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Chapter: Unraveling the Influence of Green Development on Environmental Responsibility

EMPIRICAL ANALYSIS OF THE INTERPLAY BETWEEN MUNICIPAL WASTE GENERATION, LIVING STANDARDS, AND INNOVATION IN THE EUROPEAN UNION

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Annotation. The paper examines global interlinkages among the level of municipal waste generation and the representative socio-economic, technological, and innovation factors at the level of the European Union countries. Further, we realize a hierarchical clustering of the European Union member states according to similar characteristics regarding the level of municipal waste generation, jointly with these representative socio-economic and technological factors, in order to propose adequate solutions for lower-performing states. The data covers the 2006-2021 lapse of time, and the research methodology is based on two advanced methods, namely network analysis performed through Gaussian graphical models and cluster analysis performed by the Ward method. The results highlight that the analysis only of municipal waste generation level, without other socio-economic benchmarks, would not be conclusive, as there are developed states with high levels of municipal waste generation, as well as developing countries with waste generation above the EU.

Keywords: municipal waste generation, living standards, innovation, econometric analysis, European Union.

JEL classification: C87, I31, O30, Q50.

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Introduction

Waste generation has become a global problem, directly related to how states produce and consume (Wilson et al., 2015), being a measure of the inefficiency of resource allocation at the level of any society (Zaman, Lehmann, 2013). The waste problem involves a series of negative aspects related to the environment and population health impact. Waste management has thus become one of the essential components of modern society, being considered a "fundamental human right" (UNEP, 2024) to ensure the well-being of communities. In this context, the importance of waste management becomes crucial to minimize the impact on the environment, prevent pollution, and prevent the risks of illness in the population.

The accelerated population growth of the past 15 years has become a challenge for governments worldwide as an increase in municipal waste production has accompanied it. According to official information published by the United Nations (2020), the amount of municipal solid waste generated globally in 2020 is more than 2 billion tons, with an estimated increase of approximately 70% by 2050.

Currently, technical solutions for municipal waste management are continuously being developed, starting with selective collection, recycling, incineration, and landfill disposal and ending with the application of advanced waste treatment technologies (Chang, Davila, 2008; Chen et al., 2022; Cheng et al., 2020; Elia et al., 2015; Rada et al., 2014). In this context, reducing the production/generation of municipal waste has become an important measure in waste management.

Paramount aspects of developing effective strategies and policies to reduce municipal waste generation are related to the way waste production is influenced by different economic, social and technological factors. Among the main factors of influence, the literature underpinnings highlight the demographic level, the economic development of the states, the education degree, awareness of the population and the technology level (Afroz et al., 2011; Beigl et al., 2008; Chhay et al., 2018; Chu et al., 2016; Gardiner, Hajek, 2020; Sinha et al., 2022; Van Fan et al., 2021). Therefore, the analysis of municipal waste generation, jointly with the main factors of influence, represents the foremost framework for proper solutions for efficient waste management, but also in the development of strategies to reduce the impact on the environment. The waste generation index provides insights into a community or industry's consumption and waste management habits.

In this frame of reference, we assess global interlinkages among the level of municipal waste generation (measured through the municipal waste generation index), and the representative socio-economic, technological, and innovation factors (namely, Human Development Index - HDI, poverty risk rate, net earnings and the Global Innovation Index – GII), at the level of the European Union (EU) countries. Further, we realize a grouping of the European Union (EU) member states according to similar characteristics regarding the level of municipal waste generation, jointly with these representative socio-economic and technological factors, in order to propose proper solutions for these coordinates for lower performing states. The data are gathered for a period of 16 years (2006-2021). The methodology research is based on two advanced methods: (i) network analysis performed through Gaussian graphical models (GGMs), estimated by the Extended Bayesian Information Criteria (EBICglasso) and partial correlation (PCOR) methods; and (ii) cluster analysis processed by the Ward method inset on hierarchical clustering (wardslinkage).

Previous studies provide several shreds of evidence on the influence of determinants on the level of waste generation (Antczak, 2020; Kocak, Baglitas, 2022; Liu, Wu, 2011), but without the combined

influence of socio-economic and technological factors. Several studies have focused on the distinctive analysis of socio-economic factors determining the level of municipal waste generation (Alzamora et al., 2022; Cherian, Jacob, 2012; de Morais Vieira, Matheus, 2018; Medina, 2010; Namlis, Komilis, 2019), either on technological and innovation factors that influence the municipal waste generation (Gardiner, Hajek, 2020; Sinha et al., 2022) or dealt with the correlation between economic growth and the level of municipal waste generation (Inglezakis et al., 2012; Okumura et al., 2014). Therefore, considering these previous findings, the novelty of our research comprises the synergistic analysis of municipal waste generation and the representative socio-economic factors, as well as the level of technology and innovation at the level of the EU member states.

This paper is structured in several distinct sections. In the Introduction part, the context of the research is provided, the objectives pursued, and the novelty brought by this study. A second section follows, in which an analysis of the literature is carried out, focusing on the influence of socio-economic and technological factors on municipal waste generation. Subsequently, the data used and the research methodology applied in this study are described in detail. The results obtained are then presented, and discussions are initiated to compare and correlate the results obtained in this study with those obtained by other authors in the field. The paper concludes with final remarks, including strategies proposed in this area.

1. Literature Review

The interdependence between the determinants of waste generation is complex and may vary depending on the regional and local context (Antczak, 2020; de Morais Vieira, Matheus, 2018; Inglezakis *et al.*, 2012; Liu, Wu, 2011). The works in the literature give a vast space to the investigation of the determining factors of waste generation and explore various aspects related to economic and human development, consumption, human behaviour, industrial processes, technological innovation, policies and regulations, education and awareness (Alzamora *et al.*, 2022; Cherian, Jacob, 2012; Liu, Wu, 2011; Medina, 2010; Sinha *et al.*, 2022). These works aim to understand the causes of waste generation and develop effective strategies for its reduction, recycling and disposal.

A series of studies and works from the literature (Colvero *et al.*, 2019; Giannakitsidou *et al.*, 2016; Kawai, Tasaki, 2016; Kocak, Baglitas, 2022; Okumura *et al.*, 2014; Velis *et al.*, 2023; Vujić *et al.*, 2015; Wilson *et al.*, 2012) investigate the complex link between municipal waste generation and economic and human development, highlighting the importance of sustainable development and proper waste management policy. These studies examined different countries or regions.

In a study at the global level, Wilson *et al.* (2012) assessed and compared waste management practices in 20 cities from different regions of the world by comparing Gross Domestic Income (GDI) per capita, the Human Development Index (HDI) and waste management practices. The results obtained showed that cities with higher incomes and economic development levels often presented more advanced and sustainable approaches to waste management.

Vujić *et al.* (2005) examined the connections between waste management practices and economic development in the EU-27 member states over the period 1995-2007. Their main findings highlighted the existence of a significant correlation between waste management variables and the Gross Domestic Product (GDP) of the EU-27 member states, with similar conclusions being obtained by other authors (Getahun *et al.*, 2012; Gui *et al.*, 2019; Okumura *et al.*, 2014).

Namlis and Komilis (2019) investigated the impact of GDP, HDI, unemployment rate (UR) and carbon dioxide (CO2) emissions on the waste generation rates of 13 types of solid waste using data from 10 European countries, for the period 2008-2015. The results of the study indicated that there is a significant link between socio-economic indices and the generation of municipal solid waste. In particular, a positive correlation was observed between GDP and waste generation, suggesting that *economic growth can lead to more waste production*. *HDI and UR were also found to influence waste generation significantly*.

In contrast to these perspectives, Ercolano *et al*. (2018) have undertaken a comprehensive investigation into the intricate interplay between municipal solid waste (MSW) production and economic development within the Lombardy region of Italy. This study adopts a rigorous panel data analysis approach, utilizing municipal-level data spanning from 2005 to 2011 to scrutinize patterns in waste generation. The findings of this research underscore the existence of an inversely proportional relationship between municipal waste generation and the level of economic development within the Lombardy region of Italy. This compelling observation implies that, with initial economic growth, there is an accompanying escalation in waste production. Subsequently, however, waste generation tends to diminish as societal awareness and environmental consciousness ascend.

In a parallel investigation, Inglezakis *et al*. (2012) delved into the nexus between municipal solid waste generation and economic growth within the domains of Romania, Bulgaria, Slovenia, and Greece during the period from 2000 to 2013. This study meticulously analyzed pertinent data on municipal solid waste generation alongside key economic indicators, including Gross Domestic Product (GDP) and GDP per capita, across the aforementioned four nations. Their inquiry culminated in the discernment of a substantial upsurge in municipal solid waste generation across all four countries between 2000 and 2013, an increase that can be, in part, attributed to economic growth and consumption patterns.

Kocak and Baglitas (2022) hone their focus on the intricate interplay between human development, energy efficiency, income inequality, and sustainable management of municipal solid waste across the member states of the Organisation for Economic Co-operation and Development (OECD) over the timeframe spanning from 2003 to 2018. The outcomes of this study notably indicate that human development exerts a significant influence on the generation of municipal solid waste. Moreover, the research highlights that income inequality can deleteriously impact municipal solid waste management strategies, engendering an inequitable allocation of resources and the propagation of deficient waste management practices in marginalized communities.

The relationship between waste generation and poverty rates constitutes another multifaceted research topic that has attracted the attention of several scholars (Kocak, Baglitas, 2022; Medina, 2010; Morais *et al.*, 2022). In a general sense, individuals living in impoverished conditions tend to be disproportionately relegated to substandard sanitation and frequently grapple with a shortage of access to efficient waste management services. Consequently, poverty is consistently correlated with an elevation in municipal waste generation, thereby constituting a significant impediment to the pursuit of sustainable municipal waste management (Kocak, Baglitas, 2022).

Moreover, an additional determinant of substantial import in the realm of waste management resides in the sphere of technological innovation. The connection between innovation and the quantum of municipal waste generated is notably intricate, subject to variability contingent on the specific technologies and innovations in question, alongside their modes of implementation and governance.

Advanced recycling, processing, and disposal technologies emerge as promising avenues for the attenuation of waste generation and the mitigation of environmental repercussions (Al-Salem *et al.*, 2009; Ashokkumar *et al.*, 2022; Prajapati *et al.*, 2021; Tulebayeva *et al.*, 2020). Furthermore, technological progress is intrinsically linked to resource efficiency and sustainable production paradigms that can curtail municipal waste generation (Khan and Ali, 2022).

Gardiner and Hajek (2020) have meticulously documented the interplay between investments in Research and Development (R&D) and economic performance in relation to municipal waste generation across European Union (EU) countries. This inquiry seeks to ascertain whether a reciprocal dynamic exists between these factors. The findings substantiate a discernible correlation between heightened investments in R&D and a diminution in municipal waste generation, underscoring the pivotal role played by advanced innovations and technologies in bolstering the efficacy of waste management strategies. The study concludes that a bidirectional relationship exists between municipal waste generation and economic growth. In other words, municipal waste generation can exert an influence on economic growth, and conversely, economic growth can impact municipal waste generation. Analogous results have been corroborated by other scholars (Voulvoulis, Burgman, 2019), underscoring the salience of R&D intensity in shaping waste generation dynamics, given that technological innovation can be a potent instrument for mitigating environmental challenges.

Van Fan *et al.* (2021) have undertaken a meticulous analysis, scrutinizing the correlation between waste generation, the prevalence of circular material utilization, revenues accruing from environmental taxes, and the Global Innovation Index (GII). This investigation harnesses extensive datasets encompassing the EU-27 nations and subsequently develops a robust statistical predictive model for waste generation within this consortium. While an elevation in the Global Innovation Index (GII) ostensibly conduces to a reduction in waste generation by fostering the development of more efficient technologies and judicious resource utilization, the study's results assert that GII is a less-than-adequate predictor of waste generation at the level of EU member states.

Concurrently, empirical evidence suggests that industrialization can precipitate a surge in waste production, thus contributing to environmental degradation (Shah *et al.*, 2023). Although technological advancements have engendered significant improvements in human health and overall quality of life, especially within high-income nations, unchecked technological development and excessive consumption exert substantial pressures on natural resources and concomitantly foster environmental deterioration, notably through the augmentation of waste generation (Lefèvre *et al.*, 2022).

In summary, the extant scholarly corpus offers a diverse array of perspectives and conclusions that are significantly relevant to the formulation of policies and strategies governing waste management. This necessitates judicious consideration of the distinct exigencies and challenges characterizing individual regions.

2. Data and Methodology

The interdependence between the determinants of waste generation is complex and may vary depending on the regional and local context (Antczak, 2020; de Morais Vieira, Matheus, 2018; Inglezakis *et al.*, 2012; Liu, Wu, 2011). The works in the literature give a vast space to the investigation of the determining factors of waste generation and explore various aspects related to economic and human development, consumption, human behaviour, industrial processes, technological innovation, policies and regulations. On these lines, the dataset compiled for this study comprises five hey indicators captured for all EU

member states (EU-27) during the 2006-2021 period. A detailed description, the acronym, and the data source of each variable applied in the empirical analysis are presented in *Table 1*.

Table 1. Indicators used in the empirical analysis at the EU-27 level, 2006-2021

No.	Indicators used in the analysis	U.M	Acronym	Data source
1.	Municipal waste generation index	Kilograms per capita	IGD	European Commission (2023), Eurostat [CEI_PC031]
2.	Human Development Index	Coefficient (0 to 1 scale)	HDI	United Nations Development Programme, HDRO (2023)
3.	At-risk-of-poverty rate by poverty line	%	POV	European Commission (2023), Eurostat [ILC_LI02]
4.	Annual net earnings	Purchasing Power Standard (PPS), couple with two children, both earning 100% of average earnings	EARN	European Commission (2023), Eurostat [EARN_NT_NET]
5.	Global Innovation Index	Score (0 to 100 scale)	GII	World intellectual property organization – WIPO (2023)

Source: own calculations.

Table 2. Descriptive Statistics, 2006-2021

Variables	N	Mean	Standard Deviation	Minimum	Maximum
Crude value					
HDI	432	0.87843	0.0412774	0.765	0.955
IGD	423	498.269	131.5351	247	862
POV	427	16.3693	3.865281	8.6	26.4
EARN	411	39597.8	15250.57	10744.31	75161.5
GII	243	48.7654	7.28586	35.6	63.8
N total	432				
Interpolated data					
	Count	Mean	Standard Deviation	Minimum	Maximum
HDI	432	0.87843	0.0412774	0.765	0.955
IGD	432	500.898	134.4624	247	1080
POV	432	16.4229	3.882701	8.6	26.4
EARN	432	39079.0	15301.79	8675.169	75161.5
GII	432	49.6701	7.829678	29.3	73.8
N total	432				

Source: own calculations.

Table 2 presents descriptive statistics to provide a comprehensive view of the dataset. We can see that some variables (except HDI) have missing data. Therefore, in our analysis, we used in-sample and out-of-sample interpolated data.

The municipal waste generation index (IGD) is a key indicator used in our research since it represents the quantity of municipal waste generated by an inhabitant, for one year. If municipal waste generation has lower levels, that country's situation is more beneficial. However, the quantitative benchmarks of the IGD must be analysed with caution, since the increase or decrease of its value can be influenced by a better reporting of them or a better collection of them by the population (on the background of higher education or better standard of living). This index is applied in the current study to identify countries with the most

efficient waste management practices and can provide insights into the sustainability of waste management approaches.

The research methodology embeds two advanced techniques for modelling longitudinal and cross-sectional data, namely, network analysis configured through Gaussian graphical models that are estimated by the Extended Bayesian Information Criteria with graphical least absolute shrinkage and selection operator (EBICglasso) and partial correlation (PCOR) methods, along with cluster analysis processed through the Ward method (wardslinkage) inset on hierarchical clustering.

The research hypotheses are:

H1. There are positive interconnections between municipal waste generation and the living standards (human development, poverty, earnings);

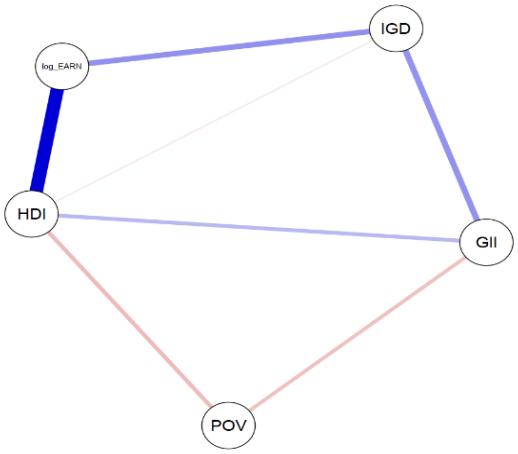
H2. There is an inverse relationship between municipal waste generation and innovative processes/techniques (if innovations are advanced, the municipal waste generation is downsized);

H3. There are significant differences between the EU MS in terms of municipal waste generation, the standard of living (human development, poverty, earnings) and the degree of innovation.

3. Results and Discussion

3.1 Results of GGM

To evaluate research hypotheses 1-2, we have applied network analysis through Gaussian graphical models (GGMs), estimated by the EBICglasso and partial correlation (PCOR) methods. The results of the visual representation of the GGMs, using the EBICglasso method (*Figure 1*) and PCOR *(Figure 1A* in *Appendix*) are similar, with some differences in their centrality plots (figures 2A and 4A in *Appendix*) and clustering plots (*Figures 3A and 5A* from *Appendix*).



Source: processed with the econometric package JASP.

Figure 1. **GGM Results by EBICglasso Method, 2006-2021**

The results (*Figure 1, Tables 1A, 2A* and *Figure 1A* in *the Appendix*) reveal that municipal waste generation (IGD) in the EU-27 countries is positively connected with human development (HDI) as its level generates

a positive impact on the degree of awareness and involvement in development activities waste management, consistent with previous studies (de Morais Vieira, Matheus, 2018; Kocak, Baglitas, 2022). According to the obtained results, the generation of municipal waste (IGD) in the EU-27 countries is negatively connected with the earnings obtained (EARN), since with the increase of average individual earnings, the tendency to buy more goods and services also increases, which can lead to an increase in the amount of waste generated, as previous studies have revealed (de Morais Vieira, Matheus, 2018; Liu, Wu, 2011; Namlis, Komilis, 2019). Finally, there is no statistical linkage between poverty and the generation of municipal waste, contrary to the opinions in the specialised literature according to which, on the one hand, poverty can aggravate the problem of waste (Kocak, Baglitas, 2022; Medina, 2010) and, on the other hand, recycling and waste collection can significantly contribute to poverty reduction in vulnerable communities (Morais *et al*., 2022).

Therefore, the first hypothesis, H1: There are positive interconnections between municipal waste generation and *living standards (human development, poverty, earnings),* is partially fulfilled.

Regarding innovation and waste generation interplay, our results show that the greater the innovation, the higher the generated municipal waste. Even if the obtained results follow some of the opinions in the specialized literature (Lefèvre *et al*., 2022; Shah *et al*., 2023), they do not confirm the H2 hypothesis. In this sense, it should be noted that not in all cases, innovations and industrialization negatively impact waste generation (Gardiner and Hajek, 2020; Van Fan *et al.*, 2021). Innovations can help develop green technologies, promote collection and recycling, and adopt more sustainable practices that reduce environmental impact (Ashokkumar *et al*., 2022; Khan, Ali, 2022). Therefore, the 2nd hypothesis, H2: *There is an inverse relationship between municipal waste generation and innovative processes/techniques (if innovations are advanced, the municipal waste generation is downsized),* is not verified by the results obtained.

3.2 Results of Cluster Analysis

To assess the third research hypothesis, H3: There are significant differences between the EU MS in terms of municipal waste generation, the standard of living (human development, poverty, earnings), and the innovation degree, we have applied the cluster analysis through the Ward method at the level of the EU-27 countries for the last year of the analysed period (2006-2021), namely 2021.

Cluster analysis aims to identify the EU-27 member states that present similar characteristics in terms of municipal waste generation, in conjunction with standard of living (human development, poverty, earnings) and innovation degree, which differentiates the countries' behavior regarding waste generation.

Table 3. Descriptive statistics of the variables, 2021

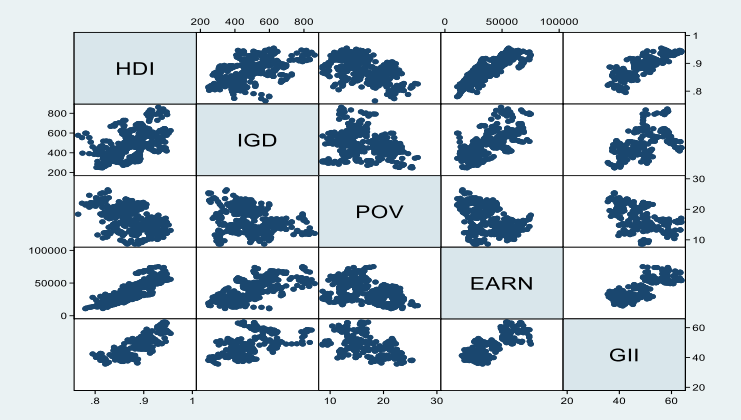
Variables	N	Mean	Standard deviation	Minimum	Maximum
HDI	27	0.8961111	0.0407566	0.795	0.948
IGD	27	551.3333	164.7945	302	1080
POV	27	16.3037	4.045936	8.6	23.4
EARN	27	46518.13	14283.24	25958.21	75161.5
GII	27	47.25556	7.450211	35.6	63.1
N total	27				

Source: own calculations.

Since some data for several indicators for 2021 were missing, we have applied the interpolation technique based on historical data since 2006.

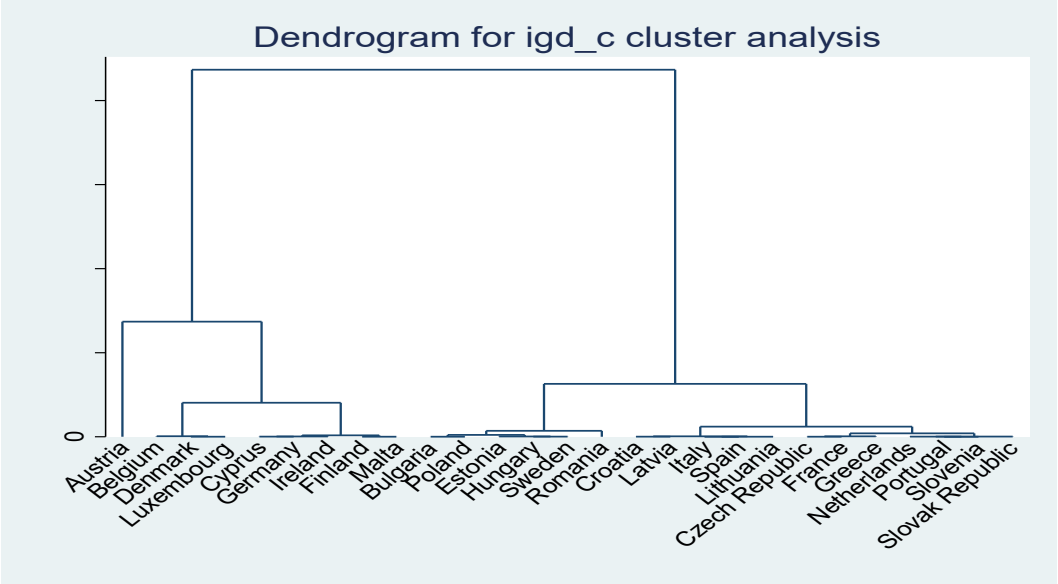
Descriptive statistics of the 2021 interpolated data are presented in *Table 3*.

Figure 2 presents the correlation matrix of the indicators analysed at the level of the EU-27 states in 2021.



Source: processed with the econometric package Stata 17.

Figure 2. **Correlation Matrix of Indicators at the Level of EU-27 States, 2021**



Source: processed with the econometric package Stata 17.

Figure 3. **Dendrogram Obtained from Cluster Analysis at the Level of the 27 EU states, 2021**

Cluster identification was performed using the "Ward method (wardslinkage)" inset on hierarchical clustering. After generating the clusters, we configured the dendrogram (*Figure 3*) to identify the number of clusters and EU countries per cluster.

Table 4. Results of the cluster analysis on the performance of the EU-27 states, 2021

Cluster		IGD	HDI	POV	EARN	GII
1	**N**	**1**	**1**	**1**	**1**	**1**
	Mean	1080	0.916	14.7	11.12117	50.9
	Standard deviation	-	-	-	-	-
2	**N**	**8**	**8**	**8**	**8**	**8**
	Mean	687.5	0.932	14.1875	10.95424	51.9625
	Standard deviation	78.60571	0.0173617	2.535709	0.1720708	4.895461
3	**N**	**6**	**6**	**6**	**6**	**6**
	Mean	377.8333	0.8625	18.05	10.5453	45.6
	Standard deviation	43.31474	0.0540916	4.207018	0.250891	9.755818
4	**N**	**12**	**12**	**12**	**12**	**12**
	Mean	503.25	0.887	16.975	10.57919	44.64167
	Standard deviation	39.63269	0.0270465	4.572671	0.2822981	6.81275
Total	**N**	**27**	**27**	**27**	**27**	**27**
	Mean	551.3333	0.896	16.3037	10.70286	47.25556
	Standard deviation	164.7945	0.0407566	4.045936	0.3045555	7.450211

Source: own calculations.

Table 5. Clusters associated with EU-27 countries, 2021

Clusters (C) 2021		**Cluster Analysis – Ward Method**
		Performance indicators
C1	Austria	***Medium to high:*** the highest index of municipal waste generation; levels of human development, net income and global level of innovation are above the EU-27 average; poverty rate is below the EU-27 mean
C2	Belgium, Denmark, Luxembourg, Malta, Finland, Ireland, Germany, Cyprus	***High:*** the highest levels of human development and global innovation; municipal waste generation and net earnings are above the EU-27 average; the lowest poverty rate in the EU-27
C3	Estonia, Hungary, Sweden, Romania, Poland, Bulgaria	***Low:*** the highest poverty rate in the EU-27; the lowest levels of human development, municipal waste generation and net income in the EU-27; the level of innovation is above the EU average
C4	France, Lithuania, Slovak Republic, Spain, Czech Republic, Slovenia, the Netherlands, Croatia, Italy, Portugal, Latvia, Greece	***Medium to low:*** the lowest level of innovation; human development, municipal waste generation, and net earnings are below the EU-27 mean; the poverty rate is above the EU-27 average.

Source: own contribution, based on data in *Table 4*.

Duda-Hart and Calinski-Harabasz stopping rules have also been applied and 4 main clusters were identified at the level of the 27 EU countries, as entailed by *Figure 3*, *Table 4*, and *Table 5*. Hence, grouping the EU-27 member states into 4 clusters reveals the highest performances achieved by countries in cluster 2 (C2), where 8 member states are included, and the lowest in cluster 3 (C3), with 6 countries included. Most EU-27 member states, respectively 12 countries, have medium to low

outcomes in terms of waste generation, standard of living and innovation (C4). In the first cluster (C1), Austria performed medium to high outcomes as regards waste generation, standard of living and innovation.

Based on these results, countries with low and medium to low outcomes (C3 and C4) must improve these dimensions to sustain a high standard of living by mitigating municipal waste generation and raising innovation. We can see that, in these clusters, there are, mostly, developing countries, that new adhered to the EU (since 2004), except Sweden (C3), due to low municipal waste generation (positive aspect), and other developed countries (C4), namely, France, the Netherlands, and Italy.

Therefore, the 3rd hypothesis, *H3: There are significant differences between the EU MS in terms of municipal waste generation, the standard of living (human development, poverty, earnings), and the innovation degree,* is fulfilled.

Conclusions

The results of our study highlight that the analysis only of municipal waste generation level, without other socio-economic benchmarks would not be conclusive, as there are developed states with high levels of municipal waste generation (like Denmark, Austria, Luxembourg, Ireland, Germany, France, Belgium, and the Netherlands), but there are also developing countries with waste generation above the EU average (the Czech Republic, Cyprus, and Malta). Usually, the economic development of a state is associated with an increase in the level of production and consumption of goods and services, which can generate an amplification of the level of waste generation (Namlis, Komilis, 2019), in the absence of effective government policies of waste management (Doran et al., 2023). Thus, sustainable economic development must reduce environmental impact by adopting ecological measures and using green technologies (Ercolano et al., 2018; Iacobuta et al., 2019).

While in developed countries, the high level of waste generation can be associated with consumption habits, the acceleration of urbanization and industrialization, the above-average level recorded by developing countries can be explained by exceeding the capacity of the waste management infrastructure, as a result of the acceleration production processes and the population's lack of adequate education and awareness.

Also, there are developed countries (Sweden, Italy), as well as developing ones (Romania, Poland, and Bulgaria) with low levels of municipal waste generation. The low level of waste generated in developed states is associated with strict government policies, advanced waste management infrastructure, and effective measures to encourage recycling by promoting education and awareness of the population (Gastaldi et al., 2020; Lindqvist, 2013; Rajendran et al., 2019; Weghmann, 2023). In developing countries, where innovation and technology are reduced, a lower level of waste generation can be associated with traditional consumption behaviour and the broader use of non-packaged products.

In conclusion, waste management is a complex problem, influenced by a series of interconnected factors such as consumer preferences, culture, innovation and industrialization, and government policies.

Current research has some caveats, mainly the limited availability of relevant data for longer time spans that accurately reveal the amplitude of the waste generation process. Future research, therefore, aims to apply additional proxies for the fundamental credentials of waste management at the European Union level.

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SAVIVALDYBIŲ ATLIEKŲ GENERAVIMAS, GYVENIMO STANDARTŲ IR INOVACIJŲ SĄVEIKA EUROPOS SĄJUNGOJE: EMPIRINĖ ANALIZĖ

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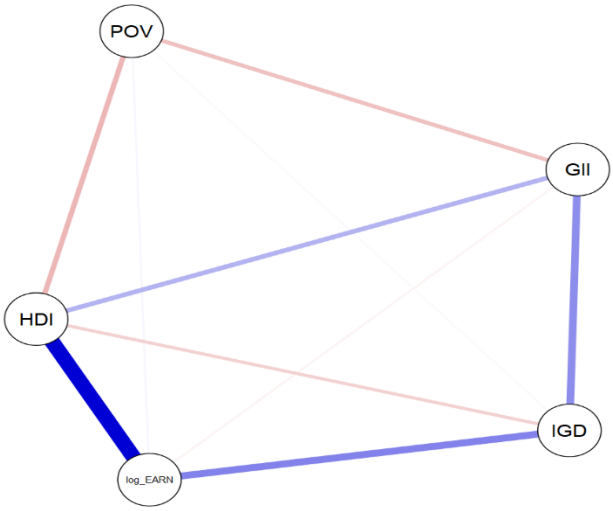
Santrauka. Savivaldybių atliekų generavimas Europos Sąjungoje yra glaudžiai susijęs su gyvenimo standartais, inovacijomis ir socialiniais-ekonominiais veiksniais. Aukštesni gyvenimo standartai dažnai lemia didesnį atliekų generavimą dėl didesnio vartojimo, o inovacijos yra svarbios atliekų tvarkymo ir perdirbimo technologijose. Ekonometrinė analizė padeda tirti šiuos ryšius, atskleisti tendencijas ir skirtumus tarp ES valstybių narių. Pavyzdžiui, pažangios ekonomikos šalys, tokios kaip Vokietija ir Austrija, viena vertus, dažnai generuoja daugiau savivaldybių atliekų, tačiau taip pat pasižymi aukšto lygio perdirbimu ir tvariais atliekų tvarkymo metodais. Kita vertus, besivystančios ES šalys, tokios kaip Kipras ir Malta, dažnai susiduria su atliekų tvarkymo iššūkiais, labiau pasikliaudamos sąvartynais. Siekiant pagerinti atliekų tvarkymo efektyvumą, pasitelkti inovatyvūs sprendimai, pvz., pažangios rūšiavimo sistemos ir duomenų analizė. Be to, siekiant sugrupuoti šalis pagal panašias atliekų generavimo ir socialinių-ekonominių savybių charakteristikas, atlikta klasterių analizė. Rezultatai padeda politikos formuotojams kurti tikslines intervencijas.

Reikšminiai žodžiai: savivaldybių atliekų generavimas; gyvenimo standartai; inovacijos; ekonometrinė analizė; Europos Sąjunga.

Appendix



Source: processed with the econometric package JASP.

Figure 1A. **GGMs Results by PCOR Method, 2006-2021**

Table 1A. Summary of Network, EBICglasso

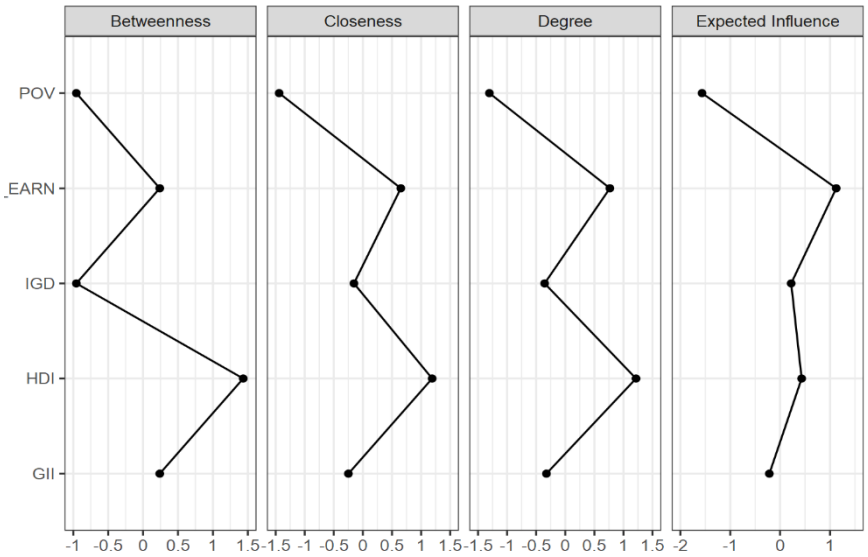
Number of nodes	Number of non-zero edges	Sparsity
5	7 / 10	0.300

Source: processed with the econometric package JASP

Tabel 2A. Summary of Network, PCOR

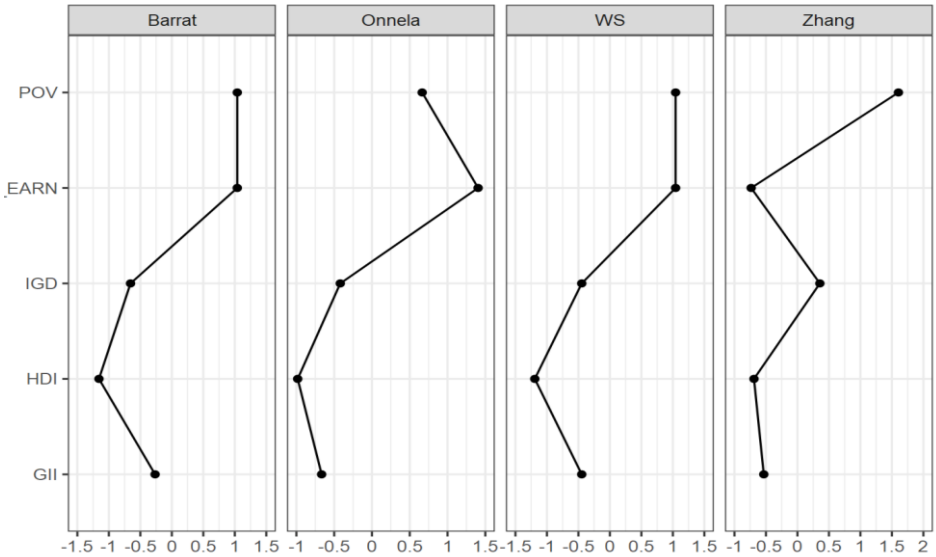
Number of nodes	Number of non-zero edges	Sparsity
5	10 / 10	0.000

Source: Processed with the econometric package JASP



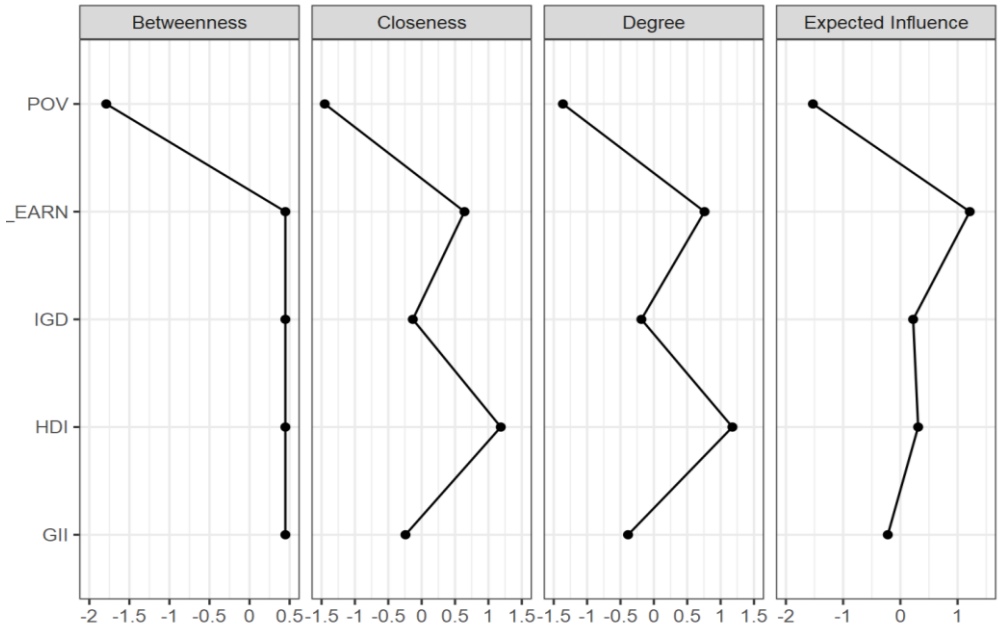
Source: processed with the econometric package JASP.

Figure 2A. **Centrality Plot, EBICglasso, 2006-2021**



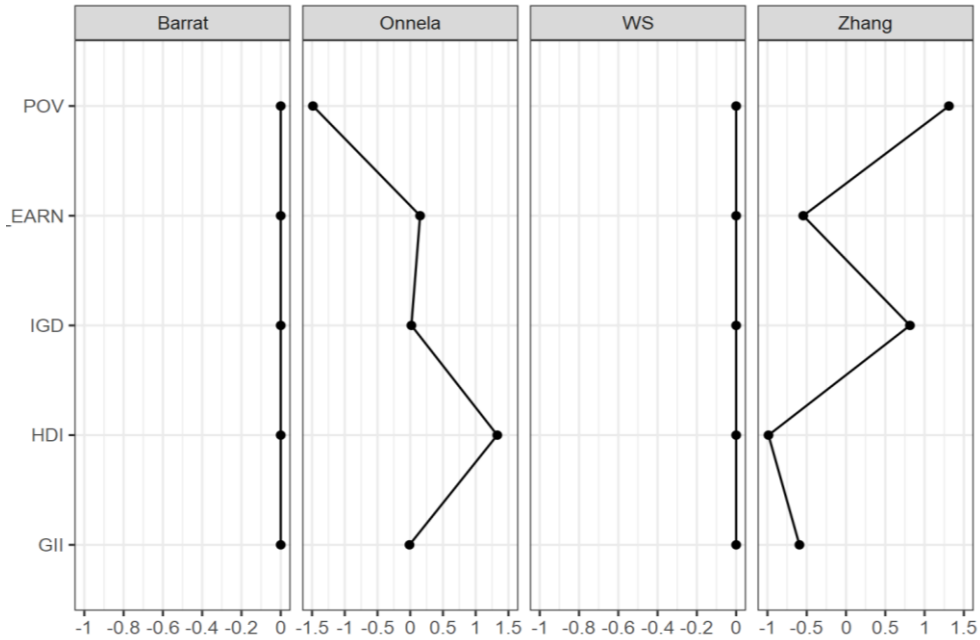
Source: processed with the econometric package JASP.

Figure 3A. **Clustering Plot, EBICglasso, 2006-2021**



Source: processed with the econometric package JASP.

Figure 4A. **Centrality Plot, PCOR method, 2006-2021**



Source: processed with the econometric package JASP.

Figure 5A. **Clustering Plot, PCOR method, 2006-2021**