Sustainable Solid Waste Management in the European Union: Four Countries Regional Analysis

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Keywords: Municipal Waste Management, EU Comparative Analysis, NUTS2 Regional classification, Circular Economy

Abstract

In the last twenty years, the EU has framed a comprehensive regulatory action aimed at shifting Waste Management practices to Sustainable Waste Management systems. The first premise is to foster waste prevention, and secondly to better treat waste residuals by promoting recycling practices. In a previous work, the authors qualitatively analysed the policies, criteria, methodologies and outcomes state-of-art of four EU-Member States (France, Germany, Italy and The Netherlands) in the transition from Waste Management to Sustainable Waste Management to Circular Economy. The study highlighted overall positive results, which are driving EU countries towards higher Municipal Solid Waste recycling rates and low dumping. This paper makes a step forward, by investigating Municipal Waste Management performances at regional level in the same EU-Member States. Specifically, it aims at assessing whether national data (outlined by the previous work) are homogenously distributed at regional stage, in order to understand how legislation is effectively applied within countries. The results confirm that Northern European countries have to a greater extent moved away from landfill in favour of higher recycling rates. Conversely, Italy and France are those displaying lower performances but with progressive improvements.

1. Introduction

In 2015, the European Union has outlined its plan for a Circular Economy (CE) with the aim to preserve growth and competitiveness while halving resource extraction through the implementation of innovative ways of production and consumption. In the last decade, indeed, price volatility and changes in the commodity market have increased the awareness toward resources-related issues and their implications on supply security and competitiveness (Domenecha and Bahn-Walkowiakb, 2018). Looking ahead, global material consumption could increase from 92 billion tonnes to around 190 billion tonnes by 2060, and greenhouse gas emissions could rise by 43% (EEA No 11/2019). Besides environmental impacts, this will generate problems of dependency, shortage, and costs inflation that societies have to face (Domenecha and Bahn-Walkowiakb, 2018).

The achievement of a Resource Efficient (RE) CE requires, among the others, the rearrangement of the traditional Waste Management (WM) operations. Indeed, WM has so far involved for the most end-of-stream solutions, which on the one hand contributed to material accumulation into landfills or into the environment, on the other to the production of harmful emissions and global overuse of virgin materials. Therefore, it emerged that linear processes do not efficiently use waste as a resource nor they have a positive impact on the environment (Silva, et al. 2017). In these concerns, the 2008 Waste Framework Directive introduced, within the EU legislation framework, the idea of a sustainable management of waste, which shall occur in compliance with the so-called waste hierarchy. The purpose of a Sustainable Waste Management (SWM) is to strengthen «the link between waste treatment and resource recovery» (Cobo and Antonio Dominguez-Ramos, 2018) by valorising end-of-life products, so to incentivize the circularity of materials. The first premise is to foster waste prevention, secondly to better treat waste residuals by promoting reuse, remanufacturing and recycling, and thirdly to reduce waste diverted into landfills. This approach will help to cut emissions generated by waste accumulation, and it will allow to save 17% -24% raw materials, which from an economic standpoint correspond to around €630 million cost saving, and increasing EU Gross Domestic Product (GDP) by 3,9% by 2030 (Domenecha and Bahn-Walkowiakb, 2018).

Over the last twenty years, EU-MSs have progressively reported positive improvements in the direction of SWM. To notice that due to the heterogeneous sources of waste (i.e. households, Small-Medium Enterprise (SME), healthcare origin, agriculture, and industry), the multiple activities and stakeholders involved (Castillo-Giméneza et al., 2019), this paper will focus on Municipal Solid Waste (MSW). This last, according to Dir 2018/851 corresponds to "*mixed waste and separately collected waste from households, and other sources that are similar to it, for nature and composition, such as "retail, administration, education, health services, accommodation and food services*". Notwithstanding the residual component on overall waste production (10% according to (Eurostat, 2018), MSW represents one of the most difficult waste sources to manage[1] (Fabrizi and Sospiro, 2017).

Despite more waste is being generated, the average EU-28 landfilling rate felt from 64% in 1996 to 23% in 2018, MSW recycled rose from 17% to 47% and MSW incinerated has increased from 67 kg per capita to 136 kg per capita (Eurostat, 2019). Notwithstanding, due to economic, social and institutional differences there are substantial disparities among EU-MSs. Indeed, just at first glance, Eurostat data suggest a considerable variation in MSW generated, from 228 kg per capita in Romania and 407 kg per capita in Latvia, where collection and recycling facilities are poorly developed, to 615 kg per capita in Germany and 511 kg per capita in the Netherlands, which report recycling rates over 50% and landfilling near to zero.

A more in-depth analysis is however required to examine the stage of implementation of WM policies and their effectiveness. The existing literature ultimately aims at measuring this process at national level. For instance, (Marin et al., 2017) (Castillo-Giméneza et al.,2019a) (Castillo-Giménez et al., 2019b) developed benchmarking techniques to assess MSs performances in municipal waste management, and investigated whether EU policies are supporting a convergence between successful/unsuccessful countries. However, the role of regions remains scarcely investigated. At the best of our knowledge only Rogge et al. (2017) have provided an analysis on MSW performance of NUTS2-regions in EU. Nevertheless, due to the decentralization of many environmental-related policies regions exerts a large influence and responsibilities in municipal waste management, which often reflects on national outcomes. Indeed, Mazzanti and Montini, (2014) highlited that several advanced countries have experienced waste related crisis due to the presence of internal hot spots that *are often regional in nature*. It emerges that, «a nation's performance is driven by the hidden evolution of sub-national clusters [..] and this creates complications when evaluating a given country's waste performance» (Mazzanti and Montini, 2014).

Against this background, this paper would contribute to make a step forward in the analysis of MSW management performance at EU-regional level. This paper represents a follow-up of the results presented in Chioatto and Sospiro (2020), in which authors qualitatively analysed MSW performance and convergence of four EU-MSs, France, Germany, Italy and the Netherlands, in order to examine policy efficacy both at national and European level efficacy to go on the direction of CE. Differently, in this paper authors will measure the performance of EU-regions (NUTS 2 level), in the same four countries, using Data Envelopment Analysis (DEA). Specifically, we will assess MSW management performances of the NUTS2- regions in France, Germany, Italy and the Netherlands. This will allow to examine how SWM transition is spreading among and inside EU countries, to identify weaknesses and efficient practices in municipal waste policies and therefore to support policymakers to design more coherent future objectives.

Summing up the contribution of this paper is twofold. We will rank and examine MSW management performances at regional level in four EU countries and compare the results with those provided in Rogge et al. (2017) for EU-regions and those provided in Castillo-Giméneza et al., (2019a, b) for EU-MSs. The aim is, to assess leading and lagging regions and to understand whether national data (outlined by previous works) are homogenously distributed at regional stage. This will indicate how legislation is effectively applied internally, and potential local-driving factors.

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[1] This derives from its heterogeneous nature, the potential impact on the environment and human health, the influential political profile of the topic, and its connection to consumption patterns.

The paper is organised as follows: Section 2 provides a literature review. Section 3 describes data and methodology undertaken in order to lead MSW management performance analysis at regional level. Section 4 presents and discuss the results, and Section 5 present the conclusions.

2. Literature Review

MSW is the product of our daily-lives. However, the environmental consequences associated with its management call for a change of direction towards more sustainable practices.

After the 2018 CE Package, the EU has revised its major WM directives. They regulate both prevention and treatment i.e. landfill, incineration (for disposal and energy recovery), recycling, and composting and digestion. In this regard, the new Dir 2018/851 has reinforced the targets on MSW recycling and reuse (55% by 2025, 60% by 2030, 65% by 2035) and Dir 2018/850 strengthened the target on MSW landfilled to less than 10% of the total amount of MSW generated by 2035. Furthermore, several definitions have been aligned, and a unique method for targets' calculation has been developed among EU Member States (MSs). However, since the subsidiarity principle applies to EU waste policy, national governments can exert a certain degree of freedom in the implementation of waste legislation. This results in a heterogeneous adoption of strategies and degree of implementation among EU-MSs, which require more investigation. On the one side, it is important to understand MSs state-of-art in the incorporation and level of compliance with WM directives. On the other side, an analysis of EU policy effectiveness is needed, with the extent to verify whether it is supporting a transition able to reduce the divergence between countries.

In the literature, Marin et al. (2017) tried to understand whether WM reorganization is decreasing or increasing EU-MSs disparities, through the application of a conventional β- and σ-convergence analysis to a dataset of 22 EU countries over the years 1995–2010. They found out that EU countries are converging toward a progressive decrease of landfilling and increase of recycling and incineration. This pattern is occurring faster in countries with stringent waste policies and with greater technological investments. Notwithstanding, structural differences on WM systems across countries still exists. These results are confirmed by Castillo-Giméneza, Montañés and J. Picazo-tadeo (2019a), which resorted DEA and Multi-Criteria-Decision-Making (MCDM) techniques to calculate a composite indicator of the performance in the treatment of MSW (EU-27). The results showed that a process of convergence has occurred after the incorporation of the 2008 Waste Framework Directive at national level, which confirms the important role of the environmental policy. However, substantial differences in the treatment of MSW still exists. Indeed, Northern and Central EU countries are generally moving their MSW treatment from landfilling to incineration, recycling and composting (best performers), whereas, Mediterranean and Eastern countries still mostly rely on landfill and display low MSW treated amounts (worst performers). Furthermore, in a more recent analysis with EU-28 Castillo-Giménez et al., (2019b) demonstrated that these results are positively related with countries' level of development, the quantity of MSW treated per capita, and the proportion of MSW recycled, composted and digested on the total waste treated.

Within this strand of research we consider necessary to clarify not only how the transition is occurring among EU countries, but also among MSs regions, from which MSW policies often starts. Indeed, it is important to notice, that waste policy competencies are divided also among regional and local authorities, which detains both decisional and operational responsibility. Therefore, a heterogeneous implementation of practices, economic, social and cultural factors may explain the unequal distribution of performances, thus the presence of successful/unsuccessful and leading/lagging regions that generate a disequilibrium in national results. In this concern, Rogge and De Jaeger (2012) benchmarked MSW management performance of EU NUTS2-regions. They used the Benefit-of-the-Doubt (BoD) techniques to create a performance indicator, which also account for the background conditions under which regions coordinate their WM, since this might influence their level of performance. The results obtained are in line with those presented by the literature on national performance: regions of EU Northern countries i.e. Austria, Belgium and Germany generally perform better in MSW management, whereas Southern EU-MS i.e. Cyprus, Italy, Malta, France and Portugal, display lower scores.

Against this background, following the approach adopted in Castillo-Giméneza et al., (2019a), we will resort DEA techniques with the extent to rank and analyse the performance in the generation and treatment of MSW at regional level of the EU-18. Despite DEA approach has been extensively used in the waste sector, there do not seem to be any other articles (except Castillo-Giméneza et al., (2019)) that utilize it to measure the performance of the EU countries in moving toward SWM, and none that take into account this phenomenon at regional level. Indeed, so far DEA has been mainly used to evaluate waste management economic efficiency. Rogge and de Jaeger (2012) have measured the cost efficiency of MSW collection and processing services, Chen, et al. (2010) and Albores et al. (2016) have evaluated the performance of Chinese incineration plants, Crociata and Mattoscio (2015) have measured recycling efficiency at local level. To notice that, DEA has also been used in Giannakitsidou et al. (2020) to rank EU countries performances, but they measured CE transition by accounting for social factors.

3. Data and methods

Dataset presentation

The analysis has been conducted on the dataset of municipal waste collected from the Statistical Office of the EU, Eurostat by means of the REQ – Regional environmental questionnaire Data aggregation. In line with Directive 2018/851 MSW corresponds to "*mixed waste and separately collected waste from households, and other sources that are similar to it, for nature and composition, such as "retail, administration, education, health services, accommodation and food services*" collected by municipal authorities, or from organisations on their behalf, which undergo different management systems (Castillo-Giméneza et al., 2019). Data are collected for each EU Member State on NUTS2 regional level classification. However, many gaps exist in the data due to the voluntary nature of reporting. Depending on availability of data for different countries the period from 2000-2013 is covered. With regard the original dataset, this study exclusively focuses on municipal waste generation and treatment data of 75 NUTS-2 regions: 16 regions in Germany, 26 regions in France (of which 5 are part of the Départements d'outre-mer), 21 regions in Italy, and 12 regions in the Netherlands. The time span examined is the period 2008-2013. Municipal waste variables comprise waste generation as input, and five waste treatment techniques as output i.e. Disposal - landfill and other (D1-D7, D12); Incineration and Energy recovery (D10, R1), Recycling material, Recycling composting and digestion (R2-R11), in accordance with Eurostat classification. Specifically, *landfill* consists of waste disposal inside or outside the land, including landfill sites that can hold waste either permanently or temporary (e.g. over one year or more in certain places). *Incineration* refers to waste combustion with and without energy recovery in the treatment process. Energy recovery follows specific energy efficiency criteria according with the EU Waste Framework Directive, (EC, 2008). Data for incineration and energy recovery were available both separately and combined, this study considers these treatments separately. *Recycling* consists of reprocessed waste implied as new input material for new uses or original ones. In last instance, *composting and digestion* concerns organic decomposition of waste that could be biodegraded under the control in aerobic and anaerobic environment. To note that, despite data are provided both in kilograms and thousand tonnes, this work is based on municipal waste volumes in thousand tonnes.

Previous analysis (i.e. Chioatto and Sospiro, 2020 and Castillo-Giméneza, et al., 2019 a,b) have highlighted that generally Northern countries, such as Germany and the Netherland achieve best results in MSW management, with high recycling rates and very low dumping. Conversely, France and Italy are placed slightly behind but display steady progresses, which demonstrate an enhancement in MSW management practices.

Methodology

This paper analyses and represents MSW management performances of EU-4 MSs at NUTS2 regional level through Data Envelopment Analysis (DEA). We have selected 75 NUTS-2 regions of four countries (we have therefore 75 decision making units) i.e., Italy, France, Germany and Netherlands from the period 2008 to 2013. The weighting in composite indicator is often challenging and to overcome these challenges, the Data Envelopment Analysis (DEA) is the most appropriate method also recognised by OECD (OECD, 2008). DEA is a mathematical programming technique, initially presented by Charnes et al. (1978) who used it in the theory of production (Farrel, 1957). Later on, Love et al. (1995) have extended DEA applicability to the economic, environmental and social domains (Zhou et.al, 2007).

The DEA has many benefits, among the others, it allows to treat different data dimensions, to normalise data, and to rank them in output units comprised between 0-1. However, besides the flexibility offered, the DEA presents several shortcomings in countries' ranking. For example, in Castillo-Giménez et.al (2019 a, b), more than one country has been assigned to the top, however this does not find correspondence with the complete ranking at national level. Other authors have also reported DEA shortcomings when comparing different decision-making unit performances. Cross country comparison seems, therefore, not be worthy as the performances are analysed sets of weightings based on country specification (Kao and Hung, 2005). In order to avoid DEA weaknesses, this study has used original weightings for different years by selecting benchmark for the respective year. Based on the highest output value (which represents the best performer from each treatment every year) we have compared and ranked each region individually and presented the regions in clusters where the countries result in the same range. Since there are many ways for the composite indicator of performance when the output is more than 1, this analysis simply calculates the average of the output results from DEA to constitute a single value for raking based on both, the desirable and non-desirable outputs. The aim of this research is to find the actual performance regardless of the country background or other factors that demands to change.

The main advantage of the DEA analysis based on the weightings assigned to the five treatment techniques as output is to build the composite performance indicator which are determined at NUTS-2 regional level. Some researchers have used the national and regional levels performance with ad hoc criteria, benefit of Doubt model which sets the criteria for each level when comparing the performance assessed as the same weightings (Castillo-Giméneza, Montañés and J. Picazo-tadeo 2019).

To compute the DEA for the constructing CI, we have different outputs from the same input at NUTS2 regional level where outputs are different waste treatment techniques also referred to the sub indicators and the input is the total municipal waste generated. The aim is to constitute the weighted average of the results from the different sub indicators to present as the Composite single value for different outputs where it is possible to rank waste management operations at regional level. Therefore, the Basic DEA-R model is used where R, represents the ratio-based Data Envelopment analysis. The ratio-based data envelopment analysis allows to present more accurate results depending on the nature of the data (Hollingsworth and Smith, 2003). The methodology applied takes into consideration the methodology applied in Gastaldi et al. (2020). However the model has been simplified.

The basic DEA model proposed by Charnes et al. (1978) of Decision-making units is simply presented by:

Efficiency = output/input

However, when there are several inputs and outputs, as in this case, the efficiency can be calculated by:

Efficiency = weighted sum of outputs/ weighted sum of inputs

There are different ways to selects the optimum weightage in above expressions, DEA can be achieved by selecting a single value for benchmarking. For several decision-making units, the efficiency can be calculated the following expression:

$$max_{w,vh_0} = \frac{\sum_{j=1}^{n} w_j y_{jk_0}}{\sum_{j=1}^{m} v_i x_{ik_0}}$$

Subject to:

$$\frac{\sum_{j=1}^{n} w_j y_{jk}}{\sum_{j=1}^{m} v_i x_{ik}} \leq 1 \qquad k = 1, \dots, z \quad \forall_{j,i.}$$

Where

z Number of units;

m Number of inputs;

n Number of outputs;

w_j Weight given to input j;

v_i Weight given to input i

This model maximises the ratio of weighted output considering the input however weight of the output is constant on the different output of the k_0.

4. Results and Discussion

The DEA analysis reveals that the best MSW management performance in the period 2008-2013 is generally led by Dutch regions, respectively followed by German, French and Italian's regions. Comparing MSs regions' in the period 2008-2013, the highest value has been registered in Flevoland (the Netherlands) with a rate of 0.64957 in 2010. By contrast, the lowest value has been observed in Course (France) with a rate of 0.029217, in 2011. Exceptionally, in 2013 the best results have been accomplished in an Italian region, namely Molise. Notwithstanding, Italian regions are generally positioned in the lowest rankings throughout the period 2008-2013.

Figure 1: Cluster representation of Municipal solid waste management performance in the year 2008

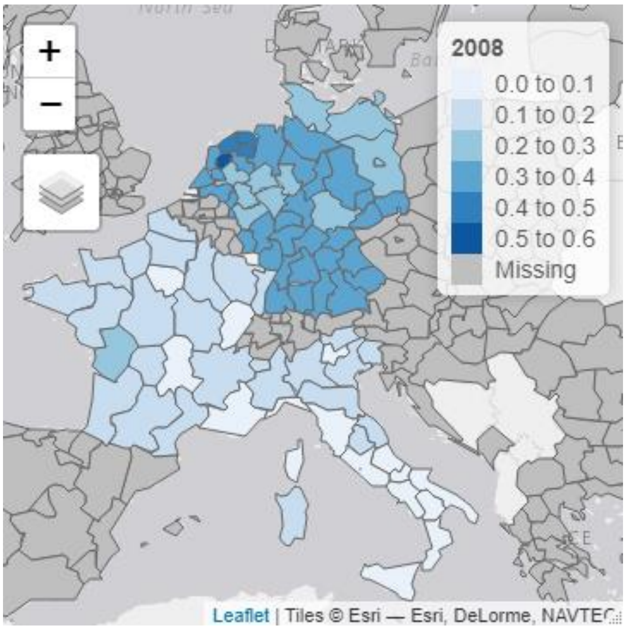

Figure 1: Cluster representation of Municipal solid waste management performance in the year 2009

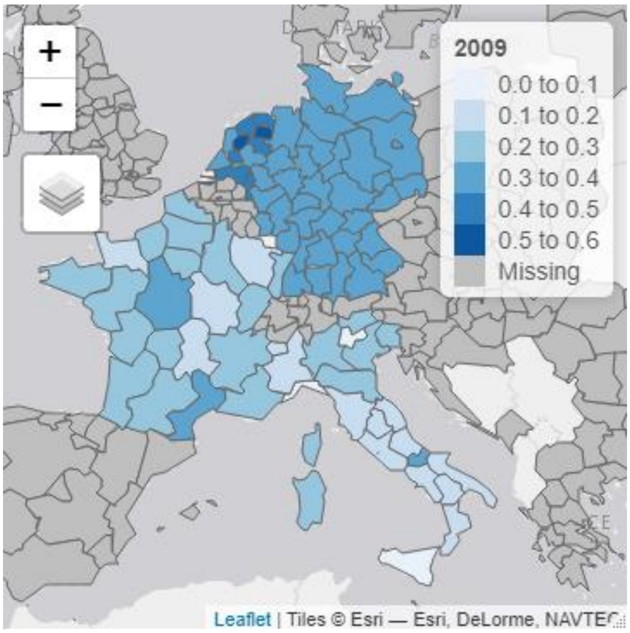

Figure 3: Cluster representation of Municipal solid waste management performance in the year 2010

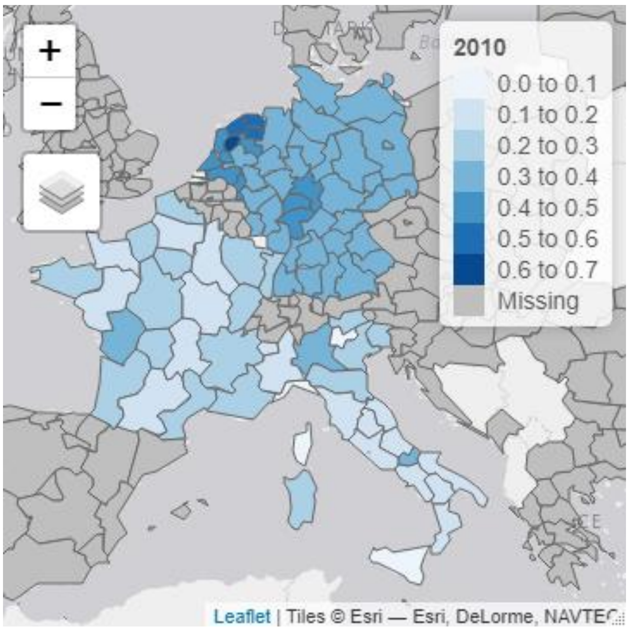

Figure 2 : Cluster representation of Municipal solid waste management performance in the year 2011

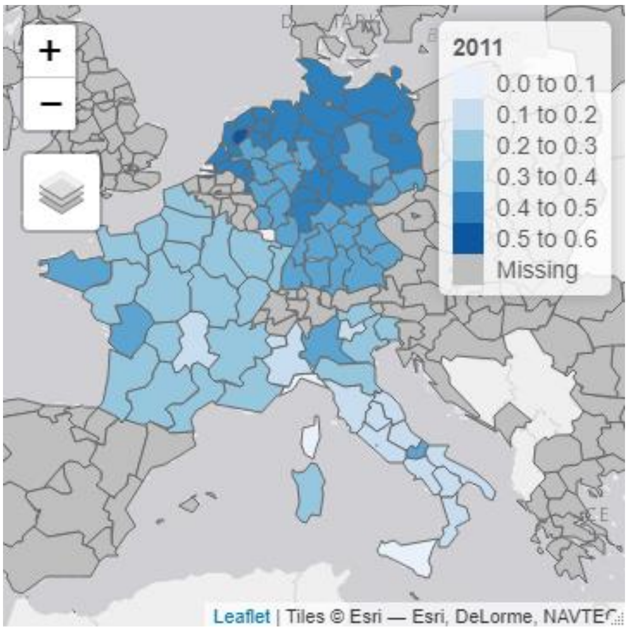

Figure 5: Cluster representation of Municipal solid waste management performance in the year 2012

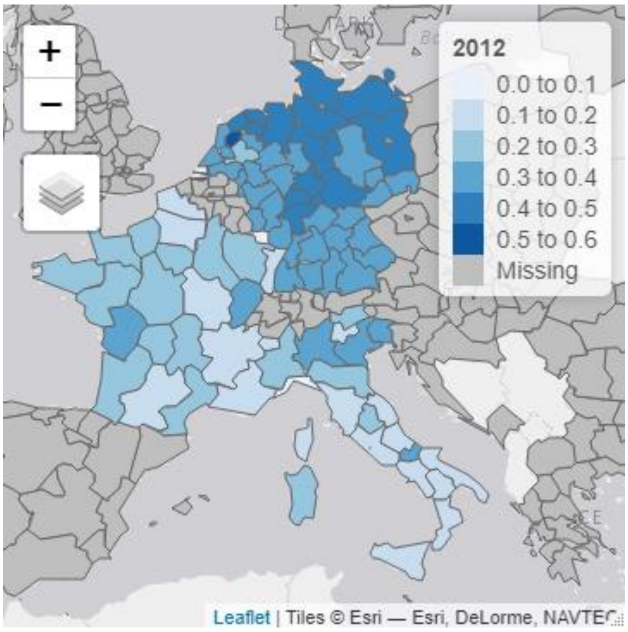

Figure 3: Cluster representation of Municipal solid waste management performance in the year 2013

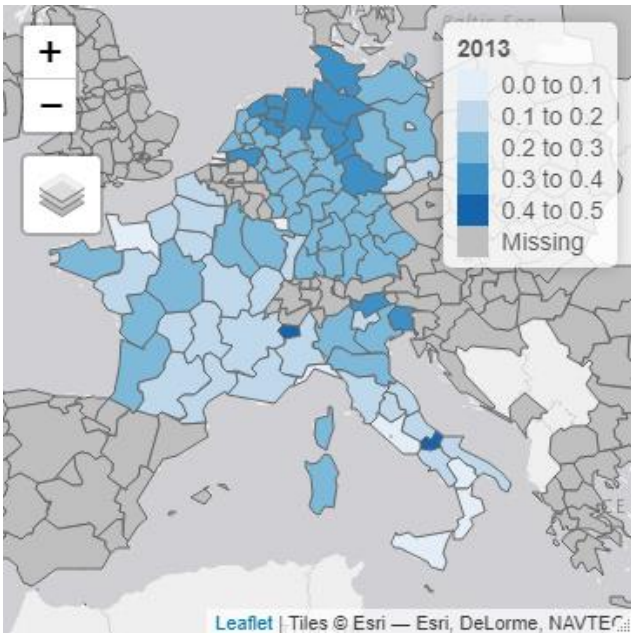

Figure 1-6 represent overall DEA results on MSW management performance of 75 NUTS-2 regions from 2008 to 2013. The maps clearly confirm that Dutch and German regions' have achieved the best MSW management performances in the period 2008-2013, especially in the Northern regions. High performance is especially observed in regions with low inhabitants and low waste generated. Here, the amount of waste diverted into landfill is low, by contrast waste incineration, energy recovery, recycling rates are high. On the other side, the analysis demonstrates that French and Italian regions generally lag behind. This is confirmed by **Table 1** that lists the top 20 performers during the period 2008-2013. Throughout the period, one French region is ranked among the best performers in 2009, one Italian region in 2012 and exceptionally two Italian regions (Molise and Valle d'Aosta) register the highest scoring in 2013 and Friuli-Venezia Giulia and Provincia Autonoma di Bolzano are positioned among the 20 best performers. Notwithstanding, it is interesting to note that French regions' are positively improving their recycling performances but still to many waste goes into landfill, and Italian regions are progressively improving their trends year by year.

These results are in line with those presented at NUTS-2 level in Rogge et al (2017), according to which NUTS-2 regions in Northern countries generally perform better in terms of MSW management compared to NUTS-2 regions situated in Southern countries. Also the analysis of MSW performance of EU-27 presented Castillo-Giménez et al., (2019a) and EU-28 in Castillo-Giménez et al., (2019b) show that best performers are Central and Northern EU countries, whereas performance decreases in Mediterranean countries

Table 1: Top 20 regions in the municipal solid waste management performance from the year 2008 to 2013

Rank	2008	2009	2010	2011	2012	2013
1	Flevoland	Flevoland	Flevoland	Flevoland	Flevoland	Molise
2	Zeeland	Zeeland	Zeeland	Zeeland	Zeeland	Valle d'Aosta
3	Drenthe	Drenthe	Drenthe	Drenthe	Drenthe	Bremen
4	Groningen	Groningen	Groningen	Groningen	Groningen	Drenthe
5	Friesland (NL)	Friesland (NL)	Friesland (NL)	Friesland (NL)	Thüringen	Friuli-Venezia Giulia
6	Limburg (NL)	Limburg (NL)	Overijssel	Brandenburg	Brandenburg	Thüringen
7	Overijssel	Overijssel	Utrecht	Thüringen	Schleswig-Holstein	Friesland (NL)
8	Noord-Brabant	Utrecht	Limburg (NL)	Overijssel	Friesland (NL)	Groningen

9	Utrecht	Noord-Brabant	Noord-Brabant	Limburg (NL)	Hessen	Schleswig-Holstein
10	Noord-Holland	Noord-Holland	Noord-Holland	Berlin	Niedersachsen	Niedersachsen
11	Rheinland-Pfalz	Zuid-Holland	Zuid-Holland	Utrecht	Mecklenburg-Vorpommern	Noord-Brabant
12	Zuid-Holland	Sachsen-Anhalt	Hessen	Hessen	Molise	Provincia Autonoma di Bolzano/Bozen
13	Niedersachsen	Hessen	Rheinland-Pfalz	Noord-Brabant	Bayern	Overijssel
14	Bayern	Rheinland-Pfalz	Thüringen	Schleswig-Holstein	Limburg (NL)	Zeeland
15	Baden-Württemberg	Niedersachsen	Brandenburg	Mecklenburg-Vorpommern	Sachsen-Anhalt	Bayern
16	Sachsen	Bayern	Sachsen-Anhalt	Niedersachsen	Overijssel	Limburg (NL)
17	Hessen	Sachsen	Niedersachsen	Noord-Holland	Berlin	Utrecht
18	Sachsen-Anhalt	Baden-Württemberg	Bayern	Zuid-Holland	Baden-Württemberg	Champagne-Ardenne (NUTS 2013)
19	Brandenburg	Thüringen	Schleswig-Holstein	Bayern	Sachsen	Saarland
20	Gelderland	Centre (FR) (NUTS 2013)	Mecklenburg-Vorpommern	Sachsen-Anhalt	Noord-Brabant	Flevoland

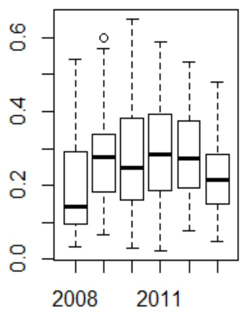

Figure 4: Composite Indicator of DEA value concentration

Figure 7 shows that the distribution of performance mostly lies below the average. In 2008, the first quartile lies below 0.1 which means around 25% of all regions have the lowest performance, while more than 25 % regions still have the low performance with the 2nd quartile value below 0.2, third quartile lies below 0.3 which is not still high and can be considered as average the last quartile extends from 0.3 to 0.54 which shows less than 25% of the regions have high performance . From year 2009 to 2013, the second quartile is below 0.3 which shows that almost 50% of regions lie below average, while only few have high performance. We do not have certain criteria to select the benchmark to rank the performance and have selected the best region for benchmark in each year, most of them comes from the Netherlands. Therefore, due to the high standard benchmark value each year that comes from Netherlands, we have many regions from Italy and France that have the low performance compared to Netherlands and Germany.

5. Conclusions

This paper has examined MSW management performance in 75 EU NUTS-2 regions situated in Italy, France, Germany and the Netherlands in the period 2008 to 2013. The analysis has been performed through DEA composite indicator and it has revealed that the most efficient EU regions in managing MW are situated in the Netherlands, respectively followed by Germany, France and Italy. Performance results' have not been assessed by resorting a fixed benchmark value, rather the best regional performer has been selected per each year and it has been used as benchmark. To note that, despite no fixed standards exist to assess performance through DEA, similar results for MSW management performance have been presented in Rogge et al (2017) and Castillo-Giménez et al., (2019 a, b). Future research can include other factors, such as demographical, economic, and social aspects, which can improve the analysis and help understanding the main reasons behind regional performances.

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