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WILL DEPOSIT-RETURN SYSTEM WILL BE EFFECTIVE IN ACHIEVING THE OBJECTIVES OF SINGLE USE PLASTIC DIRECTIVE FOR PLASTIC BOTTLES IN POLAND?

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ABSTRACT: The aim of this paper is to analyse the effectiveness of implementing the deposit-return scheme (DRS) as a tool for achieving goals in recycling and the separate collection of plastic packaging waste, as well as in promoting the circular economy in European Union (EU) countries. In this context, the prospects for the effectiveness of a future DRS in Poland were assessed. A correlation analysis between the level of plastic bottle collection and nine explanatory variables was conducted, supplemented by hierarchical cluster analysis. Our findings support the hypothesis that the deposit system is a key factor in increasing the rate of separate collection of plastic bottles. Accordingly, the introduction of a DRS in Poland is expected to effectively meet the target for plastic bottle collection set by the Single-Use Plastic Directive.

KEYWORDS: deposit-return scheme, plastic bottles, packaging waste, Single-Use Plastic Directive

Introduction

The European Union, in its sustainable development policy, has declared a transition from a linear to a circular economy (CE), in which "the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste minimised" (Closing the Loop, 2015). However, the effectiveness of these measures varies greatly across member countries. This issue also affects packaging waste: the amount of packaging waste generated per capita in 2021 rose in the EU by almost 23% compared to 2012 (Figure 1). Packaging waste generation ranged from approximately 30 kg per inhabitant per year in Bulgaria and Croatia to 200 kg in Germany. The trends over the past decade (2012-2021) are also inconsistent: in some countries, packaging waste volume decreased by 45-50%, as seen in Latvia and Malta, while in others – such as Sweden and Germany – it remained almost unchanged.

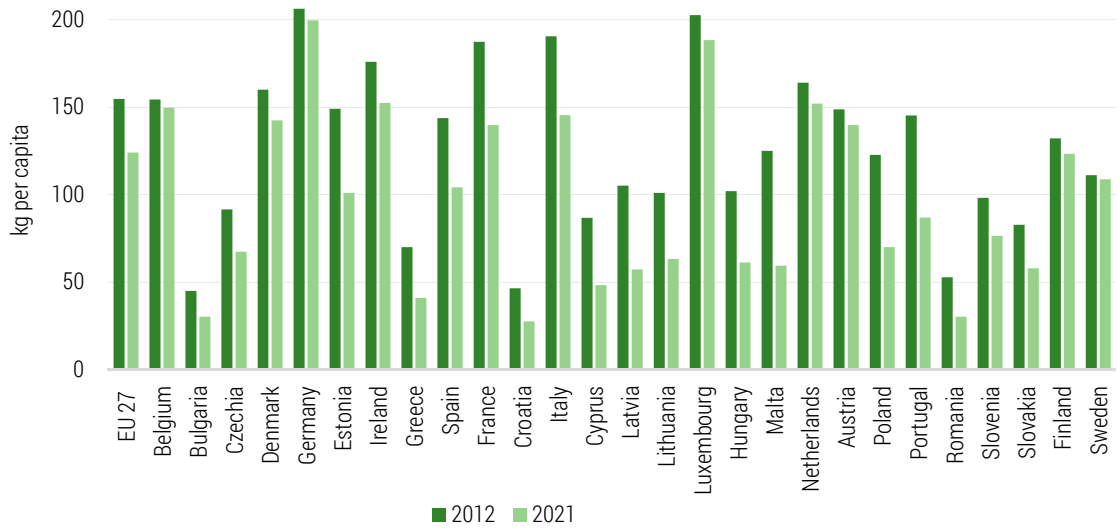

Figure 1. Packaging waste generation in the EU countries 2012-2021 [kg per capita]

Source: authors' work based on Eurostat (2024).

The level of implementation of a main objective of the packaging policy at the end-of-life stage, i.e. packaging waste recycling, also varies widely and remains far from satisfactory in some countries. At the EU level, the recycling rate for packaging waste reached 64% in 2021; however, country-specific rates vary significantly – from 38% in Romania to 80% in Belgium (Eurostat, 2024). Furthermore, between 2012 and 2021, the recycling rate decreased in some countries, although definitional differences and legal changes affecting reported numbers, as noted by Leal Filho et al. (2019), should be considered when comparing data across countries. Of particular concern is the decline in packaging recycling rates among large, highly developed EU countries such as Germany and France (Figure 2).

One of the particular challenges in the area of plastic packaging waste recycling is the recycling of plastic bottles, which can be attributed to two main reasons. Firstly, plastic bottles represent more than 20% of the total weight of plastic packaging in the EU market. These bottles are predominantly made of polyethene terephthalate (PET), although polypropylene (PP) and high-density polyethene (HDPE) are also used in production. In 2022, approximately 5 million tons of PET products were placed on the European market, of which 97% comprised packaging. Each year, about 3.4 million tonnes of PET bottles are introduced to the European market, representing nearly 70% of the total weight of PET introduced (ICIS, 2022). The structure of PET use in the European market is depicted in Figure 3.

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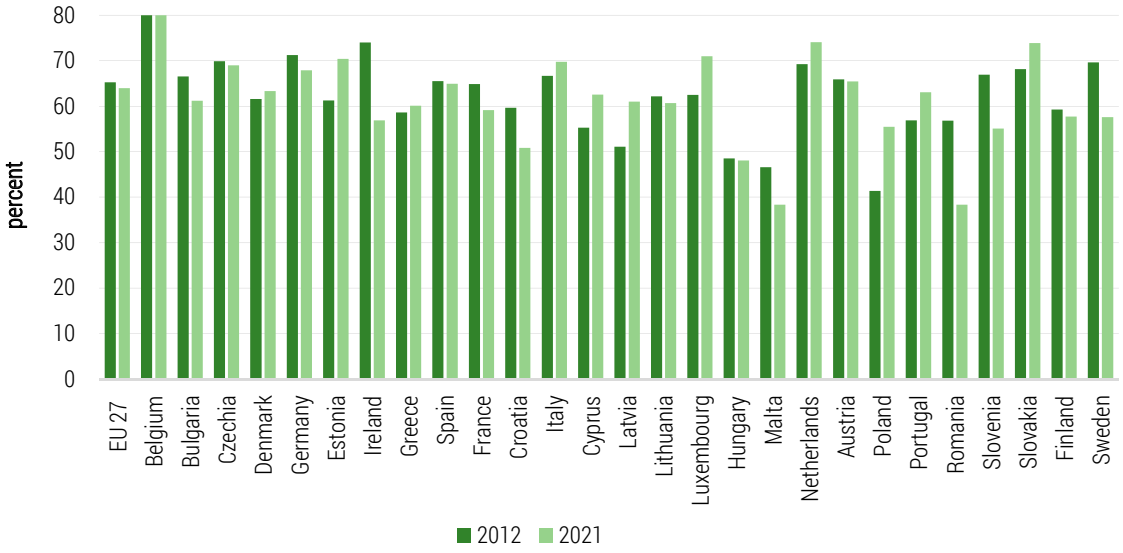

Figure 2. The recycling rate of packaging waste in the EU countries 2012-2021 [%]

Source: authors' work based on Eurostat (2024).

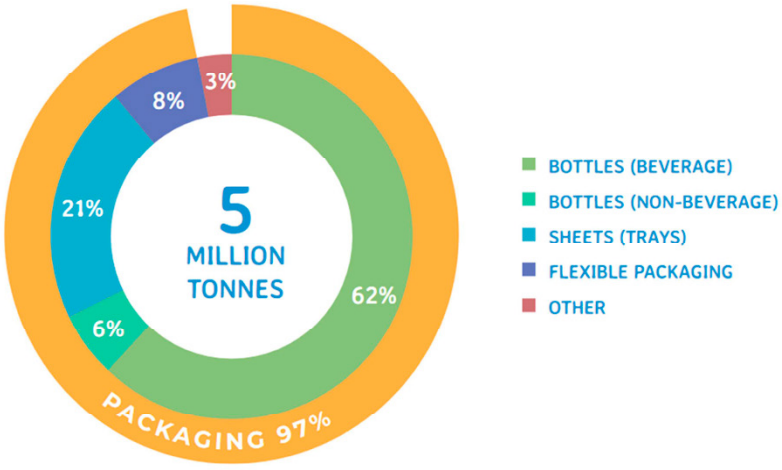

Figure 3. Breakdown of end-applications of PET placed on the market in the EU27+3 region in 2022 (excluding polyester fibres)

Source: ICIS, 2022, p. 17.

Secondly, the Single-Use Plastics (SUP) Directive has established a target of 90% separate collection of plastic bottles by 2029 (77% by 2025) and mandates recycled plastic content in new beverage bottles: 25% for PET beverage bottles from 2025 and 30% in all plastic beverage bottles from 2030. The requirement for mandatory recycled plastic content necessitates the provision of high-quality recyclate on a large scale to be reused for the production of beverage bottles. In this context, it is essential to ensure the effective operation of plastic packaging waste collection systems in EU countries.

Achieving the recycling targets for plastic packaging waste requires the use of legal and economic instruments. The legal instruments employed include bans, restrictions, and orders to utilise, as well as minimum recovery and recycling levels and minimum separate collection levels. Economic instruments encourage preferred behaviour by generating economic efficiency. These instruments encompass product fees, taxes, and deposit-return schemes (DRS), which are the focus of this paper (see, e.g., OECD, 2004; Mallick et al., 2024).

Deposit-return schemes (DRSs) aim to efficiently collect end-of-life products, including packaging, and to enhance the quality of collected materials. Such systems may be implemented for several

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specific reasons: to create incentives against littering, to collect hazardous waste to ensure that it is managed in a safe and environmentally sound manner, and to gather high-quality material for reuse or recycling (OECD, 2022). Deposit-return schemes have been widely utilised for packaging, both single-use and multiple-use, demonstrating high effectiveness.

In the case of DRS, the formal basis for their use in EU countries is Article 9 of the SUP Directive, which gives Member States the right to utilise deposit-return schemes for the separate collection of plastic waste. However, EU Member States are free to choose their own implementation approach and set of instruments and implement them in different ways. The fundamental principles and framework regulations of packaging and packaging waste policy in the European Union are common to all EU countries, but whether the DRS is applied at all, as well as how it operates, is a matter for national authorities to decide. This is one of the reasons why the effects of packaging waste policies vary significantly from country to country.

Conditions for functioning of the deposit-return scheme in Poland

Deposit-return schemes used in many countries around the world differ in the range of packaging covered, the amount of the deposit fee, the organisation of the system, and the available infrastructures. The decision to implement DRS was made by a large group of EU countries, including Poland, starting in October 2025.

In Poland, DRS functioned until the mid-1990s and covered a significant part of reusable glass packaging. However, the system was not regulated by legal acts and was bottom-up in nature. The economic transformation of the 1990s, resulting from the political transformation in 1989 and the Western patterns of consumption and linear economy that followed, resulted in the almost complete destruction of the DRS.

At the same time, the Scandinavian countries and, since 2003, Germany began to develop DRSs. Demands to reactivate the deposit system in Poland after 2000 were strongly opposed by producers. Key arguments raised were high costs and a lack of economic viability. As a result, the packaging waste management system established in Poland in 2001 did not use the deposit mechanism.

At the EU level, the integration of sustainability and circular economy principles in relation to single-use plastic products was achieved through the adoption of the SUP Directive (Directive, 2019). The Directive provides for the following economic and legal instruments for packaging waste management dedicated to single-use plastic products, including beverage bottles with a capacity of up to three litres:

- introducing extended producer responsibility schemes and transferring to manufacturers of single-use plastic products:
  - the costs of the awareness raising measures regarding those products,
  - the costs of waste collection for those products that are discarded in public collection systems, including the infrastructure and its operation, and the subsequent transport and treatment of that waste,
  - the costs of cleaning up litter resulting from those products and the subsequent transport and treatment of that litter.
- the target for a separate collection of single-use plastic bottles for recycling,
- the target on minimum recycled content for single-use plastic beverage bottles,
- the possibility of establishing deposit-return schemes.

However, the targets set by the SUP Directive will take effect in 2025. The current efficiency of packaging waste management systems in the EU Member States results from solutions that have been established in the context of the provisions of Directive 94/62 on packaging and packaging waste (Directive, 1994). The Directive established the minimum required level of material recycling for plastic packaging waste at 22.5% in 2008, and after the 2018 revision, set recycling targets for plastic packaging waste: 50% in 2025 and 55% in 2030.

Research explaining the effects of packaging waste management systems encompasses many aspects: institutional, economic, and technical. The most detailed study of the effectiveness of extended producer responsibility systems for packaging in European countries, conducted by Colelli et al., identified several factors significantly affecting the recycling rate of packaging waste in specific

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national systems (Colelli et al., 2022). Non-competitive systems proved to be more effective; specifically, for systems with one producer responsibility organisation, the recycling rate of total packaging was 8 percentage points higher than for systems with multiple PROs (on average, ceteris paribus). Costs were lower for competitive systems, although results varied by material, and for plastics, EPR costs below the European average were associated with particularly low performance. These conclusions suggest that competitive systems tend to reduce the financial burden on producers at the expense of achieving environmental targets. The available literature points to numerous economic and environmental benefits that exceed the costs of creating and operating the DRS. In the study by Colelli et al., it was found that deposit schemes increase the recycling rate by 5 percentage points for plastics and by 15 percentage points for glass (Colelli et al., 2022).

Deposit-return schemes effectively redirect waste streams from final disposal sites to recycling and reuse facilities. The additional recycling effect achieved by implementing DRS is stronger when initial recycling rates are low. The high price elasticity of the recyclate is a factor that increases the effectiveness of DRS. The success of DRS depends on the prior existence of a robust separate collection infrastructure (Linderhof et al., 2019). Alternatives to DRS, such as virgin materials taxes, advance disposal fees, recycled content standards, and recycling subsidies, are generally less efficient.

There is also a case for using this instrument in areas beyond waste management and the end-of-life phase (Walls, 2013). The DRS also supports eco-design. Introducing DRS motivates producers to achieve cost savings and use raw materials and resources efficiently (savings from a reduction in waste disposal costs for municipalities, savings from using recycled materials instead of raw materials, and emission savings resulting from recycled materials that are not stored in landfills, as well as emission savings from using recycled materials instead of raw materials) (see, e.g. Joltreau, 2022; Görgün et al., 2021).

Research conducted in Portugal showed a significant impact of DRS on changing consumer behaviour, especially among those who are less positive about recycling. The authors pointed out that inconvenience is an important factor affecting consumer behaviour. Inconvenience resulting in undesired behaviour (not returning or abandoning packaging) includes the need to store and handle waste, the availability of RVMs, RVM downtime, and even the difficulty of using RVMs due to the high demand at the only RVM on the site (Martinho et al., 2024). The conclusions about the radical change in consumer behaviour after the introduction of DRS are confirmed by research conducted in Romania. Eight months after the introduction of the system (30 November 2023), the average number of packaging returns increased from 21,700 in January 2024 to 454,000 in June 2024 and exceeded 500,000 at the beginning of July 2024. According to the results of the study conducted by Reveal Marketing Research, seventy percent of Romanians reported returning all packaging, while in November 2023, only a third of Romanians (36%) intended to partially return packaging (Tomra, 2024; Romania-Insider, 2024).

Starting in last quarter 2025, a DRS for beverage packaging will be launched in Poland. Its essence, like all systems of this type, will be to collect a cash deposit from consumers for single-use or reusable packaging. The deposit is returned when the packaging or packaging waste is returned to the appropriate separate collection system.

The implementation of the deposit system in Poland was preceded by numerous discussions and analyses aimed at finding optimal solutions, assessing investment and operating costs, and confirming that the DRS would contribute to achieving the separate collection target as required by the SUP Directive. A bottom-up approach was adopted: deposit systems are to be created by business organisations, and the legal act only specifies the requirements that these systems must meet.

The aim of the paper is to analyse the effectiveness of a DRS as a tool for achieving the recycling and separate collection targets for plastic packaging waste and building a circular economy in the European Union member states. In this context, the prospects for the effectiveness of DRS in Poland will be assessed. Our hypothesis is that the DRS allows for the effective achievement of the separate collection targets for beverage plastic bottles in Poland, as set by the SUP Directive.

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Material and methods

We verified the hypothesis using correlation analysis and hierarchical cluster analysis. We analysed the correlation between the dependent variable – the separate collection rate of plastic bottles (x1) and the following explanatory variables:

- overall recycling rate of plastic packaging waste [%] (x2),
- the existence of a deposit-return scheme [0,1] (x3),
- overall municipal waste recycling rate (x4) – the variable illustrates the overall development of the waste management system in a country,
- country economic development – GDP per capita (x5),
- Human Development Index (HDI) (x6) – a summary measure of a country's achievement in key dimensions of human development,
- The Happy Planet Index (x7) – index of human well-being and environmental impact,
- Trust in Government Index (x8) – share of people who report having confidence in the national government,
- the region of Europe a country belongs to according to the UN nomenclature (x9),
- old / new EU member state, the old EU includes EU member states before 1 January 2004, the new EU – countries that joined EU after 1 January 2004 (x10).

Table 1 provides a summary of the data used.

Table 1. Data used for analysis

Country	x1	x2	x3		x4	x5	x6	x7	x8	x9	x10
			as for 2021	Year a DRS was introduced							
Belgium	0.92	49.2	0	0	0.56	39000	0.942	38.9	47.31	3	1
Czechia	0.85	45.1	0	0	0.43	23430	0.895	46.8	28.45	4	2
Denmark	0.96	23.2	1	2002	0.58	58970	0.952	53.0	65.17	1	1
Germany	0.95	48.4	1	2003	0.69	44190	0.95	45.7	60.48	3	1
Estonia	0.86	42.5	1	2005	0.30	23650	0.899	38.3	51.92	1	2
Ireland	0.62	27.9	0	2022	0.41	88220	0.95	47.7	62.34	1	1
Spain	0.66	56.4	0	2022	0.42	25800	0.911	53.0	37.17	2	1
France	0.47	23.1	0	0	0.44	36950	0.91	52.0	43.35	3	1
Croatia	0.86	34.2	1	2006	0.31	14880	0.878	48.0	30.10	2	2
Italy	0.46	54.8	0	0	0.52	30810	0.906	49.6	35.43	2	1
Lithuania	0.92	44.8	1	2016	0.44	20110	0.879	41.0	30.38	1	2
Netherlands	0.65	48.9	1	2006	0.58	50850	0.946	50.7	58.47	3	1
Austria	0.75	30.7	0	2025	0.62	45270	0.926	45.3	61.04	3	1
Poland	0.43	37.9	0	2025	0.40	15100	0.881	40.3	25.92	4	2
Portugal	0.45	38.1	0	2022	0.30	20990	0.874	51.0	58.90	2	1
Romania	0.52	31.6	0	2023	0.11	12630	0.827	49.4	30.20	4	2
Slovakia	0.62	60.2	0	2022	0.49	18430	0.855	41.0	21.58	4	2
Finland	0.92	42.9	1	2008	0.39	45230	0.942	49.8	71.37	1	1
Sweden	0.86	23.8	1	1984	0.40	49110	0.952	55.9	63.35	1	1
Iceland	0.83	27.6	1	1989	0.26	60400	0.959	40.3	63.38	1	x
Norway	0.88	28.3	1	1999	0.37	78670	0.966	50.5	77.35	1	x

Source: authors' work based on Eurostat (2024); UNESDA (2024); OECD Datebase (n.d.); UNDP (2024); Happy Planet Index (n.d.); kaucyjny.pl (n.d.).

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Due to the availability of data on the collection of plastic bottles, the analysis was carried out for 2021. The study covered the countries of the European Union, Norway, and Iceland. The eligibility criterion for the study was the availability of data for all variables. Due to this limitation, the following countries were excluded from the analysis: Hungary, Greece, Bulgaria, Malta, and Cyprus.

Results

The Pearson correlation coefficient and the p-values are shown in Table 2.

Table 2. Correlation between the plastic bottle collection rate and the explanatory variables

		x2	x3	x4	x5	x6	x7	x8	x9	x10
x1	r	-0.076	0.701**	0.243	0.297	0.499*	-0.148	0.391	-0.441*	-0.139
	p	0.742	0.000	0.288	0.191	0.021	0.523	0.080	0.045	0.548

r – Pearson correlation coefficient, p – p-value for the coefficient (two-tailed).
** – correlation significant at the 0.01 level, * – correlation significant at the 0.05 level.

The only variable that shows a fairly strong correlation with the level of separate collections of plastic bottles is the existence of a DRS for plastic bottles in a given country. A moderate correlation (with a significance of 0.05) was also found between the level of recycling of plastic bottles and the Human Development Index. There is also a moderate relationship between the European region a country belongs to according to the UN nomenclature (significance 0.05) – Eastern European countries had significantly lower rates of bottle separate collection. In the case of the other variables, the correlation was not statistically significant; this involved the municipal waste recycling rate, the welfare of a country measured as GDP per capita, and the Trust in Government Index.

Hierarchical cluster analysis was also carried out for qualitative and quantitative variables, which allowed to indicate similarities between the countries. The results are shown in Figure 4.

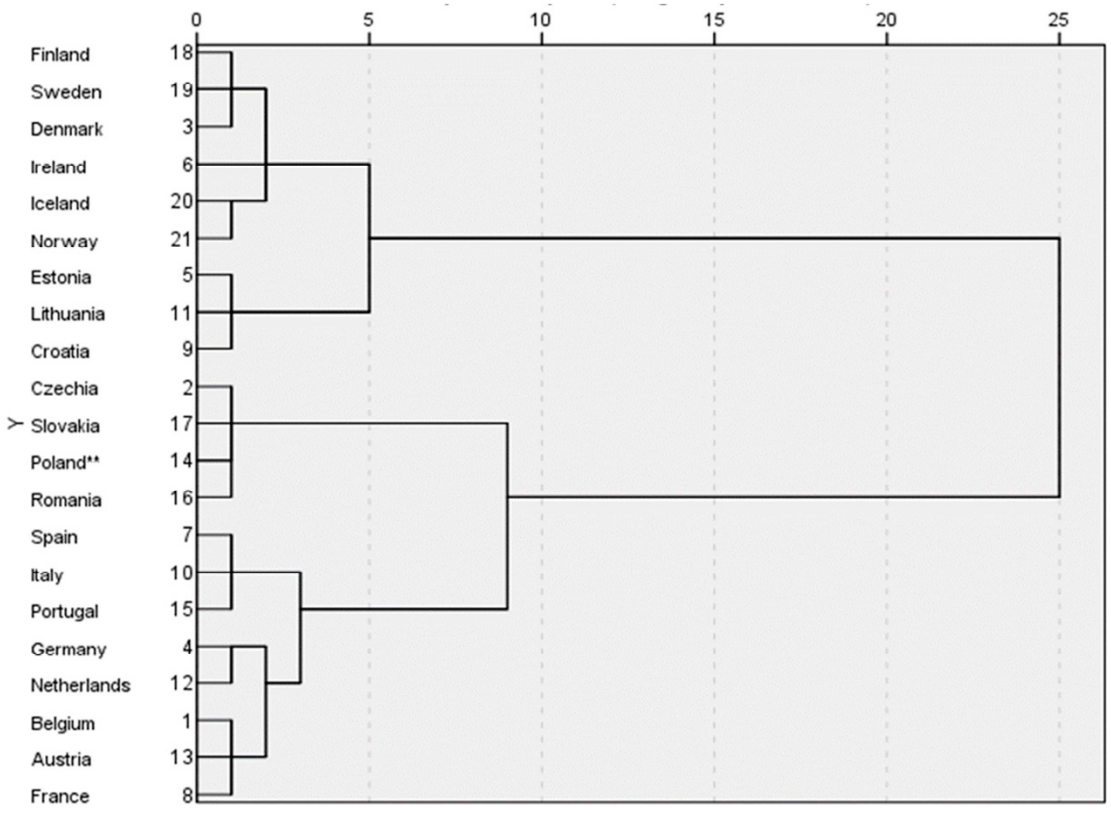

Figure 4. Dendogram using Ward linkage (for quantitative and categorical variables), distance rescaled

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The cluster analysis made it possible to distinguish five subgroups of countries with a similar configuration of the factors affecting the separate collection rate of plastic bottles, i.e.:

- Northern countries (Sweden, Denmark, Ireland, Iceland, Norway, Finland),
- Western European countries (Germany, Netherlands, Belgium, Austria, France),
- Southern European countries (Spain, Italy, Portugal),
- post-socialist Baltic countries (Estonia, Lithuania, and Croatia, which is not a Baltic state but is a post-socialist country),
- Central European post-socialist countries (Czech Republic, Slovakia, Poland, Romania).

Similar clustering was obtained in a scatter plot taking into account the rate of separate collection of plastic bottles, MSW recycling rate and the existence of a DRS (Figure 5).

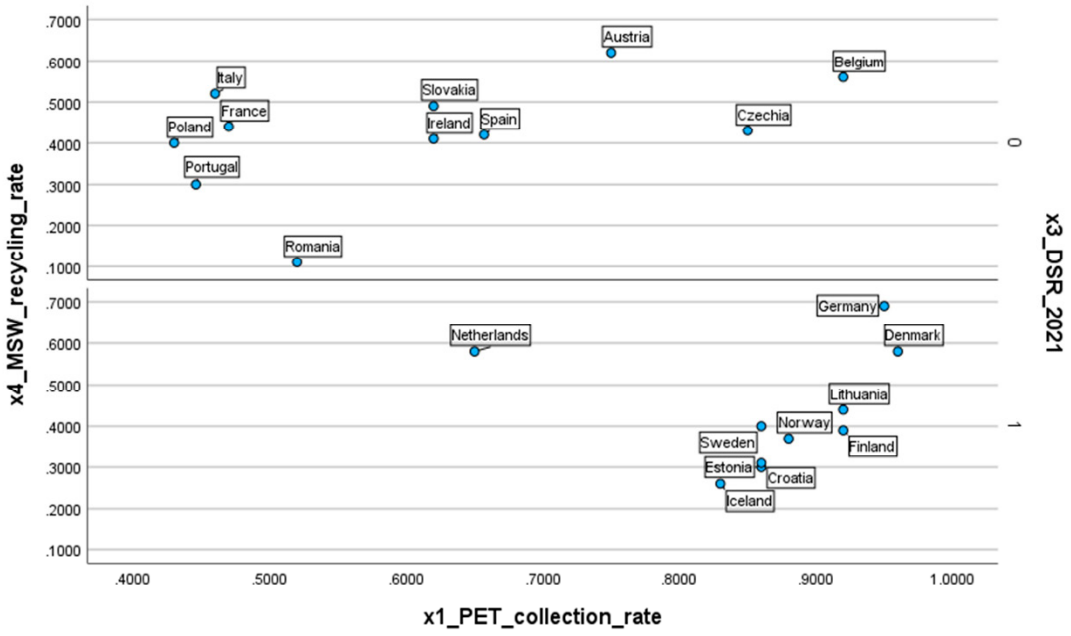

Figure 5. PET collection rate, Municipal Solid Waste recycling rate and DRS in EU countries

In all countries using DRS, the collection rate of plastic bottles exceeds 85%, with the exception of the Netherlands, where the scheme was voluntary in 2021. At the same time, high recycling rates of PET bottles covered by DRS are not necessarily accompanied by high levels of recycling of plastic waste and municipal waste in general.

There is a group of highly developed countries where a DRS is an element of a generally well-developed and effective waste management system: Denmark, Germany, and the Netherlands. Belgium is a special case in Western Europe; the collection rate of PET bottles exceeded 90% without a deposit system. This was achieved thanks to the unification of collection procedures on a national scale and the development of appropriate collection and sorting infrastructure. A similar situation exists in Austria, although the collection rate of plastic bottles is not that high (75%). In addition, in Spain, a PET collection rate of 66% was reported, which is close to the target of the set by the Directive for 2025. However, doubts are raised as to the reliability of these data, and there are also reports suggesting that 36% is more probable (Eunomia, 2024).

Exceptional examples among the Central European countries that joined the EU after 2004 and where DRS did not function in 2021 are Slovakia and the Czech Republic, where quite high levels of municipal waste recycling (49% and 43%, respectively), including plastic waste, were achieved without a deposit system.

In "transitional" countries – having both moderate municipal solid waste recycling rates and high rates of plastic bottle collection, if there is a deposit system, this means that other elements of the municipal waste management system require attention and that DRS operates within a system that

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does not necessarily meet the postulates of the circular economy. Sweden, Norway, Iceland, Estonia, Lithuania and Croatia are such cases: With DRS, the collection rate of plastic bottles is efficient, but in general, the recycling of municipal waste does not exceed 50%.

On the other hand, in the case of countries with moderately effective MSW management systems and moderate PET bottle collection rates but without DRS, it can be argued that the existing solutions have exhausted their effectiveness. The DRS, due to its effectiveness in achieving the separate collection and recycling targets for waste covered by the system, has significant potential to improve the performance of the waste management system as a whole.

Discussion and conclusions

Our analysis indicates that the existence of a deposit system is a key factor ensuring the development of the separate collection of plastic bottles and, consequently, their recycling (including for food purposes). Thus, our research hypothesis was positively verified. We expect that the introduction of a deposit system in Poland will contribute to the effective implementation of the separate collection target for plastic bottles set by the SUP Directive.

Poland is among the countries with a moderate level of municipal waste recycling (40%) and a moderate PET bottle collection rate (43%) without a deposit system. These results have been achieved within an Extended Producer Responsibility scheme for packaging that is based on competitive principles. As Colelli and co-authors (Colelli et al., 2022) concluded, such systems tend to achieve the set goals by reducing costs. In Poland, where in 2021 there was a minimum target of 22.5% recycling for plastic packaging according to the PPW Directive, and where the EPR system was designed in a way that motivates achieving goals at a minimum level, the consequence is that this goal is achieved to a large extent through the collection of PET bottles as the plastic waste stream that is easiest to collect.

The target of increasing plastic bottle recycling could also be achieved using measures other than DRS. Particular attention is paid to activities for socio-economic development and shaping public trust in government and local government institutions. As the OECD points out, low trust in governments is a threat to effective governance. Building trust in state institutions occurs by designing effective public services that meet the needs of a diverse population, making transparent policy decisions in the best social interest based on checks and balances between institutions, and ensuring public participation in decisions (OECD, 2024). Nevertheless, such processes are very long-term in nature. In the context of the SUP targets set for 2027 and 2029, the reconstruction of the waste management system towards a system based on public involvement and trust that the public authority is effective in achieving environmental objectives is unrealistic. Consequently, the authorities are forced to look for solutions to compel the public to behave in a desirable way. Such a tool in the field of waste collection is the deposit system.

The contribution of the authors

Conceptualisation, W.P. and E.S.-P.; literature review, W.P.; methodology, E.S.-P.; formal analysis, W.P., E.S.-P. and T.R.; writing, W.P., E.S.-P. and T.R.; conclusions and discussion, W.P., E.S.-P. and T.R.

The authors have read and agreed to the published version of the manuscript.

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CZY SYSTEM KAUCYJNY NA BUTELKI Z TWORZYW SZTUCZNYCH POZWOLI POLSCE SKUTECZNIE ZREALIZOWAĆ CELE DYREKTYWY SINGLE-USE PLASTIC?

STRESZCZENIE: Celem badania było przeprowadzenie analizy skuteczności wykorzystania systemu kaucyjnego jako narzędzia realizacji celów recyklingu i selektywnej zbiórki odpadów opakowaniowych z tworzyw sztucznych oraz budowy gospodarki obiegu zamkniętego w krajach Unii Europejskiej. Na tym tle ocenione zostały perspektywy skuteczności DRS w Polsce. Przeprowadzona została analiza korelacji pomiędzy poziomem selektywnej zbiórki butelek z tworzyw sztucznych, a dziewięcioma zmiennymi objaśniającymi. Wykorzystano także hierarchiczną analizę skupień. Pozytywnie zweryfikowano hipotezę badawczą, że system kaucyjny jest czynnikiem pozwalającym na skuteczną realizację celu selektywnej zbiórki butelek z tworzyw sztucznych. Tym samym można prognozować, że wprowadzenie systemu depozytowego w Polsce będzie czynnikiem pozwalającym na skuteczną realizację celu selektywnej zbiórki butelek z tworzyw sztucznych wyznaczonego przez dyrektywę Single-Use Plastic.

SŁOWA KLUCZOWE: system kaucyjny, butelki z tworzyw sztucznych, odpady opakowaniowe, dyrektywa SUP

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