




 INSTITUTO NACIONAL DE ESTATÍSTICA
 STATISTICS PORTUGAL


 90 anos de rigor e inovação
 ao serviço da Sociedade


Estimating free-riding in plastic package waste

using placed-on-market and business turnover info

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Aim

Calculate non-recycled plastic packaging waste

- Since 2021, EU contribution is based on plastic own resource:
 - Reported plastic packages placed-on-market (POM)
 - Unreported plastic packages POM

Estimate unreported plastic packages POM

- Annual business turnover (TO)
- Reported plastic packages POM

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 Introduction > basic method

Establish ratio between reported POM and TO

- $k = \frac{POM_{reported}}{TO_{reported}}$
- $POM_{unreported} = TO_{unreported} \cdot k$

Estimate total plastic packages POM

- $POM_{total} = POM_{reported} + POM_{unreported}$
- $c = \frac{POM_{reported}}{POM_{total}}$

 Introduction > basic method

Procedure

1. Divide businesses in moderately homogeneous groups
2. Define k for each chosen group
3. Estimate POM of non-reporting businesses
4. Discard groups with low-chance of free-riding

Main assumptions

- Homogenization within businesses groups
- Non-reporters are free-riders
- Unavailable TO data (e.g. foreigner businesses) are negligible

Data > data source

From Portuguese Environment Agency

- Via Municipal POM from Producer Responsibility Organizations
- Via Non-municipal POM directly from producers

From Statistics Portugal

- Businesses TO from sale of goods and sale of products
- Number of employees (NOE)
- Economic activity classification with 5 levels (CAE)

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Methods > business groups

Creating groups of businesses

- Economic activity classification: A, C, G, I, N
- Number of employees: single, micro, small, medium, large

Groups characterization

- Main variables: POM, TO, k
- Summary statistics:
 - number of observations (n)
 - total sum (t)
 - summary statistics (\hat{m} , SD, CV)
 - robust summary statistics (\tilde{m} , IQR, RCV)

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Methods > business groups

Criteria for a well-defined business group

1. Representativeness in number of businesses
2. Representativeness in businesses turnover
3. Robustness of estimate of k
4. Homogeneity of estimate of k

Selecting groups for estimating free-riding

- Educated *ad hoc* selection (36 CAE x 5 sizes = 180)
- Threshold $c \geq 0.6$ ($POM_{\text{reported}} \geq 0.6 \cdot POM_{\text{total}}$)

Methods > ratio k per business group

Different approaches

- a) Ratio of totals per group, $k_{\text{total}} = \frac{\sum_i^n POM_i}{\sum_i^n TO_i} = \frac{POM_{\text{total}}}{TO_{\text{total}}}$
- b) Mean of ratios per group, $k_{\text{mean}} = \sum_i^n \frac{POM_i}{TO_i} / n = \sum_i^n k_i / n$
- c) Median of ratios per group, $k_{\text{median}} = \tilde{m} \left(\frac{POM_i}{TO_i} \right) = \tilde{m}(k_i)$

Advantage of using median of ratios

- Analyse ratios at microdata level
- Inform about quality of estimates (e.g. confidence intervals)
- Robust to large discrepancies

 Exploratory results > distribution of businesses
Distribution of reporting businesses (*n*)

CAE	2018	2019	2020	2021	2022
A	777	740	801	842	820
C	3707	3680	3740	3695	3622
G	3500	3439	3600	3559	3517
I	116	110	134	148	141
N	63	60	63	66	68
Other	388	374	371	366	357
Unknown	234	238	273	315	241
Total	8785	8641	8982	8991	8766

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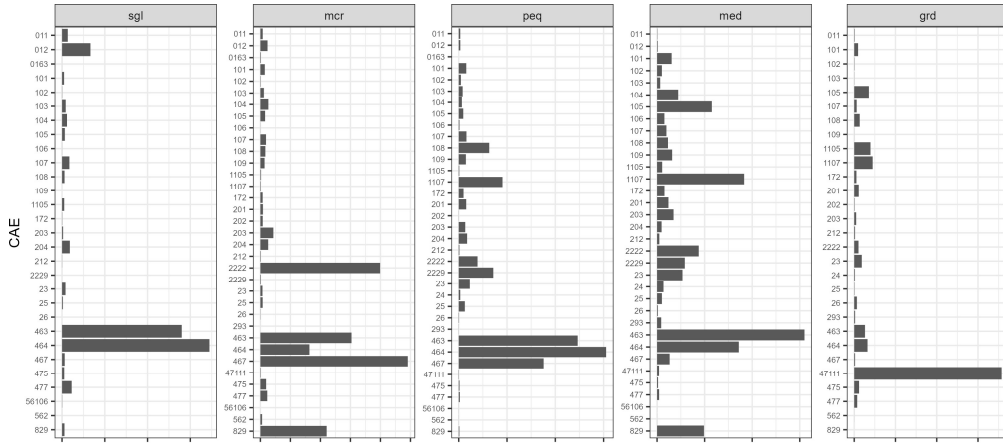
 Exploratory results > distribution of businesses
Distribution of reporting businesses (10^3 ton POM)

CAE	2018	2019	2020	2021	2022
A	0.7	0.7	0.9	0.9	0.9
C	91.8	94.2	93.7	90.5	93.5
G	125.8	130.8	123.8	130.1	135.1
I	0.2	0.2	1.0	0.6	0.8
N	4.5	4.5	4.3	4.3	4.7
Other	1.1	1.1	1.2	1.1	1.0
Unknown	1.3	1.4	1.4	1.7	1.3
Total	225.5	232.8	226.3	229.3	237.3

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Exploratory results > distribution of placed-on-market

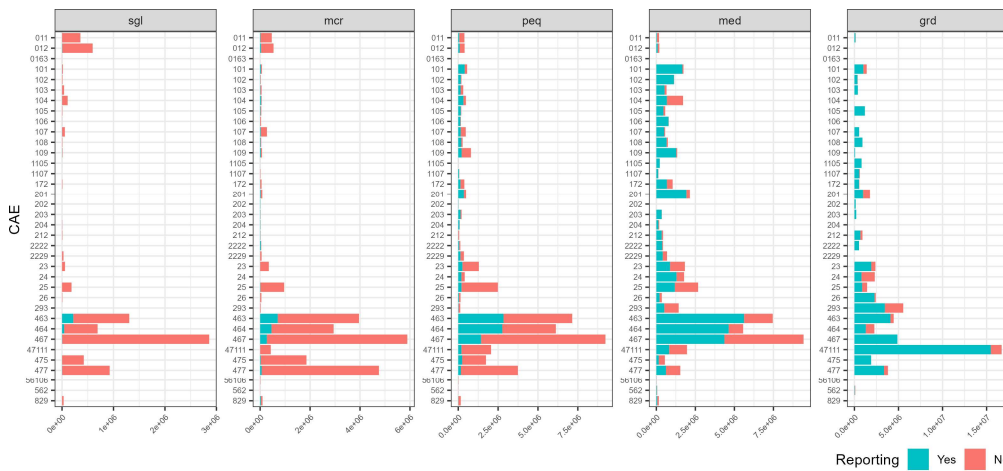
Potential free-riding in 2022 (ton POM)



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Exploratory results > distribution of turnover

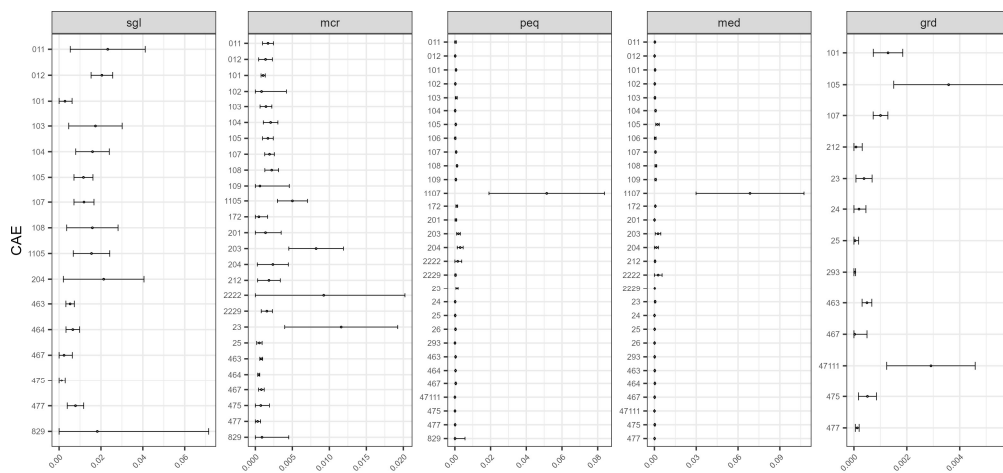
Potential free-riding in 2022 (10³ € TO)



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Exploratory results > distribution of ratio k

Potential free-riding in 2022 for $n > 4$ (kg/€ k)

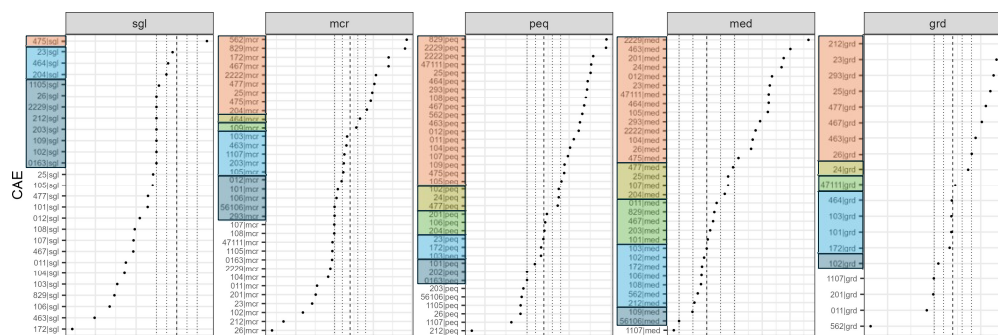


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Exploratory results > sensitive analysis of coefficient c

Free-riding estimation in 2022 (10³ ton POM)

c	$\geq 70\%$	$\geq 65\%$	$\geq 60\%$	$\geq 55\%$	$\geq 50\%$
Free-riding (%)	16.0 (6.3%)	17.8 (7.0%)	72.3 (23.3%)	82.5 (25.8%)	86.8 (26.8%)



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Exploratory results > estimating free-riding

Free-riding estimation (10³ ton POM)

	2018	2019	2020	2021	2022
Reported	225.5	232.8	226.3	229.3	237.3
Free-riding (%)	41.0 (15.4%)	43.1 (15.6%)	52.8 (18.9%)	51.2 (18.3%)	72.3 (23.3%)
Total	266.5	275.9	279.2	280.4	309.6

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Conclusions & Future work

Conclusions

1. Distribution of reporting businesses is consistent across years
2. Selection of CAE is robust across years
3. Info on POM of medium and large businesses is comprehensive
4. Estimates of k are robust in most business groups
5. Considerable sensitivity to parameter c
6. Estimates of free-riding are fairly consistent across years

Future work

- Heuristic approach to choose groups of businesses
- Avoid discarding groups of low-chance of free-riding

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Annexes > assumptions

- Complete data of municipality and non-municipality POM
- Nonoverlapping data of municipality and non-municipality POM
- T0 only from non-recycled plastic packages
- Complete data of T0 of national businesses
- **Non-reporters are free-riders**
- **Homogenization within businesses groups**



overestimation

- Negligible secondary economic activity
- No free-riding in discarded clusters
- **Unavailable T0 data (e.g. foreigner businesses) are negligible**

underestimation



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 Annexes > business groups

Categories of groups of CAE (Portuguese version of NACE)

	description	2 digits	3 digits	4 digits	5 digits
A	Agriculture, farming of animals, hunting and forestry	3	13	39	49
C	Manufacturing	24	95	230	332
G	Wholesale and retail trade; repair of motor vehicles...	3	21	91	124
I	Accommodation and food service activities	2	7	9	34
N	Administrative and support service activities	6	19	33	35

 Annexes > business groups

Categories of business sizes according to NOE

name	description	definition
sgl	Single-person businesses	NOE = 1
mcr	Micro-size businesses	$1 < \text{NOE} < 10$
peq	Small-size businesses	$10 \leq \text{NOE} < 50$
med	Medium-size businesses	$50 \leq \text{NOE} < 250$
grd	Large-size businesses	$\text{NOE} \geq 250$

 Annexes > business groups

List of potential free-riding CAE groups

NACE	Selected NACE groups
A	011__ ; 012__ ; 0163_.
C	101__ ; 102__ ; 103__ ; 104__ ; 105__ ; 106__ ; 107__ ; 108__ ; 109__ ; 1105_ ; 1107_ ; 172__ ; 201__ ; 202__ ; 203__ ; 204__ ; 212__ ; 2222_ ; 2229_ ; 23__ ; 24__ ; 25__ ; 26__ ; 293_.
G	463__ ; 464__ ; 467__ ; 47111 ; 475__ ; 477__.
I	56106 ; 562__.
N	829__.

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 Annexes > business groups

Thresholds for heuristic to choose groups of businesses

Statistics	variables	threshold
n	$POM_{reported}; To_{reported}; To_{unreported}; k.$	$n \geq 5$
n/n_{total}	$k.$	$n_i/n_{total} \geq 10\%$
t/t_{total}	$To_{reported}.$	$t_i/t_{total} \geq 20\%$
RCV	$POM_{reported}; To_{reported}; To_{unreported}; k.$	$RCV \leq 5$

- Number of observations (n)
- Total sum (t)
- Summary statistics (\hat{m} , SD, CV)
- Robust summary statistics (\tilde{m} , IQR, RCV)

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