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Moving towards a circular economy: economic impacts of higher material recycling targets*

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Abstract

The circular economy requires well-functioning waste management systems. In this regards, packaging waste management (PWM) plays a key role. The Italian PWM system bases on a consortium with operate in compliance with the extended producer responsibility. The key financial mechanism ruling the functioning of the system is the so-called environment contribution. This paper draws up potential socio-economic implications arising from higher recycling targets in the medium-term. Two scenarios are discussed: the baseline, which simulates the environmental contribution according to the current recycling rate along with the reference that reflects higher goals. Results suggest that higher recycling targets are associated with positive effects on job creation, production and value added by virtue of both direct and indirect effects. The application of the model has demonstrated significant positive socio-economic impacts achievable when defining new policies and regulations for the sector. Although limited to Italy, this paper serves as a reference for policy makers since environmental legislation and especially waste management policy deserve careful consideration in the light of the polluter pays principle and shared responsibility.

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Keywords: Material recycling, circular economy, waste management, sustainability, environment policy assessment

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1. Introduction

The efficient use of resources during their whole life-cycle including their recovery and recycling has become a prominent vehicle for maintaining production capacity and for investments in new economic activities and technology within the green economy chain. Thanks to the improved quality and quantity of available waste along with the development of the treatment plants, the secondary raw materials have become vital to the medium and long-term sustainability since the market for recycled materials is now able to create wealth under the circular economy framework. However, this also pose particularly thorny challenges related to the waste management systems. Recycling targets concur at driving the transition to a circular economy with well-known beneficial effects. Managing this transformational effort presents major challenges. In fact, recycling is a costly waste management strategy, particularly when compared to conventional land filling and disposal options [1]. This situation presents policy makers and industry with multiple new challenges, for which they need to develop new expertise.

Although Europe is engaged in a thorough reflection on how the objective of circular economy can be reached in an efficient way that is fully compatible with the jobs and growth agenda, the establishment of a common policy across European countries appears not to be achieved yet. Truthfully whereas at a European level recycling and recovery targets are the same, member states still enjoy a considerable degree of freedom with respect to the practical organization and management strategies adopted [2]. Prior research on suggests that economies will benefit from substantial net material savings and secondary materials use [3]. Nevertheless, the economic effects of recycling-related activities, as well as appraisals of economic policies promoting recycling has been only partially documented so far [4]. It is in this context that the Italian legislative framework set up a non-profit private entity financed primarily through a contribution applied to packaging sold by producers to users [5]. This paper sheds some light on the issue serving both policy-makers and the industry that shall organize operations accordingly. Accordingly, the research purpose is twofold. In fact, from a macro perspective we assess the impact based on national accounts representing supply and use of goods and services by the industry sector. In addition to this, we discuss the cost-efficiency of the Italian model that bases on a private consortium between companies producing packaging.

This paper is organized as follows: first, the current issues in packaging waste economic assessment are discussed, as well as ways to overcome some of the obstacles that deter the field's development. The following paragraphs define the field of our manuscript as well as the data collection and analysis methodologies. Next, main results from the study are presented and added to those of previous literature. This is followed by a comprehensive discussion. Our empirical analysis concludes with a discussion of implications, limitations, and potential extensions of the research.

2. Previous literature

The conceptualization of the link between economies and ecologies traces back to the sixties, see for example [6] or [7]. Both similarities and differences between the traditional and the circular economy model – which traces back to different schools of thought – have been well documented [8] also as per local development [9]. From an economic point of view, the ecological economists primarily introduced this concept [10]. Over the years, some prominent principles have emerged as identifiers: reduction, reuse and recycle [11]. Admittedly, waste management, due to the many tasks involved, the several origins of waste and the vast array of stakeholders is a fairly complex issue [12].

Many authors describe the characteristics of waste recycling systems [13] or compare institutional frameworks, recycling rates, green dot fees and, whenever possible, recycling costs and benefits [14]. Again, the packaging waste management arguably represents one of the most thought-provoking topic [15] of which a recent work analyzes similarities, trends and differences in eleven European systems with particular focus on the role of local authorities thus making a noticeable step towards international comparison [16].

Nevertheless, national systems vary considerably in design, in terms of influence of pre-existing policy and systems, methods of achieving producer compliance, fee structures, targets, waste stream prioritization and local authority involvement. Therefore, it may be argued that the financial costs and benefits of collecting and sorting packaging waste is not enough to carry out an assessment from a general welfare perspective [17]. Hence, the economic impacts in terms of the effects of recycling-related activities, has been only partially documented so far [4]. Focusing on Italy, this paper puts emphasis on the implications for the economy as a response of higher recycling targets set in Europe. Center of the Italian system in a national consortium. The consortium is supported by activities carried out by material consortia and is oriented towards cooperation with the public administration. The general principles ruling the system are the polluter pays i.e. the polluter pays for environmental damage in the form of a clean-up or taxation [18] and the shared responsibility [19] i.e. other players in the system hold part of the responsibility, and they should share the costs proportionally.

3. Research objective, methodology and framework

The research process consisted of two consequential phases which in turn were composed by sub-steps. The first phase corresponded to the estimation and forecasting of the environmental contribution. At the beginnings, we defined the variables to be included in the regression analyses. Official data were used to create our models: reports on budgetary and financial management, general packaging and packaging waste prevention and management program (PGP), specific packaging and packaging waste prevention and management program (PSP) as well as proprietary database used with permission. After that, we built and fine-tuned the models to perform the forecasts for each of the six materials. Once models fitted the data well we combined the results in such a way to obtain the aggregate environmental contribution. The estimates were generated using the well-known input-output analysis (IOA) approach through which we assessed the change in overall economic activity as the result of the corresponding change in the recycling sector. The study bases on a mixed methods research relying on both theoretical assumptions and statistical techniques and methodologies including procedures of case study analysis i.e. an empirical inquiry that investigates a phenomenon within its real life context [20] using more than one set of research methods [21].

This study foresees two scenarios: the first one (Baseline Scenario) predicts the environmental contribution up to 2020 according to current recycling trends and policies, while the second one (Reference Scenario) incorporates the marginal effects of higher recycling targets i.e. 45% in the case of plastic and 85% for paper respectively.

Since a long ago as the VI Environmental Action Program, the European Union (EU) defines the priorities and objectives of European environment policy [22]. In the context of the raw material initiative and in the following communications the recycling of waste is set as a key pillar along with other guidelines for sustainable growth [23].

The circular economy package contains measures covering the whole cycle: from production to waste management and the market for secondary raw materials [24]. No wonder that collection, especially separate urban waste collection continues to grow [14]. With the aim of achieving the recovery and recycling targets, the Italian legislative framework set up CONAI, the national packaging consortium that constitutes a unique case in Europe in terms of regulations, structure, and financial mechanism. The consortium encompasses and coordinates six material consortia for aluminum, cellular-base paper, glass, steel, plastic and wooden packaging. The system and the relations between main actors is represented in Figure 1.

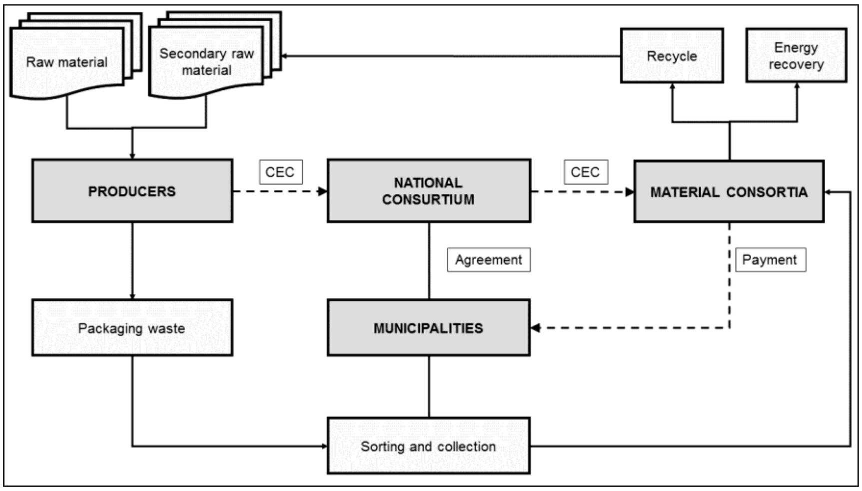


Figure 1: The system: material and money flows. Source: own elaboration based on [25]

The consortium is a non-profit private entity funded through the environmental contribution (CEC) applied to packaging sold by producers to users [5]. To place our study in a clearer context Table 1 presents a digest of operating results of the consortium.

Table 1: Packaging released for consumption, processed for recycling and recovery in 2014

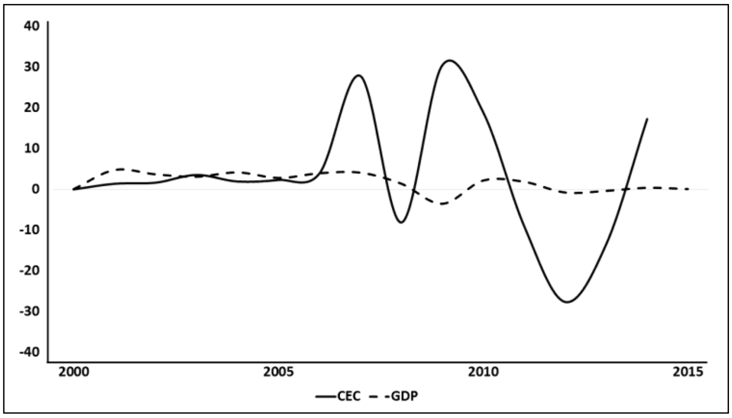
Material	Packaging released for consumption (Kt)	Packaging waste processed for recycling (Kt)	Share of recycled on released for consumption	Packaging waste overall recovery (Kt)	Percentage of overall recovery
Steel	452	336	74.30	336	74.30
Aluminum	63.4	47.1	74.30	50.2	70.30
Paper	4 378	3 482	79.50	3 859	88.20
Wood	2 578	1 539	59.70	1 626	63.10
Plastic	2 082	790	37.90	1 717	82.50
Glass	2 298	1 615	70.30	1 615	70.30

Source: [25]

The total packaging released for consumption amounts to 11 851 Kt, the packaging waste processed for recycling adds to 7 808 while the packaging waste overall recovery corresponds to 9 203 Kt.

4. Modelling the environment contribution

The contribution paid by producers of packaging is proportional to the quantity, to the weight and to the typology of the packaging material released for consumption, net of the amount of reused packaging in the previous year; it is calculated in terms of EUR/ton. The amount is irregular over time; in fact, there has been some volatility of such contribution as can be seen in graph 1 that shows the evolution in terms of yearly percentage change in comparison with gross domestic product. It is also possible to observe the instability of the contribution as from 2006; this is due to the weight of the plastic chain (roughly 75% of the total). In fact, the contribution referred to plastic changed dramatically to cope with financial shortcuts during the recent economic crisis reaching a peak in 2009-2010.



Graph 1: CEC and GDP evolution (yearly percentage change). Source: own elaboration

Firstly, we estimate the environmental contribution as per the material consortia end merge them into one in order to obtain the aggregate amount. Secondly, we use the results as an input in a general equilibrium macroeconomic model based on the IOA; this is done to capture both economic and social impacts of recycling targets on the light of different scenarios: the baseline scenario that means in line with current targets and the reference i.e. recycling rates with more ambitious targets. The statistical methodology used to study model the evolution of the CEC is the multiple linear regression of time series data.

4.1. Variables and models

The variables are defined as follows; first comes the dependent variable i.e. CEC that relates to Environmental Contribution (monetary). Second come the independent variables expressed both in thousands of tons and in euros accordingly. The Italian national packaging consortium annually compiles and provides the data and this guarantee data quality and integrity. Below the variables:

- CEC: Environmental Contribution. The consortium system is self-financing through the application of the CEC. The Contribution levies upon the so-called first transfer, which takes place when the finished packaging is transferred from the last producer to the first user within the national boundaries.
- RFC (released for consumption): quantity of packaging released for consumption. This quantity corresponds with the quantity of waste produced in the same year, thus, recyclable in order to reach the set targets. Actually, the mentioned targets are expressed as percentage of recovery on total packaging released for consumption;
- PFR (processed for recycling): quantity processed for recycling from the system. These quantities generate the costs of selective collection and sorting of packaging waste i.e. the main cost items for the chain consortia;
- rRC (ratio Revenues/total cost PFR): revenues from selling the recycled materials concur to bring down the economic need affecting the CEC amount. Quite the reverse, the cost for processing for recycling is the first CEC driver. Thus their ratio is a viable measure which contributes to the improvement of the model;
- CR (capital reserves). This variable appears only in the model related to plastic. The Environmental Contribution is closely linked to the amount of capital reserves of the consortia. When stocks tend to run out because of deficits, the CEC is set to increase and vice versa.

Provided the types of variables used in this paper, linear models provide adequate representation [26]. Consistently with common wisdom about the elements of this kind of forecasts, the information set corresponds to the described data, the projection date corresponds to 2015 and the forecast horizon is 2020. As anticipated, we first rely on a model with current (dependent) and one year lagged independents variables used as explanatory variables.

$$CEC_t = (X_{t-1} + Y_{t-1} + \cdots + Z_{t-1} +). \tag{1}$$

Eq. 1 is the generalized equation that is adapted to each material as indicated in eq. 2 in which n comprehends the six material consortia, t is the reference year while t_{-1} stands for the one-year lag.

$$m\_CEC_t^{1..n} = \propto + \beta_1(rfc_{t-1}^{1...n}) + \beta_2(pfr_{t-1}^{1...n}) + \beta_3(rrc_{t-1}^{1...n}) + \beta_4(cr_{t-1}^{1...n}) + \varepsilon \tag{2}$$

Since Eq. 2 generates the environmental contribution per each material, by combining the results, we get the aggregate environmental contribution Eq. 3 shows.

$$CEC = \sum m\_CEC \tag{3}$$

It is worth noting that the independent variables fall into all the six generated sub models but CR i.e. the variable referred to capital reserve, which only appears in the plastic related model as duly explained in the variable description.

4.2. Economic impact assessment

In this section, we assess the economic impact of higher targets in the Italian economy. Along with the baseline, we assess the socio-economic impact of the reference scenario. IO tables constitute the appropriate basis for many different types of economic analysis in this sense [27]. Precisely, IOA is an economic sub-discipline, that is especially conducive to the integration of technical information, because of the explicit way in which physical relationships are captured in the IO tables [28]. No wonder that the scholars have frequently analyzed the relationships between multipliers and specific economic sectors to calculate the impacts of shocks within specific sectors on the economy. These calculations allow an appropriate application of the Leontief demand model, thereby giving reasonable estimations about economic impacts under different conditions or hypothesis [29].

From an international perspective though there are few studies available that quantify the economic impact of specific waste management systems, because of lack of homogeneous IO tables within the same time frame.

The tables, provided by the Italian national statistics institute ISTAT, describe the domestic production processes and the transactions in products of the national economy in detail. The output of one sector becomes an input for another sector, which results in an interlinked economic system. In matrix form, an input-output table can be expressed as a sum of rows or columns: $x = aX + D$ and $x = xB = v$, with x being the total output and A the matrix of technical coefficients, B the matrix of allocation coefficients, D the final demand and v the primary inputs.

The table can be read by rows as a system of n equations: the sum of the columns of the matrix of technical coefficients as a measurement of the backward linkages a_i, while the sum of the rows of matrix of allocation coefficients as a measurement of the forward linkages b_{ij}.

Straightforward manipulations lead to $A = Z\dot{x}^{-1}$ (The point sign is used to convert a vector into a diagonal matrix). In the previous formulation, Z corresponds to a matrix (n x n) of intermediate inputs and in in the same way A defines a matrix (n x n) of technical coefficients A=[a_{ij}] where $a_{ij} = z_{ij}/x_j$ being z_{ij} the intermediate output of sector i to sector j. As a consequence, a_{ij} outlines the amount of output of industry i needed to produce an output unit of industry j and b_{ij} are the allocation coefficients that represent the share of the output of industry i sold to industry j over the total production of industry i. Moreover $B = \dot{x}^{-1}Z$ that is the matrix (n x n) of allocation coefficients corresponding to B=[b_{ij}]. Following this $b_{ij} = Zij/xi = a_{ij}\,(X_j/X_i)$. Starting from these bases the Leontief matrix can be drawn: $L = (I - A)^{-1}$ from which our assessment stems.

5. Results

A broadly positive assessment can be reached from Table 2. Even though some coefficients are not statistically significant the overall results are consistent with our purposes and seamlessly reflect the evolution of the actual CEC data as shown in Table 2.

Table 2: Regression output per material consortia

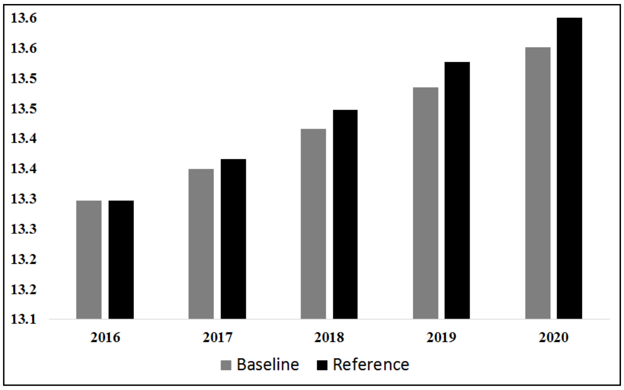
(One-year lag) Variable	(1) Plastic	(2) Paper	(3) Aluminum	(4) Steel	(5) Glass	(6) Wood
rfc_{pl}	-101	72.9**	98.841*	-43.990**	-30.108	-1.640
	(202.88)	(35.66)	(51.58)	(13.37)	(29.49)	(3.59)
pfr_{pl}	1303***	156.32**	192.92**	-4.406	63.861***	5.062
	(315.6)	(58.40)	(37.688)	(13.73)	(13.30)	(4.134)
rrc_{pl}	-1263	-598***	-61.35***	-82.253	-775.83	-219.98**
	(1856.6)	(169.47)	(14.93)	(98.32)	(605.49)	(84.66)
(cr_{pl})	-.77***					
	(.198)					
R^2		0.814	0.889	0.665	0.883	0.882
Adj. R^2		0.735	0.855	0.565	0.796	0.824

Source: own elaboration

Among the analyzed, plastic materials are the more complex with regard to the operations of selection and process to recycling and such difficulties reflect on the contribution. For this reason, a correct estimate of plastic-related contribution is essential to achieve a satisfactory goodness of fit of the overall model. Annex A.1 contains the series of data used to calculate the plastic sub-model. With respect to other materials, the sub-model related to plastic, contains an additional variable (capital reserves) that is essential to capture the volatility during the recent economic crisis that has impacted on the industry output and revenue streams. Turning to the paper chain, there is evidence that it is characterized by a high recycling rate and volatility of the variables related to revenues and expenses over time. Although the sale of materials covers a large part of operating costs, in recent years there has been a decline in the ratio revenue/costs. Annex A.2 contains the data used to calculate the paper-related model. The portion of the aluminum chain is marginal, about 1% of the total. The characteristics of the material, together with it usage in the industry are particularly suited for high recycling percentage and in the meantime negligible burdens for the consortium because of the sales. Annex A.3 contains the data used to calculate the aluminum-related model.

Steel chain shares some common characteristics with the aluminum as per the utilization. Nevertheless, the quantity released for consumption are higher and represents 3% of total. nnex A.4 contains the data used to calculate the steel sub-model. Moving on glass, one may note that the chain has always played an important role within the system; the glass-related share has constantly grown reaching 13% over the last three years as Annex A.5 shows. As concerns the wood chain in Annex A.6, it is worth noting, that it characterizes by a massive implementation of preventing measures such as reuse and regeneration. For the assessment of the economic impact of the Environmental Contribution on the Italian economy, we aggregate the estimates and forecasts set out for the individual sectors.

The model shows good accuracy in the complex. Graph 2 summarizes the outcomes in the mid-term highlighting the differences between the two scenarios: altogether the models suggest an additional expenditure of EUR 104.2mn. The impact of these two scenarios on the Italian economy, in terms of value added, employment, and total production are worth noting since these targets will underpin a more circular economy, while reducing environmental impacts and taking account of rebound effects on the environment.



Graph 2: Breakdown of CEC, baseline vs reference (values in log). Source: own elaboration

The graph put emphasis on additional CEC corresponding to the reference scenario as in Annex B. These additional resources are used to cover the additional costs consistently with the underlying paradigm of the graph is one of achieving socially efficient use of environmental resources by shifting the cost of negative externalities associated with resource use to users or polluters.

According to the statistical classification of economic activities in the European Community (NACE, Rev. 2), the Italian consortium falls into the division 38 "Waste collection, treatment and disposal activities; materials recovery". Provided the results of the models as per the share of the consortium turnover coming from the CEC and although it covers a relatively low percentage of the division (8%), one should note that the effects on the economy are thought provoking as explained below. Data presented in Table 3 are useful to compare the estimated values coming from the two scenarios and sheds some light on the total change, using 2015.

Specifically, Table 3 presents information regarding the effects on the demand, the impact on the job market in terms of units employed and finally the estimation regarding the value added. This is done according to the current goals i.e. the baseline scenario and in view of the new recycling targets, i.e. the reference scenario; the horizon is 2020.

Table 3: total output estimates up to 2020

	Baseline			Reference			Delta		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
P*	952.2	540.5	411.7	1148.6	651.7	496.87	196.5	111.3	85.0
E	3797.0	1776.0	2021.0	4381.0	2049.0	2331.0	584.0	273.0	310.0
V*	207.9	103.3	104.6	239.9	119.2	120.67	32	15.9	16.1

Source: own elaboration. P=production. E = employees, V = value added; * = EUR millions.

Table 3 presents a digest of main economic and social implications of the analyzed policy. Regardless of the point of views, it must be remembered that conceptually, social benefits arise for example income diversification opportunities for households and new economic opportunities, these opportunities fall into the indirect effects that as showed in the table represent a considerable share of the total impact. For example, the reference indirect impact sums to 43.26% as per the production, reaches 50.3% with respect to value added and raises to 53.3% as per the employment. Nevertheless, social costs can arise by imposing costs on pollution activities of businesses which cannot be off-set or passed on to customers. Results were used to develop our economic assessment using a consolidated approach. A comparison of the estimated model and the historic data indicates that the estimated model well describes real data. Overall, the examination shows that remarkable benefits in terms of job creation, value added and demand can arise in the mid-term as in Table 3. While results inspire a reflection about the adoption of a model based on private consortium between companies producing packaging, as a precaution such statement requires very thorough analysis and additional research. The results of this study will contribute to the discussion on the future of waste management and recycling programs and policies helping to better assess the implications in the mid-term. So, important efforts are needed to develop policies that allow progress to be made towards the EU targets, again, in view of the fact that environmental policy and especially waste management policy deserve careful consideration for both the composite nature of the problems to be dealt with and the technical solutions that are available [19]. In concrete terms from our analyses, we can define some recommendations to take into consideration when it comes to go from a general prospect to precise acts. To increase the system efficiency, it necessary to improve the quality of recovered secondary materials also by supporting the development of a more competitive market for secondary raw materials in such a way as to facilitate economies of scope and scale and create a more competitive business environment that allowed the development of a benchmarking framework. Policy makers shall support the investments in those companies and technologies capable of increasing the above mentioned efficiency. In addition, it must be remembered that poor comparisons across countries in prior research does not permit a straightforward extension of the results.

6. Conclusion

Recycling industry plays an important part in moving from a linear to a circular economy and higher recycling targets will prompt new challenges to waste management systems. We simulated the evolution of the CEC comparing two scenarios, the baseline where current trends were supposed to last in the next years and the reference scenario as with higher recycling targets. It was found that higher goals are associated with positive effects on job creation, production and value added. Although reported differences may appear negligible it should be stressed that this is because the outperforming current trends that are already over the established targets. Accordingly, there are positive outcomes due to of both direct and indirect effects on the economy. Although some limitations especially in terms of external validity the results can contribute to a wider economic impact analysis within countries which head to comparable targets. Some improvements could be added such as an integration with purely environmental benefits in an effort to provide a more comprehensive reference. Further research moreover shall focus on complementary equally important topics, to name but a few (i) the technological implications coming from improving green companies and related technologies that with operate in this industry (ii) implications for industrial policy analyzing, for example, the substitutional effects of secondary materials with regard on import of raw material and (iii) how higher recycling rates can contribute to reducing a country's dependence on imported raw materials and test (iv) whether and to what extent economies of scope exist.

Annex A. Historic data used to calculate the sub-models.

A.1. Plastic

Year	Released (Kt)	Recycled (Kt)	Revenues/costs (%)	Reserves (K€)	CEC (K€)
1998	1 800.00	310.00			
1999	1 850.00	396.00			
2000	1 900.00	526.00			125 800.00
2001	1 950.00	209.00	10.00		130 740.00
2002	1 951.00	299.00	6.58		130 457.37
2003	2 000.00	343.00	5.53		136 728.64
2004	2 054.00	344.00	7.89	64 529.00	137 865.48
2005	2 100.00	358.00	16.27	51 155.00	139 855.30
2006	2 202.00	380.15	19.86	41 804.00	145 139.93
2007	2 270.00	451.00	22.81	31 904.00	149 986.04
2008	2 205.00	496.00	28.11	18 590.00	145 388.32
2009	2 092.00	561.00	10.90	(25 866.00)	279 849.70
2010	2 071.00	602.89	30.68	8 931.00	333 562.00
2011	2 075.00	615.33	40.35	137 552.00	280 363.00
2012	2 052.00	610.00	30.89	223 017.00	217 465.00
2013	2 043.00	751.69	28.11	203 728.00	202 790.00
2014	2 086.00	815.75	25.43	136 361.00	263 298.00

A.2. Paper

Year	Released (Kt)	Recycled (Kt)	Revenues/costs (%)	CEC (K€)
1998	4 023.00	1 607.00		
1999	4 051.00	1 782.00		
2000	4 089.00	2 027.00		58 910.00
2001	4 160.00	445.00		59 872.00
2002	4 218.00	611.00		60 252.84
2003	4 208.00	720.00	0.96	61 166.22
2004	4 333.00	823.00	0.76	61 882.53
2005	4 315.00	924.70	0.01	61 513.78
2006	4 400.00	958.00	1.82	64 033.99
2007	4 619.00	978.00	28.03	125 508.87
2008	4 500.85	975.00	21.38	104 276.56
2009	4 092.00	1 018.00	0.08	81 866.35
2010	4 338.42	1 035.00	46.93	86 369.00
2011	4 436.20	905.00	80.15	86 858.00
2012	4 255.40	838.56	70.56	48 536.00
2013	4 107.00	819.71	62.72	24 039.00
2014	4 378.83	867.00	56.22	15 864.00

A.3. Aluminum

Year	Released (Kt)	Recycled (Kt)	Revenues/costs (%)	CEC (K€)
1998	57.00	7.00		
1999	58.30	15.10		
2000	59.20	17.90		3 950.00
2001	58.40	0.50		1 682.00
2002	59.80	1.10		2 415.29
2003	65.20	2.40	79.64	2 553.00
2004	67.30	4.30	93.17	2 607.00
2005	68.80	3.70	85.69	2 759.00
2006	71.50	5.00	98.16	2 821.00
2007	71.90	6.10	95.67	3 084.00
2008	66.50	6.30	87.95	2 960.00
2009	61.20	6.70	57.50	3 101.00
2010	64.20	8.19	87.74	4 760.00
2011	68.60	8.00	83.50	3 321.00
2012	68.50	10.08	83.65	4 473.00
2013	66.00	10.35	78.77	4 195.00
2014	63.40	11.20	86.97	4 267.00

A.4. Steel

Year	Released	Recycled (K ton)	Revenues/costs (%)	CEC (K€)
1998	600.00	27.00		
1999	618.00	44.00		
2000	600.00	97.00	8.63	8 920.00
2001	568.00	164.00	11.44	8 132.00
2002	566.00	232.00	6.99	8 553.23
2003	577.00	226.00	8.04	8 728.02
2004	606.00	224.00	12.63	9 135.28
2005	562.00	223.21	12.97	8 342.29
2006	561.38	226.47	9.12	8 333.89
2007	562.95	217.46	8.93	8 086.67
2008	536.98	209.00	13.91	7 527.63
2009	457.60	227.38	9.77	6 944.00
2010	504.32	211.75	14.27	13 689.00
2011	486.00	202.61	21.98	13 998.00
2012	439.99	200.00	29.87	12 864.00
2013	435.15	207.85	30.30	11 045.00
2014	450.49	223.36	52.51	13 394.00

A.5. Glass

Year	Released (Kt)	Recycled (Kt)	Revenues/costs (%)	CEC (K€)
1998	1 905.00	740.00		
1999	1 934.00	800.00		
2000	1 963.00	920.00		11 680.00
2001	1 993.00	230.00		12 932.00
2002	1 970.00	254.00		13 148.87
2003	2 107.00	393.00		13 516.02
2004	2 141.00	500.00		13 813.37
2005	2 117.00	603.00		13 641.78
2006	2 133.00	776.00	2.66	13 492.01
2007	2 156.00	821.00	2.45	28 177.75
2008	2 139.00	870.00	2.68	26 942.27
2009	2 065.00	956.00	0.28	23 397.53
2010	2 153.00	1 100.81	1.69	39 510.00
2011	2 314.00	1 171.00	3.98	46 897.00
2012	2 275.00	1 196.00	6.24	43 539.00
2013	2 255.00	1 230.23	11.74	42 170.00
2014	2 298.00	1 292.00	19.31	43 148.00

A.6. Wood

Year	Released (Kt)	Recycled (Kt)	Revenues/costs (%)	CEC (K€)
1998	2 360.00	880.00		
1999	2 396.00	910.00		
2000	2 479.00	868.00		6 180.00
2001	2 532.00	106.00		5 602.00
2002	2 603.00	429.00		6 471.47
2003	2 663.00	691.00		6 602.87
2004	2 787.00	643.00	35.95	6 807.81
2005	2 788.00	708.00	49.35	10 468.63
2006	2 852.00	829.23	44.96	10 931.82
2007	2 860.00	960.21	44.22	11 426.76
2008	2 720.00	920.00	28.81	10 376.62
2009	2 094.00	789.00	14.65	16 555.70
2010	2 281.48	907.06	21.13	17 555.00
2011	2 305.93	839.00	25.26	18 021.00
2012	2 283.00	693.00	20.88	16 787.00
2013	2 505.00	676.33	20.86	16 860.00
2014	2 577.66	757.16	20.41	17 117.00

Annex B: CEC, model (predicted CEC), baseline scenario and reference scenario, EUR millions.

Year	CEC	Model	Baseline	Reference
2005	255 094.40	267 105.38		
2006	265 230.78	294 197.49		
2007	350 250.87	319 240.97		
2008	322 968.31	362 091.54		
2009	437 782.73	403 773.47		
2010	528 578.00	512 856.42		
2011	482 840.00	495 575.87		
2012	366 415.00	368 171.17		
2013	320 316.00	304 652.02		
2014	380 650.00	369 426.78	369 426.78	369 426.78
2015			492 365.50	492 365.50
2016			595 730.40	595 654.30
2017			627 642.80	637 708.60
2018			671 065.70	691 817.20
2019			718 340.00	749 428.00
2020			767 638.80	809 936.40

References

[1] C. Lakhan, “Resources , Conservation and Recycling The relationship between municipal waste diversion incentivization and recycling system performance,” *"Resources, Conserv. Recycl.*, vol. 106, pp. 68–77, 2016.

[2] R. C. Marques, N. F. Da Cruz, P. Simões, S. Faria Ferreira, M. C. Pereira, and S. De Jaeger, “Economic viability of packaging waste recycling systems: A comparison between Belgium and Portugal,” *Resour. Conserv. Recycl.*, vol. 85, pp. 22–33, 2014.

[3] WEF, “Towards the Circular Economy : Accelerating the scale-up across global supply chains,” World Economic Finance, Geneva, 2014.

[4] P. van Beukering, O. Kuik, and F. Oosterhuis, “The Economics of Recycling,” in *Handbook of Recycling. State-of-the-art for Practitioners, Analysts, and Scientists*, E. Worrell and M. Reuter, Eds. Elsevier Inc, 2014, pp. 479–489.

[5] CONAI, “Packaging recovery in Italy : The CONAI System.” CONAI, Milan (IT), pp. 1–12, 2013.

[6] H. Daly, “On economics as a life science,” *J. Polit. Econ.*, vol. 76, no. 3, pp. 392–406, 1968.

[7] W. Isard, K. Bassett, C. Choguill, J. Furtado, R. Izumita, J. Kissin, E. Romanoff, R. Seyfarth, and R. Tatlock, “On the linkage of socio-economic and ecologic systems,” *Pap. Reg. Sci.*, vol. 21, no. 1, pp. 79–99, 1968.

[8] S. Sauvé, S. Bernard, and P. Sloan, “Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research,” *Environ. Dev.*, pp. 1–9, 2015.

[9] G. Di Foggia, “Steering the implementation of urban sustainability projects: Implications for policy,” *J. Environ. Manag. Tour.*, vol. 7, no. 1, pp. 5–20, 2016.

[10] K. Boulding, “The economy of the coming spaceship earth,” in *Economics, Ecology, Ethics: Essay towards a Steady State Economy*, H. Daly and W. H. Freeman, Eds. San Francisco, 1966.

[11] P. Ghisellini, C. Cialani, and S. Ulgiati, “A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems,” *J. Clean. Prod.*, pp. 1–22, 2015.

[12] M. Walls, “How local governments structure contracts with private firms: economic theory and evidence on solid waste and recycling contracts,” *Public Work. Manag. Policy*, vol. 9, no. 3, pp. 206–222, 2005.

[13] M. Rouw and E. Worrell, “Evaluating the impacts of packaging policy in The Netherlands,” *Resour. Conserv. Recycl.*, vol. 55, no. 4, pp. 483 492, 2011.

[14] D. Bianchi, “Eco-efficient recycling. The Italian recycling industry between globalization and the crisis challenges,” Edizioni Ambiente, Milano, 2012.

[15] M. Molinos-Senante, F. Hernández-Sancho, and R. Sala-Garrido, “Cost-benefit analysis of water-reuse projects for environmental purposes: a case study for Spanish wastewater treatment plants.,” *J. Environ. Manage.*, vol. 92, no. 12, pp. 3091–7, Dec. 2011.

[16] R. Cahill, S. M. Grimes, and D. C. Wilson, “Review Article: Extended producer responsibility for packaging wastes and WEEE - a comparison of implementation and the role of local authorities across Europe,” *Waste Manag. Res.*, vol. 29, no. 5, pp. 455–479, 2011.

[17] N. F. Da Cruz, P. Simões, and R. C. Marques, “Costs and benefits of packaging waste recycling systems,” *Resour. Conserv. Recycl.*, vol. 85, pp. 1–4, 2014.

[18] P. Glavič and R. Lukman, “Review of sustainability terms and their definitions,” *J. Clean. Prod.*, vol. 15, no. 18, pp. 1875–1885, 2007.
[19] G. Citroni and A. Lippi, “Pubblico e privato nella governance dei rifiuti in Italia [Public and private in the governance of waste management in Italy],” *Riv. Ital. di Polit. Pubbliche*, vol. 1, pp. 71–108, 2009.
[20] R. K. Yin, *Case Study Research, Design and Methods*, Fourth. Thousand Oaks: Sage Publications, Inc, 2009.
[21] A. G. Woodside, *Case Study Research: Theory, Methods, Practice*. Bingley, UK: Emerald Group Publisher Limited, 2010.
[22] A. Tencati and S. Pogutz, *Prevenzione e innovazione per una economia della sostenibilità [Prevention and innovation for a sustainable economy]*. Milan (IT): Egea, 2012.
[23] G. Di Foggia, “Effectiveness of Energy Efficiency Certificates as Drivers for Industrial Energy Efficiency Projects,” *Int. J. Energy Econ. Policy*, vol. 6, no. 2, pp. 273–280, 2016..
[24] European Commission, “Circular Economy Strategy Roadmap,” Brussels, 2015.
[25] CONAI, “Programma generale di prevenzione e di gestione degli imballaggi e dei rifiuti di imballaggio” Milan (IT), 2015.
[26] S. Becketti, *Introduction to Time Series Using Stata*, 1st ed. College Station: Stata Press, 2013.
[27] S. Suh, Ed., *Handbook of Input-Output Economics in Industrial Ecology*. London and New York: Springer, 2009.
[28] R. Lifset, “Industrial Ecology in the Age of Input-Output Analysis,” in *Handbook of Input-Output Economics in Industrial Ecology*, S. Suh, Ed. London and New York: Springer, 2009, pp. 3–22.
[29] L. Robles Teigeiro and B. Díaz, “Estimation of multipliers for the activity of hotels and restaurants,” *Tour. Manag.*, vol. 40, pp. 27–34, Feb. 2014.