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Evaluation of Communal Waste in Slovakia from the View of Chosen Economic Indicators

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Abstract: Waste treatment consists of activities required to make sure that waste has the least practical impact on the environment. In Slovakia, more than 50% of waste is in storage. Waste development depends on the economic situation of the state. In Slovakia, there is economic intolerance of waste treatment due to the weaker economic situation of the inhabitants. The goal of this contribution is to study the development of waste production in Slovakia in regard to economic indexes of households with the aim of improving waste management. The goal is achieved by searching for a relation between economic indexes and households by a correlation matrix and by verification of polynomial dependence. According to the results of the statistical importance, we found similarity of the regions in chosen indexes by using of cluster analysis. By this method a sustainable economy and healthy environment is guaranteed and waste is used to produce energy.

Keywords: waste economy; productivity of energy sources; circular economy; waste treatment; Slovakia

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1. Introduction

Everyone produces waste; some less, some more. The richer the country, the more waste produced by its inhabitants. The more developed the country, the higher the rate of recycled waste [1]. In northern and western European countries waste stocks almost do not exist any more. However, in countries of eastern and southern Europe more than half of the waste is in storage [2]. Slovakia is no exception. The amount of municipal waste produced increases every year [3]. The most recent data of the Statistical Office of the Slovak Republic for 2019 show up to 434.63 kg of municipal waste per capita and a high percentage of this waste in landfill (50.45%). The annual reduction of land filling has been positive; for example, in 2017 up to 61.43% of municipal waste was in landfill in Slovakia.

The European Union wants to increase waste recycling by one half of the total waste. This means we need to deal with the waste, since waste treatment allows it to be further processed into reusable materials and energy, thereby maximizing the savings of primary resources and energy, as well as reducing environmental burdens [4]. This process is referred to as recycling, a key part in the modern waste reduction hierarchy. Waste treatment must be evaluated from the view of environmental, technical, as well as economic points of view to be useful for decision-making in the case of pollution impairing living environment [5].

The basis of recycling is a properly set up waste sorting system. Thorough sorting of waste at the source provides the "cleanest" waste for recycling [6]. Activities, related to municipal waste management, including sorting, in Slovakia are provided by the local government. Its interest should be to increase communities' discipline concerning generation and sorting of municipal waste, as the level of sorting also depends on the amount of the fee paid by the municipality for depositing the waste in a landfill. This, in turn, has an impact on setting the level of the municipal waste fee for the population. Sorting can thus be considered an important step towards waste recovery. The classification process can be influenced by several factors, from building the environmental awareness of the population to socio-economic factors related to the size of the household, the level of education and also the household income [7].

The EU goal is to live in 2050 in balance with the ecologic limits of the planet and to have waste-to-energy plants that burn waste to produce energy (steam in the boiler, etc.) that can be used to generate electricity [8–10].

The present contribution is orientated to communal waste production in individual regions of Slovakia with the goal to find out the development of waste production in Slovakia in regard to economic indexes of households following a consideration of obstacles and possibilities for improving waste management. The goal of the contribution results from the actual situation: In the field of waste economy, Slovakia is significantly behind many EU countries due to a low level of recycling and a high level of municipal waste storage. According to the European Commission, the problem is in the system of collection and waste sorting, as well as worse waste treatment in socially weaker regions. The legislation on waste in Slovakia should be stricter to move from landfill to recycling and waste reduction across the whole country.

2. Present State of Problem Solving

Various authors research waste treatment and waste economy. Waste recycling can be done by composting when producing fertilizing products for the market of EU [11]. By this method, composting could mitigate the environmental risk of waste creation. Paul et al. [12] studied waste attributes, such as pollution index, ecological risk index and geo-accumulation index and also revealed adverse impacts of the deeper landfill layers on the surrounding environment and found the industrial value of waste through economic evaluation of waste treatment technologies.

Deterioration of soil quality presents consequences of open waste dumping which have resulted in growing public concern [13]. Warguła et al. [14] conducted research and development works on reducing the environmental impact of machines used to process branches in urbanized areas. They show that it is possible to reduce fuel consumption [14,15] and the emission of harmful exhaust gases [14,16,17] generated during these processes by introducing innovative fuel supply systems [14,15] or by using alternative fuels to drive machines [16–18]. The process of processing branches on the premises of households is often a requirement for collecting green waste or supporting the process of transport, storage and processing, e.g., by burning or composting thanks to reducing the volume [19]. Dangi et al. [20] studied waste creation from restaurants, hotels, schools and 72 streets, and found a greater potential for recovery of organic wastes via composting and recycling.

Roychoudhury et al. [21] incorporated a symbiotic waste reduction system with the efficient functionalism of micro and macro-conversion agents which is attributed to the synthesis of waste-derived co-products from the same platform. Their study presents a novel approach, which is capable of addressing a wide fraction of solid waste and domestic sewage, and is capable of strengthening the sustainable waste management strategy [22,23].

Worldwide, vast development of rural areas has taken place, but due to the limited economic development level, some villages lack facilities for waste treatment [24], while it is easy to find practical and mature technology to treat one kind of waste in rural area, but there is a lack of overall consideration for recycling of produced and organic waste in the village.

Moreover, electrical and electronic equipment waste can be an important source of recycling [25]. However, according to D'Adamo et al. [26], the management of electronic components still presents many challenges. In order to raise awareness about the situation in electronic and electrical waste, Pérez-Beliz et al. [27] analyzed and found an extensive number of articles have been published around the world.

To make sure of the success of any policies aiming to decrease living environment pollution, it is also necessary to resolve the growing crisis of water pollution necessary. Water treatment surveys show vast differences in different regions and cities, as water is treated more thoroughly in larger cities [28]. High and fast economic increase and urbanization worldwide have influenced water consumption; the trend has increased in recent years. In this connection, Bian et al. [29] performed an analysis of regional water use and treatment in China with the aim of finding efficient waste water systems, as well as finding inefficiencies. According to Dong et al. [30] the issue could be solved by considering plant size, capacity, climate type and environmental impact. Warguła et al. [31] indicate that the increase in nutrients for aquatic plants resulting from inefficient wastewater treatment systems or too intense fertilization of fields is a serious problem for the tourism industry, due to contamination of beaches and water reservoirs, e.g., with seaweed. Wastewater and liquid waste present an important service problem in municipalities. In this area, Vialkova et al. [32] evaluated and confirmed an energy-efficient economy for microwave irradiation, using municipal wastewater sediments [32,33].

In the area of waste tire dumps also threaten human health and living environments [34]. Worldwide, waste from tires amounts to 1.3–1.5 billion tons/year and by the end of 2025 is expected to amount to more than 2.5 billion tones. In the area of waste, tire dumps also threaten human health and living environments. In 2013, the EU countries reached 3.6 million tons of used tires. The cheapest treatment method at present is landfill and is considered to be a major threat for the environment and public health.

Therefore, the problems of waste tire recycling must be solved as well. In this connection Karagoz et al. [35] found that tire pyrolytic oil production from waste tires is important from the viewpoint of both waste management and protection of fossil fuel resource depletion. Moreover, Symeonides et al. [36] evaluated the tire waste management system in Cyprus to strengthen the circular economy [36–38].

It is profitable to study waste production in individual countries. For example, with the extensive application of decentralized sewage treatment systems in China, a study must show the environmental economic value of resources and sustainability of systems to improve the efficiency of environmental resource use and decrease or avoid waste [39]. In this area, Yang et al. [40] evaluated the environmental economic value and the sustainability of a decentralized sewage treatment plant and found a remarkable economic benefit. The reuse of treated water can bring environmental benefits that are consistent with the requirements of sustainable development; the method has a very wide application prospect in developing countries [41,42].

The presented literature review shows there are no detailed studies addressing economic indexes of households influencing waste treatment development, such as average disposable equivalent incomes of households, waste costs, net money expenditure of households, people below the poverty line per one household, measure of poverty risk, etc. This creates the space for the presented contribution research, offering an evaluation of the waste treatment from the view of productivity in communal and separated waste production and productivity of waste sorting, as well as an evaluation of the waste cost development in individual regions, which could bring attention to possible regional developments, contributing to the sustainability of the regions.

3. Materials and Methods

The goal of the contribution is to evaluate the development of communal waste creation and to evaluate the waste sorting of individual elements of communal waste. The evaluation was done in accord with households and indexes, connected incomes and expenses of households, available from the Statistical Office [43] and other economic indexes related to inhabitants' standards of living [44,45]. The evaluation is realized both for Slovakia as a whole, as well as according to the regional structure. Regions are presented as the eight following counties: Bratislavský, Trnavský, Trenčiansky, Nitriansky, Žilinský, Banskobystrický, Prešovský and Košický. The indexes are used per one household and summary indexes are used for the development of waste creation as well. The contribution also verifies the statistical importance of the factors (region and year) to the value of waste creation per household and economic indexes relating to the inhabitants' standard of living concerning the household [46,47]. We searched for the existence of a relation between indexes with a correlation matrix and verified for chosen indexes the existence of polynomial dependence. According to the results of the statistical importance we searched for the similarity of the regions in chosen indexes using a cluster analysis. The evaluation for Slovakia was carried out by region and according to development over time (years).

3.1. Indexes of the Analysis

The values of the indexes were obtained from the Statistical Office of Slovakia. Some rate indexes, used in the analysis, were calculated from the data available from the Statistical Office.

Number of inhabitants—value obtained from the website of the Statistical Office of Slovakia. Due to the fact that the number of inhabitants, as registered in the data, is the same in several different time periods, for the evaluation and comparison we chose three periods: 2006, 2012 and 2018. The difference between individual periods is the same, 6 years. In the case of other time periods, the results may be slightly different. Discussion of the exactness and reliability of the results will be mentioned in the conclusion of the paper.

Amount of communal waste in tons per year—index obtained from the website of the Statistical Office of Slovakia. From the index the volume of communal waste in tons per one household is determined; this value is also used as the productivity of communal waste.

Volume of separated waste in tons per year—index obtained from website of the Statistical Office of Slovakia. From the index the volume of separated waste in tons per one household is determined; the value is further used as the productivity of separated waste.

Productivity of waste sorting presents the index, calculated as the volume of separated waste in tons per one household/volume of communal waste in tons per one household.

Net incomes of household in euros—the index was obtained from the website of the Statistical Office of Slovakia.

Net money expenditure of households in euros—calculated from the expenses of households in euros per person per month times the average number of persons in the household times 12.

Waste cost in euros per kilogram and year—calculated from the waste cost index in euros per year/waste in kilogram: Waste costs = net expenses in euros/communal waste in kg per 1 household.

Average disposable equivalent income of households (euros/month) was obtained from the website of Statistical Office of Slovakia.

People below the poverty line per 1 household—calculated from the index of people under level of poverty/number of households, obtained from the website of the Statistical Office of Slovakia.

Measure of poverty risk: 60% median (%)—measure obtained from the Statistical Office of Slovakia [48].

The development of waste productivity was evaluated with the summary index of Laspeyers, Paasche and Fisher by comparing three periods: 2006, 2012 and 2018. In a graphical illustration of the indexes for each region there is value of the index for Slovakia due to the possibility to compare the situation in each region.

Analysis of development of waste creation was carried out by summary index. The index of communal waste volume in tons per one household is recorded as production of communal waste. Volume of produced waste in a time period and territorial unit will be marked with the sign:

$$w_{u,p}$$

where u is territorial unit and p is analyzed period.

For types of waste shortage, we will use the abbreviations CW (communal waste) and SW (separated waste); shortages and types of waste will be explained with reference to their place of use.

Number of households in a time period in the frame of a territorial unit will be marked as:

$$nh_{u,p} \tag{1}$$

where u is territorial unit and p is analyzed period.

Waste production in a time period in the frame of a territorial unit will be:

$$wp_{u,p} = \frac{w_{u,p}}{nh_{u,p}} \tag{2}$$

Summary index of waste productivity with weights from the basis period is:

$$I_V^{(L)} = \frac{\sum_{u=1}^{n} \frac{w_{u,0}}{wp_{u,0}}}{\sum_{u=1}^{n} \frac{w_{u,0}}{wp_{u,1}}} \tag{3}$$

Summary index of waste productivity with weights from the common period is:

$$I_V^{(P)} = \frac{\sum_{u=1}^{n} \frac{w_{u,1}}{wp_{u,0}}}{\sum_{u=1}^{n} \frac{w_{u,1}}{wp_{u,1}}} \tag{4}$$

3.2. Analysis of Economic and Waste Indexes from the View of Verification of Statistical Importance of Regions and Year to the Development of Index Values

The economic and waste indexes used in the analysis are as follows:

- Communal waste in t per 1 household—komnadom
- Separated waste in t per 1 household—sepnadom
- Separated waste in t per 1 household/communal waste in t per 1 household—prodsep
- Waste cost in €—waste cost
- Average household disposable income in €/month—pdepdom
- Net money expenditure of households in €—cpvd
- People below the poverty line per 1 household—ospodchnadom
- Measure of poverty risk: 60% median (%)—mieraregch
- Level of significance 0.05 was used for all statistical analysis.

The analysis consisted of two steps. The first step was the ANOVA analysis, testing whether factors of the territorial unit (region) and periods are statistically important. The second step was the choice of indexes that would be used in a cluster analysis. We chose the indexes that would be statistically important for a region. According to the results for the factor ´year´ we chose to cluster analyze two periods for which the difference between various indexes would be statistically important. ANOVA test of the statistical hypothesis of the importance of the difference between the medium values during the process of choosing according to the region and period was as follows:

$$H0: \mu_1 = \mu_2 = \ldots = \mu_n \tag{5}$$

$$HA: \mu_i \neq \mu_j \tag{6}$$

ANOVA test can be used only in the case of homogeneity of variances and normality of residuals.

4. Results

4.1. Evaluation of Communal Waste Productivity

As for the evaluation of communal waste productivity, Figure 1 illustrates calculated values of communal waste productivity in regions in the three analyzed periods. Regions are ranked by comparison with the country.

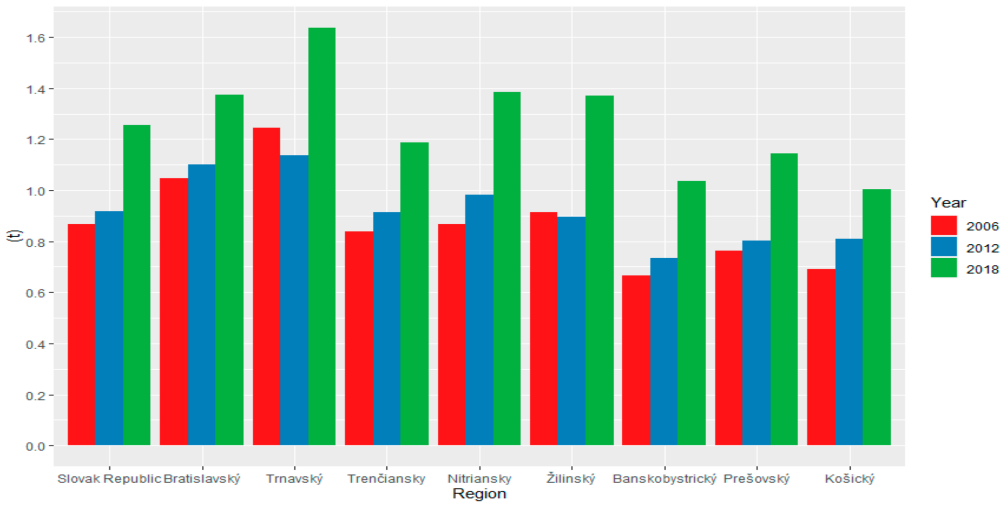

Figure 1. Productivity of communal waste in Slovakian regions.

In 2012 there is obvious smooth growth and in 2018 rapid growth of the index against the earlier period. The greatest volume of communal waste per household in 2018 was registered in the Trnavský region, the lowest in the Košický region. To evaluate the development of waste productivity, we used volume extensive indexes. The results of the indexes are given in Table 1.

Table 1. Indexes of communal waste production according to region.

Basic Period	Common Period	Laspeyres Extensive Index	Paasche Extensive Index	Fisher Extensive Index
2006	2012	1.062	1.067	1.064
2006	2018	1.455	1.460	1.458
2012	2018	1.228	1.371	1.298

Waste production between periods developed as follows:

- In 2012 it increased against basis period 2006 by 6.4%.
- In 2018 it increased against basis period 2006 by 45.75%.
- In 2018 it increased against 2012 by 29.7%.

When using summary index of waste productivity with weights from the basis period (Laspeyres extensive index), in comparing 2006 and 2018 we registered a vivid difference against the average Fisher index. In the common period 2018 the index grew against the basis period 2012 by 22.81%. Moreover, using the Paasche index, we registered a difference for the same basic and common period. In the common period 2018 the index grew against the basis period 2012 by 37.11%. The growth of waste productivity between 2012 and 2018 was caused by an increase in awareness of waste treatment in the society. Communal waste of production in time development is given in Figure 2.

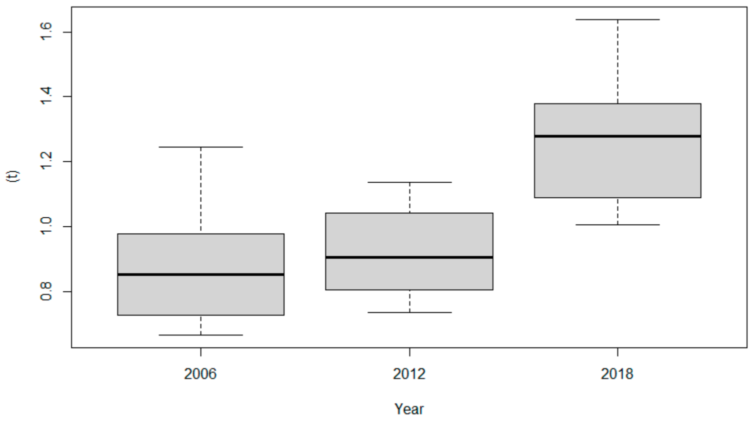

Figure 2. Development of communal waste per household.

4.2. Evaluation of Separated Waste Productivity

Figure 3 illustrates the calculated value of separated waste productivity for regions in three analyzed periods. In 2012 there is obvious smooth growth and in 2018 rapid growth of the index against the earlier period.

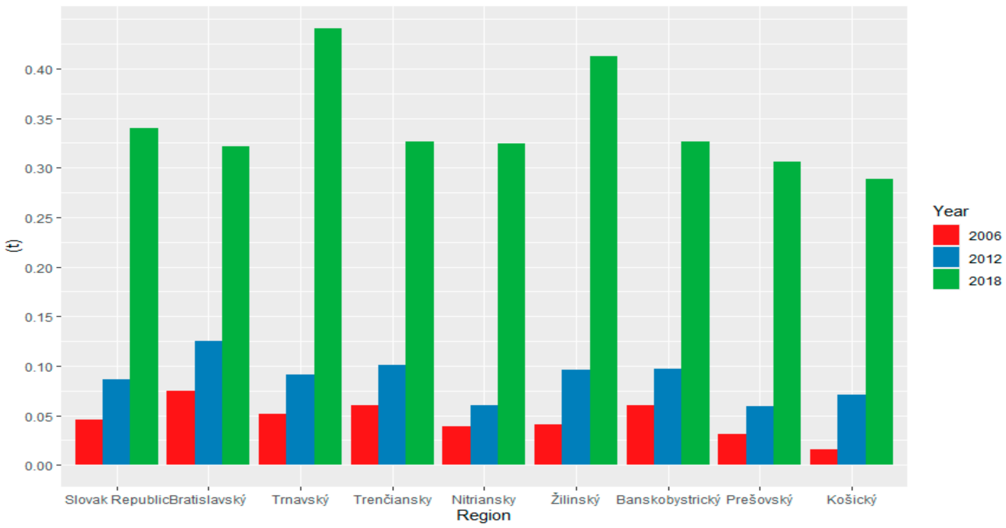

Figure 3. Productivity of separated waste.

To evaluate the development of waste production we uses extensive indexes (see Table 2).

Table 2. Indexes of communal waste production.

Basic Period	Common Period	Laspeyres Extensive Index	Paasche Extensive Index	Fisher Extensive Index
2006	2012	1.914	2.162	2.034
2006	2018	7.359	8.912	8.098
2012	2018	0.335	4.106	1.172

Production of waste sorting between periods developed as follows:

- In 2012 it increased against basis period 2006 by 103.4%
- In 2018 it increased against basis period 2006 by 709.8%.
- In 2018 it increased against 2012 by 17.2%.

Production of waste sorting in time development is given in Figure 4.

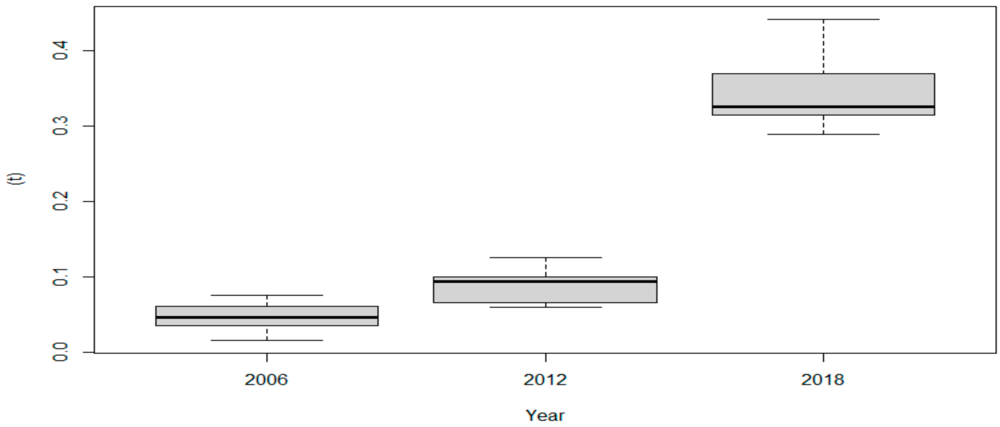

Figure 4. Development of separated waste per household.

4.3. Evaluation of Waste Sorting Productivity

Productivity of waste sorting was registered as sep/kom per household and year as percentage expression.

Figure 5 shows data of waste sorting productivity in time development according to the regions. Productivity of waste sorting between analyzed periods developed as shown in Figure 6 as follows: Support of waste sorting is visible from the increase of sorted waste by communal waste volume. According to data in Figures 5 and 6 we can state the following: In 2006 the rate of separated waste by communal waste changed by around 5%; the highest rate was in the region Banskobystrický—9%; the lowest in the region Košický—2%. In 2012 the value of the median changed over 10%; the highest separation was in the region Banskobystrický—13%; waste was sorted the least in the region Nitriansky—6%. In 2018 the medium value changed by over 27%; maximum 31% of the sorting belonged to region the Banskobystrický; waste was sorted the least in the regions Bratislavský and Nitriansky—23%.

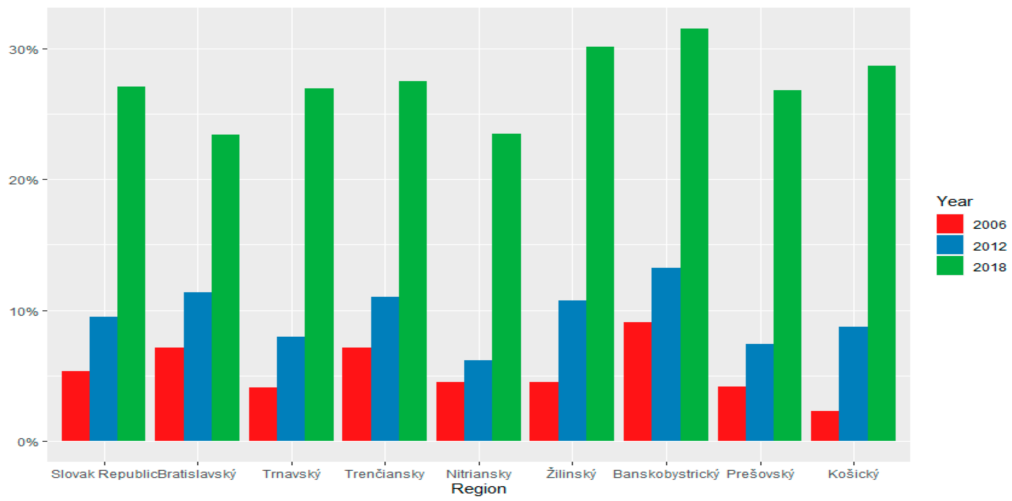

Figure 5. Development of waste sorting productivity according to the regions.

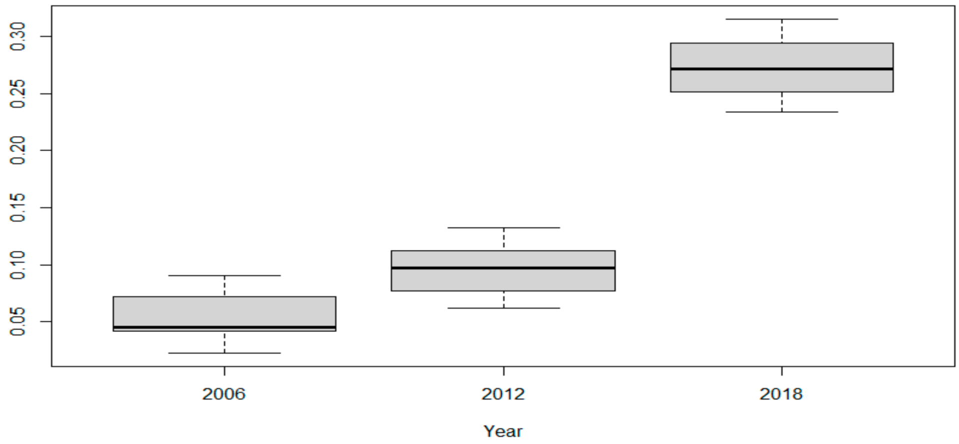

Figure 6. Development of waste sorting productivity.

4.4. Evaluation of Waste Cost

The index was created with aim of comparing the volume of communal waste in monetary terms. It presents how many euros of net income from households is produced per one kilogram of waste.

Figures 7 and 8 address the following: While in 2006 and 2012 the value of the waste cost moved in regions by between 11 and 14 €, in 2018 it was around 8–11 €. Due to the volume of communal waste per household net incomes also increased; the index development addresses the gradually decreasing production of waste over time.

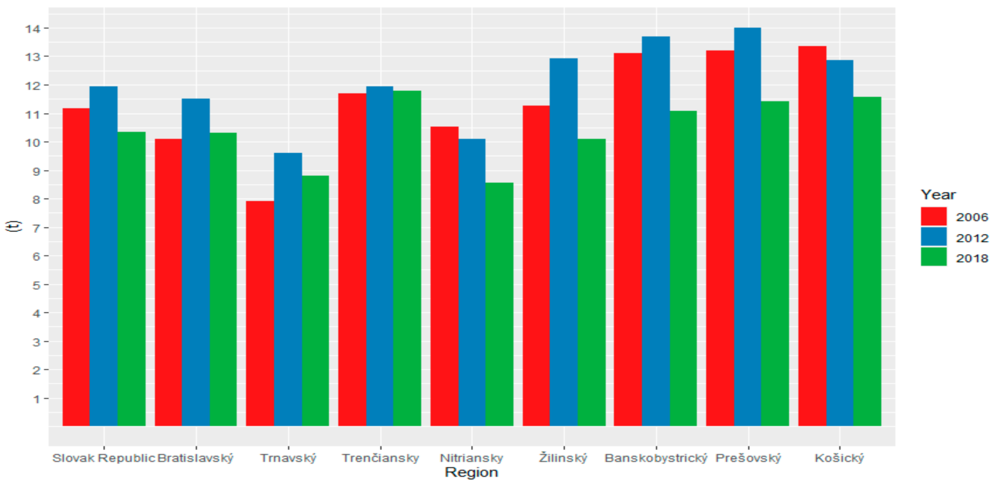

Figure 7. Development of waste cost.

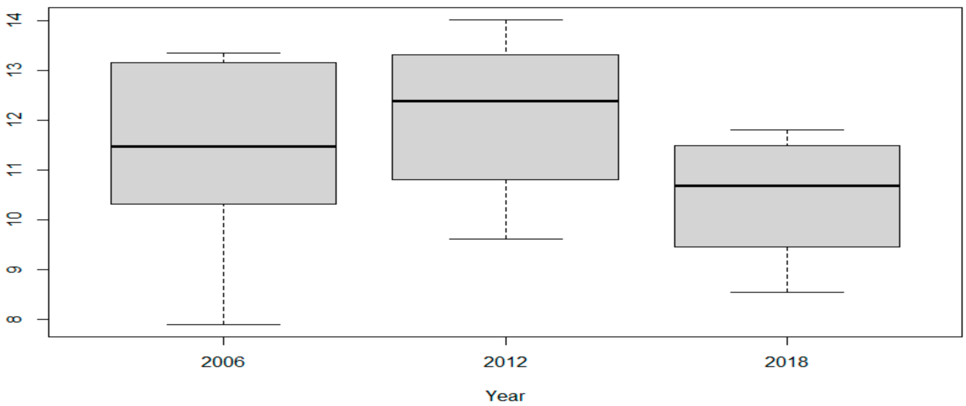

Figure 8. Development of waste cost in time (in €/kg).

The total value of waste cost changed due to the change of costs by weight in relation to the basis period—the Laspeyers index—due to the influence of waste volume change. The total value of waste cost changed also due to the influence of cost change with weight in relation to the common period—the Paasche index—due to the influence of price change.

Table 3 mentions evaluated fictitious sales of the waste, the value of the waste in prices and the volume according to the selected periods for the Paasche and Laspeyers indexes. The indexes speak of the increased waste value due to the changes in price (on decreasing the kilograms of the waste). Due to the influence of the change in waste volume, the value of the waste increased by 44% between 2006 and 2018, and by 37% between 2012 and 2018.

Table 3. Indexes of waste cost development in analyzed periods.

Basic Period	Common Period	Laspeyres Extensive Index	Paasche Extensive Index	Fisher Extensive Index
2006	2012	1.060	1.053	1.056
2006	2018	1.450	1.443	1.448
2012	2018	1.374	1.374	1.371

4.5. Analysis of Economic and Waste Indexes from the View of Verification of Statistical Importance of Regions and Year to the Development of Indexes Value

Table 4 mentions the result of the ANOVA test for chosen economic and waste indexes. We mention the value *p*, the probability of zero hypothesis rejection, in case it is correct. The periods and regions are the factors of the choice. Except as mentioned, the table mentions results of the *p* value of the Bartlett test of homogeneity of dispersion and the Shapiro Wilk test of residue normality, which means verification of whether assumptions are achieved and ANOVA test can be used.

Table 4. Results, *p* values of ANOVA test and verification of assumptions tests.

Test	Komnadom	Prodsep	Waste Cost	Pdedom	Cpvd	Ospodchnadom	Mieraregch
ANOVA/region	0.000	0.021	0.000	0.000	0.000	0.000	0.005
ANOVA/period	0.000	0.000	0.001	0.000	0.000	0.412	0.846
Bartlett test of variances homogeneity/period	0.994	1.000	0.780	1.000	0.952	0.922	0.958
Bartlett test of variances homogeneity/region	0.602	0.781	0.692	0.713	0.456	0.364	0.254
Shapiro–Wilk normality test of residuals	0.455	0.295	0.420	0.591	0.420	0.368	0.325

According to the results, as shown in the table, for the region and indexes—komnadom, prodsep, waste cost, pdedom, cpvd, ospodch, mieraregch—a valid alternative hypothesis confirmed that there was at least one pair of regions for which the medium values were statistically different. According to the results, as shown in the table, for the region and indexes—komnadom, prodsep, waste cost, pdedom, cpvd, ospodch—a valid alternative hypothesis confirmed that there was at least one pair of regions for which the average values were statistically different. The results of the p value Bartlett test of dispersion homogeneity and the Shapiro–Wilk test of residual normality are as follows: All p values were higher than the determined level of importance, which means the hypothesis of dispersion homogeneity cannot be rejected and the hypothesis of residual normality cannot be rejected either. The assumptions for ANOVA test were realized.

For the index sepnadom not all the assumptions of dispersion homogeneity were realized, nor for residual normality; therefore, the ANOVA test cannot be used. The results of the index evaluation are outlined in the following. To find out the differences between indexes, we carried out a pair comparison for period and region. In the following tables, we outline the results of the comparison of p-values, the probability of rejection of zero hypotheses—concerning whether the consistency between the medium values of the two populations is correct. Evaluation and rejection were realized at the level of importance 0.05. The results of pair comparison for the period and indexes, when at least one pair of periods is statistically important, are as follows (see Table 5):

Table 5. Pair comparison of indexes and period.

Period	Komnadom	Sepnadom	Podsep	Waste Cost	Pedom	Cpvd
Y_2012-Y_2006	0.339	0.157	0.001	0.089	0.000	0.000
Y_2018-Y_2006	0.000	0.000	0.000	0.072	0.000	0.000
Y_2018-Y_2012	0.000	0.036	0.000	0.001	0.060	0.000

According to the results, presented in the table, it is obvious that three indexes have statistically important differences between 2006 and 2012. Between 2006 and 2018 and between 2012 and 2018 five indexes have statistically important differences. In accordance with the results, we carried out a cluster analysis for 2018 and 2012. Results of the pair comparison of the indexes for the region were obtained when for at least one pair of regions there was a statistically important difference. The results are given by Table 6.

According to the results, presented in the table, we can say that for the region pairs Žilinský–Trenčiansky, Žilinský–Nitriansky, Trenčiansky–Nitriansky and Košický–Banskobystrický there is no significant difference in the values of any index. Index prodsep registered significant difference only for one pair of regions Nitriansky–Banskobystrický; therefore, it was not used in the cluster analysis. The results, presented in the table, offer an assumption for cluster analysis use; there are regions that could be more similar from the view of the chosen indexes.

Table 6. Results of pair comparison of indexes for regions.

Pair	Komnadom	Prodsep	Waste Cost	Pedom	Cpvd	Ospodchnadom	Mieraregch
Bratislavský–Banskobystrický	0.000	0.223	0.260	0.000	0.000	0.001	0.000
Košický–Banskobystrický	1.000	0.099	0.414	0.989	0.623	1.000	0.980
Nitriansky–Banskobystrický	0.002	0.011	0.004	0.962	1.000	0.755	0.668
Prešovský–Banskobystrický	0.600	0.059	0.035	0.670	0.416	0.012	0.730
Trenčiansky–Banskobystrický	0.058	0.628	0.351	0.027	0.376	0.021	0.006
Trnavský–Banskobystrický	0.000	0.078	0.000	0.187	0.308	0.036	0.011
Žilinský–Banskobystrický	0.003	0.588	0.017	0.672	0.969	0.960	0.430
Košický–Bratislavský	0.000	0.999	1.000	0.000	0.000	0.000	0.001
Nitriansky–Bratislavský	0.539	0.666	0.300	0.000	0.000	0.009	0.007
Prešovský–Bratislavský	0.001	0.990	0.919	0.000	0.000	0.000	0.000
Trenčiansky–Bratislavský	0.022	0.988	1.000	0.000	0.006	0.474	0.706
Trnavský–Bratislavský	0.059	0.997	0.007	0.000	0.007	0.331	0.540
Žilinský–Bratislavský	0.335	0.992	0.738	0.000	0.001	0.003	0.016
Nitriansky–Košický	0.004	0.909	0.179	1.000	0.453	0.654	0.989
Prešovský–Košický	0.856	1.000	0.773	0.254	1.000	0.017	0.249
Trenčiansky–Košický	0.132	0.872	1.000	0.113	0.019	0.015	0.037
Trnavský–Košický	0.000	1.000	0.004	0.553	0.015	0.026	0.063
Žilinský–Košický	0.007	0.898	0.540	0.979	0.171	0.914	0.909
Prešovský–Nitriansky	0.044	0.977	0.910	0.183	0.279	0.001	0.060
Trenčiansky–Nitriansky	0.505	0.246	0.218	0.162	0.536	0.301	0.164
Trnavský–Nitriansky	0.002	0.948	0.400	0.680	0.454	0.437	0.257
Žilinský–Nitriansky	1.000	0.273	0.989	0.996	0.996	1.000	1.000
Trenčiansky–Prešovský	0.749	0.728	0.836	0.001	0.010	0.000	0.000293
Trnavský–Prešovský	0.000	1.000	0.058	0.009	0.007	0.000	0.000
Žilinský–Prešovský	0.086	0.766	1.000	0.056	0.093	0.002	0.028
Trnavský–Trenčiansky	0.000	0.810	0.005	0.941	1.000	1.000	1.000
Žilinský–Trenčiansky	0.729	1.000	0.614	0.438	0.895	0.131	0.312
Žilinský–Trnavský	0.001	0.842	0.118	0.964	0.835	0.206	0.453

Note: For sepnadom the assumption was not met; therefore, the ANOVA test was not used to verify the factors' importance for the region and the year nonparametric Friedman rank test was used with the result p value = 0.04052. For pair comparison for the region Nemenyi's test of multiple comparisons for independent samples (tukey) was used successfully when any pair of regions confirmed a statistically important difference. Pair comparison of Nemenyi's test of multiple comparisons for independent samples (tukey) for the factor 'period' in the table is for the factor 'years'.

The following indexes were used in the cluster analysis: Komnadom, nakladovost, pedom, cpvd, ospodch and mierareg chudoby. These factors, which were originally considered, were not included: Sepnadom and prodsep. A cluster analysis was carried out for 2018 and 2012 with a subsequent comparison of results.

Analysis of development in years and of which region is the weakest and which is strongest can be done according to the mentioned graphs and the following tables. As can be seen in Figure 9: The first four graphs present indicators of waste creation, sorting and costing. All indicators were described in detail in an earlier analysis, from which results the following:

In 2018 compared to 2012 there was increase of communal waste per household, which means increased production of waste. Waste sorting, volume of separated waste per one household and the rate of separated waste by communal waste increased. Costs of waste decreased, which means kilogram production of waste in 2018 cost less to a household.

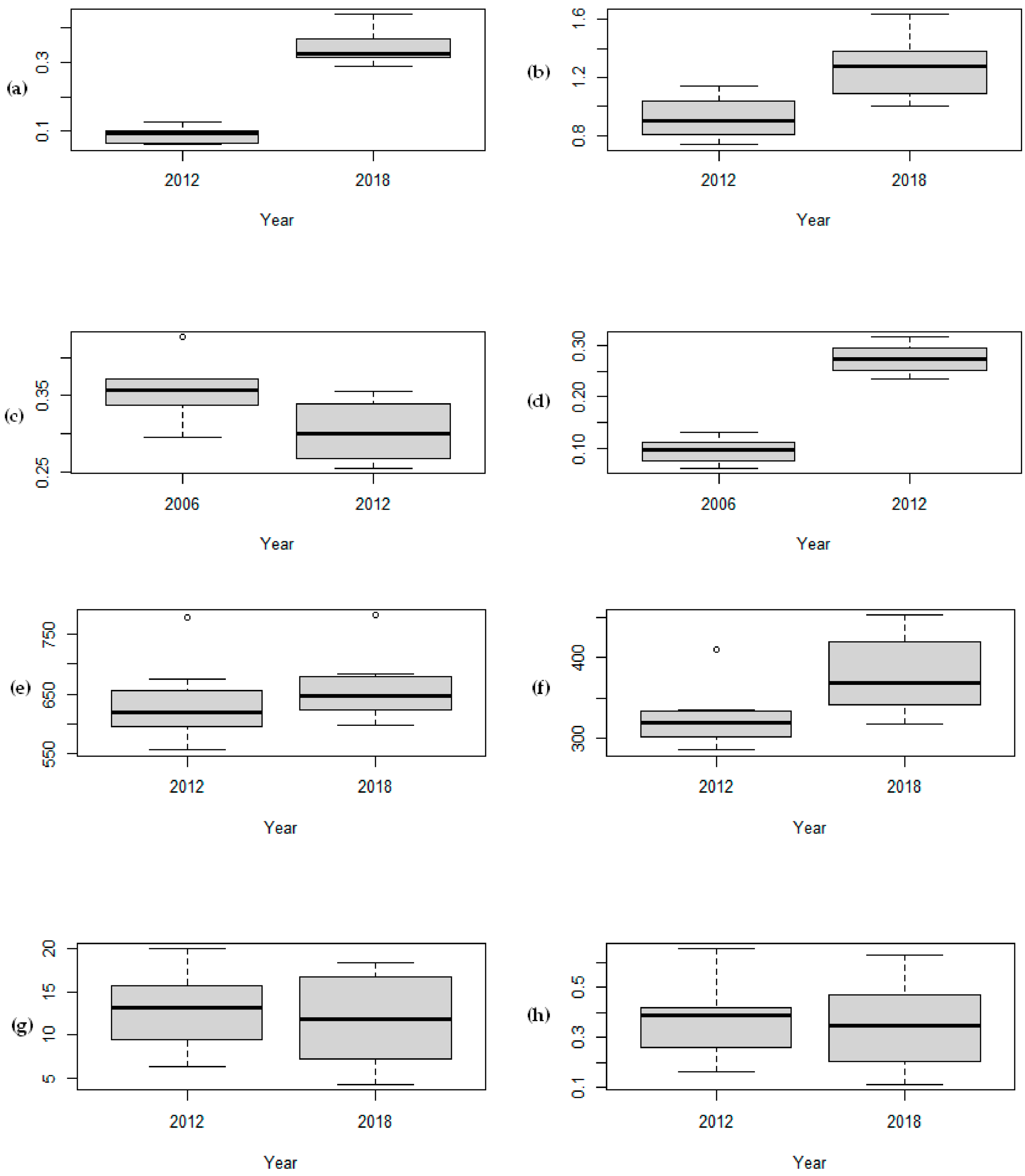

Figure 9. Comparison of the indicators for 2012 and 2018. Note: (**a**) Separated waste in t per 1 household; (**b**) communal waste in t per 1 household; (**c**) waste cost in €; (**d**) ratio of separated/communal waste; (**e**) average household disposable income in €; (**f**) net money expenditure of households in €; (**g**) at risk of poverty percentage; (**h**) people below the poverty line per 1 household.

Indicators concerning the financial situation of the households in regions and at risk of poverty are presented in the second group of four graphs.

Average disposal incomes in 2012 changed in each region by between 555 and 778 €. In 2018 the lower level changed by over 596 € and the upper level by over 782 €. In both cases, the minimal value was recorded in the region Prešovský and the maximal value was recorded in the region Bratislavský—registered by outliers. The second highest value was in 2012—674 € for the region Trenčiansky; and in 2018 for the region Trnavský—682 €.

Net money expenditure in 2012 was between 9919 and 12,663 €; the highest value is the outlier, belonging to the region Bratislavský; distribution is asymmetric (skew = 0.55).

In 2018 the levels moved upwards from 11,476 € to 14,432 €. Distribution is more symmetric (skew −0.22).

The next two indicators, presenting the state of poverty—at risk of poverty rate and people below the poverty line per one household—developed similarly.

At risk of poverty rate: In 2018 the minimum decreased from 6.30 to 4.30; the maximum decreased as well from 19.90 to 18.40. The box width in the graph shows that the differences between the most and the least threatened regions decreased. In spite of there being a registered decrease in the average value and the levels of the indicator, the value increased in the regions Banskobystrický and Košický.

The indicator "people below the poverty line per one household" in 2018 did not decrease compared to 2012 in the regions Žilinský, Banskobystrický and Košický. The results are provided in Tables 7–10.

Table 7. Input data in 2012.

Region	Komnadom	Waste Cost	Pdedom	Cpvd	Ospodchnadom	Mierarchud
Bratislavský	1.099	11.52	778.17	12,663.38	0.161	6.3
Trnavský	1.138	9.61	637.69	10,935.85	0.289	10.6
Trenčiansky	0.915	11.93	674.01	10,909.04	0.231	8.3
Nitriansky	0.983	10.10	600.71	9919.25	0.419	15.9
Žilinský	0.895	12.94	636.79	11,577.80	0.367	12.7
Banskobystrický	0.735	13.70	592.2	10,069.38	0.417	15.6
Prešovský	0.802	14.01	555.88	11,231.08	0.652	19.9
Košický	0.810	12.85	603.05	10,418.23	0.405	13.5

Table 8. Description characteristics in 2012.

Indicator	Mean	SD	Median	Min	Max	Range	Skew	Kurtosis	SE
komnadom	0.92	0.14	0.90	0.74	1.14	0.40	0.26	−1.60	0.05
waste cost	12.80	1.61	12.39	9.61	14.10	4.40	−0.32	−1.61	0.57
pdedom	634.81	67.95	619.92	555.88	778.17	222.29	0.94	−0.25	24.20
cpvd	10,965.50	888.78	10,922.44	9919.25	12,663.38	2744.13	0.55	−0.92	314.23
ospodchnadom	0.37	0.15	0.39	0.16	0.65	0.49	0.44	−0.76	0.05
mierarchud	12.85	4.40	13.10	6.30	19.90	13.60	0.02	−1.37	1.56

Table 9. Input data in 2018.

Region	Komnadom	Waste Cost	Pdedom	Cpvd	Ospodchnadom	Mieraregch
Bratislavský	1.375	10.31	782.18	14,167.32	0.112	4.3
Trnavský	1.638	8.81	682.31	14,432.99	0.229	7.9
Trenčiansky	1.187	11.80	675.23	14,007.71	0.183	6.6
Nitriansky	1.383	8.56	658.4	11,834.70	0.292	10.8
Žilinský	1.369	10.09	633.33	13,817.62	0.399	12.9
Banskobystrický	1.036	11.08	615.11	11,476.04	0.465	17.6
Prešovský	1.144	11.40	596.63	13,045.08	0.629	18.4
Košický	1.005	11.57	630.98	11,629.90	0.475	15.8

Table 10. Description characteristics in 2018.

Indicator	Mean	SD	Median	Min	Max	Range	Skew	Kurtosis	SE
komnadom	1.27	0.21	1.28	1.1	1.64	0.63	0.29	−1.34	0.08
nakladovost	10.45	1.24	10.69	8.56	11.80	3.24	−0.41	−1.63	0.441
pdedom	659.27	57.62	645.86	596.63	782.18	185.55	0.98	−0.18	20.37
cpvd	13,051.42	1232.80	13,431.35	11,476.04	14,432.96	134.50	−0.22	−1.98	435.86
ospodchnadom	0.35	0.17	0.35	0.11	0.63	0.52	0.15	−1.53	0.06
mierarchud	11.79	5.26	11.85	4.30	18.40	14.10	−0.06	−1.79	1.86

According to the calculated description characteristics we can find out how the regions changed between 2012 and 2018.

Figure 10 shows that some regions are, from the perspective of pair indexes (productivity of waste and cpvd—net incomes of households), closer than others. We calculated the Euclidean distance of all region pairs from the values of the indexes, chosen for the cluster analysis. Values of mutual distances are presented in Table 11. Euclidean distance is calculated from the standardized variables, which have medium value 0 and standard deviation 1. Individual regions present points of multivariate space, created by chosen indexes. In 2012 the closest regions were Trenčiansky and Žilinský. The next closest pair was regions Košický and Banskobystrický. Region Prešovský was close to region Košický and Banskobytrický. Region Bratislavský was not close to any of the regions.

Figure 10. Communal waste development according to the net expenses of household in 2012.

Table 11. Values of mutual distances 2012.

Region	Bratislavský	Trnavský	Trenčiansky	Nitriansky	Žilinský	Banskobystrický	Prešovský
Trnavský	3.35						
Trenčiansky	2.90	2.28					
Nitriansky	5.06	2.26	2.92				
Žilinský	3.56	2.86	1.76	2.82			
Banskobystrický	5.63	4.21	3.07	2.83	2.31		
Prešovský	6.36	5.00	4.52	3.66	2.97	2.39	
Košický	4.81	3.30	2.24	2.24	1.55	0.98	2.59

As for the Euclidean distance of regions, in the cluster analysis for 2018 we see that some regions are close; their Euclidean distance is around 1; other regions are remote (see Table 12).

Table 12. Euclidean distance of regions in cluster analysis 2018.

Region	Bratislavský	Trnavský	Trenčiansky	Nitriansky	Žilinský	Banskobystrický	Prešovský
Trnavský	2.63						
Trenčiansky	2.459	3.247					
Nitriansky	3.574	2.555	3.447				
Žilinský	3.492	2.343	2.481	2.02			
Banskobystrický	5.161	4.871	3.626	3.182	2.784		
Prešovský	5.400	4.741	3.768	3.802	2.421	1.719	
Košický	4.935	4.899	3.309	3.363	2.872	0.621	1.772

According to the results we constructed a dendogram. Clusters show a graphical presentation of a double graph: Waste productivity and net incomes of households. Cluster dendogram in 2018 (see Figure 11) and Cluster dendogram in 2012 (see Figure 12) provided information for Figures 13 and 14. Figure 13 is for the cluster dendogram Figure 11, and Figure 14 is for the cluster dendogram Figure 12.

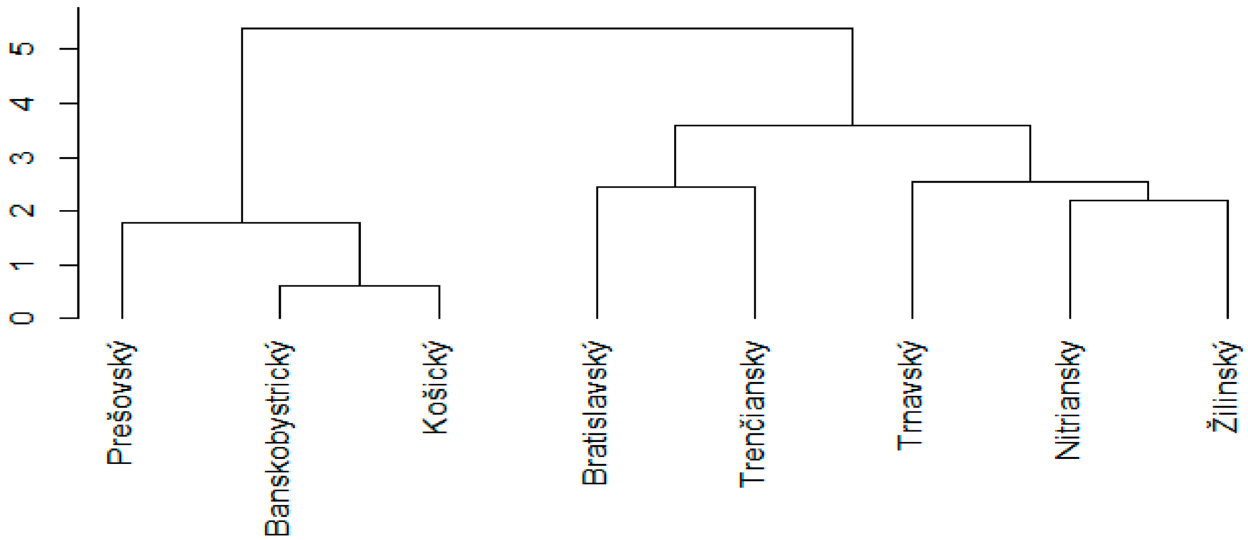

Figure 11. Cluster dendogram in 2018.

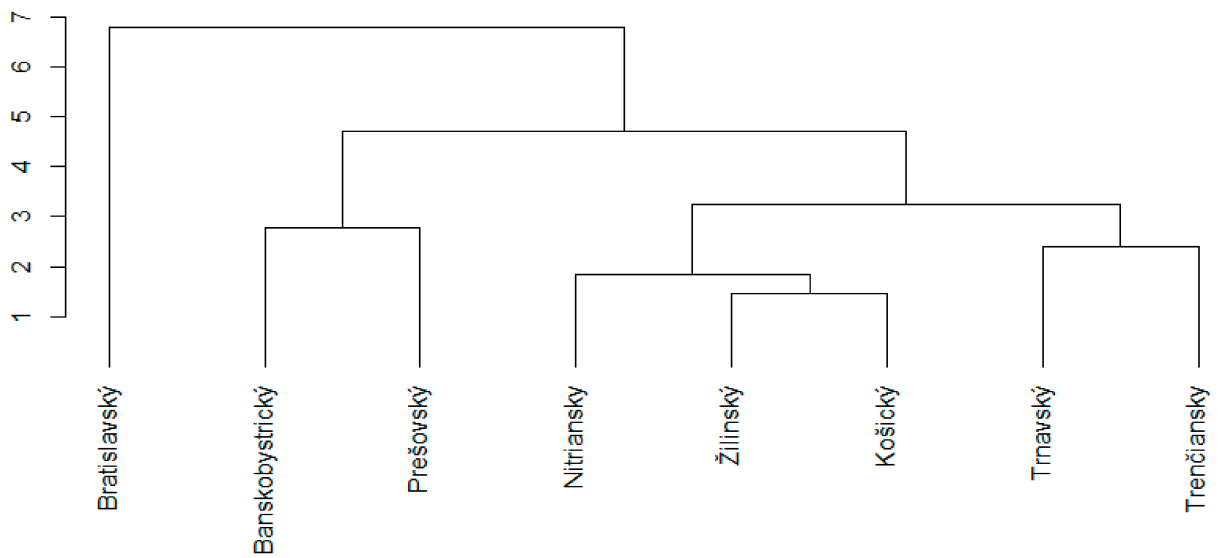

Figure 12. Cluster dendogram in 2012.

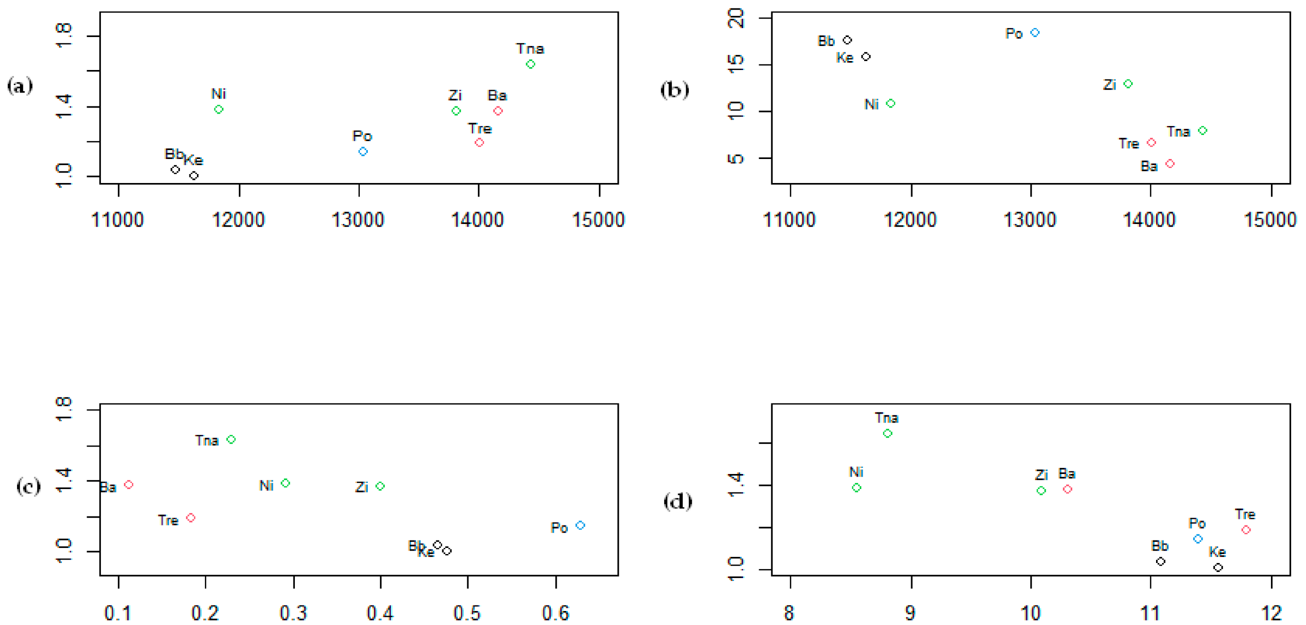

Figure 13. Comparison of indexes after clustering for 2018: (**a**) Communal waste per household in t per year according to net expenses of household in (€); (**b**) measure of poverty risk—60% of median at percentage (%) according to net expenses of household in €; (**c**) communal waste per household in t per year according people below the poverty line per 1 household; (**d**) communal waste per household in t per year according to waste costs in € with relation to kg.

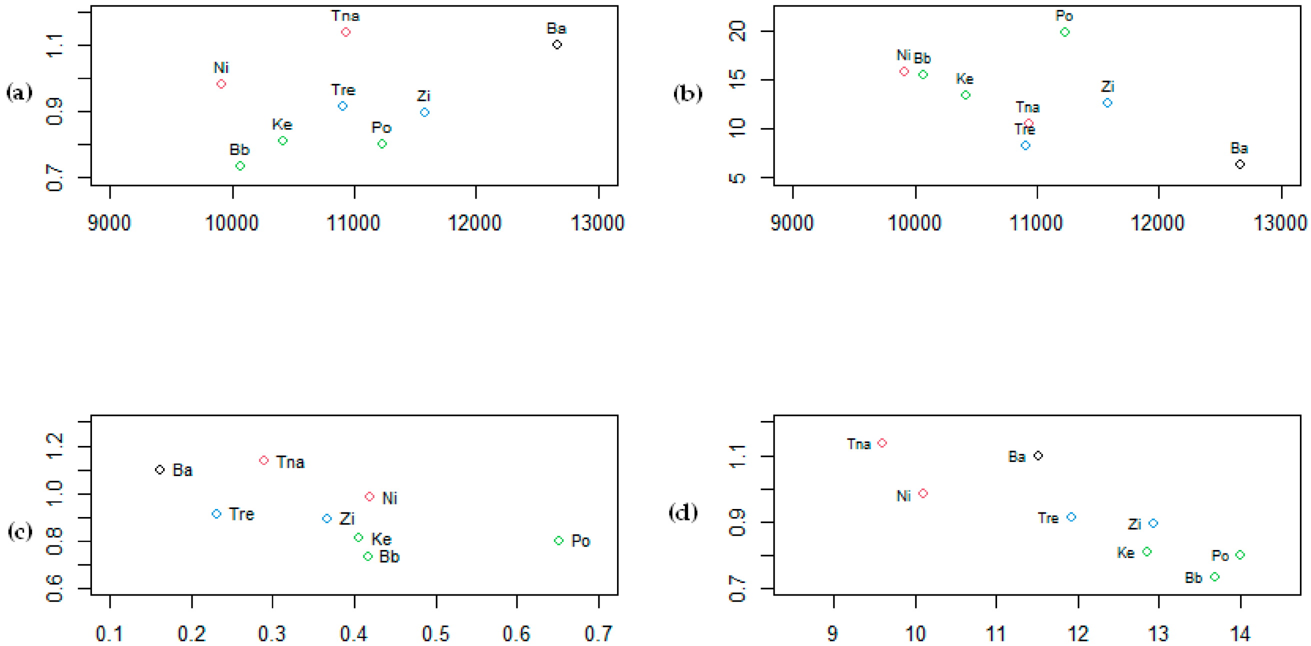

Figure 14. Comparison of indexes after clustering 2012: (**a**) Communal waste per household in t per year according net expenses of household in €; (**b**) measure of poverty risk—60% of median at percentage (%) according to net expenses of household in €; (**c**) communal waste per household in t per year according to people below the poverty line per 1 household; (**d**) communal waste per household in t per year according to waste costs in € with relation to kg.

Figures 13 and 14 illustrate pairs of indexes for individual regions. The same colors of points at Figures 13 and 14 mean individual clusters according to cluster dendrograms. As for the regions' names, for convenience, the following abbreviations are used: Bratislavský as Ba, Trnavský as Tna, Trenčiansky as Tre, Nitriansky as Ni, Žilinský as Zi, Banskobystrický as Bb, Prešovský as Po, Košický as Ke. Similar colors of points mean regions with the same cluster in the dendogram.

In 2012 the closest regions were Banskobystrický and Prešovský, Trnavský and Trenčiansky, Košický and Žilinský. Every region was close to Bratislavský.

Figure 13 shows a comparison of indexes after clustering.

When comparing dendograms in 2012 and 2018 we see a slight regrouping of region groups. While in 2012 the region Bratislavský was in any group, in 2018 it presents a pair with region Trenčiansky.

Figure 14 illustrates how the groups, created by clustering, are structured for the following pairs of indexes:

5. Discussion

The most dominant fraction in communal waste is biological decomposted waste [49]. The organic fraction in the waste amounts to around 48–69% [50]. Therefore, great attention is given to the sorting of biological decomposted waste and its evaluation. A pilot project, carries out in Ghane, showed that sorting into proper baskets would be effective in many areas, since it achieved on average more than 80% in the case of "biologically removable elements, except paper waste" and more than 75% in "other waste". High efficiency of waste sorting meant that using a one-way sorting system was proper for the households that participated. Treatment of biological waste separated from the source is still an important task due to the high rate of contamination [51].

The system of waste sorting in Slovakia is not unified. In Slovakia there are over 2800 autonomous regions and it is not possible to create a unified document for waste treatment. In some autonomies, every waste element must be separated, in other autonomies the costs of sorting and waste treatment are saved and waste is collected in common. It depends on the capacity of the autonomy to deal with waste sorting companies. On the other hand all autonomies have a goal to achieve in the area of waste economy—to be sorting 65% of waste before 2025. Presently waste sorting is at only 36%.

The Slovak Republic is aware of the importance and significance of sorting and is constantly improving the relevant systems. From the beginning of 2021, a ban was issued on the disposal of waste by landfill, unless it has undergone treatment. At the same time, waste sorting at the source is also considered waste treatment.

Awareness of the population about the need and methods of sorting plays a big role in this. For example it is necessary to teach households to sort and to recognize the recycling labels on the packaging in order to know what can be separated and how. If households are not used to separating waste, they must gradually learn new habits such as sorting biodegradable waste. This follows from the obligation of municipalities from 2021 to make sure of separate collection of biodegradable municipal waste.

Another role of municipalities in increasing the rate of waste sorting is to have a proper set up of the system [52]. It also turns out, also on the basis of experience in developed countries, that the quality of waste sorting is increased by the application of a "door to door" system, which is based on bag collection in which anonymity is eliminated. Another motivating element in the sorting process is waste charges, which should be set fairly according to the "pay for what you throw away" pattern. Residents would thus be motivated to decrease unsorted waste.

A good "mirror" for the public is also information about the production of municipal waste, sorting and management. These should show as realistically as possible that this is possible only by precise waste records, which should be provided in Slovakia by a fully functional waste management information system from 2022.

Living standard in Slovakia in 2018 increased to 78% of the EU average. Incomes and consumption of households is increasing. Most expenses are orientated towards the household and food. Consumption of food is also increasing, causing communal waste.

There is a dependence between living standard and production and sorting of communal waste, which is confirmed by the presented results of individual regions of Slovakia.

On the other hand, the more economically developed the region, the more production of communal waste; this is illustrated for example in the regions Bratislavský, Trnavský and Trenčiansky. Those regions belong to the western part of Slovakia, in which there is higher living standard for inhabitants, developed industry, better infrastructure and considerably higher inflow of foreign investment [53,54]. This approach can also be linked to the possibilities of effective use of GIS data [55] that are commonly used in such research. It has been shown that the amount of waste is growing with increasing household incomes, from which the increase in their expenditures also stems. In addition to the inhabitants and household motivation to sort waste, employees of enterprises must also be motivated to properly treat waste [56].

This paper defined new possibilities for waste evaluation through economic variables. The fact that the presented contribution deals only with economic indexes of households creates the space for the next research project: To find out the behavior of households when throwing away and separating communal waste. However, problems of household waste should also be considered, such as, wood-based waste, which means, for example, furniture [57].

6. Conclusions

The use and consumption of goods are natural and necessary parts of human societies. The more a society and a country are developed, the higher the consumption of goods, and consequently the market produces a higher volume of products. In this connection, the waste economy belongs to the one of the most important areas: Sustainable development. The hierarchy of the waste economy results from the need to minimize negative impacts to the living environment. This brings a decrease in storing and an increase in waste recycling. Various researchers are dealing with the possibilities of recycling. Proper sorting is the foundation of good recycling. Metals, paper, glass and plastics are the most common materials that are separated and have high recycling potential.

The presented paper dealt not only with the production and sorting of municipal waste in Slovakia but also with economic factors that may affect it.

In Slovakia there are rather considerable differences between individual regions, which is reflected in the research indicators, including measure of poverty risk. Results of the analysis show there is long-term poverty risk measure in the regions Prešovský, Košický and Banskobystrický. This could be caused by a lower living standard, higher unemployment, higher marginalized groups of inhabitants or a higher number of families with many children and not full families. The regions are typical due to the lower incomes, as well as lower volume of waste per household.

The results of the contribution can be used not only for evaluation of waste development over time in Slovakia, but also for evaluation of the position of Slovakia in the frame of the EU, when the situation shows the waste treatment in Slovakia is weak in comparison with the EU. This demands a change in legislative decrees and an increase in waste treatment awareness. This should result in verified systems that run effectively in the EU countries, when the systems are effective from the view of financial investment in relation to the achieved results of waste recycling.

Since the volume of mixed communal waste is not changing considerably over time, but the volume of communal waste is growing, the volume of other elements in communal waste must also be growing. Such a situation demands future research from the perspective of trends of communal waste growth, as well as from the perspective of assumed development of GDP, according to which there is the aim to find a growing trend of communal waste creation in a future period.

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