put off, despite the fact that the situation from year to year was becoming more and more dramatic. The impulse generating visible changes in the system was only provided by EU legal norms, and in practice by sanctions threatening Poland for the lack of specified, measurable effects in waste management.

The time for the necessary institutional changes came in 2011 and 2012. In the course of legislative work, the two interest groups clashed again, but this time the solution was different. It was decided that, given the very long delay in attaining correct values of municipal waste management indicators, radical systemic changes were required. Municipalities started to be responsible for municipal waste management. They also became responsible for achieving proper levels of recycling and reducing refuse intended for storage. Financial penalties were to be applied to municipalities not implementing national regulations or for a lack of compliance with municipal waste targets.

Since the introduction of new system, formal municipal waste management has covered 100% of generated municipal waste. Property owners are required to pay a fee which is defined by the municipality. The municipal council determines this fee by way of a resolution that is an act of local law [Rakoczy, 2014, p. 62]. Municipalities may base those fees either on the number of people per household, the area of the house or water consumption. This means that in Poland, no pay-as-you-throw systems are currently in place for municipal waste collected from households.

The final amount of fee is also affected by a declaration made by the householder regarding waste segregation. If a property owner declares that they have separated out recyclable materials then they pay considerably lower fees. Only those who declare that they do not want waste collected selectively pay full price. It is rare that people do so.

The problem is that some householders declare that they segregate their waste while in reality they do not. Monitoring the system, in order to crack down on such abuses represents quite a challenging task.

In general, however, it should be said that the first experiences of the ‘waste revolution’ are positive and indicate that the new system is going to help the country to meet the policy targets for municipal waste. There are still some challenges to be met, such as the need for additional refuse processing capacity and support for municipalities in carrying out their new

responsibilities in an efficient manner. Furthermore, in many municipalities the fees set in the first place were insufficient to cover the full costs of waste management and there will probably be a need to increase the fees in the near future. Other issues of concern include the varying service levels among municipalities with respect to collection frequency and practices, and know-how in public procurement processes [EEA, 2016, p. 15]. But further analysis of these problems goes beyond the scope of this article.

Methodology

The purpose of this paper is to answer the question of how other European Union countries differ from Poland in terms of the amount of household waste disposed of per capita. Two factors affecting the variable, namely the household waste collected per capita and the disposal rate (which is the proportion of the refuse destined for disposal to the total refuse generated by households), shall be analysed in this article. The logarithmic method will be used to assess the influence of the deviations of the said factors on the deviation of the volume of household waste disposed of in relation to the number of inhabitants. The values obtained for Poland will be adopted as the basis for all comparisons.

The objective of the causal analysis is to determine how various factors affect a given variable, i.e. the direction and degree of their impact [Szczecińska, 2007]. Therefore, causal analysis can answer the question of whether a particular factor causes an increase or a decrease of the studied variable, and enables us to assess how big the impact of this factor is [Turczak, 2016, p. 69].

The following notation has been adopted for the purpose of this article:

D – the quantity of household refuse designated for disposal,

T – the total amount of household waste collected (i.e., sent to recovery+ sent to disposal),

P – the size of the population,

$\frac{D}{P}$ – the quantity of household refused signated for disposal in relation to the population size,

$\frac{T}{P}$ – the total amount of household waste collected in relation to the population size,

$\frac{D}{T}$ – the disposal rate.

The examined variable $\frac{D}{P}$ can be presented as a product of factors $\frac{T}{P}$ and $\frac{D}{T}$. The value of the variable $\frac{D}{P}$ for Poland will be the basis of reference and shall be marked by $\frac{D_0}{P_0}$. In turn, the value of this variable calculated for other European Union countries will be denoted as $\frac{D_i}{P_i}$ (i = 1, …, 27). Since $\frac{D_i}{P_i} = \frac{T_i}{P_i} \cdot \frac{D_i}{T_i}$ and $\frac{D_0}{P_0} = \frac{T_0}{P_0} \cdot \frac{D_0}{T_0}$, when dividing $\frac{D_i}{P_i}$ by $\frac{D_0}{P_0}$, the result is:

(1)

$$\frac{\frac{D_i}{P_i}}{\frac{D_0}{P_0}} = \frac{\frac{T_i}{P_i} \cdot \frac{D_i}{T_i}}{\frac{T_0}{P_0} \cdot \frac{D_0}{T_0}},$$

where:

D_i, T_i, P_i − the values of variables *D*, *T*, and *P* referring to the *i*-th EU country,

D_0, T_0, P_0 − the values of variables *D*, *T*, and *P* referring to Poland.

The same can be shown in a different way, namely:

(2)

$$\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right) = \left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right) \cdot \left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right).$$

Taking the common logarithms of both sides of the equation (2), the following expression can be obtained:

(3) $$\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right) = \log\left[\left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right) \cdot \left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right)\right].$$

Then, using the logarithm property stipulating that the logarithm of a product of some numbers is equal to the sum of the logarithms of these numbers [Turczak, 2017, p. 83], the equation presented below can be derived:

(4) $$\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right) = \log\left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right) + \log\left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right).$$

The next step is to divide both sides of equation (4) by the term $\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)$. This results in the expression:

(5)

$$1 = \frac{\log\left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)} + \frac{\log\left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)},$$

where:

$\frac{\log\left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)}$ – the impact of the deviation of $\frac{T}{P}$ on the deviation of $\frac{D}{P}$,

$\frac{\log\left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)}$ – the impact of the deviation of $\frac{D}{T}$ on the deviation of $\frac{D}{P}$.

The final step is to multiply both sides of the equation (5) by the value of deviation calculated for the variable $\frac{D}{P}$. Finally:

(6)
$$\frac{D_i}{P_i} - \frac{D_0}{P_0} = \left(\frac{D_i}{P_i} - \frac{D_0}{P_0}\right)\frac{\log\left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)} + \left(\frac{D_i}{P_i} - \frac{D_0}{P_0}\right)\frac{\log\left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)},$$

where:

$\frac{D_i}{P_i} - \frac{D_0}{P_0}$ – the total deviation of $\frac{D}{P}$,

$\left(\frac{D_i}{P_i} - \frac{D_0}{P_0}\right)\frac{\log\left(\frac{T_i}{P_i} \div \frac{T_0}{P_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)}$ – the deviation of $\frac{D}{P}$ caused by the deviation of $\frac{T}{P}$,

$\left(\frac{D_i}{P_i} - \frac{D_0}{P_0}\right)\frac{\log\left(\frac{D_i}{T_i} \div \frac{D_0}{T_0}\right)}{\log\left(\frac{D_i}{P_i} \div \frac{D_0}{P_0}\right)}$ – the deviation of $\frac{D}{P}$ caused by the deviation of $\frac{D}{T}$.

Analysis of the amount of household waste designated for disposal per capita

The first task is the evaluation of the quantity of household refuse disposed of per inhabitant in the analysed countries against the value regarding Poland. Table 1 contains the relevant data.

Table 1. The amount of household solid waste disposed of (in kg per person per year)

Country	2010	Country	2012	Country	2014
Sweden	2	Austria	2	Austria	2
Denmark	21	Sweden	3	Sweden	2
Belgium	38	Netherlands	8	Netherlands	5
Germany	102	Denmark	16	Denmark	7
Netherlands	139	Belgium	55	Estonia	23
Austria	144	Germany	87	Luxembourg	51
Cyprus	177	Estonia	96	Germany	55
Poland	**197**	Italy	148	Belgium	74
Estonia	199	Cyprus	150	Ireland	76
France	217	Slovenia	151	Italy	90
Finland	225	Finland	164	Slovenia	100
Slovakia	237	Romania	170	Finland	115
Ireland	242	Spain	188	Cyprus	136
Romania	245	**Poland**	**189**	**Poland**	**153**
Spain	248	Ireland	193	Romania	159
Hungary	267	France	218	Spain	168
Slovenia	271	Slovakia	221	Lithuania	180
Latvia	278	Czech Republic	243	France	196
Croatia	283	United Kingdom	247	Hungary	197
United Kingdom	286	Hungary	255	Slovakia	211
Luxembourg	288	Latvia	259	United Kingdom	219
Czech Republic	289	Portugal	262	Czech Republic	223
Italy	305	Lithuania	265	Latvia	258
Lithuania	344	Luxembourg	271	Croatia	300
Portugal	381	Croatia	315	Bulgaria	307

Country	2010
Bulgaria	411
Greece	429
Malta	506

Country	2012
Malta	366
Greece	393
Bulgaria	421

Country	2014
Portugal	321
Greece	378
Malta	379

Source: own computation based on Eurostat database (date of access: 22.12.2017).

In 2010, in Poland 8,079,690 tons of solid household waste were collected (in 2012 – 9,577,550 tons; in 2014 – 10,330,409 tons), of which 7,471,163 tons (in 2012 – 7,209,023 tons; in 2014 – 5,834,850 tons) were disposed of by landfilling or by thermal processing without energy recovery. In fact, most of the waste disposed of was landfilled: 7,368,687 tons in 2010, 7,158,276 tons in 2012 and 5,436,900 tons in 2014.

In descending ranking, referring to the quantity of household waste disposed of per capita, Poland moved down six places to fourteenth position in 2012 and remained fourteenth in 2014.

Analysis of the amount of household waste generated per capita

The next task carried out is the assessment of the scale of household refuse production per inhabitant in each of the discussed countries in relation to the value of the same measure computed for Poland. All the data needed have been presented in Table 2.

Table 2. The amount of household waste generated (in kg per person per year)

Country	2010
Austria	146
Belgium	170
Estonia	208
Cyprus	208
Poland	**212**
Ireland	242
Sweden	252
Germany	256
Slovakia	268
Slovenia	273
Latvia	279

Country	2012
Estonia	104
Austria	135
Slovenia	153
Belgium	192
Cyprus	192
Romania	203
Germany	208
Spain	220
Ireland	223
Sweden	244
Poland	**252**

Country	2014
Slovenia	101
Ireland	110
Austria	136
Cyprus	146
Lithuania	182
Romania	182
Estonia	196
Spain	197
Finland	200
Germany	209
Sweden	226

Country	2010	Country	2012	Country	2014
Romania	279	Slovakia	252	United Kingdom	235
Croatia	284	Latvia	259	Slovakia	246
Spain	287	Lithuania	265	Italy	255
Luxembourg	304	United Kingdom	267	Hungary	256
Hungary	310	Italy	285	Latvia	260
Finland	311	Hungary	298	**Poland**	**272**
France	328	Czech Republic	302	Luxembourg	279
United Kingdom	331	Luxembourg	312	Czech Republic	284
Czech Republic	336	Croatia	317	Croatia	305
Netherlands	338	France	335	Belgium	306
Lithuania	344	Netherlands	350	Netherlands	314
Italy	373	Malta	366	Bulgaria	322
Bulgaria	411	Finland	371	France	331
Greece	429	Greece	393	Portugal	359
Denmark	463	Bulgaria	421	Greece	378
Malta	506	Portugal	434	Malta	379
Portugal	550	Denmark	452	Denmark	447

Source: own computation based on Eurostat database (date of access: 22.12.2017).

The waste generation rate in Poland has been increasing very rapidly. In 2010, the indicator was among the lowest in the European Union, but in the following years this changed. In descending order by quantity of household waste produced per capita, Poland ranked fifth in 2010, eleventh in 2012 and seventeenth in 2014.

In 2010, first position belonged to Austria, in 2012 – to Estonia, and in 2014 – to Slovenia. In turn, the highest household waste generation rate was recorded: in 2010 – in Portugal, in 2012 and 2014 – in Denmark.

Analysis of the disposal rate

The third task is the comparison of the volume of waste disposed of in proportion to the amount of household waste generated in the studied countries. The necessary data have been given in Table 3.

Table 3. The disposal rate (in %)

Country	2010	Country	2012	Country	2014
Sweden	0.8	Sweden	1.2	Sweden	0.9
Denmark	4.5	Austria	1.5	Austria	1.5
Belgium	22.4	Netherlands	2.3	Denmark	1.6
Germany	39.8	Denmark	3.5	Netherlands	1.6
Netherlands	41.1	Belgium	28.6	Estonia	11.7
France	66.2	Germany	41.8	Luxembourg	18.3
Portugal	69.3	Finland	44.2	Belgium	24.2
Finland	72.3	Italy	51.9	Germany	26.3
Italy	81.8	Portugal	60.4	Italy	35.3
Cyprus	85.1	France	65.1	**Poland**	**56.3**
Czech Republic	86.0	**Poland**	**75.0**	Finland	57.5
Hungary	86.1	Cyprus	78.1	France	59.2
United Kingdom	86.4	Czech Republic	80.5	Ireland	69.1
Spain	86.4	Romania	83.7	Hungary	77.0
Romania	87.8	Spain	85.5	Czech Republic	78.5
Slovakia	88.4	Hungary	85.6	Spain	85.3
Poland	**92.9**	Ireland	86.5	Slovakia	85.8
Luxembourg	94.7	Luxembourg	86.9	Romania	87.4
Estonia	95.7	Slovakia	87.7	Portugal	89.4
Austria	98.6	Estonia	92.3	Cyprus	93.2
Slovenia	99.3	United Kingdom	92.5	United Kingdom	93.2
Latvia	99.6	Slovenia	98.7	Bulgaria	95.3
Croatia	99.6	Croatia	99.4	Croatia	98.4
Bulgaria	100.0	Bulgaria	100.0	Lithuania	98.9
Ireland	100.0	Greece	100.0	Slovenia	99.0
Greece	100.0	Latvia	100.0	Latvia	99.2
Lithuania	100.0	Lithuania	100.0	Greece	100.0
Malta	100.0	Malta	100.0	Malta	100.0

Source: own computation based on Eurostat database (date of access: 22.12.2017).

In 2012-2014, the top place, in descending order, concerning disposal rates, was taken by the same country – Sweden. Second position belonged to Denmark (in 2010) and Austria (in 2012 and 2014). Poland moved up six places to eleventh position in 2012 and, in 2014, climbed one place to tenth position.

It is worth emphasising that in 2010 in Sweden only 0.8% (in 2012 – 1.2%, in 2014 – 0.9%) of the total household refuse was disposed of, and the remaining 99.2% (in 2012 – 98.8%, in 2014 – 99.1%) was recovered. In contrast, in the case of Greece and Malta, as much as 100% of total household solid waste was disposed of throughout those years.

Landfilling was the predominant method used for the disposal of household solid waste in Poland. According to Eurostat data, in 2010, approximately 91.2% of waste collected was disposed of in landfill, 1.3% was incinerated without energy recovery, and 7.5% was recovered (i.e. recycled, composted or incinerated at waste-to-energy plants). In 2012, those shares were as follows: 74.8%, 0.5%, 24.7%, respectively (in 2014: 52.6%, 3.9%, and 43.5%). Fortunately, the disposal rate in Poland is evidently on the decrease and, consequently, the recovery rate is on the increase.

Empirical results obtained from the causal analysis

It was established in this article that the value of the response variable – the amount of household refuse disposed of per capita – might be calculated by multiplication of 1) the volume of household refuse collected per inhabitant and 2) the quotient of the amount of waste destined for disposal and the amount of waste generated. The said relationship is as follows:

$$\frac{D}{P} = \frac{T}{P} \cdot \frac{D}{T} \quad (7)$$

The (2) ratio equality was derived from this relationship.

In the last part of this research the remaining stages of the logarithmic method will be performed. The results obtained for 2010, 2012, and 2014 are shown in Table 4.

Table 4. The importance that can be assigned to the causes of the occurring deviations of the response variable

Country	I / II	2010	2012	2014
Austria	I	**0.731** = 0.689 · 1.061	**0.011** = 0.536 · 0.020	**0.013** = 0.500 · 0.026
	II	(**−53**) = (−63) + (+10)	(**−187**) = (−26) + (−161)	(**−151**) = (−24) + (−127)
Sweden	I	**0.010** = 1.189 · 0.009	**0.016** = 0.968 · 0.016	**0.013** = 0.831 · 0.016
	II	(**−195**) = (+7) + (−202)	(**−186**) = (−1) + (−185)	(**−151**) = (−6) + (−145)
Netherlands	I	**0.706** = 1.594 · 0.443	**0.042** = 1.389 · 0.030	**0.033** = 1.154 · 0.028
	II	(**−58**) = (+78) + (−136)	(**−181**) = (+19) + (−200)	(**−148**) = (+6) + (−154)

Country	I / II	2010	2012	2014
Denmark	I II	**0.107** = 2.184 · 0.049 (**−176**) = (+61) + (−237)	**0.085** = 1.794 · 0.047 (**−173**) = (+41) + (−214)	**0.046** = 1.643 · 0.028 (**−146**) = (+24) + (−170)
Estonia	I II	1.010 = 0.981 · 1.030 (+2) = (−4) + (+6)	**0.508** = 0.413 · 1.231 (**−93**) = (−122) + (+29)	**0.150** = 0.721 · 0.209 (**−130**) = (−22) + (−108)
Luxembourg	I II	1.462 = 1.434 · 1.020 (+91) = (+86) + (+5)	1.434 = 1.238 · 1.158 (+82) = (+49) + (+33)	**0.333** = 1.026 · 0.325 (**−102**) = (+2) + (−104)
Germany	I II	**0.518** = 1.208 · 0.429 (**−95**) = (+27) + (−122)	**0.460** = 0.825 · 0.558 (**−102**) = (−25) + (−77)	**0.359** = 0.768 · 0.468 (**−98**) = (−25) + (−73)
Belgium	I II	**0.193** = 0.802 · 0.241 (**−159**) = (−21) + (−138)	**0.291** = 0.762 · 0.382 (**−134**) = (−30) + (−104)	**0.484** = 1.125 · 0.430 (**−79**) = (+13) + (−92)
Ireland	I II	1.228 = 1.142 · 1.076 (+45) = (+29) + (+16)	1.021 = 0.885 · 1.154 (+4) = (−23) + (+27)	**0.497** = 0.404 · 1.228 (**−77**) = (−100) + (+23)
Italy	I II	1.548 = 1.759 · 0.880 (+108) = (+140) + (−32)	**0.783** = 1.131 · 0.692 (**−41**) = (+21) + (−62)	**0.588** = 0.938 · 0.627 (**−63**) = (−8) + (−55)
Slovenia	I II	1.376 = 1.288 · 1.068 (+74) = (+59) + (+15)	**0.799** = 0.607 · 1.316 (**−38**) = (−84) + (+46)	**0.654** = 0.371 · 1.760 (**−53**) = (−123) + (+70)
Finland	I II	1.142 = 1.467 · 0.779 (+28) = (+81) + (−53)	**0.868** = 1.472 · 0.589 (**−25**) = (+68) + (−93)	**0.752** = 0.735 · 1.022 (**−38**) = (−41) + (+3)
Cyprus	I II	**0.898** = 0.981 · 0.916 (**−20**) = (−4) + (−16)	**0.794** = 0.762 · 1.042 (**−39**) = (−46) + (+7)	**0.889** = 0.537 · 1.656 (**−17**) = (−90) + (+73)
Romania	I II	1.244 = 1.316 · 0.945 (+48) = (+60) + (−12)	**0.899** = 0.806 · 1.117 (**−19**) = (−39) + (+20)	1.039 = 0.669 · 1.553 (+6) = (−63) + (+69)
Spain	I II	1.259 = 1.354 · 0.930 (+51) = (+67) + (−16)	**0.995** = 0.873 · 1.139 (**−1**) = (−26) + (+25)	1.098 = 0.724 · 1.516 (+15) = (−52) + (+67)
Lithuania	I II	1.746 = 1.623 · 1.076 (+147) = (+128) + (+19)	1.402 = 1.052 · 1.333 (+76) = (+11) + (+65)	1.176 = 0.669 · 1.758 (+27) = (−67) + (+94)
France	I II	1.102 = 1.547 · 0.712 (+20) = (+90) + (−70)	1.153 = 1.329 · 0.868 (+29) = (+58) + (−29)	1.281 = 1.217 · 1.053 (+43) = (+34) + (+9)
Hungary	I II	1.355 = 1.462 · 0.927 (+70) = (+87) + (−17)	1.349 = 1.183 · 1.141 (+66) = (+37) + (+29)	1.288 = 0.941 · 1.368 (+44) = (−11) + (+55)
Slovakia	I II	1.203 = 1.264 · 0.952 (+40) = (+51) + (−11)	1.169 = 1.000 · 1.169 (+32) = (0) + (+32)	1.379 = 0.904 · 1.525 (+58) = (−18) + (+76)
United Kingdom	I II	1.452 = 1.561 · 0.930 (+89) = (+106) + (−17)	1.307 = 1.060 · 1.233 (+58) = (+13) + (+45)	1.431 = 0.864 · 1.657 (+66) = (−27) + (+93)
Czech Republic	I II	1.467 = 1.585 · 0.926 (+92) = (+111) + (−19)	1.286 = 1.198 · 1.073 (+54) = (+39) + (+15)	1.458 = 1.044 · 1.396 (+70) = (+8) + (+62)
Latvia	I II	1.411 = 1.316 · 1.072 (+81) = (+65) + (+16)	1.370 = 1.028 · 1.333 (+70) = (+6) + (+64)	1.686 = 0.956 · 1.764 (+105) = (−9) + (+114)
Croatia	I II	1.437 = 1.340 · 1.072 (+86) = (+69) + (+17)	1.667 = 1.258 · 1.325 (+126) = (+57) + (+69)	1.961 = 1.121 · 1.749 (+147) = (+25) + (+122)
Bulgaria	I II	2.086 = 1.939 · 1.076 (+214) = (+193) + (+21)	2.228 = 1.671 · 1.333 (+232) = (+149) + (+83)	2.007 = 1.184 · 1.695 (+154) = (+37) + (+117)

Country	I / II	2010	2012	2014
Portugal	I II	1.934 = 2.594 · 0.745 (+184) = (+266) + (−82)	1.386 = 1.722 · 0.805 (+73) = (+122) + (−49)	2.098 = 1.320 · 1.590 (+168) = (+63) + (+105)
Greece	I II	2.178 = 2.024 · 1.076 (+232) = (+210) + (+22)	2.079 = 1.560 · 1.333 (+204) = (+124) + (+80)	2.471 = 1.390 · 1.778 (+225) = (+82) + (+143)
Malta	I II	2.569 = 2.387 · 1.076 (+309) = (+285) + (+24)	1.937 = 1.452 · 1.333 (+177) = (+100) + (+77)	2.477 = 1.393 · 1.778 (+226) = (+83) + (+143)

I – the ratio equality
II – the equation of impact effects (results in kg per person per year)

Source: own computation based on Tables 1-3.

As an example, the values obtained in 2014 for Austria shall be interpreted. The amount of household waste disposed of per capita in Austria was 2 kg and in Poland – 153 kg. Thus, in Austria it was 151 kg less (i.e. 98.7% less) than in Poland. Had the same amount of household refuse per capita been generated in Austria as in Poland, the quantity of household waste disposed of in Austria would have been 127 kg/person smaller than in the case of Poland, solely due to the lower disposal rate. Had the refuse sent to disposal in proportion to the total household refuse generated in Austria been at the Polish level, the volume of household waste disposed of in Austria would have been 24 kg/person less than in Poland, which would have been a result solely of the lower level of household solid waste production.

Conclusions

In this article, the amount of household waste generated per capita and the disposal rate have been adopted as the factors affecting the amount of household waste disposed of per capita. Causal analysis allowed us to answer the question how these factors influence the deviations in the response variable in the examined countries compared to the quantity for Poland. Calculations were performed for each EU Member State separately. The research was conducted based on data from 2010, 2012, and 2014.

The amount of household solid waste disposed of in Poland was 197 kg/person in 2010, 189 kg/person in 2012, and 153 kg/person in 2014. The amount of household refuse collected accounted for 212 kg/person in 2010, 252 kg/person in 2012, and 272 kg/person in 2014. Poland designated 92.9% of household waste for disposal in 2010, 75.0% in 2012, and 56.3% in 2014.

It has to be admitted that Poland is situated higher and higher (i.e. better and better) in the descending ranking related to disposal rate, but fares far worse in ranking by the amount of household waste generated per capita. Consequently, the location of Poland in the ranking by amount of household refuse disposed of per capita is quite poor, and the dynamics of ongoing changes in this area – in the light of this study – does not seem to be satisfactory.

When analysing the state of municipal solid waste management in Poland, it is clear that separation at source, composting of biodegradable waste, incineration with energy recovery and recycling have not yet been implemented entirely effectively. For efficient waste management in Poland, the following challenges seem to be crucial:

- Establishing an effective waste collection system;
- Reinforcing waste reuse;
- Increasing the number of facilities for municipal waste recovery;
- Reducing the amount of refuse directed into landfills.

There is also a need to increase composting of biodegradable waste. Organic waste separation, composting and then using the compost as an organic fertiliser is a sustainable way of managing biodegradable waste. In addition, to achieve higher levels of packaging recycling, it is advisable to increase the number and treatment capacity of packaging waste recycling plants.

There is no doubt that more emphasis ought to be placed on the permanent improvement and increased efficiency of the existing system. Selective waste collection at the location of waste generation should be the fundamental strategy for solid waste management in Poland. But – above all – it is extremely important to strengthen the reduction process of the generation rate.

The waste hierarchy prioritises waste prevention, followed by preparing for reuse, recycling, other recovery methods and finally disposal as the least desirable option. In the European Union, waste-related Directives, such as 2008/98/CE, now call for waste reduction as the most preferred way of tackling this problem, while in the past attention was mainly focused on targets concerning recovery rates [Alwaeli, 2015, p. 181]. Unfortunately, these EU principles, most appropriately supporting sustainable development, are not reflected in the current state of Polish solid waste management.

After the entire study carried out in this paper, it has become clear that the Polish municipal refuse management system is not yet as advanced as in many old EU countries. Poland still maintains very high rates of landfilling. Other treatment methods, such as recycling, composting, and incineration with energy recovery are also used, but on a negligible scale.

References

ABRATE, G., FERRARIS, M. (2013). *Waste generation and delinking*: *a theoretical model with empirical applications to the Italian municipalities* [in:] Waste management in spatial environments, (Eds) A. D'Amato, M. Mazzanti, A. Montini, Routledge, New York, USA.

ALWAELI, M. (2015). *An overview of municipal solid waste management in Poland. The current situation, problems and challenges*, Environment Protection Engineering 41(4), 181-193.

D'AMATO, A., MAZZANTI, M., MONTINI, A. (2013). *Waste management in spatial environments*, Routledge, New York, USA.

EUROPEAN ENVIRONMENT AGENCY, *Municipal waste management*. *Poland*, October 2016, 1-20.

EVISON, T., READ, A. D. (2001). *Local authority recycling and waste awareness publicity/promotion*, Resources, Conservation and Recycling 32, 275-291.

FULLERTON, D., KINNAMAN, T. C. (1995a). *How a fee per-unit garbage affects aggregate recycling in a model with heterogenous households* [in:] Public economics and the environment in an imperfect world, (Eds) A. L. Bovenberg, S. Cnossen, Kluwer Academic Publishers, Dordrecht, Netherlands.

FULLERTON, D., KINNAMAN, T. C. (1995b). *Garbage, recycling and illicit burning or dumping*, Journal of Environmental Economics and Management 29, 78-91.

FULLERTON, D., KINNAMAN, T. C. (1999). *The economics of residential solid waste management*, NBER Working Paper 7326.

GELLYNCK, X., VERHELST, P. (2007). *Assessing instruments for mixed household solid waste collection services in the Flemish region of Belgium*, Resources, Conservation and Recycling 49, 372-387.

HALVORSEN, B. (2004). *Effects of norms, warm-glow and time use on household recycling*, Discussion Papers 389, Statistics Norway, Research Department, Oslo, Norway.

JOHNSTONE, N., LABONNE, J. (2004). *Generation of household solid waste in OECD countries*: *an empirical analysis using macroeconomic data*, Land Economics 80, 529-538.

KAROUSAKIS, K. (2006). *Municipal solid waste generation, disposal and recycling*: *a note on OECD inter-country differences*, Working Paper, School of Public Policy, University College London, United Kingdom.

KINNAMAN, T. C. (2006). *Policy watch examining the justification for residential recycling*, Journal of Economic Perspectives 20, 219-232.

KOŁSUT, B. (2016). *Inter-municipal cooperation in waste management*: *the case of Poland*, Quaestiones Geographicae 35(2), 91-104.

KRAMER, K.-L. (2012). *User experience in the age of sustainability*: *a practitioner's blueprint*, Morgan Kaufmann, Waltham, USA.

MAZZANTI, M., MONTINI, A., NICOLLI, F. (2009). *Waste Kuznets curve, regional policies and spatial effects*: *evidence on waste generation and landfill diversion from Italy*, 8th International Conference of the European Society for Ecological Economics, Ljubljana, Slovenia, 30 June.

MAZZANTI, M., MONTINI, A., ZOBOLI, R. (2008). *Municipal waste generation and socio-economic drivers*: *evidence from comparing Northern and Southern Italy*, The Journal of Environment and Development 17 (1), 51-69.

MAZZANTI, M., ZOBOLI, R. (2009). *Municipal waste Kuznets curves*: *evidence on socio-economic drivers and policy effectiveness from the EU*, Environment and Resource Economics 44, 203-230.

PODOLSKY, M. J., SPIEGEL, M. (1998). *Municipal waste disposal*: *unit pricing and recycling opportunities*, Public Works Management Policy 3, 27-39.

RADECKI, W. (2012). *Utrzymanie czystości i porządku w gminach. Komentarz* (*Keeping cleanliness and order in municipalities. A commentary*), Wolters Kluwer Poland, Warsaw.

RAKOCZY, B. (2014). *Organisation of municipal waste management in Polish law*, Polish Yearbook of Environmental Law 4, 57-69.

RESNIK, D. B. (2012). *Environmental health ethics*, Cambridge University Press, New York, USA.

RODENBECK, S., ORLOFF, K., FALK, H. (2010). *Solid and hazardous waste* [in:] Environmental health: from global to local, (Ed.) H. Frumkin, John Wiley and Sons, New York, USA.

SHAW, P. J. (2008). *Nearest neighbor effects in kerbside household waste recycling*, Resources, Conservation and Recycling 52, 775-784.

SZCZECIŃSKA, B. (2007). *The application of the method of logarithm finding in the causal analysis of the financial results of enterprises of the food sector*, Acta Scientiarum Polonorum Oeconomia 6 (3), 99-104.

TURCZAK, A. (2016). *Differences in tourism receipts between Mexico and other countries*, Estudios en Ciencias Sociales y Administrativas de la Universidad de Celaya 6, 65-81.

TURCZAK, A. (2017). *Characteristics of saving generated by the Baltic countries*, Messenger of Armenian State University of Economics 2, 80-92.

VISCUSI, W. K., HUBER, J., BELL, J. (2011). *Promoting recycling*: *private values, social norms, and economic incentives*, American Economic Review 101, 65-70.