

Plastic packaging waste statistics in function of EPR design

A DISSERTATION

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Abstract

Accurate plastic packaging waste generation statistics are foundational to the governance of the circular economy in the European Union (EU). Yet the dominant estimation method, which derives plastic packaging waste generation statistics from producer declarations collected through Extended Producer Responsibility (EPR) schemes, is structurally vulnerable to underreporting. This study examines the extent to which the organisational design of EPR schemes influences plastic packaging waste statistics across EU Member States.

For this purpose, three governance dimensions are analysed: market structure (single vs. competing Producer Responsibility Organisations, or PROs), profit orientation of PROs, and the degree to which Member States rely on EPR-generated put-on-market (POM) data for official Eurostat reporting. The analysis draws on Eurostat plastic packaging waste data covering 2005 to 2023, EPR governance classifications from EUROPEN (2025), and national reporting methodology information from Member State quality reports. Descriptive group comparisons are the primary analytical method covering 25 Member States, supplemented by Welch's independent samples t-tests for the market structure dimension.

Three main findings emerge. First, the average reported plastic packaging waste (PPW) generation and recycling volumes per capita between 2005 and 2023 is significantly higher for Member States with single (monopolistic) PRO systems compared to Member States with competing PROs. The difference in recycling rates does not reach statistical significance. Second, PRO systems operating with a for-profit orientation report lower average PPW generation per capita between 2005 and 2023 than non-profit systems. However, large within group variability limits interpretability. Third, Member States relying exclusively on EPR-generated POM data report lower average PPW generation and higher apparent recycling rates compared to those partially or not reliant on POM data. In terms of PPW recycled per capita, the differences are minor. The pattern is consistent with systematic underreporting embedded in EPR-based data collection.

The study concludes with two policy recommendations: mandatory cross-checking of POM data against independent sources, and strengthened independent auditing of PRO declarations. Both are grounded in existing provisions of the Packaging and Packaging Waste Regulation that await consistent national implementation.

Introduction

Global plastics production reached 460 million tonnes in 2019. Packaging is the dominant end-use application, accounting for 31% of global plastic use. Unfortunately, only 15% of plastics globally are collected for recycling in 2019 (OECD, 2022). In the EU, the challenge is acute. Member States collectively generated approximately 35.28 kilograms of plastic packaging waste per capita in 2023, up from 28.17 kilograms in 2005 (Eurostat, 2026). The reported EU-27 recycling rate stood at approximately 41.7% in 2023 (Eurostat, 2026). This is still shy of reaching the 50% target mandated for 2025 under the Packaging and Packaging Waste Directive 2018/852/EU (European Union, 2018).

To address plastic packaging waste, the EU has adopted an increasingly ambitious policy framework. The Circular Economy Action Plan identified plastic packaging as a priority area for intervention (European Commission, 2020). The revised Packaging and Packaging Waste Directive (PPWD) set binding recycling targets of 50% by 2025 and 55% by 2030 (European Union, 2018). The Packaging and Packaging Waste Regulation (PPWR) goes further. It introduces minimum recycled content requirements and strengthened harmonisation obligations across Member States (European Union, 2025).

Extended producer responsibility (EPR) is the primary mechanism for operationalising these targets, requiring all Member States to establish or update compliant EPR schemes by 31 December 2024 (European Union, 2018; Filho et al., 2019). Under EPR, financial and operational responsibility for managing post-consumer packaging is transferred from public authorities to the producers who place packaging on the market (Lindhqvist, 2000; OECD, 2016; Kripalani et al., 2025). In practice, most producers fulfil this obligation collectively through a Producer Responsibility Organisation (PRO), despite substantial heterogeneity in national law and systems (Di Foggia & Beccarello, 2022). A PRO collects fees from member companies, finances collection and recycling infrastructure, and reports packaging volumes to national authorities (Colelli et al., 2022; Kripalani et al., 2025). By differentiating the fees per material or characteristics like recyclability, PROs can encourage alternatives and, in some cases, even decrease overall packaging waste generation per capita (Joltreau, 2022).

A common method for estimating plastic packaging waste generation across the EU is the put-on-market (POM) approach. This approach treats the quantity of packaging placed on the market in a given year as equivalent to the quantity of waste generated in that year

(Somlai et al., 2023). Several Member States use these declarations as the basis for their official Eurostat reporting.

This creates a structural problem. As producer's fees are calculated against these declarations, there is a direct financial incentive to minimise reported quantities. Underreporting reduces the denominator against which recycled volumes are measured, inflating apparent recycling rates without any improvement in actual performance. Somlai et al. (2023) identify several mechanisms through which underreporting occurs: free-riding by unregistered producers, partial declarations to reduce fee obligations, double-counting due to ambiguity over supply chain responsibility, incomplete coverage of smaller producers through de minimis thresholds, and gaps in cross-border and online sales data. Other studies highlight that actual plastic waste generation could be higher compared to official statistics (Cimpan et al., 2021; Material Economics, 2022). In Finland, volumes outside the EPR reporting system amounted to approximately 19% of total plastic packaging placed on the market in 2020 (Jylhä et al., 2025).

The stakes extend beyond accurate waste statistics. The polluter pays principle requires producers to bear financial responsibility proportional to the environmental burden of their products. Where statistics are distorted by the governance design of the institutions producing them, that principle is compromised. Member States whose statistics underestimate waste generation may report recycling rates that overstate actual performance. Under the plastics own resource mechanism, introduced in January 2021, Member States contribute to the EU budget based on the amount of non-recycled plastic packaging waste, making accurate waste statistics a direct fiscal obligation (European Union, 2020). Moreover, overstated recycling rates undermine the comparability of national compliance records across Member States.

Against this background, the study addresses the following research question:

"To what extent does the organisational design of an EPR scheme influence plastic packaging waste statistics across EU Member States?"

Methodology

This study adopts a descriptive comparative approach to examine the relationship between the organisational design of EPR schemes and plastic packaging waste statistics across EU Member States. The analysis draws exclusively on publicly available secondary data. Consequently, findings are presented as indicative rather than conclusive. As a supplementary element, a Welch's independent samples t-test was applied to the market structure dimension to assess whether group mean differences reached significance thresholds. Welch's t-test was preferred over Student's t-test because of the difference in sample size ($n = 7$ for Single PRO systems; $n = 18$ for Competing PRO systems). Effect sizes were calculated using Cohen's d . Assumptions of approximate normality and homogeneity of variance were verified prior to testing and satisfied for all variables. Importantly, the statistical tests were performed on period-average values across 2005 to 2023.

The analysis proceeds in two stages. In the first, Member States are grouped by each governance variable and group averages are calculated for all three outcome variables at both reference years, for the period change, as well as the average between 2005 and 2023. This enables a descriptive comparison of the outcomes against governance classifications. In the second stage, Member States are grouped by the intersection of governance variables to assess how governance dimensions interact. As there are no for-profit Single PRO systems in the sample, only the intersection of market structure and reliance on PRO data for official reporting is explored. The findings from this second stage are treated as exploratory given the small number of countries in several combined cells.

The study covers the EU-27 Member States as its primary population, from which two are excluded, reducing the analytical sample to 25 countries. Croatia and Hungary operate packaging compliance systems built around state-administered environmental funds rather than PROs under a collective compliance scheme, which are the focus of the current study. The 25 Member States retained in the sample are listed in Table 1 alongside their governance classifications.

Table 1*Overview of Member States retained in sample and their governance classification*

Member State	Market structure	Profit orientation	MS use of PRO data
Austria	Competing PROs	For profit	Partial use of PRO data
Belgium	Single PRO	Non-profit	Full reliance on PRO data
Bulgaria	Competing PROs	Non-profit	PRO data not used
Cyprus	Single PRO	Non-profit	Full reliance on PRO data
Czechia	Single PRO	Non-profit	Full reliance on PRO data
Denmark	Competing PROs	For profit	PRO data not used
Estonia	Competing PROs	Non-profit	PRO data not used
Finland	Competing PROs	Non-profit	Partial use of PRO data
France	Competing PROs	Non-profit	Partial use of PRO data
Germany	Competing PROs	For profit	PRO data not used
Greece	Competing PROs	Non-profit	PRO data not used
Ireland	Single PRO	Non-profit	PRO data not used
Italy	Single PRO	Non-profit	Full reliance on PRO data
Latvia	Competing PROs	For profit	Full reliance on PRO data
Lithuania	Competing PROs	Non-profit	Partial use of PRO data
Luxembourg	Single PRO	Non-profit	Partial use of PRO data
Malta	Competing PROs	Non-profit	Partial use of PRO data
Netherlands	Single PRO	Non-profit	Full reliance on PRO data
Poland	Competing PROs	For profit	Full reliance on PRO data
Portugal	Competing PROs	Non-profit	PRO data not used
Romania	Competing PROs	For profit	Full reliance on PRO data
Slovakia	Competing PROs	Non-profit	Full reliance on PRO data
Slovenia	Competing PROs	For profit	Full reliance on PRO data
Spain	Competing PROs	Non-profit	PRO data not used
Sweden	Competing PROs	Non-profit	PRO data not used

Three categorical governance variables are operationalised for the comparative analysis. The first distinguishes between Member States in which a single centralised PRO holds an exclusive or dominant compliance mandate (Single PRO systems, $n = 7$) and those in which multiple PROs compete for producer membership (Competing PRO systems, $n =$

18). The second captures the profit orientation of PROs, distinguishing between predominantly non-profit systems ($n = 18$) and for-profit or commercially structured systems ($n = 7$). Both variables are derived from the EUROPEN Overview of Member States' EPR Schemes, published in October 2025 by the European Organisation for Packaging and the Environment (EUROPEN, 2025), which provides the most comprehensive and consistently structured comparative overview of national EPR scheme design currently available at EU level. Each classification was cross-checked against publicly available national sources, including the websites of national EPR authorities, national legislative summaries, and country-specific guidance published by the European Environment Agency. Where the EUROPEN overview and national sources diverged, the most authoritative national source was used, with the discrepancy noted.

The third governance variable measures the extent to which Member States rely on EPR-generated put-on-market (POM) data for their official Eurostat reporting of plastic packaging waste generation. It is operationalised from the national metadata quality reports that Member States submit to Eurostat under Commission Implementing Decision (EU) 2019/665 (European Union, 2019). These reports provide a self-reported percentage indicating the share of the official figure derived from EPR scheme data, which was used to construct a three-category classification: full reliance (100%, $n = 10$: Belgium, Cyprus, Czechia, Italy, Latvia, the Netherlands, Poland, Romania, Slovakia, and Slovenia), partial use (between 0% and 100%, $n = 6$: Austria, Finland, France, Lithuania, Luxembourg, and Malta), and non-use (0%, $n = 9$: Bulgaria, Denmark, Estonia, Germany, Greece, Ireland, Portugal, Spain, and Sweden).

The outcome variables plastic packaging waste generation per capita (kilograms per capita), plastic packaging waste recycled per capita (kilograms per capita), and plastic packaging recycling rate are drawn from Eurostat (Eurostat, 2026; Eurostat, 2026). The observation period spans 2005 to 2023, representing the range for which most data is available. Remaining missing values were completed using the last observation carried forward approach. The countries and years affected are Bulgaria (2020 and 2023), Cyprus (2023), Greece (2020), Poland (2020 and 2021), and Romania (2023). This approach is not expected to alter the findings given the small number of imputed observations relative to the full time series.

Findings

The 25 Member States show considerable variation across all governance dimensions and outcome variables. Table 2 provides an overview of the number of Member States at the intersection of market structure and profit orientation, indicating these two dimensions are not independently distributed. All 7 single PRO systems operate on a non-profit basis, while among the 18 competing PRO systems both profit orientations occur.

Table 2

Sample size for the intersection between market structure and profit orientation

	For profit	Non-profit	Total
Competing PROs	7	11	18
Single PRO	0	7	7
Total	7	18	25

With respect to reliance on EPR-generated POM data for official reporting and market structure dimension (see Table 3), Member States operating single PRO systems seem to rely more exclusively on EPR data to report plastic packaging waste generated, 71% of Single PRO Member States compared to only 28% of Member States operating competitive systems. However, it is important to note that of the 10 full-reliance Member States, 5 operate single PRO systems and 5 operate competing systems.

Table 3

Sample size for the intersection between market structure and MS use of PRO data

	Competing PROs	Single PRO	Total
Full reliance on PRO data	5	5	10
Partial use of PRO data	5	1	6
PRO data not used	8	1	9
Total	18	7	25

Before examining variation by governance category, it is useful to describe the distribution of the outcome variables across the full sample. Table 4 presents descriptive statistics for all three variables at the 2005 and 2023 reference years. The average reported waste generation across the 25 Member States increased from 26.86 to 33.17 kilograms per capita between 2005 and 2023, while the standard deviation narrowed from 11.18 to 8.80. This could indicate some convergence across Member States over the period. The average recycled plastic packaging waste per capita more than doubled from 6.10 in 2005 to 13.42 kilogram per capita in 2023. The average recycling rate rose from 22.40% to 41.21%. For both recycled per capita and recycling rate, the standard deviation remained broadly stable between 2005 and 2023, suggesting that Member States improved similarly.

Table 4

Mean and standard deviation for each outcome variable across retained Member States

Descriptive statistics	2005		2023	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Plastic packaging waste generated per capita	26.86	11.18	33.17	8.80
Plastic packaging waste recycled per capita	6.10	3.59	13.42	3.83
Plastic packaging recycling rate	22.40%	9.82%	41.21%	10.43%

Finding related to the dimension market structure

On average, plastic packaging waste (PPW) generated per capita is higher for single PRO systems ($M = 38.14$ kg per capita, $SD = 11.27$) between 2005 and 2023 compared to competing systems ($M = 22.47$ kg per capita, $SD = 7.51$). However, the gap in reported PPW generated narrowed considerably during the observation period. PPW generated for single PROs improved from 38.14 kg per capita in 2005 to 35.27 kg per capita in 2023. As opposed to the observed increase among Member States with competing PROs from 22.47 kg per capita in 2005 to 32.36 kg per capita in 2023. Based on the supplementary Welch's t-tests, applied to period-average values for each of the 25 Member States in the sample, the difference in PPW generated is statistically significant ($p = .010$) with a very large effect size ($d = -1.606$). Given the small size of the Single PRO group, these results should be read alongside the descriptive analysis rather than as a substitute for it.

Single PRO systems also report significantly more recycled plastic packaging waste per capita ($M = 9.42$ kg versus $M = 4.81$ kg; $p = .011$; $d = -1.474$). The pace of improvement between 2005 and 2023 is slightly higher for competing PROs. Between 2005 and 2023, competing PROs improved PPW recycled from 4.81 kg per capita to 12.73 kg per capita, while single PROs improved from 9.42 kg per capita to 15.21 kg per capita. A similar pattern is observed for the recycling rates of both groups. However, the difference in average recycling rates (26.2% for single PROs versus 20.9% for competing PROs) does not reach statistical significance ($p = .241$).

Table 5

Overview of outcome variables by market structure

Descriptive statistics		2005		2023		Mean over observation period
		<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	
Competing PROs	PPW generated per capita (kg)	22.47	7.51	32.36	5.58	22.47
	PPW recycled per capita (kg)	4.81	2.78	12.73	3.69	4.81
	PPW recycling rate (%)	20.90%	9.75%	39.60%	10.40%	20.9%
Single PRO	PPW generated per capita (kg)	38.14	11.57	35.27	14.65	38.14
	PPW recycled per capita (kg)	9.42	3.44	15.21	3.84	9.42
	PPW recycling rate (%)	26.24%	9.64%	45.36%	10.06%	26.2%

The primary differentiator between market structure types therefore appears to be the scale of operations rather than recycling efficiency. Single PRO systems handle substantially larger absolute volumes of both generated and recycled waste, yet their recycling rate advantage is modest. This pattern is consistent with a confounding effect of economic development, as Single PRO systems may be concentrated in higher-consumption Member States where waste generation is driven by factors independent of PRO governance design (Lorang et al., 2022).

Findings related to the dimension profit orientation

The comparison between non-profit and for-profit PRO systems yields a more nuanced picture. Member States allowing for-profit PROs consistently reported lower average waste generation: 22.16 kilograms per capita in 2005 and 32.58 kilograms per capita in 2023, compared with 28.69 and 33.40 kilograms per capita respectively for non-profit systems. The

PPW generated did increase more in the for-profit category. Notably, the reported PPW recycled is almost identical for both groups.

Due to the lower reported PPW generated and almost identical recycled PPW, Member states with for-profit systems reported a higher recycling rate between 2005 and 2023. By 2023, for-profit systems reached 42.3% and non-profit systems 40.8%. Non-profit systems achieved a larger improvement resulting from a smaller increase in PPW generated.

Table 6

Overview of outcome variables by profit orientation

Descriptive statistics		2005		2023		Mean over observation period
		<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	
For profit	PPW generated per capita (kg)	22.16	7.53	32.58	5.43	22.16
	PPW recycled per capita (kg)	6.10	3.24	13.60	4.14	6.10
	PPW recycling rate (%)	26.96%	10.39%	42.33%	13.10%	27.0%
Non-profit	PPW generated per capita (kg)	28.69	11.99	33.40	9.94	28.69
	PPW recycled per capita (kg)	6.10	3.80	13.35	3.82	6.10
	PPW recycling rate (%)	20.62%	9.29%	40.78%	9.61%	20.6%

Findings related to dimension reporting basis

The most consistent and substantively significant pattern in the analysis concerns the relationship between a Member State's reliance on EPR-generated POM data and its reported waste generation levels and recycling rates. Full-reliance Member States reported the lowest average PPW generation at both reference points: 24.88 kilograms per capita in 2005 and 29.05 kilograms per capita in 2023. Partial users reported 26.28 and 32.96 kilograms per capita respectively. Non-users reported the highest averages, at 29.44 kilograms per capita in 2005 and 37.90 kilograms per capita in 2023. The gap between the full-reliance and non-use groups widened from 4.56 to 8.85 kilograms per capita over the observation period.

The consequences for reported recycling rates follow directly. In 2005, the full-reliance group reported an average recycling rate of 24.6%, partial users 20.3%, and non-users 21.4%. By 2023, the full-reliance group reached 49.3%, partial users 33.2%, and non-users 37.6%. The full-reliance group thus records both the highest 2023 recycling rate and the strongest

improvement over the period. It is also notable that partial users record the lowest 2023 recycling rate of the three categories.

Table 7

Overview of outcome variables by reporting basis

Descriptive statistics		2005		2023		Mean over observation period
		<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	
Full reliance	PPW generated per capita (kg)	24.88	11.08	29.05	4.76	24.88
	PPW recycled per capita (kg)	5.82	2.92	14.34	3.34	5.82
	PPW recycling rate (%)	24.57%	10.38%	49.26%	8.42%	24.6%
Partial use	PPW generated per capita (kg)	26.28	12.45	32.96	2.73	26.28
	PPW recycled per capita (kg)	5.99	4.93	10.99	2.79	5.99
	PPW recycling rate (%)	20.28%	10.15%	33.20%	6.96%	20.3%
Not used	PPW generated per capita (kg)	29.44	11.29	37.90	12.48	29.44
	PPW recycled per capita (kg)	6.49	3.68	14.02	4.54	6.49
	PPW recycling rate (%)	21.39%	9.67%	37.61%	8.53%	21.4%

This pattern cannot be attributed to higher absolute recycling volumes alone. Full-reliance countries increased average recycled volumes from 5.82 to 14.34 kilograms per capita over the observation period. Non-users increased from 6.49 to 14.02 kilograms per capita, and partial users from 5.99 to 10.99 kilograms per capita. The differences in absolute recycled volumes across the three groups are modest relative to the scale of the recycling rate divergence.

The comparison indicates that the difference in recycling rates could be driven by lower reported waste generation denominators. This is consistent with past critiques on the put-on-market approach (Somlai et al., 2023). Exclusive reliance on EPR scheme declarations could suppress the reported generation figure through producer underreporting incentives, incomplete registration, and the treatment of cross-border sales.

Findings related to the intersection of market structure and reporting basis

The combined analysis, grouping Member States by the intersection of market structure and reporting basis, confirms that the full-reliance pattern holds across both PRO system types. Among competing PRO systems, full-reliance countries ($n = 5$) consistently reported lower PPW generated, 16.43 kg per capita in 2005 and 28.56 kg per capita in 2023. Partial

users within competing systems ($n = 5$) reported 21.95 kg and 33.02 kg per capita respectively. Non-users within competing systems ($n = 8$) reported 26.57 kg per capita and 34.32 kg per capita. Despite the differences in recycled PPW per capita, full-reliance countries also report the highest recycling rates in 2005 and 2023, as well as the observation period average.

Among single PRO systems, the 5 full-reliance countries' average reported PPW generation is again the lowest and even declined from 33.33 to 29.54 kilograms per capita. The remaining two reporting categories contain only a single country each and should be interpreted with particular caution. Luxembourg, the sole partial-use single PRO country, reported 47.93 kg per capita in 2005 and 32.62 kg per capita in 2023. Ireland, the sole non-user within single PRO systems, reported 52.41 kg per capita in 2005 and 66.53 kg per capita in 2023, the highest reported generation in the sample.

Table 7

Overview of outcome variables by market structure and reporting basis (Mean)

Market	Reporting	PPW Recycling rate		PPW generated		PPW recycled	
		2005	2023	2005	2023	2005	2023
Competing PROs	Full	23.1%	48.7%	16.43	28.56	3.82	13.85
	Partial	18.4%	32.1%	21.95	33.02	4.35	10.66
	Not used	21.1%	38.6%	26.57	34.32	5.72	13.32
Single PROs	Full	26.0%	49.8%	33.33	29.54	7.82	14.83
	Partial	29.6%	38.8%	47.93	32.63	14.18	12.65
	Not used	24.1%	29.6%	52.41	66.53	12.64	19.66

Across all three governance dimensions, the most consistent association in the data is between full reliance on EPR-generated POM data and lower reported waste generation combined with higher apparent recycling rates. Market structure and profit orientation show more moderate and compositionally complex associations with the outcome variables. All patterns are descriptive in nature and cannot be attributed definitively to governance design without controls for confounding variables.

Discussion and conclusion

The preceding analysis examined the extent to which the organisational design of EPR schemes influences plastic packaging waste statistics across 25 EU Member States, drawing on three governance dimensions and three reported outcome variables covering the period 2005 to 2023. The central objective was to explore the tension at the heart of EU plastic packaging waste governance: Member States rely on data for which there is a financial incentive to underreport. For 10 out of 25 Member States it is even the primary source of data. Where the governance design of the PRO does not adequately counteract that incentive through auditing or oversight, the statistical record of waste generation may be systematically incomplete. If this is the case, reported recycling rates may reflect the structural limitations of the reporting system as much as genuine improvements in waste management performance.

In summary, the analysis yields three key findings, of which the third is the most analytically significant and carries the greatest implications for EU waste policy. First, Member States operating single PRO systems consistently report higher plastic packaging waste generation per capita than those operating competing systems throughout the observation period, and also report higher average recycling rates. Supplementary statistical testing confirms that differences in waste generation and absolute recycling volumes between the two groups are statistically significant and carry large effect sizes. The difference in reported recycling rates does not reach statistical significance. The higher reported generation in single PRO countries is consistent with the argument that centralised systems operating under close regulatory oversight are better positioned to validate producer declarations and cross-check them against independent data sources. Another possible explanation is that single PRO Member States tend to be higher-income economies, which is correlated with high consumption (Lorang et al., 2022; Mullane et al., 2026).

Second, Member States operating for-profit PRO systems report lower average plastic packaging waste generation and a smaller improvement in recycling rates over the observation period than those operating non-profit systems. While this pattern is consistent with the theoretical expectation that commercial competitive pressure may erode the rigour of declaration auditing, the heterogeneity of the for-profit group limits the confidence with which a governance effect can be attributed to profit orientation specifically.

Third, Member States that rely exclusively on EPR-generated put on market data for their official reporting of plastic packaging waste generation report substantially lower waste

generation and substantially higher apparent recycling rates than those partially or not using EPR data. The gap in average recycling rates between the full-reliance group and the other groups increased, even though the difference in recycled PPW per capita was negligible. For this reason, the analysis indicates lower PPW generation denominators could be the driver of the higher recycling rate. This is also consistent with the structural underreporting mechanisms, including free-riding, incomplete producer registration, and the financial incentive to minimise declared volumes, documented in the literature (Jylhä et al., 2025).

This study makes two principal contributions to the existing literature on EPR governance and packaging waste statistics. Firstly, the theoretical case for underreporting in EPR-based POM systems is well established, and several country-level studies have identified concrete data gaps in national EPR datasets. This study contributes to this body of knowledge by systematically comparing EU Member States through the lens of governance design. It shows that the pattern of potential underreporting holds at the population level.

The second contribution is analytical. By distinguishing between governance dimensions (i.e., market structure, profit orientation, and reporting methodology) and examining their relationship with plastic packaging waste statistics, the study demonstrates that the reliability of packaging waste statistics is not uniform across EPR governance types. This finding has implications for how the EU assesses Member State compliance with recycling targets, as the current study indicates they may be less reliable than previously assumed.

The findings point to two concrete areas in which EU regulatory and institutional action could improve the reliability and transparency of plastic packaging waste statistics. The most urgent recommendation concerns the methodology for estimating plastic packaging waste generation. The current approach, which permits Member States to rely exclusively on EPR-generated POM data for official reporting, creates the risk for systematically underestimating plastic packaging waste generation. The PPWR and the revised Eurostat guidance already point in the direction of mandatory cross-checking between POM data and alternative sources such as waste analysis, production statistics, and trade data. Nevertheless, there is still a lot of potential for harmonisation. In any case, Member States currently relying exclusively on EPR data should be supported in developing the methodological capacity to apply complementary estimation approaches.

The second recommendation concerns PRO oversight and auditing. The analysis provides preliminary indications that governance arrangements associated with weaker oversight (i.e., competitive multi-PRO systems) are associated with lower reported waste generation in ways consistent with underreporting. Independent audits of PRO declarations, minimum verification standards for producer registration, and published coverage data could reduce information asymmetry between PROs and authorities. The PPWR provides the legal basis, but consistent national implementation is needed.

Limitations and directions for future research

The study's principal limitation is its descriptive nature. No controls are applied for confounding variables such as GDP per capita, infrastructure maturity, or consumption patterns. The governance associations identified can therefore not be treated as governance effects in a causal sense. The supplementary statistical analysis partially addresses this by testing whether observed group mean differences are robust to conventional significance thresholds. It does not, however, resolve the underlying problem. The tests were applied to period averages across 2005 to 2023, which obscures temporal dynamics and diverges from the reference year approach used in the main descriptive analysis. More importantly, the single PRO group contains only seven Member States, limiting statistical power and making results sensitive to individual country values.

A second limitation is the static governance classification. The EUROOPEN data reflect institutional arrangements as of October 2025, applied to an observation period beginning in 2005. Member States that reformed their EPR systems during this period are represented by their current rather than historical governance profile. This may distort the context in which earlier data points were generated.

These limitations point to two clear priorities for future research. The first is a panel data study that regresses reported waste generation and recycling rates on governance variables while controlling for structural confounders, using dynamic governance classifications that capture changes over time. The second is a more granular analysis of the reporting methodology variable. This should examine not only whether EPR data is used as the reporting basis, but the specific mechanisms through which coverage gaps are estimated and corrected. This would allow us to identify if more rigorous correction procedures are associated with closer convergence between reported and estimated actual waste generation.

More broadly, the findings underscore that the reliability of waste statistics is a function of the organisational structure that produces them. The accuracy of EU circular economy monitoring, the credibility of compliance assessments, and the integrity of the Own Resource mechanism all depend on the quality of these statistics. Ensuring that EPR governance design is aligned with reliable reporting should not be a technical footnote to waste policy. It is a foundational condition for the policy's effectiveness.

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