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PACKAGING WASTE MANAGEMENT: FINANCIAL SUPPORT AND COST EFFICIENCY IN PORTUGAL AND ITALY

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Dissertation submitted as partial requirement for the conferral of

Master of Science in Economics

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Abstract

The dissertation focuses on the topic of packaging waste management and treats the subject from two different approaches. From a qualitative point of view, it aims to compare the compliance schemes implemented in Portugal and Italy and the model of calculation of the financial support to local authorities. Moreover, from a quantitative point of view, it aims to evaluate the relative cost efficiencies, in both its time invariant and time varying components, by means of stochastic frontier analysis. Regarding the first objective, the main difference between the financial transfers to the local authorities are the presence, in Portugal, of a factor evaluating the quality of the service; while, in Italy, the implementation of a progressive financial compensation, based on different bands for the quality of the waste collected. Furthermore, in the second part, a deterministic time invariant persistent cost efficiency and a stochastic time varying residual cost efficiency are estimated from two panel data, one for each country. The results obtained for the Portuguese system show a little impact of time varying inefficiencies and set the sector on an overall cost efficiency which is half the score of the most efficient firm in the panel. For Italy, the analysis detected a higher impact of time varying factors on the overall cost efficiency of the sector, which, on average, is about one third of the efficiency of the best entities.

Key words: Packaging waste, financial support, panel data, stochastic cost frontier.

JEL category: C33, Q53.

Resumo

A presente dissertação discute a gestão de resíduos de embalagens e analisa o tema a partir de duas abordagens diferentes. Do ponto de vista qualitativo, visa comparar os esquemas de conformidade implementados em Portugal e na Itália, e o modelo de cálculo do apoio financeiro às autoridades locais. Além disso, sob ponto de vista quantitativo, pretende-se avaliar as eficiências de custo relativas, nas suas componentes variantes e invariante no tempo, por meio da análise de fronteira estocástica. Em relação ao primeiro objetivo, as principais diferenças entre as transferências financeiras para as autarquias locais são a presença, em Portugal, de um fator de avaliação da qualidade do serviço; enquanto, em Itália, existe a implementação de uma compensação financeira progressiva, baseada em faixas diferentes para a qualidade dos resíduos coletados. No que respeita à segunda parte, uma eficiência determinística de custo persistente e invariável no tempo e uma eficiência residual estocática de custo, e variável no tempo, estimadas a partir de dois panel data, um para cada país. Os resultados obtidos para o sistema português mostram um pequeno impacto de ineficiências variáveis no tempo, e definem o setor com uma eficiência de custo geral que é metade do score apresentado pela empresa mais eficiente no panel. No que concerne a Itália, a análise detetou um impacto maior dos fatores variáveis no tempo na eficiência geral de custo do setor, que, em média, é cerca de um terço da eficiência da melhor entitade.

Palavras-chaves: Resíduos de embalagens, suporto financeiro, panel data, fronteira estocástica de custo.

Categorias JEL: C33, Q53.

Acknowledgments

I would first like to thank my supervisor, prof. Henrique Monteiro, for his continuous support and his guidance throughout the elaboration of this dissertation. His help and advice have been fundamental in the finalization of the analysis.

Secondly, I would like to thank my co-supervisor, Ms. Carla Pinto, for suggesting the topic and for her help in the collection of the data for the Portuguese system.

I would also like to thank my internship supervisor, Liliana, and the director of our department, Ms. Elvira Grilo Carlota, for their understanding and for allowing me to dedicate these last days to the conclusion of the dissertation.

Moreover, I could not have made it without the infinite support of Sofia and Nathália, always there for me in the most difficult times of this journey, helping me to stay positive and focused. My gratitude goes also to my flatmate Elisabete.

As they say, last but not least, I want to thank my family, my parents and my sister. If I have achieved these results, it is because I grew up with the outstanding role models that you are. Thanks for always supporting me in pursuing my goals. Thank you also to Anna, Benedetta e Alessandra, you made me who I am today.

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Abbreviations

ANCI – National Association of Italian Municipalities

APA – Portuguese Agency for the Environment

CAGERE – Committee for Monitoring the Management of Packaging and Packaging Waste

CIAL – Aluminum Packaging Consortium

COMIECO – National Consortium for Recovery and Recycling of Cellulose-based Packaging

CONAI – National Packaging Consortium

COREPLA – National Consortium for the Collection and Recovery of Plastic Packaging

COREVE – National Consortium for the Collection, Recovery and Recycling of Glass Packaging Waste

DEA – Data Envelopment Analysis

DGAE – Directorate General for the Economic Activity

DGEG – Directorate General for Energy and Geology

DKR – Deutsche Gesellschaft für Kreislaufwirtschaft und Rohstoffe mbH

DSD – Dual System Germany

ECAL – Liquid Packaging

EGF – Empresa Geral do Fomento

ERSAR – Water and Waste Services Regulatory Authority

FLSA – Financial Support to Local Authorities

GLS – Generalized Least Squares

IHPC – Harmonized Consumer Price Index

INE – National Institute of Statistics

IRAR – Water and Waste Regulatory Institute

ISPRA – Institute for Environmental Protection and Research

ISTAT – Italian National Statistical Institute

LCA – Life Cycle Assessment

LCIA – Life Cycle Impact Assessment

MSWM – Municipal Solid Waste Management

OECD – Organization for Economic Co-operation and Development

OLS – Ordinary Least Squares

PEAD – Plastic Polyethylene Packaging

PERN – Packaging Export Recovery Note

PERSU – Strategic Plan for the Urban Waste

PET – Plastic Polyethylene terephthalate Packaging

PPW – Packaging and Packaging waste directive

PRN – Packaging Recovery Note

RICREA – National Consortium for Recovery and Recycling of Steel Packaging

RILEGNO – National Consortium for the Collection, Recovery and Recycling of Wooden Packaging Waste

SGRU – System of Urban Waste Management

SIGERU – Integrated Management System for Agricultural Packaging and Residues

SIGRE – Integrated System of Management of Packaging Waste

SIGREM – Integrated System for Waste Medicinal Products and their Packaging

SIRAPA – Integrated System of Registry for the Portuguese Environment Agency

SIRER – Integrated System for Electronic Registration of Waste

SPV – Sociedade Ponto Verde

1. Introduction

Waste management, and in particular urban waste and packaging waste management, over the years became an always more recurrent topic in the field of environmental and resource economics.

As a matter of fact, centuries of economic growth and industrial development, without any serious concern about the management and recycling of waste, have left the world with the need to take urgent actions to restructure the world economy towards more sustainable production models. The poor management of waste has not only led to the pollution of the oceans, to the creation of conditions for the breeding of vectors[1] and transmission of diseases, and to the harm of animals which feed themselves on the residuals; but it also, affected directly the economy through, for instance, diminishing tourism.

The publication "What a Waste 2.0" of the urban development series by the World Bank (2018), reports that in 2016 2.01 billion tons of municipal solid waste were produced worldwide, with, at least one third not being managed in an environmentally safe manner. Developed countries generate about one third of the total waste in the globe, even though they account for only 16% of the global population. Based on the amount of waste produced and how it is managed, mainly due to landfilling without any sort of gas capture mechanism, the report estimates that about 1.6 billion tons of carbon dioxide were generated in 2016, around the five percent of the total global emission of greenhouse gases.

Moreover, of the total waste collected in the world, about 70 percent is disposed by landfilling or openly dumped, while only 19 percent is recycled or reused and only 11 percent is invested in energy recovering practices, such as incineration. The projections for the year 2050 are not much comforting. According to the report, municipal waste will grow to 3.40 billion tons, mainly pushed by the development of middle-income countries, which, according to the estimation, will lead to the emission of 2.6 tons of greenhouse gasses.

Worldwide, the European Union is one of the pioneers in urban and packaging waste management, as the data of Eurostat confirms ("Municipal waste statistics - Statistics Explained," 2018). In 2015 the amount of municipal waste generated per person was 477 kg, a decreasing trend compared to the all-time high 527 kg of 2002; in addition, 46 percent of this

[1] For instance, poorly managed solid waste management, left without a proper treatment, is one a common Ae. aegypti larval habitats, the vector of the dengue ("WHO | Environmental management," 2017).

waste has been recycled or, when applicable, composted. Moreover, the annual pro capita packaging waste generated was 116.3 kg, ranging from 51.2 kg in Croatia to the maximum of 222.2 kg in Germany, with Italy and Portugal both above average with respectively more than 200 kg and about 155 kg of packaging waste generated, with packaging in paper and cardboard representing the main packaging waste material, more than the double of glass and plastic packaging. Furthermore, over the 2006–2015 period, the generated quantities of paper and cardboard packaging waste and plastic packaging waste have slightly increased, respectively from 31.6 million tons to 36.4 and from 15 million tons to 16.3, while the ones of glass and metal packaging waste have decreased from 16.5 million tons to 16.2, and from 4.8 million tons to 4.5 ("Database - Eurostat," 2018).

The need for more efficient urban and packaging waste management systems has therefore climbed to the top of the priorities for the conversion to a sustainable circular economy, and while the treatment and disposal activities play a fundamental role in the process, it all begins with the collection activities. For this reason, the study will focus on the collection of urban solid and packaging waste in Portugal and Italy, on the incentive and subsidies given to the actors which perform the collection of packaging waste, and on the efficiency of the systems of collection of urban solid waste in the two countries. The choice of the two countries was mainly determined by the fact of comfortably understanding information in both national languages.

The dissertation will develop through three distinct main parts. A first block, with chapter one and two, which comprehends the present introductory chapter and the following, a review of the main literature on the specific areas of urban and packaging waste management, with a focus on the studies on the compliance schemes of European packaging waste management systems and on cost-efficiencies of urban and municipal waste management.

The second part will focus packaging waste. Through a qualitative descriptive analysis, it will first describe the institutional and legal framework, in chapter three, unfolding first the European system and the directives which regulate the packaging waste sector and the consequent implementation of such norms in the national legislations of Portugal and Italy. Moreover, chapter four will focus on the details of the compliance schemes applied to the two systems, with a special focus on the models of calculation of the financial support to local authorities (FLSA) and the rules and conditions which apply to these subsidies. In the last section of this chapter a brief comparison between the two countries will present the main differences between the packaging waste management strategies adopted in both countries.

Finally, the third part includes the quantitative analysis. The relative efficiency of the collection systems in the two countries will be evaluated through stochastic frontier analysis techniques. In this part, the subject of the analysis for Portugal will be expanded from the subset of packaging waste to the total urban waste collected. The decision of basing the efficiency analysis on this greater bundle of materials was taken given two main considerations. First of all, the actors who perform the collection of urban waste are the same who carry out the packaging waste collection; secondly, and as a consequence, the data available on the costs of the collection activities do not come disaggregated for each flow of material. For Italy, the quantities in the analysis, and the respective costs, are the five fractions of materials of packaging waste, yet they also include the external fractions of non-packaging waste of the same materials. This last part of the dissertation will first describe the methodology used in the analysis, followed by a section with the description of the data, and last it will present the results obtained from the analysis.

The closing chapter of the dissertation presents the conclusions that can be drawn from the analysis made in the previous sections.

2. Literature Review

In this literature review I present the main contributions made until today to the study of urban waste management, with a specific focus on packaging, and the efficiency of the collection systems. Afterwards, I will review the literature on European packaging waste management and in particular on the Portuguese and the Italian systems. Finally, I will state what the contribution of my research to the academic studies of such phenomenon.

The analysis of waste management has evolved through time since the 1970's with the creation of many models, which have been revisited and updated as new information became available and new challenges emerged. A small set of articles offer an exhaustive review of the modelling proposals introduced in the last century, namely: Gottinger (1988), MacDonald (1996), Berger, Savard, & Wizere (1999), Tanskanen (2000) and, more specifically, Morrissey & Browne (2004).

The first solid waste management models proposed in the 1970's where all focusing on the optimization of specific aspects of the system; for instance, vehicle routing in Truitt, Liebman, & Kruse (1969), where the authors estimate the number of daily truck routs as a function of the population density, the frequency of the pick-up of urban waste and the traffic haul distance, and it then simulates two scenarios, one with a collection schedule of two days per week, and the second with a triweekly frequency. In general the models of this decade were mainly dealing with the cost minimization of mixed waste management (Gottinger, 1988).

Berger et al. (1999) pointed out a few limitations of the model, such as the static time dimension limited to a single period and the general absence of recyclables, which makes it unfit for planning a long term management strategy (MacDonald, 1996). Almost all of the publications in this decade that actually dealt with recycling came from the United States, and they focused on the identification of the optimal rate between disposal of waste and its recycling (Plourde, 1972; Smith, 1972).

In 1980's the focus shifted to a wider range of aspects of Municipal Solid Waste Management (MSWM) systems through the expansion of the objective of previous models (Tanskanen, 2000) also to recycling operations (Englehardt & Lund, 1990; Kaila, 1987). Moreover, although the main issues that concerned the authors in this period were economic, some of them started to recognize the social issues linked to the optimization of waste collection (Morrissey & Browne, 2004). Finally, the great majority of previous models were only concerned with waste already generated, and not with measures to prevent its production (Morrissey & Browne, 2004).

Later, in the 1990's, recycling and other recovery methods (reuse, energy recovery and composting) were finally recognized as an important factor in the planning of MSWM, and were therefore introduced as variables in the great majority of the optimization models (Tanskanen, 2000). Moreover, the concept of Integrated Solid Waste Management[2] was developed towards the end of the decade, influencing the literature of the period which considered model which would permit to optimally choose the best management practice among a portfolio of options, for different flows of waste (Morrissey & Browne, 2004). Furthermore, in the end of this decade, the social dimension also started to be considered by a greater number of authors along economic and environmental aspects.

Finally, Morrissey & Browne (2004), in their work, divided the existing models for the study of solid waste management into three different groups: models based on cost benefit analysis, models based on life cycle analysis, and models based on multi-criteria decision analysis. Pires, Martinho & Chang (2011) gave a different classification in their extensive review on the analytical tools and techniques for solid waste management analysis, where they also reserved a specific section to the subject of packaging waste, among the overall topic of solid waste. They divided between cost-benefit analysis, optimization models, forecasting models, simulation models, and integrated modelling systems, appreciated by nine tools of analysis[3].

In the same decade, a few other important works were published in North America and Israel on specifically the efficiency of their waste management systems. Lavee (2008), as previously done for the United States and Canada (Plourde, 1972; Smith, 1972), inquired the optimal percentage of recycling with respect to disposal in Israel. Other authors focused on the search of economies of scale and economies of scope in recycling systems (Bohm, Folz, Kinnaman, & Podolsky, 2010; Callan & Thomas, 2001; Lavee & Khatib, 2010). Bohm et al. (2010) used quadratic functions and found economies of scales in 428 communities in the United States, as the average cost of disposal was always decreasing; Callan & Thomas (2001) focused on 110

[2] Integrated solid waste management is a comprehensive approach focused on a sustainable and optimum management of the resources available. The covers generation, segregation, transfer, sorting, treatment, recovery and disposal of solid waste in an integrated manner, with the aim of applying the best methods for minimizing the squandering of money and the unnecessary use of resources.

[3] The nine tools are: Management information system, decision support system, system and expert system; Scenario development; Material flow analysis; Life cycle assessment; Risk assessment; Environmental impact assessment; Strategic environmental assessment; Socioeconomic assessment; Sustainable assessment (Pires et al., 2011).

municipalities of Massachusetts and found constant return to scale for disposal and increasing return to scale for the recycling activities, and finally also in Israel some economies of scale were observed (Lavee & Khatib, 2010). The work of Bohm at al. (2010) is also important for its recognition of the determinants and the explanatory variables of the costs of waste managing, which also other authors have inquired (Bel & Fageda, 2010). Last, interesting is the work of Boskovic, Jovicic, Jovanovic, & Simovic (2016) who created a tool, a plug-in for Excel, for the calculation of a cost function for waste collection through the curbside system.

Focusing, then, on the studies on the efficiency of waste management in European countries, Soukopová, Vaceková, & Klimovský (2017) analyzed the differences between the cost efficiencies of 2056 municipalities in Czech Republic, and through the use of OLS regressors they concluded that private-public partnerships are the most expensive practices, while contracting out to a private company leads to cost reduction, especially for bigger municipalities. Rogge and De Jaeger (2012), in their paper, propose an adjusted version of the efficiency measurement technique data envelopment analysis to study 293 municipalities in Belgium; their model is particularly appropriate for the cases where it is not confirmed the importance of the material of the different fractions of municipal solid in the calculation of the total costs. Moreover, another study, this time with subjects the Spanish local authorities (Pérez-López, Prior, Zafra-Gómez, & Plata-Díaz, 2016) uses an interesting approach, a meta-frontier efficiency analysis, by means of order-*m* frontiers, to evaluate the efficiency of the different models of governance of the entities responsible for the operation of waste collection in solid waste systems. Their results showed that while private-public partnerships are generically the most suitable in their collection activities, inter-municipal cooperation is the best option for small municipalities and contracting out seems the best practice for the municipalities with more than 20,000 inhabitants.

Furthermore, the literature concerning directly European packaging waste management started indeed to appear only after the introduction of the directive of the European Commission 94/62/EC, known also as the Packaging and Packaging waste directive (PPW). Since its introduction, all member states have developed different management systems in order to meet the targets and the objectives of the new legislation, opening thus new horizons in the study of waste management. The Commission has produced and commissioned several reports on the effects and the results of the PPW directive, RDC-Environment & Pira International (2003) conducted an evaluation of costs and benefits for the achievement of the reuse and the recycling targets set in the directive. They proceeded with a cost-benefit analysis and a life cycle analysis in order to evaluate both the economic and the environmental effects of the new compliance systems in the EU15. Nevertheless, they pointed out how the cost-benefit analysis was not yet a mature instrument, specifically to quantify the environmental effects into monetary terms.

Besides the work of the commission, several authors have also studied the different systems developed in European countries. Larsen, Merrild, Mollet, & Christensen (2010) analyzed the environmental and economic impact of the Danish compliance scheme, they also used a cost-benefit and a Life Cycle Assessment (LCA) approach, yet they particularly focus on the environmental aspect of the problem, concluding with recommendations on the recycling targets that should be established in order to best improve the results of the LCA. A similar research was previously conducted by Emery, Davies, Griffiths, & Williams (2007) in Wales. Different is the approach chosen by Alwaeli (2010), where the author focuses on the product charges that producers of packaging and recycle operators would pay if recycling targets were not met, and he used this data together with the production and recycling rates to forecast whether or not the system would allow for an increase of the targets themselves. Another study, this time in Sweden, aimed to find the determinants of collection rates in Swedish municipalities using a regression model; their most surprising results were that the distance from the recycling centers, the population density and the urbanization rates all turned out to be statistically and economically insignificant (Hage & Söderholm, 2008), probably due to the diverse funds given to different municipalities.

One of the most prolific research projects on packaging waste management in Europe is, without a doubt, the EIMPack project. It is a research project located in the Technical Institute of the University of Lisbon and supported by the European Investment Bank, it concentrates mainly on seven European countries: Portugal, France, Germany, Romania, Italy[4] and Belgium, and has produced in-depth research reports and many articles on both single European countries (Cabral, Ferreira, Simões, da Cruz, & Marques, 2013; da Cruz, Simões, & Marques, 2012; EIMPack, 2014c, 2014b; Ferreira, Cabral, da Cruz, & Marques, 2014; Ferreira, Cabral, da Cruz, Simões, & Marques, 2014; Marques, da Cruz, & Carvalho, 2012), and comparative work as well (da Cruz, Ferreira, Cabral, Simões, & Marques, 2014; EIMPack, 2014a; Ferreira, Cabral, da Cruz, Simões, & Marques, 2017; Ferreira, Cambral, & De Jaeger, 2014). They have focused mainly on the description of the institutional framework in the countries subjected to their analysis, and on the environmental and economic effects of the

[4] The authors take into consideration the whole country when describing the industry and the compliance scheme implemented there, but when running the analysis, they take into consideration only the region of Lombardia.

recycling systems; yet, other authors produced studies dealing also with social impacts in Portugal (Ferrão et al., 2014). A description of the packaging waste management systems of Italy and Portugal is given in the respective reports (EIMPack, 2014c, 2014b), where the channels of financial support to local authorities are explained, and the policies of collection and sorting are described.

The methodology used by the team of researchers in their final report (EIMPack, 2014a), and throughout most of their publications, is a cost-benefit analysis, in this particular case integrated by Life Cycle Impact Assessment, aiming to also quantitatively measure the environmental impacts that the compliance systems have on society. Their analysis takes into consideration municipalities, or groups of municipalities, and separates the costs which the local authorities sustain for the collection and sorting operations from the benefits they gain. To calculate the costs, they collected data on the return on capital, depreciation of assets (both debt and equity) and operational costs, while the benefits are divided into a financial component, formed by the direct financial supports to the municipalities from either the Green Dot companies or public entities, subsidies to investments and other revenues which could come for instance from the sale of non-packaging waste. They then added an economic component which resembles the opportunity costs of dealing with the waste in alternative ways. Moreover, through the life cycle impact assessment they were able to quantify also the environmental impact of recycling, adding to the cost section the environmental costs of selective collection and sorting, while in the benefit section, the environmental opportunity costs saved with the compliance scheme, and the environmental benefit. According to the type of methods used in the LCIA the results they reached were different, the ones for the Portuguese situation were the following:

> *"In the economic and environmental balance achieved with the Ecovalue08 method, the benefits represent 137% of the costs. For the economic and environmental balance achieved with the Eco-costs2012 method the benefits amount to 196% of the costs. For the Stepwise2006 method the benefits covered the costs in 183% (…) The benefits from recycling represents 15, 35 and 60 euros per tons of packaging waste selectively collected attained for the Ecovalue08, Stepwise2006 and Eco-costs2012 methods, respectively."* (EIMPack, 2014a, p. 50)

Concerning the case of Italy, the authors were able to observe from their results that the system of the region Lombardia was sustainable whenever the economic and the environmental opportunity costs and benefits are included in the analysis. In such case, indeed, the benefits covered 197%, 218% and 202%[5] of the costs (EIMPack, 2014b). Nevertheless, the Portuguese and Italian recycling systems were found to be not sustainable whenever the economic perspective and the environmental impacts monetarized through LCIA were not considered (EIMPack, 2014a). The industry, as a matter of fact, is not completely recovering all costs through the systems of extended producer responsibility[6]. The results were also published in a separate article where it is suggested that the financial support to local authorities could theoretically be reduced as, taking into consideration the economic and environmental perspective, the countries proved to be sustainable (Ferreira et al., 2017). Moreover it was observed that the section of the benefits derived from the recycling of the sorted materials overcomes the costs derived from the selective collection and sorting activities, demonstrating thus not only the environmental advantages of recycling, but also its economic ones (Ferreira et al., 2017).

The Italian case has also been analyzed by Rigamonti, Ferreira, Grosso, & Marques (2015) who performed a similar study on the country, always running the analysis on the data of the region of Lombardia. The methodology they used is same cost-benefit analysis used in the EIMPack project, in this case without the integration of the environmental impacts, and, therefore, just taking into consideration the economic and the financial perspectives. They concluded, in accordance with (EIMPack, 2014b), that the industry, from a strict financial point of view, was not sustainable, the benefits overcame the costs only when the opportunity costs were taken into consideration. The authors concluded by giving some suggestions on how to improve the sustainability of the packaging waste management system, for instance, they proposed to calculate Green Dot fees on concepts of eco-design and financial support to local authorities on the efficiency and the composition of the waste collected. In the end, they introduced the idea of developing a system of Pay-As-You-Throw inspired on the Belgian model. Furthermore, an exhaustive description of the Italian consortium system of packaging waste management and its institutional and legal framework, both nation and inside the

[5] Once again, the value of the environmental impact varies according to the methods chosen for the Life Cycle Impact Assessment. The three values correspond respectively to the following methods: Ecocosts2012, Stepwise2006 and Ecovalue08.

[6] Extended Producer Responsibility is a concept introduced in the PPW directive, according to which the costs of the recycling activities should fall upon the producers of packaging themselves. Almost all member states thus implemented financing systems which allowed the municipalities to cover the costs which they burden. A different system has been put in place in the UK. For more on the European compliance schemes and the introduction of Extended Producer Responsibility: (Marques & da Cruz, 2015). For an exhaustive analysis on the concept of extended producer responsibility: Massarutto (2014).

European Union, is provided by Di Marcantonio Mosco (2012), alongside the analysis already made in EIMPack (2014b).

Finally, within the framework of the EIMPack project two other articles were published. The first reported the same cost-benefit methodology used in the studies presented above, but it portrayed a comparative analysis between the Portuguese system and the Belgian one (Ferreira, Cambral, et al., 2014). Using the results of a precedent article on the economic viability of the industry in Portugal (da Cruz et al., 2012), the authors performed the same analysis on Belgium, and aside from the technique used in the study, the article represents an exemplary comparative work on different European packaging waste management systems. Furthermore, Marques et al. (2012) proposed an efficiency analysis of the Portuguese recycling system performed with a non-parametric DEA methodology based on the model of Charnes, Cooper, & Rhodes (1978) with both oriented and non-oriented methods. Their results showed an inefficiency greater than 20%, possibly due to the lack of appropriate incentives to the municipalities from the financial mechanism of support (Marques et al., 2012), they therefore suggested that more incentives should be given to allow the development of the recycling segment. Another important result was the absence of economies of scale in the recycling market, and the lack of a dominant technology that could improve the performances of the agents.

To conclude, given the review above of the literature dealing with the topic of packaging and urban waste, this dissertation aims to fill the gap of the absence of efficiency analysis of the Portuguese and the Italian urban waste collection systems. Moreover, although several authors, and by last the EIMPack research team, have described the main features of the different management framework in the two countries, no one has given the proper attention yet to the models of calculation of the financial support to local authorities, and to the how those differ between countries. The dissertation will thus cover these two voids in the academic research on packaging waste management and on the efficiency of urban waste collection activities.

3. Institutional Framework

3.1. Communitarian Institutional Framework

The first European communitarian action concerning the implementation of a common strategy for the management of packaging waste was the directive 85/339/EEC. The directive introduced norms regulating the production, marketing, use, recycling, refilling of liquid beverage containers intended for human consumption, as well as rules for the disposal of such products. Despite its intention of encouraging the harmonization of the environmental policies across member states, the directive failed to discourage the development of different national management schemes for packaging waste across the European community (Marques, Cruz, Ferreira, Simões, & Pereira, 2013). As a result, barriers to the free movements of goods started to arise as well as challenges to the free competition due to the introduction of cheap secondary materials into the common market from countries with more evolved subsidized recycling schemes[7].

In the 90s, the directive 94/62/EC on packaging and packaging waste was adopted to overcome the threats to the common market[8] and to reduce the environmental impact of packaging waste (Marques et al., 2013). Establishing a set of common rules for the well-functioning of the internal market and progressive recovery targets for the transition to a sustainable circular economy, the directive widened its scope, as opposed to the directive 85/339/EEC, to both commercial and industrial packaging waste, as well as urban and household-originated waste. Although it requires member states to implement compliance schemes to achieve its target, and to prevent the production of packaging, as well as its final disposal, it leaves to each country the freedom to develop its own policies to meet the objectives of the directive.

The PPW directive also gave an exhaustive definition of what packaging and packaging waste are. Packaging is any product used to contain, protect, handle, deliver and present goods (both

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[7] For instance, the Danish government in 1980 prohibited the selling of beer and soft drinks in "one way" bottles and cans, allowing only for the use of licensed refillable containers. Then, in 1984, foreign producers were permitted to export beverages into the country in non-licensed containers, yet only up to a maximum quantity, while having to set up their own collection systems. Producers and trade groups from the other Members States complained directly with the Commission against the violation of the right to free movement for goods and the distortions to the competition regime (as the Danish producers could refill the packaging recovered and sell it in the common market) (Gehring, 1997).

[8] Article 18 Freedom to place on the market: "*Member States shall not impede the placing on the market of their territory of packaging which satisfies the provisions of this Directive.*"

raw materials and processed goods) from the producer to the user or consumer. It can be made of various materials, such as plastic, paper, cardboard, glass, metal or wood. It can be divided in primary, secondary or tertiary packaging: primary packaging consists in the packaging of a single sale unit at the point of purchase; secondary is that packaging which allows for grouping of several sale units at the point of purchase, and whose removal does not affect the product characteristics; tertiary packaging is the one which allows for a better transport or handling of either sale units or groups in order to avoid possible damages. It is then considered waste that packaging which falls under the general definition of "waste" given in the directive 75/42/EEC: any substance which the holder discards, intends or is required to discard.

Moreover, the PPW directive introduced recovery and recycling targets to be met by all member states. In its first version, at the time of its approval in 1994, countries were required to recover at least 50%, with a maximum of 65%, of the packaging waste produced and to recycle at least 25%, with a maximum of 45%, all by the end of 2001. Also, at least 15% of each packaging waste material had to be recycle within the same deadline. Finally, some exceptions were allowed, namely for Greece, Ireland and Portugal whose deadlines were postpone to the end of 2005, due to their socio-geographic features. The presence of many islands and rural communities would not make it possible to reach the goals set by the commission in time.

The directive 94/62/EC has then been amended several times[9], yet the acts in 2004 and 2015 brought the most relevant changes and innovations. With the Directive 2004/12/EC of the European Parliament and of the Council the definition of packaging has been updated with more criteria in the recognition of materials into this category. But, most importantly, new targets were introduced which incremented the percentages of packaging waste which each country should recover and recycle. These are the percentages still in place today. The amending directive rose the targets for recovery to 60% and for overall recycling to 55%, with a maximum of 80%, all to be achieved before the end of 2008; moreover, at least 60% of glass

[9] The directive 94/62/EC has been amended by the following acts:

- Regulation (EC) No 1882/2003 of the European Parliament and of the Council of 29 September 2003
- Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004
- Directive 2005/20/EC of the European Parliament and of the Council of 9 March 2005
- Regulation (EC) No 219/2009 of the European Parliament and of the Council of 11 March 2009
- Commission Directive 2013/2/EU of 7 February 2013
- Directive (EU) 2015/720 of the European Parliament and of the Council of 29 April 2015

and paper should be recycled, 50% of metal, 22.5% of plastic and 15% of wood[10]. Once again, Portugal, Greece and Ireland were able to benefits from an extension of the deadline until the end of 2011. New member states which entered the European Union in 2004 and later in 2007 have also gotten longer periods of time to meet the targets[11]. In 2015 the PPW directive was also amended by Directive 2015/720/EC of the European Parliament and of the Council which established a set of rules specifically for plastic bags.

One of the main innovations brought by PPW Directive is the concept of "extended producer responsibility": the idea that the costs of dealing with packaging waste should fall upon the producer themselves, and neither on local authorities nor consumers. The principle has also been introduced concerning the management of other flows of waste in the European Union, for instance residuals from used lubricants to batteries and packaging of electronic waste (European Commission, 2010). Moreover, the Organization for Economic Co-operation and Development (OECD) strongly recommends the application of the extended producer responsibility in waste sectors, not only for its effectiveness in reaching outstanding recycling targets, but also for its efficiency in promoting secondary markets (Massarutto, 2014; OECD, 2001).

Most compliance schemes adopted voluntarily or mandatorily, according to their national legislation, the trademark "Green-Dot", entering therefore in the so-called "Green-Dot system". The symbol is a protected trademark issued by PROEurope s.p.r.l., the packaging recovery organization Europe, founded in 1995 after the approval of the Directive 94/62/EC. The symbol was created with the intention of avoiding trade barriers within the common market, once it is the same for all countries[12] which joined the organization; if producers, to assure that the products were created in a systems based on the extended producer responsibility principle and aims to reach the recycling targets of the PPW Directive, were forced to use different national trademarks, this would be of obstruction to the imports and

[10] Wood packaging waste did not have a specific recycling target in the first version of directive 94/62/EC, only with the amendment of the directive 2004/12/EC member states are obliged to recycle at least 15% of the material.

[11] Deadlines for new member states: 31 December 2012 for the Czech Republic, Estonia, Cyprus, Lithuania, Hungary, Slovenia and Slovakia; 31 December 2013 for Malta and Romania; 31 December 2014 for Bulgaria and Poland; 31 December 2015 for Latvia; no deadline for Croatia until now.

[12] The countries whose national compliance schemes and licensed entities have joined PROEurope are the following: Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, France, Germany, Greece, Hungary, Ireland, Israel, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Turkey. In the United Kingdom, PROEurope has concluded a co-operation agreement with a similar system named "VALPACK".

exports in the Union. Although the use “Green-Dot” symbol does not appear as a mandatory practice in any of the European directives, its use brings an added value to the products, showing that thy were manufactured in a sustainable system. In order for manufacturers to attach the “Green-Dot” logo on their products, the entity licensed to manage the packaging waste flows in their country, to which the producers pay a fee, has to be a member of PROEurope; Italy is among the few countries where the compliance scheme implemented did not turn to the “Green-Dot” logo.

3.2. Portuguese Institutional Framework

The first normative act creating a system of solid waste management in Portugal was the Decree-Law n. 488/85 from the 25th of November. The decree implemented a framework of practices which included different actors in the systems: enterprises, ministries with competences on the subject, local authorities and final consumers.

Only a decade later, the regulation of the packaging waste sub-sector began with the incorporation into the national legislation of the Directive 94/62/EC by means of the Decree-Law n. 366-A/97 from the 20th of December[13]. The act brought to the implementation of the first Integrated System of Management of Packaging Waste (SIGRE) in 1998, the integrated system of packaging waste management, managed by the Sociedade Ponto Verde (SPV), with the aim of achieving the targets of the directive of the European Parliament and Council and introducing the producer responsibility principle. The Decree-Law was further amended by two legislative acts, namely the Decree-Law 162/2000 from the 24th of July and the Decree-Law n. 92/2006 from the 25th of May. The former equals the responsibilities of producers of urban and non-urban packaging as well as producers of packaging for the final consumer in the managing system, to solve some applicability issues of the old norms, brought to the Committee for monitoring the management of packaging and packaging waste (CAGERE) by the economic actors, while the latter Decree-Law modifies the recovery and recycling targets according to the new Directive of the European Parliament and Council 2004/12/CE.

[13] A previous act, the Decree-Law n. 322/95 from the 28th of November, already incorporated once the Directive 94/62/EC in the Portuguese legislation. However, it did not comply with the duty of notification stated in article 16 of the Directive and was replaced by the Decree-Law n. 366-A/97 form the 20th of December.

The main actor intervening in the market are mainly 4, the national waste authority, the sector regulator, the companies licensed to manage the system and the municipalities (Marques & da Cruz, 2015).

The Portuguese Agency for the Environment (APA), among all its sector of jurisdiction, is the highest authority related to the waste and packaging waste sector in the country. Its mission is to implement, monitor and support the national environmental strategies and promote a sustainable development. APA is responsible for issuing the licenses for waste management operations and for specific flows, moreover, it also own the operational and administrative control over the transfers of waste (EIMPack, 2014c). Furthermore, with the Decree-Law 178/2006 from the 5th of September, which incorporated the Directive of the European Parliament and Council 2006/12/EC, a new register of all packaging produced or imported and of the packaging waste treated or disposed was implemented, the Integrated System for Electronic Registration of Waste (SIRER), nevertheless, it has been later incorporated into the Integrated System of Registry for the Portuguese Environment Agency (SIRAPA), an integrated platform for data collection managed by APA. Producers of urban waste who employ more than 10 employees and enterprises which produce more than 1.100 liters of waste per day, must register to the platform (Marques & da Cruz, 2015); indeed, the SIRAPA also allows to observe the quantities of packaging waste produced.

The second actor in the system is the regulatory agency. With the Decree-Law 362/98 from the 18th of November the new statute of the Water and Waste Regulatory Institute (IRAR)[14] was approved, appointing to the institute regulatory competences, as states in the text of the act:

> *"(…) entendeu o Governo ser necessário substituir a figura do referido observatório por uma entidade reguladora com atribuições ampliadas no que se refere à promoção da qualidade na conceção, execução, gestão e exploração dos mesmos sistemas multimunicipais e municipais*[15]." (Decree-Law 362/98, preamble)

Only with the Decree-Law 207/2006 from the 27th of October that the IRAR was finally renamed in Water and Waste Services Regulatory Authority (ERSAR), the regulatory entity for water and waste services, with the prerogative to guarantee the structural regulation of both

[14] The Institute was created in 1995 with the Decree-Law 147/95 from the 21st of June, as an independent body with independence regarding budget and administration, however under the supervision of the Ministry of Environment, Planning and Regional Development.
[15] "the government believed necessary to substitute the insititute with a regulatory body issuing binding instructions to correct the irregularities found in the design, implementation, management and operation of multimunicipal and municipal systems under concession arrangements."

the water and the solid waste sector, contributing for a better organization and functioning of the markets and intervening in the definition of policies, among other objectives.

Furthermore, proceeding with another actor operating in the industry, there are currently three enterprises licensed for the management of the packaging waste sector: SPV, Novo Verde and Amb3e. They are responsible for the implementation of the extended producer responsibility principle and the creation of their own integrated systems of management of packaging waste (SIGRE); producers and retailers subscribe to these enterprises in order to delegate their responsibility to ensure the right treatment for the disposal of the packaging they produce or sell. In exchange, they pay a financial compensation for covering the costs of the activities and the services of the three actors.

The sector has been managed for years, since 1997, in a monopoly regime, with the only SPV owning the license to operate in the sector, and ensuring the recycling, recovery and take back of the packaging waste flows. The two other management entities have seen their license approved by the Ministry of the Economy and the Ministry of the Environment to enter the market only in the last couple of years. SPV had its license renewed in 2016 by the Order n.º 14202-E/2016 from the 25th of November, while Novo Verde was allowed to enter the sector with the Order 14202-D/2016 from the 25th of November; both licenses cease their validity in the end of 2021. Amb3e received the permission to operate in the managing of packaging waste in 2017 with the Order n.º 6907/2017 from the 9th of August, although it was issued a year later, with respect to the other two enterprises, it expires as well in the end of 2021. Amb3e, besides the activity in managing packaging waste, was also already licensed for managing the electrical and electronic equipment waste and batteries and accumulators waste; in this sense, it created the integrated system known as SIGRE-Electrão.

Moreover, two more entities operate outside the boundaries of the SIGRE, specifically VALORMED which is responsible for managing the Integrated System for Waste Medicinal Products and their Packaging (SIGREM) and VALORFITO which operates in the Integrated Management System for Agricultural Packaging and Residues (SIGERU). The first one was appointed in 2015 with the Order n.º 9592/2015 from the 24th of August, while the entity responsible for the packaging waste originated in the agriculture sector had its license approved in 2017 with the Order n.º 6560/2017 from the 28th of July.

The last main actors in the industry are the municipalities, which are legally the competent authorities for the management of urban waste conforming the Decree-Law n.º 178/2006 from the 5th of September, which transposed into national law the Directive n.º 2006/12/CE, and later amended by the Decree-Law n.º 73/2011 from the 17th of July. The local authorities have implemented municipal, inter-municipal and multi-municipal systems to meet their responsibilities with respect to the waste flows they are entitled to, either directly operating the services, with or without financial autonomy, or by delegating their competences to cooperatives and private companies through concession agreements. The municipal systems are usually in charge of the collection of retail packaging waste, while bigger systems take care of wholesale packaging waste, usually multi-municipal companies consist of partnerships between the public sector, represented by the Empresa Geral do Fomento (EGF), and the municipalities which the system covers (Cabral et al., 2013). On the Portuguese territory, in 2014, were operating 12 multi-municipal organizations, 8 inter-municipal companies, 4 associations of municipalities, and one private enterprise which was allowed to operate in the system (Marques & da Cruz, 2015). Today there are 12 multi-municipal organizations and 11 inter-municipal companies, each one of them constituting its own System of Urban Waste Management (SGRU). While in the past the partnerships were owned in majority by the EGF, making thus the entities managing the multi-municipal systems mostly public, lately a considerable injection of private capital in the sector has caused the EGF to lose the majority of equities in the partnership, opening the sector to the privatization (ERSAR, 2017).

Finally, a peculiar aspect of the Portuguese normative system is that, with the Decree-Law 152-D/2017 from the 11th of December, the management of all specific flows of residuals have been regulated by the same code of rules which applies to the management of the specific flows of packaging wastes.

Moreover, one of the main features of the Portuguese institutional framework, which differentiates it from the other continental schemes implemented in other European member states, is the fact that once the packaging residuals are transferred from the municipalities to a company licensed to operate in the sector, it also legally transfers the property rights on the residuals, which come to belong to the company managing them.

3.3. Italian Institutional Framework

The first Italian legal framework dealing with waste residuals was the Order of the President of the Republic n.ª 915/1992 from the 10th of September. The framework separated the competences of the central state from the ones of regions, districts and municipalities, but it did not promote practices of recycling or reuse, practices not considered in the normative text. For this, and other reasons, the different governments had to directly intervene to adjust several aspects of the framework created.

Furthermore, the PPW Directive 94/62/EC was transposed into the Italian legislation with the Decree-Law n.º 22/1997 from the 5th of February[16], which established the CONAI packaging waste managing system. It was later substituted by the Legislative Decree n.º 152/2006 from the 3rd of April, known also as the Consolidated Bill on the Environment, which unifies in the same normative text all the legislation which applies to the different sectors which affect the environment.

The National Packaging Consortium (CONAI) is a consortium of companies, which, according to its website, today are more than 850,000, producers of packaging and, according to art.º 224, number 1, of the Consolidated Bill on the Environment, has a private legal status and it is a no-profit body, ruled by its own statute approved by the Ministry of the Environment and the Ministry of Economic Development. The Statute is inspired by the principles of transparency, effectiveness, efficiency and fair competition and defines the nature, the objectives, the competences and the duties of the Consortium.

The CONAI, as indicated in art.º 224, number 3, of the Consolidated Bill on the Environment, and previously in art.º 41 of the Decree-Law n.º 22/1997, is responsible for:

a) The definition, together with the local authorities, of the spatial divisions in the integrated system for the collection, the sorting and the transportation of the materials collected through differentiated collection to recovery or sorting centers;
b) The definition, together with the local authorities, of the general conditions for the pick-up, by the producers, of the selected waste arriving from the differentiated collection;
c) The elaboration and, consequently, update of the "General program for the prevention and the management of packaging and packaging waste";
d) The conclusion of programming agreements with the economic actors to encourage the recycling and the recovery of packaging waste, and guarantees their implementation;
e) Acting as guarantor and compulsory body between its subordinated Consortia and the other economic actors; especially in the repartition of the environmental contribution;

[16] Which also transposed the Directive on Waste 91/156/CEE and the Directive on Hazardous Waste 91/689/CEE.

f) The orientation and guarantee of the necessary link between local authorities, consortia and other economic operators;
g) The organization, together with the local authorities, of the informative campaigns considered useful in the implementation of the "General program";
h) The repartition between producers and users of the burdens of the differentiated collection, of recycling, of the recovery of packaging waste, proportionally to the total quantities, weight and category of the packaging materials, net of the quantities of the packaging used and reused in the previous year for every category of material, determining and charging members with the environmental contribution;
i) The promotion and the co-ordination with the management of other waste flows;
j) The incentive and the promotion of volunteer agreements between the consortia and the alternative systems of packaging waste management;
k) The transmission to the National Observatory for Residuals of data and information when required;
l) The acquisition form public and private entities, national or foreigner, of data related to the flows of packaging waste in entrance and in exit from the national territory and the data of the economic operators involved[17].

The article 223 of the Consolidated Bill on the Environment also created the legal basis for the formation of consortia *ad hoc*, where each consortium is responsible for managing the operations related to a specific material of packaging waste. All Consortia are independent no-profit bodies, ruled by their own statutes, approved by the competent ministries, and internal regulation, in similarity with CONAI, and all are constituted by the companies producers of packaging and possibly by recyclers and collectors, with previous agreement by the members of the consortium (Di Marcantonio Mosco, 2012). They are: the National Consortium for Recovery and Recycling of Steel Packaging (RICREA) founded 1997; the Aluminum Packaging Consortium (CIAL) founded in 1998; the National Consortium for Recovery and Recycling of Cellulose-based Packaging (COMIECO) founded in 1998; the National Consortium for the Collection, Recovery and Recycling of Wooden Packaging Waste (RILEGNO) founded in 1998; the National Consortium for the Collection and Recovery of

[17] The last competence was introduced into the Consolidated Bill on the Environment, in its art.° 224, by means of the second corrective Decree n.°4/2008, and, in accordance with the art.° 178, number 1, it is considered, together with the collection, elaboration and use of the data from CONAI, an activity of relevant public interest pursuant to the art.° 53 of the Legislative Decree n.° 196/2003 from the 30th of June (Di Marcantonio Mosco, 2012).

Plastic Packaging (COREPLA) founded in 1997; and the National Consortium for the Collection, Recovery and Recycling of Glass Packaging Waste (COREVE) founded in 1997.

The six Consortia are not member of CONAI, which does not have any direct or indirect control over them, as confirmed by the Answer of the 9th of June 2005 by CONAI to the Italian Antitrust Authority, which inquired the needing of such a structured sector facing the absence of market failures:

> "*il sistema CONAI-Consorzi di filiera è dunque un sistema – integrato ma costituito da soggetti giuridici autonomi e indipendenti – interamente costituito dagli imprenditori che producono e utilizzano gli imballaggi*[18]".(CONAI, 2005, p. 1)

Together with the Consortia which constitute the CONAI system, the other main actor in the Italian packaging waste management system is the National Association of Italian Municipalities (ANCI), which represents most of the Italian municipalities[19]. The association was founded in 1946[20] and it is today regulated by its own statute approved in its XII assembly held in Catania the 19th and 20th of November of 1999. According to the art.º 1 of its statute, the ANCI, as the most representative association, holds the role to institutionally represent the Italian municipalities in the relations with the other bodies of the government and public entities and it pursues the interests of the local authorities; for instance, it carries out the negotiations and signs the agreements with the CONAI.

In accordance with the art.ª 222, number 1, of the Consolidated Bill on the Environment, the local authorities have to provide proper systems of differentiated collection of packaging waste, so that the consumers can deliver to the public service its waste residuals separating the packaging managed by the CONAI from the domestic residuals and other packaging waste. The systems must be put in place following the principles of efficiency, efficacy and cost-effectiveness. The municipalities, *ex* art.º 220, number 4, and art.º 222, number 3, are also entitled to promote and raise awareness on the use of recycled packaging, through the improvement of market conditions and the review of possible legislation which limits its reuse.

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[18] "the CONAI-Consortia system is indeed a system – integrated yet constituted by autonomous and independent juridical subjects – fully constituted by entrepreneurs who produce and use packaging".
[19] In July there were 7041 municipalities which were members of ANCI, out of the total of 7954 municipalities in Italy. The members of the association count for the 90% of the total population.
[20] A first version of ANCI was founded in 1901 with its constitutive congress in Parma, yet, with the instauration of the fascist regime and the involvement of Italy in the Second World War, it was dismantled.

Furthermore, the cooperation between the system of Consortia and the local authorities on the management of packaging waste, which aims to guarantee the principle of shared responsibility between producers, users and municipalities (Di Marcantonio Mosco, 2012), is regulated by the framework agreement CONAI-ANCI, as stated in art.º 224, number 5, of the Consolidated Bill on the Environment, a document which defines the boundaries of actions of the two main group of actors and divides the responsibilities, the rights and the duties among them. The document is then completed by six Technical Appendixes, one for each of the Consortia which constitute the CONAI system, where the terms and conditions for the managing of each of the six materials of packaging are detailed and described.

The first framework agreement was signed on the 8th of July 1999 and its validity was extended until the 31st of December 2008; a second version has then been edited and subscribed on the 23rd of December 2008 and ceased to produce effects on the 31st of March 2014[21]. Today, the relations between the Consortia and the local authorities are regulated by the third edition of the framework agreement which began to be operative on the 1st of April 2014 and will be effective all throughout the 31st of March 2019, all the Technical Appendixes were also approved together with the main text, with the exception of the Technical Appendix ANCI-COREPLA, where the parts agreed on the terms only on the 1st of January 2015.

Finally, up until 2006 there was a separate body of the Ministry of the Environment, the National Observatory on waste, to overlook the whole system, to check the quality of the residuals collected and delivered to the Consortia by the municipalities and to approve different autonomous management systems which producers might implement, as allowed by the art.° 221 and 223 of the Legislative Decree n.° 152/2006. All these competences have now been taken on by the Ministry itself, more specifically by its General Direction on the Safeguard of the Territory and Water Resources and its VI Division of integrated management of the waste cycle and connection with the supporting organisms.

[21] The second framework agreement, in its first edition, was supposed to cease its effects a year earlier, in 2013, yet its validity was extended to the first semester of 2014.

4. Compliance Schemes

Following the approval of the PPW Directive, packaging waste management systems started to develop in all member states of the European Union with both similar and unique features. First, there is a clear distinction in the way that continental states and the United Kingdom have approached the issue. The continental systems are all based on a philosophy of "pushing" the flows of packaging waste towards their final treatment by providing funding for the operations performed by the local authorities and the entities responsible for the management of the sector (Perchard & Bevington, 2016). On the other hand, the British system is considered a "pulling" system, where residuals are attracted towards the end of the recovery and recycling chain through the selling of Packaging Recovery Notes (PRNs) and Packaging Export Recovery Notes (PERNs) by reprocessors and recyclers. Producers have indeed to demonstrate that they contribute to the achieving of the goals set by the PPW Directive by purchasing an amount of PRNs or PERNs able to cover the quantity of packaging they produced. It is relevant to mention also that the price of the notes is not fixed, it is left to be decided by the market and it thus floats according to demand and supply mechanisms.

Moreover, among the continental systems, the German one stands out for some peculiarities for presenting a dual system of collection of packaging waste. Indeed, together with the municipalities which, as in the majority of compliance schemes in the European Union, have the responsibility of collecting the packaging waste, in Germany such activity is also performed by the DKR, a subsidiary of the Dual System Germany (DSD), one of the companies which manage the system and also holds the rights for the issue of the "Green-Dot" symbol. DSD used to be a public company, yet, in 2004, the German government decided to privatize it and open the market encouraging a competition regime, therefore, today there are nine private companies operating in the country. Still, the only one which owns the shared responsibility of collecting the residuals is DKR.

4.1. The Portuguese compliance schemes

Portuguese companies which produce packaging, or which import packaging, have to subscribe to one of the three companies in charge of the compliance schemes and pay an admission fee as part of the implementation the extended producer responsibility principle. The model of calculation of those financial contributions, developed independently by the three companies, must be approved by both the APA and the DGAE, and the earnings are to be reinvested into their operations and the financial support to local authorities.

Those who decide to sign up with SPV need to pay a “Green-Dot” fee, which confers the right to apply the “Green-Dot” symbol, by PROEurope, on the packaging products. The value due to the company is determined based on a function of the weight of the products, the quantity of the packaging which was placed in the market, and the kind of material of packaging, all information which are declared in the Annual Declaration from the producers to SPV. The function is the following:

Value to pay = Weight of packaging x Quantity of packaging x Material (4.1)

The variable *Material* is represented by a percentage, updated every year, which characterized each material of packaging (glass, paper and cardboard, ecal, plastic, aluminum, steel, other materials) and the type of packaging: primary packaging, service packaging, shopping bags and multipacks. For instance, plastic shopping bags and aluminum cans will have a different weight in the function.

Moreover, there are two different kinds of payment which are due to SPV: the initial financial contribution, which is payed at the moment of the subscription to the “Green-Dot” company, and which establishes the validity of the contract signed by the parts; and the yearly financial contribution, payed every year following the signing of the contract and calculated with base on the products produced every year by the subscriber. The values to be payed, furthermore, also depend on the kind of annual declaration that the producers deliver to SPV, as, in fact, there are three different types of declaration: the minimum declaration, the simplified declaration, and the detailed declaration. In the first case, the amount due is fixed yearly by SPV, and for the year 2018 it sums up to 120€, while in the second and third options, the value is determined by function 4.1. In the simplified declaration, SPV estimates the quantities and the weights of the packaging of their clients, while in the detailed declaration the data from the previous year are the ones to be taken into consideration to estimate the quota payed. Finally, the companies have also the option of paying the first financial contribution with retroactivity, independently from which kind of declaration they decide to fill out; in this case companies have to add 100€ if they deliver a minimum declaration, or, if they deliver a simplified declaration or a detailed declaration, they pay an additional value based on respectively the estimated data for the previous year and the real data available for the prior period.

Novo Verde has a different model for the determination of the financial contributions it charges its subscribers. The values are defined by the weight of the packaging produced and a percentage which is yearly determined by Novo Verde. The percentages are calculated on the base of the different materials of packaging, as the in the model of SPV, and on the type of packaging: primary packaging, service packaging, multipack and shopping bags. Moreover, there is a minimum annual financial contribution of 150€ which companies have to pay if their fee, once calculated, results to be less. Furthermore, although Novo Verde is not a partner of PROEurope and it is not allowed to confer the “Green-Dot” symbol to its clients, it allows for the use of another symbol, the “Novo Verde” symbol, which still certifies that the producers of packaging joined a compliance scheme which upholds the principle of the extended producer responsibility.

Amb3e also is in charge of its own integrated system of packaging waste management, the SIGRE-Electrão, and applies annual fees to its clients as financial compensation for its activities. Its model is quite similar to the one adopted by Novo Verde, both quite simpler than the one which SPV has developed. The value of the payments is calculated based on the weight of the products entering the market and their nature, as there are difference percentages for each kind of packaging material and typology of packaging, in accordance with the other two companies. Nevertheless, contrary to the models of its competitors, Amb3e does not impose any minimum financial contribution.

Carrying on with the presentation of the compliance scheme, the collection and the sorting operations concerning packaging waste are, as explained in the previous chapter, responsibilities of the local authorities. The pickup of the packaging residuals is performed with selective collection methods, which can either assume a “curbside system” approach or a “bring system” approach; in the former, a system of door-to-door collection is implemented, while in the latter, drop-off points are instituted for the users of packaging to leave their waste. Almost all municipalities in the country have delegated the responsibility of the selective collection in the area of their competence to inter-municipal or multi-municipal companies and association of municipalities, all with the exception of 28 municipalities[22] in the areas of Lisbon, Oporto, Vale do Sousa and Central Alentejo, where each municipality remained in charge of performing the operation of collecting the packaging residuals (ERSAR, 2017). In the framework of the new Strategic Plan for the Urban Waste (PERSU 2020), which aims to

[22] The data report the situation in 2016, when the report on PERSU 2020 was published by ERSAR.

boost the efficiency and the levels of recovery and recycling in the Portuguese waste management sector, the majority of the systems which perform the selective collection operations has met the target fixed for the year 2016. On average, in continental Portugal, were collected 36 kg/inhabitant. The goal for 2020 is to collect 47 kg/inhabitants, proving the need for further investment in the sector in order to reach the targets of the PERSU 2020 (ERSAR, 2017).

The companies managing the sector receive the waste collected and sorted by the SGRUs, and pay a financial support to compensate for the activities they have performed in gathering the flows of packaging waste. The financial transfer is performed in accordance with article 5 of the Decree-Law n.° 366-A/97 and the article 7 of the Order n.° 29-B/98 in their emended form, conforming to which the entities in charge of the packaging waste management systems have to conclude contracts with the municipalities and the companies managing multi-municipality or inter-municipality networks, and moreover, in the article 4, number 4, and article 5, number 3, of the Decree-Law n.° 366-A/97 it is also stated that the companies which have implemented a SIGRE have the duty to provide financial transfers in support of the local authorities, to balance the augmenting costs of all the operations they oversee.

The model of calculation of such support is defined in the Order 14202-D/2016 and it is equal for all entities licensed for the management of the sector. According to the legislative act, the financial transfers are composed of three main factors: a base support value, an efficacy coefficient, and the quality of the service. The value of the support for material *i* is given by the quantity of *i* collected (Qi) and the base value ($VC(EP)$), which differs between materials and different groups of SGRUs according to their proportion in respect to a sample case. This latter is expressed in €/ton. The following formula portrays such relation:

$$VC^* = VC(EP) \times Qi \quad (4.2)$$

Where VC^* is therefore the financial support for material *i* expressed in €/ton.

The second element which contributes to the overall transfer is the efficacy coefficient. Calculated by APA, it has been introduced as in instrument of reward and punishment with respect to the results of the local authorities in terms of minimum standards reached in the previous financial year:

$$Efficacy\ coefficient_t = \frac{Recovery_{it}}{Goal_{it}} \quad (4.3)$$

Here, $Recovery_{it}$ represents the quantity pro capita recovered in year t, while $Goal_{it}$ represents the recovery standard for the SGRU of material i in year t. Such standards are set in the Order n.° 7111/2015 for the years 2017, 2018, 2019 and 2020 in kg per capita. Furthermore, the value of the efficacy coefficient is so defined that it is limited between the range 0,8 and 1,035.

Finally, the last component is an adjustment factor directed to introduce in the total value of the financial support to local authorities an indication for the quality of the services provided by each SGRU:

$$\textit{Adjustment quality of service} = 1 + K_t \quad (4.4)$$

In the formula 4.4, K_t is a coefficient of correction of the financial transfers and can assume the values of either 5%, 0%, -5% or -10%, based on three discriminating factors (Id1; Id2; Id3):

i. Id1: density of eco-points, with a reference value of 200 inhabitants for eco-point;
ii. Id2: distance between eco-points, with a reference value of maximum 200 meters;
iii. Id3: accessibility of the service of selective collection in accordance with the indicator of the Regulatory Entity of Water and Waste Services (ERSAR), with reference values “unsatisfying”, “median” and “good”.

Based on the three variables listed, the value of K_t is therefore defined:

i. $K_t = 5\%\ \textit{if}\ Id1 \leq 180 \vee Id2 \leq 180 \vee Id3 = Good$. If the SGRUs show Id1 or Id2 with a percentage lower than 10% of their reference values, or if the value of Id3 is “Good”, then the financial transfer will be incremented of 5%.
ii. $K_t = 0\%\ \textit{if}\ (180 < Id1 \leq 240 \vee 180 < Id2 \leq 240) \wedge (Id3 = Unsatisfying \vee Id3 = Median)$. If the SGRUs show Id1 or Id2 with a percentage between 10% lower and 20% higher with respect to their reference values and Id3 “Unsatisfying” or “Median”, no adjustment will be put in place.
iii. $K_t = -5\%\ \textit{if}\ (240 < Id1 \leq 280 \vee 240 < Id2 \leq 280) \wedge (Id3 = Unsatisfying \vee Id3 = Median)$. If the SGRUs show Id1 or Id2 with a percentage between 20% and 40% higher with respect to their reference values and Id3 “Unsatisfying” or “Median”, the transfers will be affected by a decrease of 5%.
iv. $K_t = -10\%\ \textit{if}\ (Id1 > 280 \vee Id2 > 280) \wedge (Id3 = Unsatisfying)$. If the SGRUs show Id1 or Id2 with a percentage higher than 40% of their reference values and if the value of Id3 is “Unsatisfying”, then the financial transfer will be decreased of 10%.

Alongside the financial support, a bonus is included in the invoice sent to the SGRUs based on the goals reached and the quality of the service. The formula for the calculation of such bonus is given in article 1, comma 7, of the Order n.º 14202-C/2016, and it takes into consideration the former three factors which contribute in defining the financial transfer. The formula 4.5 is thus expressed:

$$Pt = \sum_{i=1}^{m} VC_{i,t}\ (EP)\ x\ Q_{i,t}[Efficacy\ Coefficient_t\ x\ Adjustment\ Quality\ of\ Service_t - 1]\ (4.5)$$

The values of the efficacy coefficient for the calculation of the bonus, which complements the transfer, are given by the APA at the end of each year and are integrated by the entities managing the packaging waste in their invoices starting with 1st of January of the following year. Analogous is the value used for the quality adjustment, which is informed by the ERSAR in the end of each year.

Finally, the base financial support for the materials collected through a selective collection mechanism, sorted, and then delivered by the SGRUs to the SIGREs, is indicated in the following table, as expressed in the Order n.º 14202-C/2016:

Group	SGRUs	Financial Compensation (€/ton)						
		Glass	Paper	Plastic	Steel	Aluminum	ECAL	Wood
A	Ambilital AMCAL Ecobeirão Ecolezíria Resíduos do Nordeste Resialentajo Resiestrela Valnor Valorminho	60	238	686	776	925	750	36
B	Ambisousa Braval GESAMB Resitejo Resulima Valorlis	46	213	641	747	851	670	36
C	Algar Amarsul ERSUC Resinorte Suldouro	36	173	545	649	761	564	36
D	Tratolixo Valorsul Lipo	32	159	531	631	741	548	36

Table 1 Financial compensation for selective and sorted collection

Moreover, for that waste which has not been collected through selective collection, and then it has been sorted, the values to be taken into consideration for the base financial support are the one of table 2:

Group	SGRUs	Financial Compensation (€/tons)						
		Glass	Paper	Plastic	Steel	Aluminum	ECAL	Wood
A	Ambilital AMCAL Ecobeirão Ecolezíria Resíduos do Nordeste Resialentajo Resiestrela Valnor Valorminho	23	89	257	290	346	280	-
B	Ambisousa Braval GESAMB Resitejo Resulima Valorlis	17	80	239	279	318	250	-
C	Algar Amarsul ERSUC Resinorte Suldouro	13	65	204	243	284	211	-
D	Tratolixo Valorsul Lipo	12	59	199	236	277	205	-

Table 2 Financial compensation for unsorted waste

The four different groups (A, B, C, D) differ for density of the population covered and dimensions of the area covered by each SGRU.

The values are subjected to yearly updates by the APA and the DGAE, taking into consideration the harmonized consumer price index (IHPC) of the last 12 months, published in the website of the National Institute of Statistics (INE), and in accordance with the indicators of efficacy and quality used to calculate the bonus each year.

Moreover, there are some qualitative and quantitative standards to be respected in order for the Green Dot companies to retrieve the cargos from the networks of municipalities. The Order n. 15370/2008 integrated by the Information n. 209/08/DFEMR-DLRF from the Portuguese Environment Agency, set all the rules and conditions to be respected. The most important are resumed in the table below:

Material	Percentage of Packaging in the Composition of the Cargo	Minimum Quantity
Glass	≥ 98%	25 tons
Paper	≥ 95%	23 tons
Paper - ECAL	≥ 95%	23 tons
Plastic - PEAD	≥ 95%	11 tons
Plastic - Wraps	≥ 94%	20 tons
Plastic - PET	≥ 96%	10 tons
Steel	≥ 90%	20 tons
Aluminum	≥ 90%	5 tons
Wood	≥ 96%	3 tons

Table 3 Quality and quantitative standards for selective collection

The paper, ECAL and wood waste cargos delivered to the each SIGRE are also subjected to a humidity analysis. Such procedure was implemented to measure with a greater accuracy the real weight of the materials retrieved. For the cellulose materials, if the concentration of humidity is between 10% and 25%, the cargo is accepted but the official weight registered to calculate the financial compensation is readjusted; with a concentration above 25% the cargos are rejected. With wooden packaging waste, if the concentration of humidity is higher than 25%, the cargo is accepted with a readjustment on the weight of the stock.

Moreover, the qualitative standards for steel and aluminum change when those materials are extracted from slags, and not collected through the common methodologies of collection. In this case the percentage of steel has to be at least 70% and the minimum quantity allowed is the amount which fits in the designated wagons. For aluminum, the percentage decreases to 55% and, as before, the minimum quantity is the filling of the truck.

Concerning the financial support for the unsorted recovery, the transfers vary according to process in which the packaging waste is sorted and separated from the undifferentiated waste. There are indeed different coefficients for mechanic treatment and biological treatment, composting, and the incineration process of energy recovery. The value of the support is equal for all SGRUs, and it is proportionate to the quantities of materials processed; the base values are shown below:

Processes	Financial Compensation (€/ton)						
	Glass	Paper	Plastic	Steel	Aluminum	ECAL	Wood
Mechanical and biological treatment	71	112	136	131	180	142	-
Composting	-	23	-	-	-	-	23
Energy recovery	-	-	-	89	567	-	-

Table 4 Financial compensation for fractions in unsorted waste

Also, for the packaging waste collected through unsorted collection, there are some boundaries on the quality and quantity of the materials delivered to the Green Dot companies. The indicators can be found in the document of Technical Specifications from the Portuguese Environmental Agency and the DGAE. A resume of the most important aspects is presented below:

Material	Percentage of Packaging in the Composition of the Cargo	Minimum Quantity
Glass	≥ 98%	25 tons
Paper	≥ 95%	23 tons
Paper - ECAL	≥ 95%	23 tons
Plastic - PEAD	≥ 85%	11 tons
Plastic - Wraps	≥ 90%	20 tons
Plastic - PET	≥ 90%	10 tons
Steel	≥ 90%	20 tons
Steel - Mixed	≥ 90%	21 tons
Aluminum	≥ 90%	9 tons
Aluminum - Mixed	≥ 90%	10 tons
Wood	≥ 96%	3 tons

Table 5 Quality and quantitative standards for unsorted collection

Once again, the packaging in paper and wood are also subjected to a humidity analysis, while these further measurements are not applied to ECAL waste. The values of the parameters are the same as for the selective collection. Also, steel and aluminum retrieved from slags fall under the same parameters as the materials collected with the selective collection.

Finally, as last step of the scheme, to ensure the valorization of the packaging waste and its best treatment, once it comes to belong to the companies managing the compliance schemes, the flows of residuals are redirected to the authorized recyclers, which pay a net-back value for the acquisition of the flows of residuals. The value is not fixed, it floats with the changing of the prices in the markets of materials, therefore it can even come to assume a negative value, and in this case SPV, Novo Verde or Amb3e are the ones to pay the recyclers for receiving the waste.

4.2. The Italian compliance schemes

In Italy, the producers and the users of packaging must join a compliance scheme as imposed by the art.º 221 of the Consolidated Bill on the Environment, in the category of the producers fall all the suppliers of packaging materials, the manufacturers of packaging, the packaging converters and the importers of empty packaging and materials; while the latter group comprehends the traders, the distributers, the fillers of packaging and the importers of filled packaging. Usually[23] the final users of the packaging are excluded by this duty, those who acquire the packed goods but do not exercise any trading or distributing activity of the products, moreover, although the agricultural companies are not bounded to the subscription by law, they still have to pay a fee for the packed products they import or buy.

In the case of the association with the CONAI, which is the main entity managing packaging waste in the country and holds an informal monopoly in the sector, the subscribing company has to pay an admission fee of 5.16€, to which it increases a variable fee for those which have gained earnings greater than 500,000.00€ in the previous year. Under no circumstances, the total subscription fee cannot exceed the value of 100,000.00€. The payment of the admission fee turns the company into a member of the Consortium, which implies the right to a sit in the general assembly and the right to one vote on the issues debated in the institution, moreover, to those who also pay a variable fee, are conferred as many votes as many times the total amount can be divided by the admission fee (5.16€).

Furthermore, the producers, besides joining the CONAI in their own category, can also subscribe to one or more of the Consortia of the CONAI system according to the type of materials that they deal with; concerning the users, they can also voluntarily join the other Consortia. The adhesion is made at the moment of the subscription to the CONAI where, in the applying documents, the companies can also indicate to which other consortium of the system they would like to join to fulfill their obligations respecting the extended producer responsibility principle.

Moreover, each year, the members of the CONAI must pay an Environmental Contribution to the Consortium, a financial transfer to compensate the costs of the selective collection and the transportation of the materials. The value of the compensation is calculated based on the material and the weight of the packaging which each companies declares to the CONAI, however, in 2016, the board of the Consortium decided to expand the criteria on which the Environmental Contribution is calculated, starting with the products of plastic packaging; for the other kinds of packaging the criteria remained the two presented above: material and

[23] The end users are obliged to join a compliance scheme when: they carry out a commercial activity with the products they bought, even if marginal with respect to their own main business; they buy directly from a foreign country packed goods or empty packaging for the exercise of their own business; they buy empty packaging on the national territory for the exercise of their own business.

weight. For plastic packaging, indeed, three more factors are taken into consideration when determining the value to be played by the members of the Consortium: "selectability", recyclability and the circuit of destination of the packaging once it turns into waste.

The first criterion resumes whether or not the product it is easily selectable once it reaches a sorting center, it must thus present a few characteristics to fulfill this requirement. First of all, its minimum dimensions should allow the automatic machines installed in the centers to detect it, and, therefore, its bearing plane should not be lesser than 5x5 cm. Moreover, it has to be detectable by the optical sensors which operate in the sorting centers, and it should come in a minimum of selectable and homogenous quantity of at least 2% of the bundle of plastic packaging waste.

Regarding the recyclability, it is essential for this criterion the existence of one or more recyclers which treat the plastic packaging with a mechanic or chemical-organic procedure in order to produce a secondary material. There should also exist one or more companies which use in their production chain the recycled material created by the recyclers, and its quantity should be enough to supply the industrial production.

The last criteria, which concerns the destination of the packaging, it takes into consideration whether the products are used essentially to supply the business to business channel or the domestic one. In the former option the collection and treatment are simpler because the high quantitative and qualitative concentration of such packaging allows the companies to directly ship them to the professional operators for their final treatment. On the other hand, the latter option contains packaging which are collected in the urban circuit as they are consumed by their final user in the domestic context.

From the analysis of the three criteria for the plastic packaging, three different groups (A, B and C) of materials were identified, each one of them with a differentiated value for the environmental contribution to be payed to the CONAI: selectable and recyclable packaging from the business to business circuit, selectable and recyclable packaging from the domestic circuit, non-selectable and/or non-recyclable packaging with the current technologies. The values of the environmental contributions for each material of packaging are reported in the following table:

Material	Environmental contribution (€/ton)
Aluminum	35.00
Glass	13.30
Paper	10.00
Plastic	Group A: 179.00; Group B: 208.00; Group C: 228.00
Steel	8.00
Wood	7.00

Table 6 Environmental contribution for material

The municipalities are then responsible for collecting the packaging waste which entered the urban circuit, and it thus has households' origins. They therefore set up collection schemes according to the curbside system or the bring system, with the drop-off center playing a little role compared with the other technics of collection, and can be performed either with mono-material practices or multi-material (Rigamonti et al., 2015). What happens in many cases is that the municipalities delegate their responsibility to public companies. Of this latter option, there are numerous schemes[24] put in place in Italy which require a first pre-treatment of separation between the materials which are jointly collected (Giugliano, Cernuschi, Grosso, & Rigamonti, 2011), yet it is important to acknowledge that in the majority of cases this first step in the Italian system of packaging waste management does not collude with the sorting activities, it just represent a previous separation among the materials whose nature is evidently different (Rigamonti et al., 2015). Furthermore, the collection schemes have to be designed specifically under the principles of efficacy, efficiency, cost-effectiveness and transparency of the service as reported in the Legislative Decree 152/2006.

The residuals collected are then transmitted to the Consortia of the CONAI, in accordance with the Consolidated Bill on the Environment, and in exchange the local authorities receive a financial transfer which covers the costs of the activities they have carried on in the boundaries of the packaging waste system. The values of such support and the procedures to deliver the flows of waste differ for each kind of material and each consortium, in this sense, all details are defined in the six technical appendixes to the ANCI-CONAI Agreement.

[24] For example: paper and plastic; paper, plastic, aluminum and ferrous metals; plastic, aluminum and ferrous metals; glass, paper, aluminum and ferrous metals; glass, aluminum and ferrous metals; paper, glass, plastic and aluminum (Rigamonti et al., 2015).

The agreement indeed consists of a main general body and six technical appendixes, one for each individual consortium of the CONAI system, where the specific operations for the different materials of packaging waste are described. The framework agreement covers mainly the recovery of packaging waste from urban origins, but not only; in the case of RICREA and CIAL, it also regulates the residuals from other facilities.

In all appendixes the responsibilities are divided between the local authorities, which have to perform the collection and the sorting activities and deliver the packaging waste, and the consortium in charge of the specific material, which will proceed with directing the flows of waste towards its final treatment, being it recycling, reusing or disposal. The parts stipulate single conventions among them, which could be already redacted as in the case of COMIECO or COREPLA, or which leave more freedom of action as in the conventions signed with CIAL, yet, they all follow the objectives and bend to the conditions expressed in the technical appendixes of the framework agreement.

The packaging waste collected is delivered to the designated consortia through platforms which are agreed upon from both parts and which serve not only as pick-up points, but also, in most cases, as pre-treatment facilities. The platforms are chosen through different criteria, according to the material delivered, nevertheless, a compensation is always given to the local authorities for the transportation of the packaging waste with respect to the distance it must cover.

Moreover, it is in the technical appendixes that the models of calculation of the financial compensation are explained in all their components and variables. The financial support should also stimulate the dimensional growth of the activities of local authorities without affecting the quality of the service, and, for this reason, the compensations are proportionally linked to the quality of the material collected. Furthermore, the base values are adjusted every year to the 95% of the inflation rate registered in the previous year, in accordance with the National Inflation Index.

Finally, the public administrations have the duty to turn in the data they own on the quantities, the costs and the quality of the materials they deal with in the system of packaging waste management. The data have to be introduced in a web portal managed by CONAI and ANCI, helping to safeguard the transparency in the sector and limit the cases of mismanagement of waste. Moreover, the consortia take upon themselves to organize events to raise awareness among the population on the right practices to assume when disposing waste. Generally set up in collaboration of the municipalities, these tasks aim to increase the quality of the materials collected targeting directly the consumers. The duty to engage in this kind of events and activities is expressed in each technical appendix, showing therefore the importance which is recognized to the sensitization on the topic among the population.

The characteristics which are peculiar to the single technical appendixes will now be highlighted.

4.2.1. FSLA for steel packaging waste

The agreement with RICREA regulates the conditions upon which the municipalities should collect and deliver the steel packaging waste to the consortium, and the details of the respective financial transfer. The collection of the steel residuals should be operated by multi-material road containers, and, as second step, the waste should be sorted to separate the packaging in steel from other materials. The platforms to be used for the delivery are agreed upon between the parts giving priority to those sites which make available magnetic separation systems, if the local authority decides to use a different platform, without any previous agreement, RICREA holds the right to deny any compensation for the activity carried out by the public administration. RICREA must proceed with the recovery of the material in seven working days from the notification of the municipalities. In case of a late pick up, the local authorities can apply a penalty fee of 10% on the financial transfer made by the consortium, which increases to 20% after 18 working days. After 30 working days, RICREA will also be charged with the eventual costs of disposal of the waste. The recovery, however, is only guaranteed if the municipality meets the minimum weight of 15 tons.

Regarding the quality of the cargos, five different quality levels have been recognized by the consortium. To identify to which quality level the materials delivered by the local authorities belong, a structured analysis has been developed divided in the following steps:

i. Identification of a representative sample, with a minimum weight of 100 kg, and collected from different points of the platform, following the principle of quartering, or other methods which ensure the representativeness of the sample;
ii. Weighting of the sample;
iii. Sorting intra-sample of the single parts;
iv. Identification of fractions of similar products (steel which is not packaging);
v. Identification of impurities;

vi. Weighting of the identified sub-categories;

vii. Calculation of the percentage of impurity according to the following equation (3.6):

$$\%Impurity = \frac{Weight\ Impurity\ x\ 100}{Weight\ Impurity + Weight\ Steel\ Packaging + Weight\ Fraction\ SImilar\ Products}\ (4.6)$$

At the moment in which a municipality and RICREA sign a convention, they agree on the quality of the material which will be presented, because it would not be feasible to perform the quality analysis on every bundle of materials which is delivered to the platforms. Still, the consortium holds the right to check whether the quality goals are being met or not through programmed and random evaluations of the cargos.

Based on the percentage of external fractions (impurity) present in the cargo delivered, the compensations to the local authorities are thus defined:

Quality Level	External Fractions (Impurities)	Financial Support 2018 (€/ton)
Excellent	Until 2%	116.64
1	Between 2% and 5%	104.76
2	Between 5% and 10%	88.56
3	Between 10% and 15%	68.04
4	Between 15% and 20%	45.36

Table 7 Financial support for steel packaging waste

In the case of a percentage of external fractions higher than 20%, RICREA holds the right to refuse to financially compensate the whole quantity presented by the local authority, meaning then that it will proceed with the transportation of the cargos without paying any support to the municipality.

Furthermore, RICREA also is responsible for managing the steel packaging waste collected from sites of mechanical treatment for undifferentiated urban waste and sites of treatment of combustion bottom ashes of undifferentiated waste.

Regarding the materials recovered from sites of mechanical treatment, it is responsibility of the local authority to proceed with the sorting operations and present the bundle of steel packaging waste to RICREA. To encourage the practice of selective collection, the value of the financial support and the operational conditions applying to these operations are not the same as the ones listed above for, indeed, the selective collection.

The consortium accepts the cargos only if the minimum weight of 20 tons of steel packaging waste is met; yet, in case of late recovery from the platform by RICREA, after eleven working days from the notification of the delivery of the stock of steel waste, the consortium is subjected to a 10% penalty on the financial transfers it owns to the municipality. After twenty working days the penalty rises to 20% and after thirty working days the costs of disposal are also accredited to the consortium.

The levels of quality recognized for this category are only three, the following table shows the respective compensations:

Quality Level	**External Fractions (Impurities)**	**Financial Compensations 2018 (€/ton)**
1	Until 10%	60.00
2	Between 10% and 20%	50.00
3	Between 20% and 30%	30.00

Table 8 Financial compensation for steel packaging from sites of mechanical treatment

Finally, the material recovered from sites of treatment of combustion bottom ashes for undifferentiated waste is subjected to the same rules and boundaries as the materials collected from the sites of mechanical treatment. The only difference can be found in the amount of quality levels and the compensations recognized by the consortium to the local authorities:

Quality Level	**External Fractions (Impurities)**	**Financial Compensations 2018 (€/ton)**
1	Until 10%	40.00
2	Between 10% and 20%	30.00

Table 9 Financial compensation for steel packaging from sites of treatment of combustion bottom ashes

4.2.2. FSLA for aluminum packaging waste

The agreement with CIAL not only sets the terms for the recovery of aluminum packaging waste, but also expands its discipline to some fractions of similar material, therefore aluminum which is not packaging, such as accessories of packaging, for instance: caps. The delivery of such materials is performed through a separate channel and in compensated by financial support only if it does not overcome the quantity of packaging delivered; in this scenario, CIAL will only operate the recovery of the material, without paying any financial support to the local authorities.

The compensations for the collection of caps are also defined according to the quality of the cargos, and assume the following values:

Quality Level	External fractions	Compensation 2018 (€/ton)
A	Until 10%	150.14
B	Between 10% and 20%	100.27

Table 10 Financial support for aluminum caps

Furthermore, when calculating the value of the support, CIAL and the public administration agreed on holding as a reference the following proportions in the collection operations: 45% of the materials collected through road containers for multi-material collection; 50% through selective collection door-to-door; and 5% through selective collection from drop-off centers, public platforms.

The calculation of the financial transfer for materials collected by selective collection is, once again, based on the quality of the cargos delivered by the municipalities, thus assuming the values resumed in the table:

Quality Level	External fractions	Compensation 2018 (€/ton)
A+	Until 2%	557.39
A	Between 2% and 5%	456.05
B	Between 5% and 10%	304.03
C	Between 10% and 15%	152.02

Table 11 Financial support for aluminum packaging

In case of delivery with external fractions higher than 15% of the materials in the cargo, CIAL can refuse the whole bundle.

The technical appendix also regulates the activities of pretreatment of pressing and crushing the materials once they are collected and sorted. If the local authorities take this responsibility upon themselves, they receive a financial compensation of 38.51 €/ton for the pressing of packaging waste of quality levels A+ and A, and they are entitled to 15.00 €/ton for the crushing of cargos with a specific weight of at least 100 km/m^3.

As RICREA, CIAL is also in charge of the management of packaging waste from non-urban origins. Indeed, the local authorities also deliver aluminum packaging waste collected from sites of mechanical sorting and energy recovery plants. The compensations are defined as follow:

Quality Levels for Mechanical Sorting Plants	External fractions	Compensation 2018 (€/t)
A	Until 10%	250.68
B	Between 10% and 20%	130.35

Table 12 Financial support for aluminum packaging from sites of mechanical treatment

Quality Levels for Energy Recovery Plants	External fractions	Compensation 2018 (€/t)
A	Until 10%	300.80
B	Between 10% and 20%	200.54

Table 13 Financial support for aluminum packaging from sites of energy recovery

Finally, the minimum weight required for the withdrawal by CIAL is 3 ton in all three cases. The limit rises to 6 ton for the waste of urban origins which has already been pretreated, and 10 ton for the crushed waste collected from the two other sources.

4.2.3. FSLA for wood packaging waste

As indicated in the technical appendix with RILEGNO, the platforms for the delivery by the municipalities and the withdrawal by the consortium of wooden packaging waste are chosen together by the two parts of the conventions, yet, they should be located inside a radius of 25 km from the municipality. If there are not any facilities which satisfy some minimum requirements of capacity and operational means, RILEGNO will pay 1.10 €/ton/km for every kilometer exciding the 25 km radius. Moreover, in case of small islands which find their drop off points on the mainland, RILEGNO will pay a financial support of 30.00 €/km to compensate the transportation operations performed by the insular municipalities. Furthermore, the consortium also recognizes financial incentives in the amount of 20% of the base value of the compensations to those who manage the collection and sorting activities through ecological platforms or directly in fruits and vegetables markets.

Also, as the quality of the service provided is a fundamental factor in the definition of the value of the support, the definition of the quality level is thus appointed after an evaluation divided in defined steps, similar to the one performed for RICREA and the other consortia:

a) Identification of a representative sample, with a minimum weight of 100 kg, and collected from different points of the platform, following the principle of quartering, or other methods which assure the representativeness of the sample;
b) Weighting of the sample;
c) Sorting intra-sample of the single parts;
d) Weighting impurities (impurities are waste which is not wood);
e) Calculate the percentage of impurity:

$$\%\text{Impurity} = \frac{(Weight\ Sample - Weight\ Wood\ Packaging)\ x\ 100}{Weight\ Sample} \quad (4.7)$$

The financial burden of the analysis falls upon RILEGNO, which will perform controls only if previously schedule with the local authority. The financial compensations are then linked to the percentage of external fractions present in the cargos. 16.70 €/ton are recognized to those cargos with less than 2.5% of external fractions, 8.35 €/ton for bundles with impurities between 2.5% and 5% of the total weight, and none if the level is greater than 5%.

Moreover, the local authorities can also decide to operate together the collection of the urban wooden packaging waste gathered through selective collection and the voluminous wooden waste from domestic use. In this case the financial support decrease to the values of 3.8 €/ton for cargos with less than 2.5% of impurities, 1.8% if the weight of the external fractions is between 2.5% and 5% of the total weight, and none for higher levels of impurities.

Finally, although there is not yet a common model for the calculation of the financial support, a new project for the implementation of a system dedicated to the recycling of cork is being put in place, with the cooperation also of wineries, bars and restaurants.

4.2.4. FSLA for paper and cardboard packaging waste

The local authorities can choose between two different options of conventions with COMIECO. The first option concerns only packaging waste gathered through unsorted collection, with elimination of the fraction of similar materials before the delivery, and selective collection. The second option is a convention for the delivery of the packaging waste collected with no prior sorting activities. Both can be executed through two different methodologies: convention in entrance (IN), where the measurement of the quantities and the evaluation of the quality of the cargos are performed when the materials are delivered to the platforms; and conventions in exit (OUT) where these evaluation operations are conducted when the materials leave the platforms and have thus already been subjected to pretreatments.

The platforms are usually individuated together by the two parts of the convention, yet, the municipalities can identify platforms on their own in case of conventions of the second option. Here, only the methodology OUT is applicable, and the conventioneer must ensure the realization of sorting, pressing and identification activities before the materials are delivered to COMIECO.

To provide a better organization of the necessary activities for each flow of waste, the local authority has the duty to inform COMIECO, until the 31st December of each year, of the estimated monthly quantities of materials that it will deliver considering their users base. In case of a persistent distortion of the quantities estimated and then presented of more than 20% per month over a period of three years, and without any notification to COMIECO, the consortium has the right to charge a penalty fee on the public administration, charging the extra costs that the consortium has been subjected to.

Furthermore, with the objective of defining the financial compensations, the recovery operations are supposed to be divided in two different methods: 51% of the total packaging waste should be collected through municipal drop-off points or collective road containers; while 49% through a recovery door-to-door. Moreover, there are two different categories of collection practices: a collection of cellulose packaging waste and generic paper; and a selective collection of only cellulose packaging waste. The ratio between the quantities collected with the two methodologies is set to be higher than 2.8. To those who succeed in achieving the ratio, the compensations are so defined: 96.50 €/ton incremented by 2.50 €/ton for waste collected through a proximity selective collection.

If the municipalities achieve a ratio equal or lower than 2.8, the transfer is recognized only if the quantity stays in the boundaries of the registered packaging waste which is put on the market yearly. To the quantities which exceed this limit, only 33% of the compensation is recognized. Yet, if the municipality proves that the increase of selective collection resulted in a decreased of cellulose packaging waste in the undifferentiated waste, then the financial transfer is made in its totality. Those conditions apply to both options of conventions, each one according to the materials that the local authorities are obliged to deliver; moreover, for the conventions of option one there is also a financial support recognized for the delivery of the fractions of similar materials which corresponds to additional 13.00 €/ton.

The compensations are then subjected to the quality of the materials delivered, the discriminant is the percentage of external fractions in the cargos, as in all other technical appendixes, intended as non-cellulose materials which are not parts of the packaging. Regarding the conventions in of option one, the following table resumes the quality levels and the adjustments to the financial transfers:

Quality Level	**External fractions**	**% of Compensation**
1° level	EF≤1.5% and EF+FSM≤10%	100%
2° level	1.5%<EF≤4% and EF+FSM≤10%	75%
3° level	EF>4% and EF+FSM≤10%	50%
4° level (Cat. A)	EF<1.5% and EF+FSM>10%	35%
4° level (Cat. B)	1.5%<EF≤4% and EF+FSM>10%	25%
4° level (Cat. C)	4%<EF≤10% and EF+FSM>10%	15%
4° level (Cat. D)	EF>10%	0%

Table 14 Financial support for paper and cardboard packaging

In conclusion, the next table shows how the quality of the materials affects the compensations in conventions of the second option:

Quality Level	**External fractions**	**Adjustment to the Compensations**
1° level	Until 3%	100%
2° level	Between 3% and 6%	75%
3° level	Between 6% and 10%	50%

Table 15 Adjustment on the quality of paper and cardboard packaging

In addition, whenever the external fractions represent more than 10% of total weight of the paper packaging waste delivered, no financial support is given.

4.2.5. FSLA for plastic packaging waste

There are two different types of conventions, as defined in the agreement with COREPLA, which the local authorities can apply too: a “Simplified” Convention for the delivery of mono-material products, and an “Ordinary” Convention for the delivery of multi-material waste.

Once the type of convention is chosen, the municipalities must indicate which kind of flow of materials will they deliver to COREPLA, among four different options:

i. FLOW A: Mono-material delivery of urban origin;
ii. FLOW B: Mono-material delivery of non-domestic origins, yet subjected to the public service, with a strong presence of tracers;
iii. FLOW C: Mono-material delivery of urban origin, dedicated to the delivery of plastic packaging for liquids;
iv. FLOW D: Multi-material delivery of urban origin.

The tracers are materials which are used as indicators for the non-domestic origins of different bundles of waste. They are thus used to fix objectives and verifiable criteria, among which, for instance, can be found: packaging film and other flexible packaging bigger than an A2 format (42 x 59.4 cm), packaging of expanded polystyrene and rigid packaging with a greater capacity than 20 liters.

In both cases of “simplified” conventions and “ordinary” conventions and for all the four flows identified in the technical appendixes, the material is brought to the nearest platform by the local authorities. If it is located at a distance greater than 25 km from the municipality, the consortium will add to the overall financial transfer 2.02 €/ton/km for every kilometer exciding the limit, until a maximum of 50 km.

Moreover, the local authorities also have the option to proceed, in an early stage, with the pressing operations in a different platform, which is independently chosen by them, without therefore the need of the approval of COREPLA. Then, only in a second step, the packaging waste will be devolved to the agreed platform either by the municipality itself, if the distance between the two platforms is less or equal to 25 km, or by COREPLA, if the distance exceeds 25 km. In the case of an “ordinary” convention, the pre-treatment will also include the sorting of the material, therefore, from this point, only the option of mono-material is feasible. On the other hand, in the “simplified” case, the consortium will pay the local authority 20.00 €/ton to cover the costs of the pressing process and of transportation; yet, this is only applied if the minimum weight of the cargo of 11 ton is met. While in the latter case, where COREPLA has the responsibility of transportation of the material, if the minimum weight of 17 ton respected, a financial transfer of 36.00 €/ton will be added to the base support. Finally, in the case of small islands, the local authorities oversee the naval transportation, which will be compensated by an amount of 30.36 €/ton, independently of pretreatment of pressing.

The net value of the financial support issued by the consortium differs according to the type of convention signed by the municipalities. In the case of mono-material delivery it is defined in such way:

$$CN = Cu \times IC - (Cfes + Cfer) \times FE \quad (4.8)$$

While for the "ordinary" convention the formula does not take into account the reward for the sorting operations:

$$CN = Cu \times IC \quad (4.9)$$

In equation 4.8 and 4.9, the variable *Cu* is the unitary compensation for plastic packaging waste, and it assumes different values according to the kind of flow which the materials belong to, based on their quality, as defined above in the beginning of this section:

Type of Flow	**Cu (€/ton)**
Flow A	303.00
Flow B	80.00
Flow C	394.00
Flow D	295.00

Table 16 Financial support for flows of plastic packaging

To complete the formulas, *IC* is the quantity of plastic packaging waste, while *FE* is the external fraction. In this last category are included all the residuals which are not made of plastic, the waste that, even though it is plastic packaging, it is considered dangerous, the packaging waste which is not totally empty, with a tolerance of 5% of its capacity, and finally, the packaging waste from hospitals and the fish boxes from non-domestic origin. This fraction is subjected to two costs which also appear in the equations 4.8 and 4.9: *Cfes* is the separation cost to sort the materials, the compensation for this activity is 104.74 €/ton; and *Cfer* is the management cost and it is compensated with a value between 90.00 and 130.00 €/ton.

Furthermore, each flow must respect some characteristics for the cargo of materials to be eligible for the category to which the municipalities have declared join in the moment of the signing of the convention with COREPLA. In flow A there must not be a percentage of tracers higher than 20% of the total weight of the bundle, and a percentage higher than 20% of external fraction. Also, for flow B, the percentage of "impurities" must not overcome the 20% of the weight. Furthermore, in flow C the total percentage of packaging for liquids must account for more than 90% of the total weight, leaving thus 10% to other fractions. Finally, for flow D, the percentage of must be limited to 20% of the total weight.

Regarding the external fraction, if it corresponds to a percentage of the total weight between 20% and 30%, in the case of delivery of standard mono-materials, the total transfer to the municipalities is null. Moreover, if the percentage is found higher than 30%, then COREPLA will also demand the cost of the management of the impurities to the local authorities. If the delivery contains material already pressed, then the refunds for the costs will be issued already after the presence of a 20% of external fraction.

The analysis on the quality of the material are regulated in detail by the appendix 1 and 4 to the technical appendix, to verify the belonging of the cargos delivered to the category of flows stated by the local authorities.

In conclusion, the two parts of the conventions also take upon themselves to incentive the use of recycled plastic to help the development of an environmental culture and a structured and mature market for the material.

4.2.6. FSLA for glass packaging waste

The technical appendix ANCI-COREVE to the ANCI-CONAI agreement, first of all, determines the constitution of a technical commission of four members, two nominated by ANCI and two nominated by COREVE, with the objective to improve the quality of the system and the homogeneity of actions among the actors. With no compulsory powers but with the ability of issuing recommendations and technical opinions, it is funded by COREVE, which invests in the maintenance of the commission 0.50 € for each ton of glass packaging waste collected by the municipalities and delivered to the consortium.

Moreover, going deeper in the operational aspects of the agreement, the local authorities must identify the platform that they will use to perform the drop-off of the waste materials, which must meet some necessary structural conditions and dispose of proper means to load cargos of 30 tons and more. Subsequently they must notify COREVE of the decision. The costs and the responsibility of managing the platforms and its activities are assigned to the local authorities, who, on the other hand, can also choose, as a formal condition in the convention signed with COREVE, to directly deliver the materials in the plants of the consortium, without relying on platforms. In both case the quantity expected to be delivered with each cargo coming in is 30 tons; if the amount is not met, in the option of relying on a platform, the consortium can charge the municipalities for the extra costs that it has been subjected to in order to transport a semi-full cargo of materials.

Furthermore, when a platform is used, it is responsibility of COREVE to pick up the glass in seven working days from the notification of the local authorities. Once this period expires, a fine will be charged on the consortium of 3% of the value of the standard transfer, after 18 days it increases to 6%, and after 30 days it reaches the value of 9%. When no platform is used, COREVE recognizes a compensation for the transportation costs of 0.165 €/ton/km until the distance of 50 km, furthermore, for a distance between 50 km and 100 km it decreases to 0.11 €/ton/km and for greater distances between 100 km and 150 km it becomes 0.088 €/ton/km.

To calculate the value of the financial transfers, the materials are divided based on the quality of the cargos. The following table resumes the values and the quality levels:

Quality Level	**Impurities (%) (1)+(2)+(3)+(4)+(5)**	**Infusible (%) (3)**	**Compensation (€/ton)**
A	Until 1%	Until 0.3%	45.50
B	Until 2%	Until 0.4%	42.00
C	Until 3%	Until 0.5%	39.00
D	Until 4%	Until 0.8%	27.00
E	Until 6.5%	Until 1.5%	5.00

Table 17 Financial support for glass packaging

The numbers displayed in table 17 correspond to the various components which are identified as externa fractions, impurities, respectively:

1) Metallic packaging;
2) Non-metallic packaging, different from glass packaging;
3) "*Infusibles*[25]";
4) Other impurities;
5) Laminated glass and crystal glass.

[25] This category corresponds to materials such as ceramic, porcelain and rocks.

In the advent of a delivery of a cargo with a stock of packaging waste whose quality falls below the level E, as shown in table 17, the local authorities will gain no compensation and will be charged with the cost of management of the materials in question.

Coming back now to the analysis of the overall Italian compliance scheme, started in the section 3.2, after the subscription of producers and users to the CONAI system and the payment of the Environmental Contribution to enhance the principle of extended producer responsibility, and the implementation of the collection schemes by the municipalities with the consequential delivery of the waste flows to the individual Consortia and the determination of the financial support to local authorities, the residuals are then managed by the six competent entities.

As in the case of Portugal, once the packaging waste it is transferred to the Consortia, they also acquire de property rights of the residuals, with the only exception of wooden packaging waste. RILEGNO, indeed, does not become the owner of the waste flows once they are delivered through its platforms, it just operates activities of management and supervision on the sector and promotion and reporting on the waste flows which enter the system, as confirmed in the juridical hearing of the 5th of February 2008 in front of the Antitrust Italian Authority.

The last step in the system of management of the Italian packaging waste run by CONAI is represented by the transfer of the residuals from the Consortia to their final treatment, being it recycling, energy recovering, reuse etc. There is no binding regulation which standardized the practices which determine the procedures by which the packaging waste is given to the recycling companies, therefore, each consortium has implemented its own policy dealing with the issue. For instance, COREPLA distributes the materials it has received from the selective collection of the municipalities using a system of monthly auctions which allows to capture the fluctuations in the market of raw and secondary materials[26]. The system has proved to give outstanding results and, as a result, it permitted to keep the environmental contribution for plastic packaging still (Di Marcantonio Mosco, 2012). Also, COREVE has implemented, following the example of COREPLA, a system of telematics auctions Concerning wooden packaging waste, as RILEGNO does not own the materials, the municipalities themselves can sign contracts with the recyclers and define together the financial compensation, without

[26] The only other system of this kind in Europe was implemented in Belgium, with the difference that the auctions are made on an annual basis, making thus the waste bought by the recyclers a “future” (Di Marcantonio Mosco, 2012).

consulting or previously informing the consortium. CIAL, with the aluminum packaging it receives, supplies all the Italian foundries which have applied for this kind of supplying chain and which fulfill all legal obligations. On the other hand, RICREA has implemented a distributive system in collaboration with a network of associations, whom, under the principle of solidarity, manage to connect each municipality with the nearest recovering site. Finally, the distribution methods of COMIECO have led to some inquires by the Antitrust Authority for their lack of transparency in how the recyclers and recovering site were chosen by the consortium, given also the fact that paper is one of the materials whose residuals generate the highest positive values.

4.3. Comparison

The two European systems of packaging waste management implemented in Portugal and Italy present many similarities, along with the other continental systems implemented in other member states. They both adopted a “push” strategy to direct the packaging waste flows towards collection and final treatment, and both appointed the responsibility for the collection activities to the local authorities, behind the payment of a financial support.

Nevertheless, they also present important differences. First of all, the regime in which the authorities managing the sector operate, it presents today different features. Indeed, while in Italy the consortia of the CONAI system operate in a monopolistic regime without any real competition in the management of the packaging waste flows; in Portugal, starting with 2018, the market was opened to the entrance of new players. Alongside SPV, which has been for years the only company to be granted the license for implementing a SIGRE, recently, also Novo Verde and Amb3e have been licensed by the government to manage the flows of Portuguese packaging waste. Although the market cannot be considered a pure monopoly anymore, because of the multiple players operating in it, entry barriers still hamper the sector to the point of neglecting the entrance of new players without previous permission of the competent Ministry.

Regarding strictly the collection activities, in both countries the role is legally conferred to the municipalities. Yet, in Portugal, contrary to the Italian case, the services are carried out by inter-municipal associations and multi-municipal companies, once controlled by the EFG, and now with private capitals representing the majority of their equities. On the other hand, in Italy, the task is carried out by the local authorities themselves which organize independently the kind of collection system which they intend to implement in their territory of jurisdiction but can also contract out to public owned companies. The municipalities, moreover, are represented by the ANCI in their relations with the CONAI and with the other consortia of the system; yet, the Association does not play any role in the organization of the activities of selective or undifferentiated collection.

In both systems, the packaging waste is then delivered to the competent authorities, who upon acquisition of the residuals, pay a financial support to the local authorities to cover the operational costs of the collection. The models of calculation of these financial transfers, although they are based on common principles, present some differences between the two countries. In both countries the financial contributions are calculated based on the weight of the waste presented by the local authorities which is multiplied by a specific coefficient for each of the materials of packaging waste; the coefficients are adjusted every year, in both countries, together with the inflation rate.

The quality of the residuals delivered is also taken into consideration when calculating the financial transfers in the two system, yet, in different terms. In the Portugal there are strict limitations for the presence of impurities in the waste picked up by selective collection, and if the quality of the bundle falls under the percentage of external fractions allowed, the cargo is not retrieved. On the other hand, in Italy, the consortia recognize different values of compensation for different bands of quality levels of the packaging delivered. The more external fractions are present, the less the value of the financial support will be, until reaching a level where the materials are not compensated with the payment of the transfer.

Furthermore, in Portugal, the values of the financial support to local authorities take also into consideration the quality of the collection service operated by the SGRUs. Based on several criteria such as the distance of eco-points and the accessibility of the service, the SIGREs recognize an additional compensation to those who score best in the factors in analysis, while they penalize those who score poorly. Such criterion is not applied in the Italian model, where the consortia do not consider the management of the collection practices, yet, they subsidize the transportation of the bundles of waste until the platforms where they must be delivered for being retrieved by the consortia.

Finally, there are also two substantial differences between the two models, the first one concerns the role that the actors in the industry have into raising awareness among the population on the importance of the recycling and waste separation. In Italy, indeed, this duty is expressed in the agreement between the parts (ANCI and the consortia) and both assume the responsibility to organize sensitization campaigns among their areas of jurisdiction. Although the text is relatively vague when formalizing this duty, it is still relevant that it has been introduced in the technical appendixes. Furthermore, the second difference is that while the Portuguese model is approved and promulgated by Decree-Law, and it does involve a role of the government and the central state in the definition of the financial transfers; in Italy the financial supports to local authorities are determined between the two parts which sign the framework agreement completed by the technical appendixes. Even though it does imply any direct consequence in the model of calculation used in the two country, this formal difference highlights the more prominent role of the consortia in the Italian system, with respect to the SPV, Novo Verde and Amb3e in Portugal.

To conclude, the two compliance schemes do not present any relevant diversity, their managing actors both charge their members with a subscription fee and an annual contribution to fund their activities and the payment of the financial support to local activities, and they also gain net-back value from the selling of the materials to recyclers and reprocessors.

5. Cost Efficiency Analysis

This third section of the dissertation will focus on the estimation of the relative cost efficiency of the actors responsible for the collection of urban and packaging waste. Although the packaging waste sector constitutes a single and separate market once the materials are delivered to the competent agents (the Italian consortia and the Portuguese companies licensed to manage the sector), there is an overlap with the urban waste sector regarding the collection phase, as the agents performing these activities usually do it in an integrated system. For these reasons, the models which will be estimated do not concern the packaging materials only, as it is unfeasible, at the moment, to find disaggregated data on the specific flows of packaging waste residuals. Therefore, the model for Portugal will represent the total costs of the activities of the 23 SGRUs in the urban waste sector. For Italy is was possible to extract more specific data, namely for the different fractions of materials of urban waste which contain packaging materials. I will thus consider packaging waste together with non-packaging waste of the same material.

For this reason, the two countries will be modeled with two different functions and the analysis will be run separately. Nevertheless, the methodology applied to the two countries will be the same one, and the information about both systems will be organized in panel data.

Therefore, the main objective will be to identify the efficiency of each sector, represented by the time invariant persistent cost efficiency of the entities in the panels, which will allow for a classification of the utilities based on their efficiency scores. In a second step, I will estimate the time variant residual cost efficiency leading the computation of the overall cost efficiency. All models will be estimated using the software Stata, version 13.1.

5.1. Methodology

The methodology applied was taken from a reference book on stochastic efficiency analysis in Stata (Kumbhakar, Wang, & Horncastle, 2015). In particular, it will be replicated the model 11 of the chapter on panel data analysis (Kumbhakar & Heshmati, 1995), which builds upon the model proposed by Schmidt and Sickles (1984).

The methodology, as described in Kumbhakar et al. (2015) develops through four different steps. I first will obtain consistent estimators for the regressors through the generalized least squared methods with either fixed effects or random effects, using the Hausman test (Hausman,

1978) to choose between the two. Secondly, I will calculate the time invariant persistent cost inefficiency through the residuals of the estimation carried out in the former step. Then, a stochastic frontier estimated by maximum likelihood will be used to obtain values for the parameters associated with the random error and the time varying residual inefficiency. Last, the JLMS technique (Jondrow, Knox Lovell, Materov, & Schmidt, 1982) it will be possible to calculate the value of the residual cost inefficiency for all observations in the panel.

The model considered is the following:

$$c_{it} = \beta_0 + \boldsymbol{w'_{it}\beta} + \epsilon_{it} \qquad (5.1)$$

Where
$$\epsilon_{it} = v_{it} - u_{it} \qquad (5.2)$$

$$u_{it} = u_i + \tau_{it} \qquad (5.3)$$

Where the dependent variable is total costs (c_{it}), and it is explained by a bundle of independent variables ($\boldsymbol{w'_{it}}$) and the composed error (ϵ_{it}). The composed error is given by the difference between a zero mean random error $v_i \sim i.i.d.N(0, \sigma_v^2)$, and the overall cost inefficiency parameter (u_{it}), which is further decomposed into a persistent, time invariant, component, (u_i), and a residual time varying inefficiency (τ_{it}), both of which positive. While the former is time invariant and only firm-specific, the latter is also time-specific, which allows us to distinguish between the inefficiency caused by the management practice, which is usually consistent over time, and the sporadic inefficiency of single years, but which rarely have a time trend.

Incorporating the information expressed in the equations 5.2 and 5.3, in the case of fixed effects, with the firm-inefficiency correlated with the explanatory variables, the model in 5.1 can be rewritten as:

$$c_{it} = a_i + \boldsymbol{w'_{it}\beta} + \omega_{it} \qquad (5.4)$$

Where
$$a_i = \beta_0 - u_i - E(\tau_{it}), \qquad (5.5)$$

$$\text{and } \omega_{it} = v_{it} - \left(\tau_{it} - E(\tau_{it})\right). \qquad (5.6)$$

The new component in 5.6 is a zero mean and constant variance error, which is suitable for the estimation of the fixed-effects model through the generalized least squared method.

In the case of random effects, where the inefficiency of the entities in the panel is not correlated to the regressors in the model, a further transformation is required to allow for the individual effects, a_i, to be a random variable with zero mean. In this case the model of 5.1 can be rewritten in the following expression:

$$c_{it} = \beta_0^* + \boldsymbol{w'}_{\boldsymbol{it}}\boldsymbol{\beta} - u_i^* + \omega_{it} \qquad (5.7)$$

Where $\beta_0^* = \beta_0 - E(u_i) - E(\tau_{it}),$ *(5.8)*

$$u_i^* = u_i - E(u_i), \qquad (5.9)$$

and $\omega_{it} = v_{it} - (\tau_{it} - E(\tau_{it})).$ *(5.10)*

Now, both the error component in 5.7 and u_i^* (5.9) are random variables with constant variance and zero mean, which make this version of the model also suitable for the estimation through GLS methods.

As anticipated, to decide which estimation method should be applied to the model, the Hausman test will be implemented. The test considers the estimators resulting from both methods, and then compares them to find out if the explanatory variables in the model present correlation with the error component. The null hypothesis of the Hausman test is that both random and fixed effects estimators are consistent, yet the random effects estimator is also efficient, while the alternative hypothesis considers that the fixed effects estimator is consistent while the random effects estimator is inconsistent, because correlation was found between the regressors and the error.

The test computes the following calculation:

$$H = (\hat{\beta}_{FE} - \hat{\beta}_{RE})'[V(\hat{\beta}_{FE}) - V(\hat{\beta}_{RE})]^{-1}(\hat{\beta}_{FE} - \hat{\beta}_{RE}) \sim \chi^2_{\mathrm{k}}. \qquad (5.11)$$

I will run the Hausman test and either accept or reject the null hypothesis I will be able to use GLS regression on the proper version of the model presented so far, and to get the estimators for the explanatory variables, completing the first step of the methodology.

The second step aims to calculate the persistent cost inefficiency of the individuals in the panel. In the fixed effect methods, once the estimators have been computed, the pseudo residuals can be predicted by intuitively rewriting the equation 5.4 as:

$$r_{it} = c_{it} - \boldsymbol{w'}_{\boldsymbol{it}}\boldsymbol{\beta} \qquad (5.12)$$

Where $r_{it} = a_i^* + \omega_{it}$ *(5.13)*

By calculating the mean of the pseudo residuals, it is possible to get an estimation of a_i^*, given that ω_{it} is a zero-mean error, thereafter it is thus possible to obtain the value of the persistent individual cost inefficiency from the formula:

$$u_i = \widehat{a_i^*} - \min_i(\hat{a}_i) = \overline{r_i} - \min_i(\overline{r_i}) \quad (5.14)$$

$\overline{r_i}$ is the mean of the values of the pseudo residuals of the firms in the panel over the years. Finally, to be able to get a score for the persistent cost efficiency of each entities, it is enough to compute the following operation, presented in Battese & Coelli (1988):

$$P\_CE_i = \exp(-u_i) \quad (5.15)$$

By construction, the most efficient entity of the panel reaches the maximum score of 1, and it is considered fully efficient. The scores of the other units in the panel are then calculated taking as reference the value most efficient.

On the other hand, if in the first step the Hausman test does not reject the null hypothesis and a random effects estimator is used, then the process of estimation of P_CE_i presents some differences from the procedures just described.

With random effects it is possible to predict the pseudo residuals from the GLS estimation by rewriting equation 5.7:

$$\widetilde{r_{it}} = c_{it} - \boldsymbol{w'}_{it}\widehat{\boldsymbol{\beta}} - \beta_0^* \qquad (5.16)$$

From where, always according to equation 5.7, u_i^* can be estimated. The individual persistent cost inefficiency is then obtained from:

$$u_i = u_i^* - \min_i(u_i^*) \quad (5.17)$$

And, as in the former procedure, the efficiency scores for the persistent cost efficiency can be calculated through equation 5.15. Also with random effects, the most efficient unit is considered to score a perfect 1, and the other entities' scores are calculated based on this reference.

Once the efficiency scores have been calculated, in one of the two available estimation methods, it is then possible to rank the units in the sample according to their permanent cost efficiency levels, from the most efficient to the least one. Furthermore, the following step of the analysis is to estimate the stochastic frontier for the estimation of the parameters of the residual inefficiency. Starting from this third step, it does not matter if the model has fixed or random effects, the method is the same in both situations.

For the estimation of the stochastic frontier, it is necessary to make a further assumption, which is that $\tau_{it} \sim i.i.d.N^{+}(0, \sigma_\tau^2)$, therefore imposing to the residual cost inefficiency a half normal distribution. The stochastic frontier estimated is quite simple, after having obtained values for $\boldsymbol{\beta}$ and u_i, it is possible is to calculate the residuals:

$$\eta_{it} = c_{it} - \boldsymbol{w'}_{it}\boldsymbol{\beta} - u_i \qquad (5.18)$$

The residuals are then treated as dependent variables in the stochastic frontier estimation to estimate β_0, σ_v^2 and σ_τ^2. The log-likelihood function[27] appears thus as:

$$L(\beta_0, \sigma, \lambda) = cons - ln\, \sigma + ln\Phi\left(-\frac{\omega_{it}\lambda}{\sigma}\right) - \frac{1}{2}\left(\frac{\omega_{it}}{\sigma}\right)^2 \qquad (5.19)$$

Where $\lambda = \frac{\sigma_v}{\sigma_\tau}$, $\sigma^2 = \sigma_v^2 + \sigma_\tau^2$, $\omega_{it} = \tau_{it} + v_{it} = \eta_{it} - \beta_0$, and Φ is the cumulative distribution function of the standard normal variables (Kumbhakar & Heshmati, 1995). The estimates of the three parameters needed, the intercept, the variance of the residual cost inefficiency and the variance of the random error are then obtained by maximizing the log-likelihood function.

Once the log-likelihood function is maximized, the last step of the methodology (Kumbhakar et al., 2015) is to calculate τ_{it} for all observations in the panel through JLSM technique (Jondrow et al., 1982). The residual inefficiency can be estimated either from the mean or the mode of the conditional distribution of τ_{it}:

$$\widehat{\tau_{it}} = \frac{\hat{\lambda}\hat{\sigma}}{(1+\widehat{\lambda^2})}\left[\frac{\hat{\lambda}\omega_{it}}{\hat{\sigma}} - \frac{\Phi\left(\frac{\hat{\lambda}\omega_{it}}{\hat{\sigma}}\right)}{\Phi\left(\frac{-\hat{\lambda}\omega_{it}}{\hat{\sigma}}\right)}\right] \qquad (5.20)$$

$$\widetilde{\tau_{it}} = \begin{cases} \widehat{m_{it}} & if\ \omega_{it} \leq 0, \\ 0 & otherwise \end{cases} \qquad (5.21)$$

Where $\widehat{m_{it}}$ is $\frac{\lambda^2\,\omega_{it}}{(1+\widehat{\lambda^2})}$. Kumbhakar & Heshmati (1995) report that the advantage of using the mode would be that it can also be considered the maximum likelihood estimator for the residual inefficiency given ω_{it}. Now that the residual inefficiency has been estimated, the efficiency scores can be retrieved using Battese & Coelli (1988)'s formula, as in function 5.9.

[27] The function 5.19 refers to a single observation.

Finally, to calculate the overall cost efficiency, which gives a more complete representation of the units' cost efficiencies, combining both persistent and residual components, it is only necessary to use equation 5.3 to calculate the overall cost inefficiency (u_{it}) and get the efficiency scores with the formula by Battese & Coelli (1988).

5.2. Data

Regarding the choice of the explanatory variables and the definition of the cost function, I took as reference Antonioli & Filippini (2002), whom, in their article published in the Review of Industrial Organization, define a total cost function and a variable cost function for the collection of waste in Italy.

Concerning the Portuguese system, the data were organized in a strongly balanced panel data defined yearly by the time variable, *t*, covering the period from 2011 to 2015, and by the panel variable, *id*, which gives a scalar value to each utility of the panel, namely the 23 SGRUs, listed in the variable *name*, and available in appendix 1.

The dependent variable represents the total costs of the activities of the 23 utilities with two observations which for the total costs of Ecobeirao and Resialentejo for, respectively, 2011 and 2015. The values were collected from ERSAR databases accompanying their annual report on water and waste services in Portugal (RASARP). The Reports and the data on the evaluation cycle of the quality of the service provided to the users, are freely available on the webpage of the regulatory entity (http://www.ersar.pt/pt).

In line with the reference taken for the analysis (Antonioli & Filippini, 2002), the explanatory variables include one output variable and three input prices. The output, *tcol*, was identified as the total weight, measured in tons, of waste collected, whose values were also retrieved from the publications of ERSAR. Moreover, the input prices are the price of capital (*pk*), the price of labor (*pl*) and the price of fuel (*pf*).

The first was computed by dividing the costs of capital by the units of capital owned by the SGRUs. Two assumptions were, therefore, made. First, the costs of depreciation and amortization were assumed to represent the total costs of capital, and secondly, the units were counted as the number of eco-points which each firm owned in each of the five years of the analysis. While the costs were collected from the annual reports and accounts of the 23 entities, the quantity of eco-points was reported by ERSAR in the data and indicators published every year. Given how the variable was defined, the unit of measurement is euros for unit of capital.

The price of labor indicates the wage of the employees working in the waste sector, measured in euros. The data was taken from the database of INE, which reports the average wage for workers in the sector of capture, treatment and distribution of water, sanitation, waste management and de-pollution. The values are disaggregated for the number of employees operating in the companies[28] and for the five years between 2011 and 2015. Moreover, the data also distinguish between the regions where the firms operate, the values of the wages thus differ based on whether the area is in the North, in the Central region, in the metropolitan area of Lisbon, in Alentejo (Center-South) or in the Algarve (South).

Furthermore, the price of fuel represents the average price of diesel to the consumers in continental Portugal. Measured in euros per liter, it was retrieved from a database made available from the Directorate General for Energy and Geology (DGEG) on their website (http://www.dgeg.gov.pt/).

Finally, two more explanatory variables were included in the model, the number of sorting and transference platforms owned by the SGRUs and the average altitude of their operational area. The former, *sort*, was collected from the database of ERSAR; the latter, on the other hand, was calculated from the individual altitudes of all councils in continental Portugal available on the INE website (http://ine.pt/), and it is measured in meters. The average altitude was chosen to see if in higher areas the costs increase, assuming that in higher regions more fuel is used for climbs.

The main statistical indicators of the variables for the Portuguese system are summarized in the following table, *id_unique* was introduced in order to give a reference value to each single observation in the panel.

[28] The wages are divided between one to four, five to nine, ten to nineteen, twenty to forty-nine, fifty to ninety-nine, one hundred to two hundred and forty-nine, two hundred and fifty to five hundred and more than five hundred people employed in a company.

Variable	Obs	Mean	Std.Dev	Min	Max
tc	113	1.37E+07	1.51E+07	750972.3	5.68E+07
tcol	115	198868.6	185244.9	13095	829747
pl	115	908.772	112.8502	662.84	1363.31
pf	115	1.344355	0.082742	1.208803	1.4503
pk	115	1743.264	1043.943	20.05114	5191.646
sort	115	4.947826	3.125569	1	12
alt	115	217.1387	176.7869	26.51	696.26
id_unique	115	58	33.34167	1	115
id	115	12	6.662279	1	23

Table 18 Statistical information on variables for Portugal

Finally, the total costs function for the collection of urban waste in Portugal, after imposing linear homogeneity in input prices, by dividing the monetary variables by one of the input prices (Antonioli & Filippini, 2002), can be written as:

$$\log\left(\frac{tc_{it}}{pf_{it}}\right) = \beta_0 + \beta_{col}\log(tcol_{it}) + \beta_k\log\left(\frac{pk_{it}}{pf_{it}}\right) + \beta_l\log\left(\frac{pl_{it}}{pf_{it}}\right) + \beta_{sort}\log(sort_{it}) + \beta_{alt}alt_i + \epsilon_{it} \quad (5.22)$$

For what concerns the Italian system, the panel data is a balanced panel but with gaps. The time variable comprehends the years of 2008, 2009, 2011, 2014 and 2015. Also, as for the model for Portugal, the panel variable, *id*, was generated from *name*, a list of 19 Italian regions[29], the highest local authorities in which the Italian state is divided, available in appendix 1. The data, therefore, represent the aggregate activity of the municipalities in each region.

The variables of total costs and total quantity collected, were retrieved from the annual reports on urban waste of the Institute for Environmental Protection and Research (ISPRA). It is important to highlight that ISPRA collects its data through the MUD declaration[30], a document which all municipalities need to fill out every year and deliver to institute with the information on the quantities and costs of their urban hygiene services, which also comprehend the waste management activities. However, every year there is a percentage of municipalities which does not deliver the declaration, does it with a delay, or, more commonly, delivers the document

[29] Italy is actually divided in 20 regions: Abruzzo, Basilicata, Calabria, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Lazio, Liguria, Lombardia, Marche, Molise, Piemonte, Puglia, Sardegna, Sicilia, Toscana, Trentino-Alto Adige, Umbria, Valle d'Aosta, Veneto. The region of Valle d'Aosta has been excluded from the analysis because of the lack of information regarding their municipalities' waste management operations. Nevertheless, Valle d'Aosta is the smallest, least populous region, and with the lower density in Italy. For this reason, the analysis should not be affected by its omission.

[30] Modello unico di dichiarazione ambientale.

without filling out all its parts. For this reason, the published data are the direct expression of just a sample of municipalities in the country, whose size is: 31.7% of the municipalities in 2008; 31.4% in 2009, and 31.6% in 2011. For the last two years of the analysis, the representativiness of the sample increases to 33.6 in 2014 to drop back to 31.1% in 2015.

Moreover, the dependent variable of total costs, *tc*, represents the costs of collection, transportation and sorting operations of the five different fractions of urban waste which include packaging waste. The exact flows of materials collected, whose weight in tons defines the output variable *tcol*, which concur in generating the costs of the dependent variable are labeled by the following CER codes[31]:

- CER 105101 and 200101 for paper and cardboard waste;
- CER 150107 and 200102 for glass waste;
- CER 150102 and 200139 for plastic waste;
- CER 150104 and 200140 for metallic waste;
- CER 150103, 200137 and 200138 for wood waste.

Furthermore, for the Italian model the same input prices, of the previous model, were considered. The variable *pk* was calculated from the total costs of capital retrieved from the reports of ISPRA, divided by the number of sorting platforms in each region, and therefore measured in euros per unit. The costs of capital are the sum of three separate components, namely amortizations, provisions and remuneration of capital, while the use of the platforms as the reference unit of capital stands on the assumption that a fixed stock of capital corresponds to each platform, for instance a fixed number of vehicles and machines dedicated to the pre-treatment operations.

The price of labor, *pl*, was collected from the Italian statistical yearbooks of the Italian National Statistical Institute (ISTAT) and represents the average wage of workers in the water and waste sector by geographical area (north-east, north-west, center, south and islands). Moreover, the price of fuel is the annual average price of diesel to the consumer and its values were recovered from the database of the Ministry of the Economic Development.

Finally, two more variables complete the panel. One is the percentage of population of each region which lives in a mountainous area, *mount*, and the second one is a dummy variable called *south* which gives the value of one to the southern regions. The percentage of population

[31] The CER codes form a European common labeling to recognize the different fractions of waste.

living in a mountainous area is expected to have a positive effect on the costs, as more fuel would be required to collect the waste from this percentage of population. The dummy was chosen to see if the geographical position of the region had an effect on the costs, possibly through spill-over effects between neighbor regions.

As for the previous model, the main statistical information for the variables of the panel are shown in a table:

Variable	Obs	Mean	Std.Dev	Min	Max
tc	95	1.18E+07	1.64E+07	118881.1	8.08E+07
tcol	95	101438.2	157598.9	675	713857.3
pk	95	2923.435	2127.906	92.92308	9344.048
pf	95	1.486484	0.168152	1.23375	1.7266
mount	95	0.212708	0.243003	0.002	1
south	95	0.631579	0.484935	0	1
pl	95	2076.762	143.5214	1841.58	2341.298
id_unique	95	48	27.56810	1	95
id	95	10	5.506283	1	19

Table 19 Statistical information on variables for Italy

Finally, the total costs function for the Italian system, after imposing linear homogeneity in input prices, can be written as:

$$\log\left(\frac{tc_{it}}{pf_{it}}\right) = \beta_0 + \beta_{col}\log(tcol_{it}) + \beta_k\log\left(\frac{pk_{it}}{pf_{it}}\right) + \beta_l\log\left(\frac{pl_{it}}{pf_{it}}\right) + \beta_{mount}\log(mount_{it}) + \beta_s south_i + \epsilon_{it} \qquad (5.23).$$

5.3. Results of the Portuguese system

The calculation of the relative cost efficiency of the individuals in the panel data referring to the Portuguese system, has been achieved by replicating the methodology presented in section 5.1 on the total cost function 5.22. But before regressing the function with GLS, I conducted a prior analysis on the regressors chosen, by generating a correlation table to see whether the explanatory variable may be indeed correlated one with the other. For the correlation table, see the appendix 2.

After this preliminary step, the Hausman test was applied to the estimators generated through both fixed effects and random effects GLS methods. The results of the test (0.3206) confirmed the null hypothesis; therefore, random effects were chosen to estimate the model.

The results of the estimation method chosen are the following:

R-sq:	overall	=	0.9058
Wald	chi2(5)	=	265.04
Prob >	chi2	=	0.0000

ltc	Coef.	Std.Dev	z	P>|z|
ltcol	1.0083110	0.073060	13.80	0.000
lpk	0.1404622	0.028778	4.88	0.000
lpl	0.6158023	0.197660	3.12	0.002
lsort	0.1375715	0.083618	1.65	0.100
alt	0.0002026	0.000431	0.47	0.638
_cons	1.4988220	1.468097	-1.02	0.307

Table 20 Results of the GLS estimation with random effects

First, the overall r-squared shows that the regressors that were picked, to estimate the total costs, are responsible for 91% of the variance of the dependent variable; and the null hypothesis of the Pearson's chi2 test, that all coefficients are equal to zero, is rejected Moreover, the variables appear to be significant, except for the average altitude and, if we consider only variables with a p-value below 5%, also of the number of platforms.

Most importantly, the coefficients have the expected signs, and by construction of the function, they represent the cost elasticities of the explanatory variables, with the exception of the estimator of the average altitude. The quantity of waste collected is highly significant and has a cost elasticity almost equal to one, implying that an increase of 1% in the weight of the urban waste collected will have the same effect on the costs, increasing them of 1%. The results thus imply that the collection function has constant returns to scale, and that marginal cost is constant and equal to average cost. Furthermore, the two input prices confirm the well-behavior of the cost function, which is indeed increasing with respect to both output and prices. The cost elasticity of the price of capital is estimated to be around 0.14, while the cost elasticity of the average wages in the sector, the price of labor, is estimated to be 0.62.

Moreover, the effect of the variable *lsort* seems to be more complex to explain. In fact, if the positive sign of the estimator could have been expected due to the increase of labor and capital which more platforms would require, on the other hand, the effect could have been counterbalanced by the savings in fuel. Yet, as of the results of the GLS estimation, total costs seem to be increasing in the number of platforms.

In addition, the average altitude, besides not being significant, also has a coefficient really close to zero while the expectations on the estimator of the variable were of a positive effect on the total costs. They were not confirmed.

Finally, as linear homogeneity in input prices was imposed in the definition of the cost function, it is also possible to extrapolate from the results of the random effects estimation, the value of the cost elasticity of the price of fuel. An increase of 1% in the price of fuel is estimated to generate an increase of 0.24% in the total costs of the activity carried out by the 23 SGRUs.

Once the cost function was estimated, it was possible to extract the residuals and, from there, to calculate the persistent time invariant cost efficiency. The average persistent cost efficiency of the Portuguese collection system of urban waste was calculated to be 58.17%, while the table below shows the individual firms ordered according to their efficiency scores, from the most efficient, to the least one.

name	P_CE	name	P_CE
Ambisousa	100.00%	Resíduos do Nordeste	57.70%
Amarsul	81.00%	Resiestrela	54.08%
Resinorte	77.13%	Valorlis	51.71%
Algar	71.53%	Resialentejo	46.94%
Resulima	71.24%	Suldouro	45.34%
Gesamb	70.77%	Amcal	44.56%
Valorsul	67.65%	Valnor	43.94%
Ecolezíria	65.93%	Ersuc	42.01%
Valorminho	64.31%	Resitejo	38.38%
Ambilital	63.63%	Lipor	32.18%
Braval	59.95%	Tratolixo	29.11%
Ecobeirão	58.81%		

Table 21 Persistent cost efficiencies of the SGRUs

The most efficient firms are Ambisousa, Amarsul and Resinorte, while the ones with the lowest persistent cost efficiency scores are Resitejo, Lipor and Tratolixo. An important reminder, already explained in section 5.1, is that by construction the most efficient firm receives a score of 100% and that the scores of the other firms are estimated on that reference. It is however possible to observe the efficiency gap intra-sector with 8 SGRUs performing with a persistent cost efficient lower than the 50% of the most efficient firm. Moreover, the second firm is separated from Ambisousa by 19 percentage points, which increase to more than 20 when the third most efficient firm is considered.

After the persistent cost efficiency was calculated, the stochastic component of the model was estimated through maximum likelihood. The purpose of the residual cost inefficiency estimated at this point is to allow for an inclusion of time varying inefficiencies which should resume the effects of specific events which affected the efficiency of the firms, but which lasted only for a short period of time. Once the values for CE_R were obtained, it was then computed the overall efficiency of the sector; the average scores are the following:

Variable	Obs	Mean	Std. Dev.	Min	Max
CE_R	113	0.9092422	0.0389994	0.6923070	0.9699664
P_CE	115	0.5816994	0.1658207	0.2910651	1
OCE	113	0.5308608	0.1569535	0.2466719	0.9348380

Table 22 Average cost efficiencies of the Portuguese system

From the results obtained from the stochastic frontier analysis it appears that the cost inefficiencies of the firms in the sector is mainly due to persistent cost inefficiencies, rather than residual ones. The mean of the residual cost efficiencies is indeed really high compared with the time invariant part, which indicates that the overall cost inefficiencies that affect the SGRUs are probably due to management practices which take a long time to change and adapt to optimal choices. Moreover, it thus seems that sporadic yearly event did not have a strong impact on the minimization of the costs of the firms, in fact the minimum score for residual cost efficiency is almost 70%. In fact, when looking at the ordered scores of the overall cost efficiencies, Ambisousa, Amarsul and Resinorte still occupy the top standings with all their observations, while Tratolixo, Lipor and Resitejo stay at the bottom. The ranking of the observations for overall cost efficiency is available in appendix 3.

Finally, the average overall efficiency in the sector is set on 53%. Nevertheless, it is important to acknowledge the fact that the model treats firms-effects as persistent cost inefficiency lowers the overall cost efficiency because unobserved time invariant regressors are not recognized by the model (Kumbhakar et al., 2015).

5.4. Results of the Italian system

The efficiency analysis of the Italian system will follow the four steps of the methodology described in this chapter using the total cost function 5.23. Similar to what I have done in the previous section, I first generated a correlation table to perform a preliminary analysis on the independent variables chosen to express the total costs of the collection of the five separate fractions of urban waste. For the correlation table, see the appendix 2.

Afterwards, the Hausman test was applied to the estimators of both the GLS regression methods with fixed and random effects. With a p-value of 0.2450, the null hypothesis was not rejected, and both estimation techniques would produce consistent results; between the two, fixed effects methods were chosen as they produced more convincing results. Moreover, as fixed effects do not allow for the use of time invariant, the dummy variable south was dropped from the analysis.

The results of the fixed effects estimation are presented below:

R-sq: overall = 0.918

F(4,72) = 168.62
Prob > F = 0.0000

ltc	Coef.	Std.Err	t	P>|t|
ltcol	0.9841633	0.043850	22.44	0.000
lpk	0.0860781	0.045220	1.90	0.061
lpl	0.0269698	0.193211	0.14	0.889
mount	0.7403964	0.723894	1.02	0.310
_cons	3.7075050	1.626940	2.28	0.026

Table 23 Results of the GLS estimation with fixed effects

The r-squared overall value is 91% so the model is suitable for explaining the variance of the dependent variable, and the p-value of the F-test rejects the null hypothesis of all the coefficients being zero. The coefficients are all as expected, the cost function is increasing in both output and input prices, confirming that the costs function chosen grows monotonically in input prices. The cost elasticity of the quantity collected is about 98, while for the two input prices which appear in the function is quite low, an increase of 1% in the value of the prices would generate an increase in the costs of only 0.09% and 0.03%. Also in this case we almost have constant returns to scale in the collection function associated at the costs function in analysis. The cost elasticity of the price of fuel, however, is high; through the imposed property of linear homogeneity of the cost function in input prices, it is possible to extract the elasticity of *pf*, which is about 88.

Furthermore, also the percentage of population living in a mountainous area has a positive effect on the total cost, possibly because it drives up the volume of fuel needed to carry out the collection of the five fractions of urban waste in analysis, as we expected. Finally, the price of labor and the variable *mount* do not appear significant in the regression, while the total quantity collected of the five fractions of the materials of packaging waste is highly significant.

After the estimation of the cost function, it was possible to predict the residuals and calculate the persistent cost efficiency, always following the proper methodology for fixed effects. The average persistent cost efficiency in Italy is about 38.99%, a low value which denotes a lack of homogeneity among the Italian regions in their persistent cost efficiencies. As for the previous model, I reported the list of the entities, together with their efficiency sores, in the table below:

name	P_CE	name	P_CE
Trentino Alto Adige	100.00%	Puglia	31.68%
Umbria	68.95%	Friuli Venezia Giulia	29.28%
Emilia Romagna	52.72%	Molise	29.02%
Veneto	50.05%	Lazio	26.94%
Liguria	49.28%	Calabria	25.22%
Lombardia	42.36%	Abruzzo	24.30%
Toscana	42.02%	Campagna	24.05%
Marche	38.86%	Sardegna	19.53%
Piemonte	35.98%	Sicilia	14.95%
Basilicata	35.54%		

Table 24 Persistent cost efficiencies of the Italian regions

The region with the highest persistent cost efficiency is Trentino Alto Adige, followed by Umbra and Emilia Romagna; the lower score belongs to Sicilia, with Sardegna and Campagna occupying the 18th and 17th place. Once again, to the most efficient region is assigned the score of 100% by construction and all the other regions are weighted respectively against this reference. The results show that the first two regions are really efficient comparatively to the other districts of Italy, in fact Emilia Romagna and Veneto, which are located in third and fourth place, perform their collection activities with roughly half of the persistent cost efficiency of Trentino Alto Adige.

Furthermore, once the deterministic persistent efficiency has been calculated, I estimated the stochastic frontier to obtain the residual cost efficiency and, consequently, the overall cost efficiency. The three average cost efficiencies are presented in the following table:

Variable	Obs	Mean	Std.Dev	Min	Max
CE_R	95	0.8775460	0.04905	0.69135	0.95676
P_CE	95	0.3898617	0.19373	0.14947	1
OCE	95	0.3420035	0.17107	0.12969	0.91661

Table 25 Average cost efficiencies of the Italian system

Contrary to the previous model, in Italy the time varying factors have a greater impact, which could be explained by the larger gap in the time variable defining the panel data. The average overall cost efficiency is 34%, yet, it does not take into consideration neither observed nor unobserved time invariant regressors (Kumbhakar et al., 2015). Also in this system, the inefficiency might be originated by non-optimal management practices which, in a sector shielded from competition, could be more resistant to change. The ranking of the observations for overall cost efficiency scores is available in appendix 3.

Finally, when observing the individual overall cost efficiency for each *id_unit*, it shows that, although there is no notable difference among the most efficient regions, at the bottom of the list, Abruzzo and Calabria had many observations in the final spots, mixed with the ones of the observations of Campagna. In those specific years, therefore, they displayed a higher residual cost inefficiency, which implicates for their overall scores to be lower.

6. Conclusions

The dissertation developed the topic of packaging waste management from different angles, both qualitative and quantitative, building an all-around analysis to the phenomenon. Starting with the review of the main contributions in the literature on the topic, I highlighted how new models and entire new fields of studies, like packaging waste, have been explored to face the new challenges that academics where trying to overcome. Until the present days where, on the topic of packaging waste management, there is a clear research path opened by the EIMPack project which analyzes the sector through cost-benefits analysis, while the stochastic efficiency analyses are uniquely directed to the wider category of urban solid waste.

In the dissertation, even though for Portugal I estimated an urban waste collection system, with Italy I tried to partially fill the void in the literature on stochastic efficiency analysis on packaging waste management. I succeeded only partially, because the model, given the data available, was not only considering costs and quantities of packaging, but also of non-packaging of the same materials.

Following this first part, I have then built an institutional and legal framework to the subject, with the intent of helping the reader to contextualize the sector of packaging waste management first in the European Union, and then in Portugal and in Italy. Such framework was fundamental in the development of the qualitative analysis of the fourth chapter, where, without the technical notions presented, it would have been impossible to go into details in the structure of the compliance schemes implemented in the two countries. The identification of the main players in the sector also offered a different insight angle on the topic.

Furthermore, the main focus of the qualitative analysis has been the financial support to local authorities, to understand how they are calculated, what the conditions that must be respected are, and how do they differ between the two countries. One of the main features of the Italian model of financial support, which is not presented in Portugal, is the creation of numerous bands of quality levels for the materials delivered to the competent agencies, remunerated consequently with decreasing values as the percentage of impurities and external fractions increases. On the contrary, one feature of the Portuguese model which is not replicated in the Italian calculations of the financial transfers is the premium variable and the variable on the quality of the service provided.

Coming now to the quantitative analysis, the stochastic relative cost efficiency analysis. This chapter represented the part of the dissertation closer to the area of the master program in economics itself. For Italy and Portugal, I have created a panel data with total costs, quantity of waste collected and the prices of capital, labor and fuel, both panels covering five years, with the Italian time variable presenting gaps. For both countries I estimated a time invariant persistent cost efficiency, a time varying residual cost and an overall cost efficiency. The results of the two model cannot be compared between each other as they represented two diverse categories of waste and were also estimated using different methods, one with random effects and the second with fixed effects.

Regarding the estimation of the model for Portugal the very low values of the residual inefficiency might suggest that the losses of efficiency in the Portuguese urban waste collection are mainly due to time invariant factor, which according to the authors of the methodological procedures should be interpreted as management practices which fail to minimize the cost. But the low values of residual inefficiencies could be also explained by the short period of time that the panel covers. Moreover, the average overall efficiency of 53% and the scores of the persistent efficiencies suggest a balanced sector, with no high polarization, where the majority of the firms stays close to the average value.

The estimation of the Italian cost efficiency in the collection of the specific fractions of urban waste, on the contrary, showed a greater impact of the residual cost inefficiency on the overall scores, producing changes in the list of regions ordered, first, by persistent cost efficiency. The sector, on average, appears to be balanced in the results, with the presence of a region which performs with an outstanding efficiency, Trentino Alto Adige, compared to the other regions. Given the methodology applied, this affected all the efficiency scores of the other regions, resulting in the low value of the average overall cost efficiency of 34%.

Finally, a result which I was not expecting to find, and might lead to further investigation on other countries, is the fact that the collection functions which is related to our cost functions both have constant returns to scale, as the cost output elasticities where both really close to one. Furthermore, the dissertation leaves also room for other further studies on the subject, for instance calculating the cost efficiencies of the two systems, separating the firm effects from the persistent efficiency, and computing a more accurate overall cost efficiency.

Appendix 1

- List of the 23 SGRUs:

name	*id*
Ambilital	1
AMCAL	2
Ecobeirão	3
Ecolezíria	4
Resíduos do Nordeste	5
Resialentajo	6
Resiestrela	7
Valnor	8
Valorminho	9
Ambisousa	10
Braval	11
GESAMB	12
Resitejo	13
Resulima	14
Valorlis	15
Algar	16
Amarsul	17
ERSUC	18
Resinorte	19
Suldouro	20
Tratolixo	21
Valorsul	22
Lipo	23

Table 26 Values of the variables "name" and "id"

- List of Italian regions:

name	*id*
Abruzzo	1
Basilicata	2
Calabria	3
Campania	4
Emilia Romagna	5
Friuli Venezia Giulia	6
Lazio	7
Liguria	8
Lombardia	9
Marche	10
Molise	11
Piemonte	12
Puglia	13
Sardegna	14
Sicilia	15
Toscana	16
Trentino Alto Adige	17
Umbria	18
Veneto	19

Table 27 Values of the variables "name" and "id"

Appendix 2

- Correlation table of the explanatory variables of the model for Portugal:

	ltcol	lpl	lpk	lsort	alt
ltcol	1				
lpl	0.2810	1			
lpk	0.0034	0.1969	1		
lsort	0.0632	0.0609	-0.1807	1	
alt	-0.2720	-0.1241	-0.1990	0.4328	1

Table 28 Correlation table of the variables for Portugal

- Correlation table of the explanatory variables of the model for Italy:

	ltcol	lpk	lpl	mount	south
ltcol	1				
lpk	0.4489	1			
lpl	0.2088	-0.0021	1		
mount	-0.2339	-0.2026	-0.0133	1	
south	-0.6014	-0.1286	-0.3712	-0.1818	1

Table 29 Correlation table of the variables for Italy

Appendix 3

- Ranking of SGRUs for OEC:

name	id	CE_R	OCE	name	id	CE_R	OCE	name	id	CE_R	OCE
AMBISOUSA	4	93.48%	93.48%	AMBILITAL	3	93.16%	59.92%	SULDOURO	18	95.74%	43.41%
AMBISOUSA	4	93.37%	93.37%	VALORSUL	23	88.04%	59.56%	AMCAL	5	96.36%	42.94%
AMBISOUSA	4	92.79%	92.79%	VALORSUL	23	88.03%	59.55%	Resialentejo	16	91.26%	42.83%
AMBISOUSA	4	92.27%	92.27%	Ecolezíria	9	89.98%	59.32%	AMCAL	5	94.88%	42.28%
AMBISOUSA	4	88.17%	88.17%	AMBILITAL	3	91.47%	58.83%	SULDOURO	18	92.63%	42.00%
AMARSUL	2	94.66%	76.68%	VALORMINHO	22	92.24%	58.69%	AMCAL	5	93.74%	41.77%
AMARSUL	2	93.59%	75.81%	AMBILITAL	3	90.49%	58.20%	VALNOR	20	93.96%	41.28%
AMARSUL	2	90.33%	73.17%	VALORMINHO	22	91.18%	58.02%	ERSUC	8	96.19%	40.41%
AMARSUL	2	90.07%	72.96%	VALORMINHO	22	90.95%	57.87%	AMCAL	5	90.51%	40.34%
RESINORTE	13	94.56%	72.93%	Ecolezíria	9	87.66%	57.79%	SULDOURO	18	88.86%	40.29%
AMARSUL	2	89.79%	72.73%	AMBILITAL	3	87.97%	56.58%	VALNOR	20	91.56%	40.23%
RESINORTE	13	92.95%	71.69%	VALORMINHO	22	88.77%	56.48%	Resialentejo	16	85.69%	40.22%
RESINORTE	13	92.78%	71.56%	BRAVAL	6	93.81%	56.24%	SULDOURO	18	88.03%	39.91%
RESINORTE	13	90.25%	69.61%	Resíduos do Nordeste	17	97.00%	55.96%	VALNOR	20	90.82%	39.90%
ALGAR	1	94.20%	67.38%	ECOBEIRÃO	7	94.50%	55.58%	SULDOURO	18	87.77%	39.80%
RESINORTE	13	87.30%	67.33%	ECOBEIRÃO	7	94.22%	55.41%	VALNOR	20	89.67%	39.40%
RESULIMA	15	93.97%	66.94%	BRAVAL	6	91.27%	54.72%	VALNOR	20	89.63%	39.38%
RESULIMA	15	92.72%	66.05%	BRAVAL	6	91.27%	54.72%	ERSUC	8	92.92%	39.04%
ALGAR	1	92.13%	65.90%	BRAVAL	6	90.76%	54.41%	ERSUC	8	92.44%	38.84%
GESAMB	10	92.64%	65.56%	BRAVAL	6	90.71%	54.38%	RESITEJO	14	96.47%	37.03%
ALGAR	1	91.56%	65.49%	Resíduos do Nordeste	17	93.56%	53.98%	ERSUC	8	84.90%	35.67%
ALGAR	1	91.39%	65.37%	Resíduos do Nordeste	17	92.89%	53.60%	RESITEJO	14	91.87%	35.26%
RESULIMA	15	91.64%	65.28%	ECOBEIRÃO	7	89.27%	52.50%	ERSUC	8	83.00%	34.87%
GESAMB	10	92.07%	65.16%	RESIESTRELA	12	94.31%	51.01%	RESITEJO	14	89.99%	34.54%
GESAMB	10	91.97%	65.09%	ECOBEIRÃO	7	85.64%	50.37%	RESITEJO	14	89.33%	34.29%
GESAMB	10	91.91%	65.04%	Resíduos do Nordeste	17	87.01%	50.20%	RESITEJO	14	81.45%	31.27%
RESULIMA	15	90.33%	64.35%	RESIESTRELA	12	92.55%	50.05%	AMCAL	5	69.23%	30.85%
VALORSUL	23	94.86%	64.17%	RESIESTRELA	12	91.94%	49.72%	LIPOR	11	93.28%	30.02%
GESAMB	10	90.54%	64.08%	VALORLIS	21	95.17%	49.22%	LIPOR	11	92.16%	29.66%
RESULIMA	15	89.85%	64.01%	VALORLIS	21	93.90%	48.56%	LIPOR	11	92.13%	29.65%
ALGAR	1	89.15%	63.76%	RESIESTRELA	12	89.52%	48.41%	LIPOR	11	91.87%	29.57%
VALORSUL	23	93.90%	63.52%	RESIESTRELA	12	87.84%	47.51%	TRATOLIXO	19	96.63%	28.13%
VALORSUL	23	91.55%	61.93%	VALORLIS	21	88.79%	45.92%	TRATOLIXO	19	92.49%	26.92%
Ecolezíria	9	93.75%	61.81%	VALORLIS	21	88.34%	45.68%	LIPOR	11	82.63%	26.60%
Ecolezíria	9	93.15%	61.41%	VALORLIS	21	88.04%	45.53%	TRATOLIXO	19	86.59%	25.20%
Ecolezíria	9	92.85%	61.21%	Resíduos do Nordeste	17	76.94%	44.39%	TRATOLIXO	19	86.10%	25.06%
AMBILITAL	3	94.20%	60.58%	Resialentejo	16	93.48%	43.88%	TRATOLIXO	19	84.75%	24.67%
VALORMINHO	22	94.37%	60.05%	Resialentejo	16	93.15%	43.72%				

Table 30 Ranking of SGRU's for efficiency scores

- Ranking of regions for OCE:

name	id	CE_R	OCE	name	id	CE_R	OCE
Trentino Alto Adige	17	91.66%	91.66%	Piemonte	12	80.57%	28.99%
Trentino Alto Adige	17	91.39%	91.39%	Puglia	13	90.66%	28.72%
Trentino Alto Adige	17	90.02%	90.02%	Puglia	13	90.05%	28.53%
Trentino Alto Adige	17	86.77%	86.77%	Basilicata	2	79.66%	28.31%
Trentino Alto Adige	17	79.83%	79.83%	Puglia	13	87.52%	27.72%
Umbria	18	95.68%	65.97%	Puglia	13	87.29%	27.65%
Umbria	18	91.58%	63.14%	Puglia	13	86.87%	27.52%
Umbria	18	87.40%	60.26%	Friuli Venezia Giulia	6	91.77%	26.88%
Umbria	18	86.69%	59.77%	Molise	11	92.23%	26.77%
Umbria	18	69.13%	47.67%	Friuli Venezia Giulia	6	90.51%	26.51%
Emilia Romagna	5	90.35%	47.64%	Molise	11	91.12%	26.45%
Liguria	8	95.38%	47.00%	Friuli Venezia Giulia	6	88.50%	25.92%
Emilia Romagna	5	88.74%	46.79%	Friuli Venezia Giulia	6	88.22%	25.83%
Emilia Romagna	5	88.71%	46.77%	Molise	11	88.37%	25.65%
Emilia Romagna	5	87.94%	46.37%	Lazio	7	92.76%	24.99%
Emilia Romagna	5	86.95%	45.84%	Molise	11	85.15%	24.71%
Veneto	19	91.14%	45.62%	Molise	11	83.64%	24.27%
Veneto	19	91.06%	45.58%	Lazio	7	89.25%	24.04%
Liguria	8	89.51%	44.11%	Friuli Venezia Giulia	6	81.78%	23.95%
Veneto	19	87.85%	43.97%	Lazio	7	88.27%	23.78%
Veneto	19	86.05%	43.07%	Calabria	3	92.65%	23.37%
Veneto	19	85.53%	42.81%	Calabria	3	92.32%	23.28%
Liguria	8	85.60%	42.18%	Lazio	7	86.30%	23.25%
Liguria	8	83.74%	41.27%	Abruzzo	1	94.72%	23.02%
Liguria	8	80.90%	39.87%	Abruzzo	1	93.84%	22.81%
Toscana	16	91.68%	38.53%	Lazio	7	84.30%	22.71%
Lombardia	9	90.86%	38.49%	Campania	4	93.60%	22.51%
Toscana	16	90.71%	38.12%	Campania	4	92.91%	22.34%
Toscana	16	90.17%	37.89%	Calabria	3	88.13%	22.23%
Lombardia	9	89.17%	37.77%	Abruzzo	1	89.25%	21.69%
Lombardia	9	88.58%	37.52%	Campania	4	89.61%	21.55%
Lombardia	9	87.77%	37.18%	Calabria	3	85.08%	21.46%
Lombardia	9	86.01%	36.43%	Calabria	3	80.45%	20.29%
Marche	10	93.23%	36.23%	Campania	4	83.40%	20.06%
Marche	10	92.52%	35.95%	Abruzzo	1	79.57%	19.34%
Toscana	16	84.91%	35.68%	Campania	4	75.65%	18.19%
Toscana	16	83.10%	34.92%	Sardegna	14	92.23%	18.01%
Marche	10	88.57%	34.41%	Abruzzo	1	73.05%	17.75%
Marche	10	86.69%	33.68%	Sardegna	14	90.89%	17.75%
Piemonte	12	93.31%	33.58%	Sardegna	14	90.17%	17.61%
Piemonte	12	91.42%	32.90%	Sardegna	14	89.49%	17.48%
Basilicata	2	91.55%	32.54%	Sardegna	14	75.12%	14.67%
Basilicata	2	91.18%	32.40%	Sicilia	15	90.43%	13.52%
Piemonte	12	88.56%	31.87%	Sicilia	15	90.09%	13.47%
Basilicata	2	89.17%	31.69%	Sicilia	15	88.27%	13.19%
Basilicata	2	88.41%	31.42%	Sicilia	15	86.88%	12.99%
Piemonte	12	84.61%	30.45%	Sicilia	15	86.76%	12.97%
Marche	10	75.54%	29.35%				

Table 31 Ranking of the regions for efficiency scores

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