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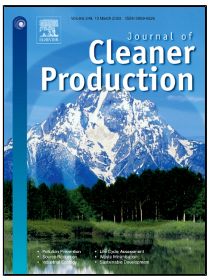

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PII:	S0959-6526(20)30265-1
DOI:	https://doi.org/10.1016/j.jclepro.2020.120218
Reference:	JCLP 120218
To appear in:	*Journal of Cleaner Production*
Received Date:	25 March 2019
Accepted Date:	21 January 2020

Please cite this article as: Francesco Silvestri, Francesca Spigarelli, Mattia Tassinari, Regional development of Circular Economy in the European Union: a multidimensional analysis, *Journal of Cleaner Production* (2020), https://doi.org/10.1016/j.jclepro.2020.120218

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(Number of words: 7,765)

Regional development of Circular Economy in the European Union: a multidimensional analysis

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Abstract

Within the framework of EU policies and measures to develop the Circular Economy (CE) model, the paper sheds light on a relevant and important topic not so well debated in the literature, i.e. the adoption of CE at the regional level. Our key research question is: how do European Regions differ in terms of implementation of the CE? In order to address this question, we build two composite indicators - the Circular Economy Static Index (CESI) and the Circular Economy Dynamic Index (CEDI) - that permitted both a static and a dynamic evaluation of the CE performance of European regions (NUTS 2). This double reading of CE performances has allowed us to classify the European regions into four groups, on the basis of the results of our analysis. The "Never give up" group (1) is characterized by above-median performance for both the composite indicators; this group includes some of the most developed and innovative regions in Europe (including France: Île de France, Belgium: Brabant Wallon, Antwerpen and Région de Bruxelles, Germany: Berlin and Hamburg, and Spain: Catalunya). The group "Satiated and sleepy regions" (2), namely those regions where CESI is performing well, but the CEDI shows low values, incorporates many of the richest regions in Europe, for example, Freiburg, Germany and the Comunidad de Madrid, Spain and includes some of the more developed regions in Italy. The "The best is yet to come" group (3), is characterized by low values for CESI and high performance in CEDI, most of those falling into these groups are regions from Eastern Europe. The "We don't mind" group (4), is composed of the regions with modest values on both Indexes, and is characterized by the presence of very low performing regions, including the majority of Italian regions. The novelty of this approach with respect to literature and the policy implications of our findings are then discussed.

Keywords

Circular economy; European Regions; Composite indicators; dynamic and static performance.

* We would like to express our gratitude to the anonymous reviewers, for having provided very useful inputs and insights.

1. Introduction

The European Union (hereafter EU) has been encouraging the adoption of the principles of the Circular Economy (hereafter CE), through specific polices and measures designed to achieve a significant impact throughout the entire cycle of the use of resources, from production and consumption, to waste management and the market for secondary raw materials (European Commission, 2019). In this context, even though subjected to the same CE policies and the same recycling targets (Sakai et al., 2011), EU countries have different histories and speeds along the road to circularity, showing "a strong divide (…), in terms of ambition and actual reuse rates" (Reike et al., 2018: p. 251).

This paper is grounded on the perspective that the dissimilarities in performance related to the CE are generated not at the State Member level, but rather at the regional (NUTS 2) level. This is because of both the idiosyncratic features of the single EU Regions and of the different treatment they are subjected by EU development and environmental programmes, which are notoriously differentiated on a regional basis as regards objectives, actions and economic resources. In this context, our key research question is: how do European Regions differ in terms of adoption and implementation of the CE?

This paper sheds light on an important topic that is not being debated enough in the literature. Indeed, as we will argue, one of the clearest gaps in the CE processes is the inadequate monitoring and evaluation of their implementations through the use of composite indicators (namely *Indexes*, able to assess complex phenomena by summarizing the value of different variables). While preparatory studies have identified some sets of indicators potentially useful for evaluating CE performances (see, e.g., Geng et al., 2012 and 2013; EASAC, 2016), the construction of a comprehensive CE Index to capture CE performance as multidimensional phenomenon seems to be missing. The available studies focused on assessing adoption and implementation of the CE, have been conducted mainly by using one-dimensional indicators, such as waste management (EEA, 2009, Zaman et Lehman, 2013, Park et Chertow, 2014), manufacturing (Golinska et al., 2015; Huang, 2006), water use (Leeuwen et al., 2012), or energy consumption (Preston, 2012, Ren et al. 2013). Furthermore, analysis evaluating CE performances have been mainly conducted at national level, essentially ignoring the CE impact at the regional level.

In order to address these gaps, the central intuition of this paper is to apply the notion of a composite indicator to construct two new *Indexes* and evaluate the CE performances in European regions according to a multidimensional analysis. More specifically, we build two *Indexes* leveraging on the notions of CE developed by the European Commission (2015) and of Sustainable

Development (hereafter SD) (WCED, 1987) to assess static and dynamic performances of 169 European NUTS 2 regions in terms of CE.

2. Literature review

2.1 The Circular Economy concept: roots and definitions

One accepted issue with respect to CE, is the lack of both a conceptual clarity and a commonly accepted definition for it (Yuan et al., 2008; Lieder and Rashid, 2015; Reike et al., 2018). A systematic literature review by Sacchi Homrich et al. (2018) points out the absence of consensus regarding terminology and definitions of CE; the same conclusions were recently proposed by Korhonen *et al.* (2018) who described CE as an "essentially contested concept".

A good contribution in the search for the theoretical origins of the notion, was provided recently by a stream of literature oriented towards discerning key conceptual elements of CE, mainly in comparison to the concept of SD (Ghisellini et al., 2015; Geissdoerfer et al., 2017). In this perspective, Geissdoerfer et al. (2017) summarized the main similarities and differences between SD and CE, revealing that the literature considers CE as either: a necessary condition for sustainability, a beneficial relation, a trade-off, or, a regenerative system. For example, Andersen (2007) suggested that CE is somehow used to refer to specific resources, while SD has a broader, more encompassing, meaning in terms of future trajectories for well-being. In this sense SD can be considered a collective long-term goal, which may be pursued through CE processes, involving the exploitation of resources, the direction of investments and the orientation of technological development (WCED, 1987).

On this view, following the seminal studies of Kenneth Boulding (1966) and Nicholas Georgescu-Roegen (1971), which introduced the notion of SD and, later, of Pearce and Turner (1990), presenting their model of the circular economic system, a close interaction between economics and the environment has been widely recognized (Brown, 2002; Chu et al., 2007, Dempsey et al., 2011; Reike et al., 2018, Ghinoi et al., 2019).

As for the implementation of a sustainable system, CE acts to maximise the positive *environmental*, *economic* and *social* effects of human activity, and in order to achieve mutually supporting progress and competitiveness (Domenech and Bahn-Walkowiak, 2019; Ghinoi et al. 2019).

Building on this line of reasoning, in this study we adopt a CE definition that is consistent with the pursuing of SD goals. As emphasized by the European Commission, CE can be identified as an economic process *"(...) where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised* [as] *an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and*

competitive economy. *Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages for Europe"* (European Commission, Com 2015).
Beside offering a comprehensive understanding of the scope of the CE and of its connection with the SD, this notion is also extremely useful to the purpose of this work, that is measuring, in a comprehensive way, European Regions performance in terms of CE.

2.2 The geographic dimension of Circular Economy

Along with the increasingly emphasis from a theoretical point of view, the concept of CE has inspired many programmes and regulations at national level (Geissdoerfer et al., 2017).
In 2002, Japan introduced the Basic Law for Establishing a Recycling-Based Society. However, China was the first country to explicitly refer to CE in a normative act, with the 2009 Circular Economy Promotion Law.
In Europe, Germany was a pioneer country, with the implementation of the Dual System for waste collection and of the Closed Substance Cycle and Waste Management Act. In Denmark (The Danish Government, 2018) efforts have been focused on product design, in order to promote a shift in business models and design strategies (Bocken et al. 2016; den Hollander et al., 2017). This is being done even for complex consumer products, such as electronics or automobiles (Tam et al. 2019) or for production that uses modern technologies (Sauerwein et al., 2019). Many research centres at University level and EU funded projects have been focused on CE, contributing to the diffusion of CE principles.[1] In 2015, the European Commission promoted the introduction of the European CE package (Ghinoi et al., 2019).

However, so far results have been rather disappointing: in Europe, the average recovery and recycling rate for all forms of waste is half-way towards meeting the targets set for circularity (Reike et al, 2018), while most developing countries demonstrate a lack of regulation, insufficient funds dedicated to CE, and the absence of expertise and education (Diaz 2017); this is true even for BRIC countries as demonstrated by Ghosh et al. (2016) with respect to India, Russia, South Africa and Brazil.
In the context of the theoretical contribution to evaluate the CE performance, a rather neglected aspect is the CE impact at the regional level. Strongly underpinned by national policies in the US

[1] To the best of our knowledge, research centres or research groups investigating the CE are present at the Ecole de Ponts Business School, Paris, at the University of the Basque Country, at the University of Ferrara (Italy), at the Southern Denmark University, at Kristianstad University, East Anglia University, Vrije Universiteit Amsterdam
For an overview of R&D devoted to CE topics in some EU countries, see the report produced within the EU funded project Moveco on "Mobilizing Institutional Learning for Better Exploitation of Research and Innovation for the Circular Economy" (Moveco, 2017).

(EPA, 2015), Japan (UNEP, 2013), and China (Geng et al., 2012), and studied mostly at the urban (Wang et al. 2018; Petit-Boix and Leipold, 2018; EMF, 2017), or at the industrial park level (Geng, 2012; Yuan et al., 2006), the meso-level represented by regional focus has still attracted little attention from scholars. Indeed, the review by Ghisellini et al. (2015) passes from the eco-cities level to National policy implementation, while a search through the regional literature allows to find only a few such cases, all on Chinese Provinces (see infra).

Nonetheless, the support of regional policies is essential to implement CE principles, considering the relevance to, and importance of, wider territories than urban areas, and also the need for a more focused approach than on CE at the national level. Indeed, the whole development strategy of EU – the so called *Cohesion Policy* - is designed and implemented at the regional level, so it is crucial on the one hand, to see how the CE infiltrates the development policy of the EU as first economy in the world for GDP (Eurostat, 2017); on the other hand, because of this focus on Regions, the EU offers an ideal area to see whether the regional level is relevant to, and important for the success of CE policies.

In this area of study two distinct currents can be found in the literature: the first is related to a rather isolated literature on Chinese provincial and sub-provincial cases. Huanzheng et al. (2009) focused on the Zhejiang Province, claiming that it had experienced sustained growth even in the absence of resource conditions thanks to four "cardinal points" inspired by the CE: recycling waste; industrial agglomeration; central wholesale market; and a privatising system. Another paper, by Jiang (2011) proposed a new system to measure regional CE development by applying the Fuzzy Comprehensive Evaluation Method to three Provinces in China (Jiangsu, Heilongjiang, and Qinghai). Lastly, Geng et al. (2009) outlined the regional CE initiatives that had been successful in Dalian, a Prefecture level Town and sub-provincial territory in Southern China, detailing the focus and the goals of the program. The authors identify several challenges that these initiatives have faced, including the lack of incentives for older industries to transition to sustainability; the lack of financial support to extend the CE concept, and a broad-based need for improving public awareness and participation in CE initiatives.

The second stream of literature dealing with the CE at the regional level, is the one originating in EU programs and projects, which produced a collection of documents (guidelines, lay reports, recommendations, …) directed to stakeholders and policy makers, rather than to the scientific community. For example, the EU Cohesion Policy 2014-2020 deals with the CE issue by financing waste management projects, innovation in Small-Medium Enterprises (SMEs), resource efficiency and low-carbon investments. They leverage additional private funding and are complemented by other EU funding sources, such as LIFE (devoted to environmental innovations), COSME (SME

competitiveness), URBAN (city innovation) and Horizon 2020 (applied research and development)[2].

In the literature on the European cases, Brink et al. (2017) analysed the situation of the CE in the EU Outermost Regions, which often meet obstacles when sourcing of raw materials (due to limited resources) and when disposing of waste, posing a challenge to developing a CE.

Adopting a less specific view, Bačová et al. (2016) claimed that regional authorities have an important role in launching and accelerating the transition to the CE: that of setting clear framework conditions or, directly, supporting local and regional stakeholders. According to Bačová et al. (2016), since CE implementation is affected by geographic, environmental, economic and/or social factors, the diversity of territorial contexts translates into different needs and opportunities that any CE approach should address, so that Regions with higher green performance might need less support with the transition to CE than other regions (Bačová et al., 2016, p. 6).

2.3 Monitoring and evaluating CE: a review on most accepted indicators

One of the clearest gaps in the CE literature and practice is the inadequate monitoring and evaluation of its implementations through the use of a set of robust indicators: to the best of our knowledge, there has been very little work published by either scholars or practitioners on the issue and even these are frequently relegated to some single current of the broader notion of CE, such as waste management (EEA, 2009, Zaman et Lehman, 2013, Park et Chertow, 2014), manufacturing (Golinska et al., 2015; Huang, 2006), water use (Leeuwen et al., 2012), or energy consumption (Preston, 2012, Ren et al. 2013). However, a preparatory work on defining indicators that can be used to evaluate the performance of national and regional economies in terms of CE, is almost available only in articles from China, in Li and Zhang (2005), Shi and Zhang (2005), Zhu and Qiu (2008), Geng et al. (2012 and 2013), Yu et al. (2013), and in the European context, in EASAC (2016).

The first nationally focused CE indicators were released by China. They are based upon the so called "3R principles", namely Reduction, Reuse and Recycle. More specifically, the Chinese CE Evaluation Indicator System provides two separate sets of indicators: 22 indicators articulated in four categories set to be used at macro-level, for national-level analysis, and 12 indicators divided

[2] For example, an Horizon 2020 project particularly focused on CE is SCREEN - Synergic Circular Economy across European Regions (www.screen-lab.eu), that proposed a mapping tool to analyse each partner region's appliance to CE issues. The analysis is concentrated on smart specialisation strategy and regional capabilities with respect to actual and potential CE applications and symbiosis, and the CE circularity potential of each region is assessed through a meta-model based on inter-organizational cooperation. Another particularly interesting EU project on CE has been the GREECO project - Territorial Potentials for a Greener Economy (www.espon.eu/programme/projects/espon-2013/applied-research/greeco-territorial-potentials-greener-economy), that demonstrated through a set of case histories that developing a strategic vision of a region is a major driver for fostering regional CE.

in four groups used for assessing the state of CE development at the industrial parks level (Geng et al., 2012). Besides of the shortcomings highlighted by the same authors, the most relevant being the lack of social indicators and the presence of barriers to the effective and efficient implementation of such indicators (Geng et. al., 2012), the Chinese system fails to provide a unique composite indicator to deal with the polymorphic nature of CE and to recap at least a subset of the 22 proposed indicators.

The EASAC (2016) approach to CE indicators is richer and oriented to SD, providing a set of 26 indicators grouped into sustainable development, environment, material flow analysis, societal behaviour, organizational behaviour and economic performance. Furthermore, authors of the EASAC report claim throughout the work for the construction of a composite indicator for communicating trends in a CE, even showing a "potential" formula for it. But the proposed composite indicator combines together just four of the 26 original indicators, with neither specific nor scientific explication[3], so that the report concludes that "*While EASAC is not suggesting any specific composite indicator, it does recommend that the [European] Commission explore (..) the concept further to aim at a credible and easy to understand indicator of circularity*" (EASAC, 2016, p. 26).

This framework highlights evident shortcomings in the definition and adoption of composite indicators useful to assess the national and regional performance in terms of CE.

3. Material and methods

3.1 Methodology

In this section we aim at evaluating the CE performance of 169 European NUTS 2 regions, by building two composite indicators. Generally, composite indicators or *Indexes* (see, e.g., Saisana et al., 2004) are employed by social scientists to compare social units (such as cities, regions, nations) with respect to multiple dimensions of social life. For example, they are commonly used to compare different countries' performances in terms of competitiveness, health, education, human rights, corruption, ecological footprints, technological innovations, and social cohesion (see, e.g., OECD, 2008).

The first composite indicator we built – the Circular Economy Static Index (CESI) – identifies the static dimension of CE performance, namely the adoption of the CE as it is at any given time. The second Index – the Circular Economy Dynamic Index (CEDI) – reveals improvements in CE

[3] The four components are: a. energy productivity (GDP/total primary energy supply); b. GDP per capita (GDP/population); c. recycle rate; d. carbon dioxide emissions. The simplistic formula is: (a*b*c)/d.

performances, by providing a dynamic insight into CE adoption. We combine the two *Indexes* to assess the performance of the EU regions in a double-dimension matrix.

The method adopted for calculating these composite indicators is a two-step procedure:

(1) normalization of the original data

(2) aggregation of the variables in order to obtain a composite measure of the phenomenon/a of interest.[4]

Normalization is necessary before aggregation, whenever original data have different scales and dispersions. Each of the original variables is normalized in the interval (0,1) so that a transformed value tending to 1 is assigned to the best regions, while a transformed value tending to 0 identifies the worst cases. For all other regions, the transformed value is a number between 0 and 1. Indicating with X_{jk} the value of the k-th variable for the region j, with Y_{jk} the corresponding normalized value, $T_k(\cdot)$ is the function for normalizing the k-th variable:[5]

(Equation 1) $$Y_{jk} = T_k(X_{jk}) = \frac{X_{jk} - min(X_{1k},\dots,X_{Jk}) + \frac{1}{J}}{max(X_{1k},\dots,X_{Jk}) - min(X_{1k},\dots,X_{Jk}) + \frac{2}{J}}$$

In the second step, the normalized variables are aggregated by applying an appropriate combination function. This phase implies the choice of the combination function and the weighting to assign to each variable, in order to incorporate their different degrees of importance in the composite indicator. In our case, we choose weights of the variables in a way that the different dimensions of CE we consider all have the same weight (see the next Section). The variables are combined by applying the additive function, obtaining for each region j the values of the composite indicator:

(Equation 2) $$Z_j = -\sum_{k=1}^{K} w_k (Y_{jk})$$

where K is equal to the number of variables of the composite indicator; Y_{jk} is the normalized value of the k-th variable for the j-th region; and W_k is the weight given to the k-th variable. The higher the value of the composite indicator, the higher the CE performances of the European regions.

[4] For further details on the methodological aspects related to composite indicators see, for example, Arboretti *et al.* (2007), Bonnini *et al*. (2009), Marozzi (2009), Fayers and Hand (2012).

[5] To avoid Y_{jk} values equal to 0 or 1, which may cause computational inconsistencies in the aggregation step, correction factors 1/J and 2/J are added respectively to the numerator and denominator.

3.2 The *Circular Economy Static Index* (CESI) and the *Circular Economy Dynamic Index* (CEDI): the selection of the variables

We built two different composite indicators to measure CE performance at the regional level, using data from the Eurostat data base (https://ec.europa.eu/eurostat). These *Indexes* show different ways of depicting CE performance, both in static and dynamic terms.

The elicited variables are the same for CESI and CEDI, besides of the fact that in the second case they are considered in terms of growth from a starting year (2010, 2011 or 2012) to a final one (2011, 2012, 2013 or 2015). As anticipated, 11 variables have been chosen within the set of available items in Eurostat database, to reflect the adopted definition of CE (EC 2015), i.e. covering the fields of recycling ("*the value of products, materials and resources is maintained in the economy for as long as possible*"), waste management ("*the generation of waste minimised*"), low carbon and resource efficient orientation ("*to develop a [...], low carbon, resource efficient [...] economy*"), sustainability and competitiveness ("*to transform our economy and generate new and sustainable competitive advantages for Europe"*).

The set of adopted variables is depicted in Table 1.

[Table 1 about here]

Two issues in this framework claim for a deeper explication: 1. the use of life expectancy, transport accidents and of different kinds of diseases as a proxy of the low carbon orientation of the region, and 2. the way we consider the sustainability concept.

Referring to the former, while data for the CE analysis at national level are largely available, the main problem is the lack of data and indicators of low carbon performance (typically CO_2, NO or PM emissions, fossil fuel consumption or percentage of renewable energy produced and consumed) at the regional level in Eurostat. For this reason, we use proxy variables directly related with carbon emission. They are: (1) "Transport accidents", that show a direct correlation with transport emission in the EU-27, so that in the 15 core countries we observe a strong reduction of both phenomena, while in the European Newly Associated Countries a slight increase in road accidents is statistically associated with a similar increase in transport emissions (Török, 2017); (2) "Malignant neoplasms", since medical studies found a significant association between exposure to NO_2 in ambient air and breast cancer (Keramatinia et al., 2016), and a significant direct relationship between exposure to traffic exhaust pollutants (namely nitrogen dioxide, NO2) and leukemia among young children

(Hsu-Huei et al. 2008); (3) "Diseases of the circulatory system", that have been found linearly and significantly correlated with $PM_{2.5}$ emission (Maté et al., 2010).

With respect to the relation with SD, besides of adopting a CE definition highly calling into question the issue of sustainability, we want to point out our adhesion to the literature that recognizes CE as deeply rooted in the tripartite SD notion (see *supra*). To reinforce this concept, the Circular Economy Static Index (CESI) considers the three different dimensions of SD: socio-health, economic, and environmental. Each dimension has an identical weight in the calculation of the total value of the composite indicator.[6] Corresponding reference variables are assigned to each dimension, as indicated in Table 2.

[Table 2 about here]

The 11 variables adopted in the CESI describe CE performance from a *static* standpoint: according to the CESI, regions at the top in the ranking have already achieved, when compared to others, high social and health performance (e.g. high life expectancy), high economic performance (e.g. high levels of GDP), and have lower level of environmental impact.

The Circular Economy Dynamic Index (CEDI) considers the same three dimensions of CE (socio-health, economic, and environmental) in order to capture improvements regional CE performance over time. In this case too, each dimension has the same weight in the calculation of the total value of the Index. Specifically, the CEDI considers the same 11 variables included in the CESI from a *dynamic* perspective, as indicated in Table 3. [7]

[Table 3 about here]

The variables included in the CEDI reflect the CE performance of EU regions from a *dynamic* perspective, ranking at the top those regions with the highest growth rates for the CE variables, even if these results may appear weak, when looking at the levels achieved in absolute terms (which is an aspect evaluated through the previous Index – CESI). By considering the "growth rates" of the selected variables, CEDI captures improvements (or deteriorations) in performance over time. In short, the CEDI places, at the top of the rankings, those regions that are growing faster from an

[6] Basically, the choice of the weighting methods or of the weight to be assigned to each dimension and variable is an arbitrary decision in studies using composite indicators, manifesting itself as "a source of contention" (see OECD, 2008, p. 31). In this paper we decided to assign the same weight to each dimension to emphasise an equal relevance of environmental, economic and socio-health aspects related to the CE.

[7] Since the database we use (Eurostat) contains data collected for different temporal periods, we built the CEDI by employing slightly different periods of analysis in order to deal with the limited availability of data.

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economic and socio-health standpoint, and, contextually to this performance, are improving (or not worsening) in terms of environmental performances compared to other regions (in line with the concept of *sustainability*). The CEDI also places at the top of the ranking those regions where economic growth is not alternative to environmental quality, as emphasised by studies that either reject the Environmental Kuznets Curve (Karousakis, 2009; Tisdell, 2001; Mazzanti and Zoboli, 2009) or accept its N-shaped version (Grossman and Krueger, 1995; Torras and Boyce, 1998).

To sum up, while the *static* Index (CESI) tends to reward those regions with higher absolute performances on CE variables (even when their performance is static), the *dynamic* Index (CEDI) tends to reward those regions moving towards improvements (even though they may exhibit low performances in the CE in absolute terms).

The following section presents the results of applying the two *Indexes* to the European case.

4. Results and Discussion

Applying the first Index (*CESI*) to 169 European regions, made it possible to identify different performance in terms of the CE. At the top of the ranking, stand Centre Europe regions, which are characterized by high levels of income. As shown in the Table 4, according to CESI, the top-15 best performing regions are in France, Germany, The Netherlands and Belgium, with the only outlier, being the Spanish Comunidad de Madrid (see Appendix 1 for the entire CESI ranking).

[Table 4 about here]

For a broader picture, Figure 1 is a map of the European regions according to the CESI performances.

[Figure 1 about here]

Figure 1 shows low and medium-low CESI values for Eastern Europe and Southern Italy. This result is substantially in line with other studies conducted on the environmental and economic performances of European regions.

Figure 2 compares our map of the European regions according to the CESI index with the Regional green economic performance calculated by ESPON EU in 2010. ESPON uses 10 indicators for the green economy, i.e. with a stronger emphasis on environmental and energy issues ("Renewable energy production, Land take per GDP unit, Green products and service offered, Green Patents, GVA per energy unit, GDP per CO2 unit, Environmental and natural assets, Emission of air

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pollutants, Life expectancy, and Exposure to air pollution). The two maps are largely consistent in showing the separation between "central" and "peripheral" regions in terms of the CE and green performance.

[Figure 2 about here]

Moving a step further on in describing CE performance at the regional level, the second index (*CEDI*) evaluates CE performance from a *dynamic* perspective. Table 5 shows the Top 15 European regions according to the CEDI (see the whole CEDI ranking in Appendix 2). Based on this different perspective, along with some regions in France, Belgium, Spain and Austria, the best CE performances are achieved by regions in Eastern Europe. A more general view of the CEDI performance is offered by the Figure 3, which shows the map of European regions coloured according to the CEDI.

[Table 5 about here]

[Figure 3 about here]

With reference to Figure 3, which considers the dynamic performances of EU regions, our analysis seems to bring some original and interesting results. In this context, even though Eastern Europe regions generally achieve a low CESI performance (Figure 1), they have high and medium-high values of CEDI. Indeed, the two *Indexes* (CESI and CEDI) show different ways of conceiving CE performances, highlighting the fact that even though some regions may have quite different starting conditions (base level) in terms of absolute CE performance (which is indicated by the CESI), they still are able to move faster towards improvements (i.e. with higher dynamic performances, as indicated by the CEDI).

Here, it is also useful to look at CESI and CEDI performances in comparison with the concentration of European structural funds, which finance projects in line with the concept of CE (improvement in the environmental quality of production and territories; innovation; improvement in the quality of life; local development). Figures 4 and 5 compare the CESI/CEDI performances and the regions lagging behind for competitiveness and employment in the 2007-2013 period, those which were targeted for the allocation of EU structural funds.

[Figure 4 about here]

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[Figure 5 about here]

It is clear to see that, on the one hand, the CESI index is higher in the Central European, French and Northern Italian areas, which received less structural funding in the seven-year period 2007-13, before the data were collected for the Index (2012-2016) (Figure 4). On the other hand, there seems to be some consistency between the concentration of funds (in red Objective 1 NUTS 2, i.e. the EU regions that had benefitted from higher levels of EU Structural Funding) and higher values of the CEDI, in particular for the Eastern Europe regions (Figure 5). One possible interpretation of this comparison is that European Structural Funds play an important role in fostering the development of a CE in a region: where the funds were concentrated in the past (programming cycles 1993-1999 and 2000-2006), there is now a good *static* situation of the EC; where they have concentrated more recently, there is a promising *dynamic* condition for the CE. This seems to suggest a sort of catch-up dynamic similar to that which was theorized in terms of economic growth by Barro and Sala-i-Martin, (1992), such that the European regions that were lagging behind in the development of the CE are recovering, often thanks to European Structural Funds.

At a more general level, the dual reading of CE performance presented here would suggest that, in order to properly classify CE performance at the European level, it is important to find ways to allow a broader and more multidimensional notion of the way CE evolves. In this regard, the two *Indexes* could be used in combination, to map and classify European regions according to their CE static-dynamic performances. The graph below shows the performance of each region according to the CESI and CEDI (Figure 6). Each region is placed on the graph on the basis of a pair of values determined by the ordinal rank obtained according to the CESI (x-axis) and to the CEDI (y-axis). Overall, the graph maps all the regions considered in the analysis, subdividing them into four quadrants. This framework makes it possible to classify the European regions according to four groups.

The "Never give up" group (the bottom left quadrant) is characterized by above-median performances for both *Indexes*. These regions have a good level of attention paid to the CE, and also keeps this attention alive by improving performances over time. They include some of the most developed and innovative regions in Europe (including France - Île de France; Belgium - Brabant Wallon, Antwerpen and Région de Bruxelles; Germany Berlin and Hamburg; Spanish Catalunya), but also some more surprising regions, such as Portugal Norte, France - Pas de Calais and Brittany.

The second group is made up of the "Satiated and sleepy" regions (the top left quadrant), in which the CESI records good performances, but CEDI performances are low, suggesting a loss of

dynamism in terms of support for the CE. Among these are many of the richest regions of Europe: Germany – Freiburg; Spain - Comunidad de Madrid; and some of the most developed regions in Italy (Lombardy, Veneto, and the Province of Trento).

One very interesting group is the "The best is yet to come" (the bottom right quadrant), which is characterized by a low value for CESI (below median CE performance in absolute terms), and high performance in CEDI. It mostly includes those regions of Eastern Europe that entered the EU after 2004.

Finally, the "We don't mind" group (the top right quadrant), given by those regions with a modest value of both *Indexes*, where there are, for instance, the majority of Italian regions.

Figure 7 shows how the four groups of regions are localized on the EU map.

Overall, this analysis seems to provide a useful and complete informative framework to examine the CE performance, with possible applications, for example, for planning and evaluating EU policies for the promotion of CE processes.

[Figure 6 about here]

[Figure 7 about here]

5. Conclusions

Our study offers a contribution to research on the CE from three innovative aspects. The first one is the focus on the regional dimension and, in particular, on the NUTS 2 regions in the EU. By focusing upon regions, it has been possible to formulate an analysis of the CE at the meso-level.

The second concerns constructing a composite indicator capable to return the multidimensional nature of CE. To the best of our knowledge, it is the first study where a complete and statistically robust Index is built and used to analyse CE performance.

Finally, we perform the analysis in order to formalize different ways of conceiving the CE phenomenon, namely offering a static (CESI) and a dynamic (CEDI) reading of the performances of the European regions in terms of the CE.

The coaction of those three new features offers a useful and complete informative framework for examining CE performance at the regional level. Applying CESI and CEDI to the European case has allowed us to relate CE performance to the level of European structural funding, a policy measure designed to support local development, social cohesion and sustainability at the European level. Our analysis suggests there is a catch-up dynamic within the CE, e.g. the European regions which were lagging furthest behind do improve, relatively, over time. Our interpretation is that

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European structural funds play an important role in implementing the CE in the EU regions but are not the only factor. There are "outliers", i.e. regions whose CE performance does not seem to be affected by EU structural funding. These are the "Best is yet to come" group (who received funding until 2006), and the "We don't mind" group (funding since 2007). Based on this one can conclude that EU financing though structural funds do play a prominent in nurturing, encouraging, CE policies, but other policies and/or socio-economic features are also relevant.

Indeed, balanced, enduring development of the CE within Europe will also be influenced by complementary and interconnected policies and initiatives developed at the Country level. Consider, for example energy transformation in Germany (*Energiewende*), which is moving the country towards a low-carbon, nuclear-free economy supporting the full implementation of the CE cycle. Disruptive political changes could interfere in the process. The impact of *Brexit* would have on the full development of the CE is an example: the UK has opposed EU environmental laws in the past, therefore the type of "exit" might have consequences on UK commitment to the CE (Bell, 2019).

Our study could offer ideas for further analysis exploring the effective existence of convergence processes. Another possible line of research could be the reasons behind any diversity, or similarity, in CE performances in trans-border or neighbouring regions within the same Country, as a way of analysing the real role played by national and regional institutions in fostering the emergence and development of CE processes, building on the intuitions *à la* Acemoglu and Robinson (2012) regarding the role of institutions for growth and development.

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References

Acemoglu, D., Robinson, J. (2012), Why Nations fail: The Origins of Power, Prosperity, and Poverty, New York, Crown Business,

Andersen, M. S. (2007). An introductory note on the environmental economics of the circular economy. *Sustainability Science*, 2(1), 133-140

Arboretti, G. R., S. Bonnini, and L. Salmaso. (2007). "A performance indicator for multivariate data." *Quaderni di Statistica* 9 (1): 1-29

Bačová M., Böhme K., Guitton M., van Herwijnen M., Kállay T, Koutsomarkou J., Magazzù I., O'Loughlin E., Rok A. (2016), Pathways to a circular economy in cities and regions, http://urbact.eu/sites/default/files/policy_brief_on_circular_economy.pdf, Accessed 1st October 2018

Barro R. J., Sala-i-Martin, J. (1992), Convergence, *Journal of Political Economy*, 2

Bell A. (2019), What impact will Brexit have on the circular economy?, Environment Journal, 1st March 2019, available at: https://environmentjournal.online/articles/what-impact-will-brexit-have-on-the-circular-economy/

Bocken Nancy M. P., Ingrid de Pauw, Conny Bakker & Bram van der Grinten (2016) Product design and business model strategies for a circular economy, Journal of Industrial and Production Engineering, 33:5, 308-320, DOI: 10.1080/21681015.2016.1172124

Bonnini, S., L. Corain, A. Cordellina, A. Crestana, R. Musci, and L. Salmaso (2009). "A Novel Global Performance Score with Application to the Evaluation of New Detergents." In Bini, M., P. Monari, D. Piccolo, and L. Salmaso (eds). *Statistical methods for the evaluation of educational services and quality of products*, *Contribution to Statistics*. Heidelberg: Physica-Verlag

Boulding K. (1966), The Economics of the Coming Spaceship Earth, In: Jarrett H. (Editor), *Environmental Quality in a Growing Economy*, pp. 3-14. Baltimore, Johns Hopkins University Press

Brown, L. (2002). *Eco-economy: building an economy for the earth*, Orient Blackswan

Clark, W. C. (2007). Sustainability science: a room of its own. *Proceedings of the National Academy of Sciences*, 104(6), 1737

Dastoorpoor M., Idani E., Khanjani N. , Goudarzi G., Bahrampour A. (2016), Relationship Between Air Pollution,Weather, Traffic, and Traffic-Related Mortality, *Trauma Mon.,* 21(4)

Dempsey, N., Bramley, G., Power, S., et Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. *Sustainable development*, 19(5), 289-300

den Hollander M.C., Conny A. Bakker, Erik Jan Hultink (2017), Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms, in Journal of Industrial Ecology, 21 (3), 517-525.

Diaz L.F. (2017), Waste management in developing countries and the circular economy, Waste Manage. Res. 35 (1)

Domenech T., Bahn-Walkowiak B. (2019), Transition Towards a Resource Efficient Circular Economy in Europe: Policy Lessons From the EU and the Member States, "Ecological Economics", 155, 7-19.

EASAC, European Academies Science Advisory Council (2016), *Indicators for a circular economy*, EASAC policy report 30, November 2016, www.easac.eu, accessed 19/10/2017

EEA, European Environment Agency (2009). *Municipal Waste Generation* (CSI 016/WST 001) - Assessment published Dec 2011, available: http://www.eea.europa.eu/data-and-maps/indicators/municipal-waste-generation/municipal-wastegeneration-assessment-published-4, accessed 19/10/2017.

Ellen MacArthur Foundation (EMF) (2017), Cities in the Circular Economy: an Initial Exploration, https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Cities-in-the-CE_An-Initial-Exploration.pdf, accessed 1/10/2018

Environmental Protection Agency US Gov. (EPA). (2015). *Economic Incentives*, http://yosemite.epa.gov/EE%5Cepa%5Ceed.nsf/webpages/EconomicIncentives.html, accessed 09/10/2017.

European Commission (2015), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee of the Regions, Closing the loop - An EU action plan for the Circular Economy, COM (2015).

European Commission (2019), Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the implementation of the Circular Economy Action Plan, COM(2019).

Fayers, P.M., and D.J. Hand. (2002). "Causal variables, indicator variables and measurement scales: an example from quality of life." *Journal of the Royal Statistical Society: Series A* 165 (2): 233-261

Geissdoerfer M., Savaget P., Bocken N.M.P. et Hultink E.J. (2017). The Circular Economy – A new sustainability paradigm?. *Journal of Cleaner Production*, 143, 757-768

Geng Y., Zhub Q., Doberstein B., Fujitad T., (2009), *Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China*, Waste Management, Volume 29, Issue 2, February, Pages 996-1002

Geng, Y., Fu, J., Sarkis J., Xue, B. (2012). Towards a circular economy indicator system in China: an evaluation and critical analysis. *Journal of Cleaner Production* 23, 216-224.

Geng Y., Sarkis, J., Ulgiati S., Zhang P. (2013). Measuring China's circular economy. *Science*, 339 (6127), 1526-1527.

Georgescu-Roegen N. (1971), *The entropy law and the economic process*, Cambridge (Mass.)

Ghinoi S. Silvestri F., Steiner B. (2019), Toward the creation of novel food waste management systems: A network approach, "Journal of Cleaner Production" https://doi.org/10.1016/j.jclepro.2019.118987

Ghisellini P., Cialani C., Ulgiati S. (2015), A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, doi: 10.1016/j.jclepro.2015.09.007

Ghosh S.K., Debnath B., Baidya R., De D., Li J. (2016), Waste electrical and electronic equipment management and basel convention compliance in Brazil, Russia, India, China and South Africa (BRICS) nations, "Waste Manage. Res.", 34, (8), pp. 693–70

Golinska P., Kosacka M., Mierzwiak R., Werner-Lewandowska K. (2015). Grey Decision Making as a tool for the classification of the sustainability level of remanufacturing companies. *Journal of Cleaner Production* 105, 28-40.

Grossman, G. M., Krueger, A. B. (1995), Economic Growth and the Environment, *Quartely Journal of Economics*, 2.

Heshmati A. (2016). A Review of the Circular Economy and its Implementation (No. 431). *Royal Institute of Technology*, CESIS-Centre of Excellence for Science and Innovation Studies

Huang H.P. et Bi J. (2006), Evaluating Regional Circular Economy Based on MFA: A Case Study in Wujin District of Changzhou City. *Resources Science*, Vol. 28, No. 6, 20-27

Huanzheng D., Bin L., Haijun D. (2009), *Circular economy and regional economic development in the Zhejiang province, southern China*, Int. J. Environmental Technology and Management, 11/4

Hsu-Huei W., Shang-Shyue T., Chih-Cheng C., Hui-Fen C., Trong-Neng W., Chun-Yuh Y. (2008), Childhood Leukemia Development and Correlation with Traffic Air Pollution in Taiwan using Nitrogen Dioxide as an Air Pollutant Marker, *Journal of Toxicology and Environmental Health*, 71/7

Jiang G. (2011), Empirical Analysis of Regional Circular Economy Development-Study Based on Jiangsu, Heilongjiang, Qinghai Province, *Energy Procedia* 5, 125–129

Karousakis K. (2009), The drivers of MSW generation, disposal and recycling: examining OECD inter-country differences. In: Mazzanti, M., Montini, A. (Eds.), *Waste and Environmental Policy*, Taylor & Francis Group, Routledge

Keramatinia A., Hassanipour S, Nazarzadeh M., Wurtz M., Monfared A.B., Khayyamzadeh M., Bidel Z., Mhrvar N., Mosavi-Jarrahi A. (2016), Correlation Between Nitrogen Dioxide as an Air Pollution Indicator and Breast Cancer: a Systematic Review and Meta-Analysis, *Asian Pac J Cancer Prev.* 17(1)

Korhonen J., Nuur C., Feldmann A., Eshetu Birkie S. (2018), Circular economy as an essentially contested concept, *Journal of Cleaner Production* 175

Leeuwen C., Frijns, J., Wezel J., et Ven A. (2012). City Blueprints: 24 Indicators to Assess the Sustainability of the Urban Water Cycle. *Water Resources Management, 26*(8), 2177-2197

Li W., et Zhang T. (2005). Research on the Circular Economy Evaluation Index System in Resource Based City [J]. *Science of Science and Management of S. et T*, 8, 18

Lieder M., Rashid A. (2015), Towards circular economy implementation: a comprehensive review in context of manufacturing industry, "Journal of Cleaner Production", 115, pp. 36–51

Marozzi, M. (2009), "A composite indicator dimension reduction procedure with application to university student satisfaction", *Statistica Neerlandica* 63 (3): 258-268

Maté T., Guaita R., Pichiulec M., Linares C., Díaz J. (2010), Short-term effect of fine particulate matter (PM2.5) on daily mortality due to diseases of the circulatory system in Madrid (Spain), *Science of The Total Environment*, 408/23

Mazzanti M., Zoboli R. (2009). Municipal waste Kuznets curves: evidence on socio-economic drivers and policy effectiveness from the EU, *Environmental Resource Economics*, 44 (2)

Moon J. (2007). The contribution of corporate social responsibility to sustainable development. *Sustainable development*, 15(5), 296-306

Moveco (2017), Transnational Report on R&D Activities in Circular Economy, available at: www.interreg-danube.eu

OECD (2008). *Handbook on Constructing Composite Indicators*. Paris: OECD

Park J. J., Chertow M. (2014). Establishing and testing the "reuse potential" indicator for managing waste as resources. *Journal of Environmental Management* 137, 45-53.

Pearce D. W. et Turner R. K. (1990). *Economics of natural resources and the environment*. JHU Press

Petit-Boix A., Leipold S. (2018), Circular economy in cities: Reviewing how environmental research aligns with local practices, *Journal of Cleaner Production 195.*

Prieto-Sandoval V., C. Jaca, M. Ormazabal (2018), Towards a consensus on the circular economy, Journal of Cleaner Production, *Vol. 179, 605-615.*

Reike D., Vermeulen W.J.V., Witjes, S. (2018), The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options, "Resources, Conservation & Recycling", 135, pp 246–264,

Ren J., Manzardo, A., Toniolo S., Scipioni A. (2013). Sustainability of hydrogen supply chain. Part I: Identification of critical criteria and cause-effect analysis for enhancing the sustainability using DEMATEL. *International Journal of Hydrogen Energy* 38, 14159-14171.

Sacchi Homrich A., Galvão Lorena Gamboa Abadia G., Marly M. Carvalho (2018), The circular economy umbrella: Trends and gaps on integrating pathways, *Journal of Cleaner Production*, Volume 175, 525-543

Sachs J.D. (2005). Challenges of sustainable development under globalisation. *International Journal of Development*, 4(2):1–20

Saisana M., Saltelli A., & Tarantola, S. (2005). Uncertainty and sensitivity analysis techniques as tools for the quality assessment of composite indicators. Journal of the Royal Statistical Society Series A, 168, 307–323.

Sauerwein M., Eugeni Doubrovski, Ruud Balkenende, Conny Bakker (2019), Exploring the potential of additive manufacturing for product design in a circular economy, Journal of Cleaner Production, Volume 226, 2019, Pages 1138-1149, https://doi.org/10.1016/j.jclepro.2019.04.108.

Shi L. et Zhang T.Z. (2005). Circular Economy Indicators to Evaluate Regional Development-Take Guiyang as an Example. *China Population, Resources and Environment*, Vol. 15, No. 5, 63-66

Steurer R., Langer M.E., Konrad A., et Martinuzzi, A. (2005). Corporations, stakeholders and sustainable development: a theoretical exploration of business–society relations. *Journal of Business Ethics*, 61(3), 263-281

Tam E., Soulliere K., Sawyer-Beaulieu S. (2019), Managing complex products to support the circular economy, Resources, Conservation and Recycling, Volume 145, 124-125, https://doi.org/10.1016/j.resconrec.2018.12.030.

ten Brink P., M. Kettunen, Watkins E. (2017), *Expert Group on Green and Circular Economy in the Outermost Regions: Final Report*. For DG Regional and Urban Policy, European Commission.

The Danish Government (2018), Strategy for Circular Economy, available at: https://mfvm.dk/publikationer/publikation/pub/hent-fil/publication/strategy-for-circular-economy/

Tisdell C. (2001), Globalisation and Sustainability: Environmental Kuznets Curve and the WTO, *Ecological Economics*, 39

Török, A. (2017), Comparative Analysis Between The Theories Of Road Transport Safety And Emission, *Transport*, 32

Torras M., Boyce J. K. (1998), Income inequality, and pollution: a reassessment of the environmental Kuznets curve, *Ecological Economics*, 2

United Nations Environmental Program (UNEP). (2013). The Japanese Industrial Waste Experience: Lessons for rapidly industrializing countries, http://www.unep.org/ietc/Portals/136/Publications/Waste%20Management/UNEP%20DTIE_Japanese%20waste_english_web.pdf, accessed 05/10/2017

Wang N., Chi Kin Lee J., Zhang J., Chen H., Li H., (2018), Evaluation of Urban circular economy development: An empirical research of 40 cities in China, *Journal of Cleaner Production*, Volume 180, Pages 876-887

World Commission on Environment and Development (WCED), (1987), Our Common Future, Oxford, Oxford University Press

Yu Y., Chen D., Zhu B., Hu S., (2013). Eco-efficiency trends in China, 1978-2010: Decoupling environmental pressure from economic growth. *Ecological Indicators* 24, 177-184.

Yuan Z., Bi J., Moriguichi Y., 2008, The circular economy: a new development strategy in China, "Journal of Industrial Ecology", 10 (1-2), pp. 4–8

Yuan Z., Bi J., et Moriguichi, Y. (2006). The circular economy: A new development strategy in China. *Journal of Industrial Ecology*, 10(1-2), 4-8

Zaman A. U., Lehmann, (2013). The zero waste index: a performance measurement tool for waste management systems in a "zero waste city". *Journal of Cleaner Production* 50, 123-132.

Zhu D.J. et Qiu S.F. (2008). Eco-Efficiency Indicators and Their Demonstration as the Circular Economy Measurement in China. *Resources and Environment in the Yangtze Basin*, Vol. 17, No 1, 1-5

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Declaration of interests

X The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Appendix 1. Ranking according to the CESI (Source: authors)

			Normalized Variables											
		Weight	0.0833	0.0833	0.0833	0.0833	0.1111	0.1111	0.1111	0.0833	0.0833	0.0833	0.0833	
Rank	**Country code**	**Region**	Life expectancy 2015	Diseases of the circulatory system (rate) 2015	Malignant neoplasms (rate) 2015	Transport accidents (rate) 2015	GDP at current market prices (euro per inhabitant) 2015	Total intramural R&D expenditure (Euro per inhabitant) 2013	Total amount of fractional patents inv. per year 2013	Waste generated (tonnes per inhabitant) 2011	Waste recycling - composting and digestion (tonnes per inhabitant)	Artificial land (percentage) 2015	Estimated soil erosion by water (Tonnes per hectare) 2012	**CESI value**
			(+)	(-)	(-)	(-)	(+)	(+)	(+)	(-)	(+)	(-)	(-)	
1	FR10	Île de France	0,951	1,000	0,978	0,975	0,857	0,359	1,000	0,571	0,117	0,763	0,963	0,773
2	DE21	Oberbayern	0,769	0,794	0,758	0,817	0,840	0,511	0,668	0,584	0,135	0,884	0,886	0,693
3	DE11	Stuttgart	0,750	0,754	0,712	0,855	0,757	0,620	0,649	0,590	0,069	0,833	0,892	0,680
4	BE31	Prov. Brabant Wallon	0,731	0,889	0,683	0,845	0,607	1,000	0,041	0,636	0,008	0,757	0,877	0,635
5	DE71	Darmstadt	0,692	0,755	0,635	0,831	0,765	0,328	0,365	0,555	0,144	0,849	0,938	0,612
6	FR71	Rhône-Alpes	0,913	0,939	0,790	0,841	0,485	0,203	0,468	0,453	0,109	0,914	0,742	0,603
7	DE12	Karlsruhe	0,702	0,731	0,643	0,863	0,641	0,387	0,333	0,573	0,052	0,804	0,921	0,592
8	DE14	Tübingen	0,759	0,758	0,746	0,729	0,615	0,403	0,202	0,674	0,017	0,890	0,880	0,590
9	ES30	Comunidad de Madrid	0,999	0,940	0,915	0,949	0,467	0,122	0,111	0,679	0,002	0,821	0,834	0,589
10	NL41	Noord-Brabant	0,711	0,891	0,529	0,799	0,625	0,236	0,578	0,371	0,136	0,712	0,989	0,588
11	NL31	Utrecht	0,769	0,929	0,780	0,921	0,726	0,247	0,070	0,424	0,022	0,720	0,998	0,579
12	DE60	Hamburg	0,654	0,802	0,545	0,989	0,985	0,307	0,088	0,566	0,007	0,537	0,992	0,578
13	BE21	Prov. Antwerpen	0,759	0,850	0,713	0,816	0,661	0,254	0,091	0,579	0,091	0,731	0,985	0,572
14	NL32	Noord-Holland	0,721	0,915	0,641	0,912	0,801	0,193	0,117	0,450	0,026	0,723	0,986	0,571
15	BE10	Région de Bruxelles-Capitale	0,654	0,929	0,965	0,947	1,000	0,213	0,031	0,674	0,005	0,000	0,982	0,568
16	NL33	Zuid-Holland	0,740	0,911	0,626	0,947	0,609	0,179	0,165	0,458	0,262	0,612	0,986	0,568
17	NL23	Flevoland	0,750	0,983	1,000	0,933	0,449	0,108	0,010	0,502	0,012	0,898	0,979	0,568
18	BE24	Prov. Vlaams-Brabant	0,807	0,861	0,719	0,761	0,604	0,347	0,079	0,658	0,027	0,655	0,915	0,565
19	DEA2	Köln	0,644	0,741	0,554	0,960	0,601	0,248	0,306	0,538	0,062	0,753	0,937	0,561
20	DE25	Mittelfranken	0,625	0,675	0,567	0,798	0,621	0,330	0,298	0,534	0,058	0,874	0,931	0,561
21	ITC4	Lombardia	0,875	0,796	0,406	0,792	0,534	0,106	0,295	0,522	0,653	0,804	0,556	0,554
22	DE91	Braunschweig	0,586	0,622	0,430	0,825	0,596	0,640	0,105	0,532	0,033	0,876	0,940	0,553
23	FR62	Midi-Pyrénées	0,894	0,880	0,660	0,739	0,427	0,317	0,097	0,515	0,081	0,953	0,764	0,550
24	DE13	Freiburg	0,750	0,750	0,678	0,701	0,545	0,205	0,233	0,577	0,055	0,884	0,892	0,550
25	AT34	Vorarlberg	0,798	0,815	0,891	0,921	0,651	0,152	0,061	0,641	0,002	0,920	0,446	0,549
26	AT31	Oberösterreich	0,711	0,722	0,788	0,719	0,615	0,281	0,108	0,378	0,203	0,906	0,788	0,546
27	FR42	Alsace	0,798	0,914	0,691	0,904	0,444	0,116	0,076	0,441	0,050	0,855	0,932	0,536
28	ES51	Cataluña	0,894	0,887	0,747	0,846	0,396	0,090	0,172	0,498	0,002	0,902	0,774	0,535
29	DEB3	Rheinhessen-Pfalz	0,654	0,688	0,546	0,834	0,524	0,217	0,255	0,477	0,094	0,867	0,922	0,534
30	DE26	Unterfranken	0,692	0,665	0,608	0,890	0,561	0,187	0,119	0,505	0,047	0,886	0,900	0,529
31	DE30	Berlin	0,615	0,818	0,555	0,983	0,537	0,273	0,215	0,620	0,019	0,339	1,000	0,526
32	AT13	Wien	0,606	0,727	0,715	1,000	0,747	0,388	0,071	0,331	0,165	0,200	0,947	0,525
33	DE27	Schwaben	0,721	0,710	0,672	0,763	0,559	0,100	0,131	0,561	0,028	0,896	0,888	0,524
34	NL22	Gelderland	0,731	0,890	0,554	0,865	0,497	0,174	0,073	0,165	0,278	0,810	0,995	0,523
35	DEA4	Detmold	0,673	0,680	0,582	0,824	0,530	0,148	0,100	0,650	0,027	0,886	0,918	0,523
36	ES22	Comunidad Foral de Navarra	0,951	0,894	0,641	0,669	0,421	0,113	0,014	0,557	0,002	0,967	0,840	0,521
37	FR82	Provence-Alpes-Côte d'Azur	0,836	0,891	0,552	0,768	0,446	0,173	0,170	0,213	0,336	0,912	0,669	0,519
38	ITC1	Piemonte	0,807	0,691	0,251	0,701	0,416	0,130	0,095	0,529	0,998	0,894	0,500	0,519
39	ES21	País Vasco	0,903	0,861	0,454	0,882	0,450	0,140	0,040	0,587	0,002	0,902	0,793	0,519
40	ES62	Región de Murcia	0,807	0,905	0,927	0,835	0,246	0,034	0,012	0,612	0,002	0,898	0,847	0,519
41	FR51	Pays de la Loire	0,836	0,895	0,595	0,794	0,427	0,080	0,059	0,454	0,040	0,890	0,951	0,518
42	DEA1	Düsseldorf	0,577	0,706	0,365	0,945	0,608	0,143	0,348	0,542	0,033	0,618	0,958	0,517
43	BE22	Prov. Limburg (BE)	0,807	0,884	0,739	0,682	0,446	0,085	0,021	0,516	0,035	0,798	0,959	0,513
44	AT32	Salzburg	0,798	0,807	0,871	0,699	0,715	0,154	0,018	0,393	0,044	0,955	0,400	0,512

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45	AT22	Steiermark	0,692	0,678	0,616	0,662	0,530	0,380	0,098	0,493	0,045	0,943	0,673	0,512
46	FR43	Franche-Comté	0,788	0,892	0,657	0,717	0,356	0,149	0,031	0,483	0,009	0,953	0,920	0,511
47	ES52	Comunidad Valenciana	0,807	0,856	0,742	0,849	0,275	0,045	0,062	0,620	0,002	0,902	0,838	0,510
48	NL21	Overijssel	0,711	0,895	0,543	0,827	0,482	0,112	0,033	0,452	0,028	0,833	0,997	0,510
49	FR52	Bretagne	0,759	0,857	0,514	0,850	0,400	0,123	0,113	0,389	0,111	0,878	0,902	0,509
50	NL11	Groningen	0,634	0,866	0,453	0,776	0,690	0,201	0,012	0,326	0,051	0,798	0,991	0,508
51	BE23	Prov. Oost-Vlaanderen	0,711	0,842	0,581	0,699	0,499	0,198	0,057	0,571	0,051	0,686	0,947	0,508
52	BE25	Prov. West-Vlaanderen	0,759	0,802	0,580	0,701	0,530	0,106	0,040	0,513	0,109	0,725	0,953	0,504
53	AT33	Tirol	0,798	0,806	0,813	0,739	0,645	0,290	0,043	0,452	0,125	0,984	0,000	0,502
54	FR23	Haute-Normandie	0,682	0,895	0,552	0,819	0,408	0,091	0,089	0,352	0,036	0,918	0,946	0,499
55	ES24	Aragón	0,855	0,786	0,519	0,828	0,359	0,050	0,019	0,625	0,002	0,988	0,800	0,498
56	ES23	La Rioja	0,923	0,826	0,593	0,640	0,354	0,043	0,002	0,666	0,002	0,963	0,816	0,497
57	ITH3	Veneto	0,884	0,770	0,531	0,678	0,450	0,077	0,120	0,559	0,205	0,827	0,640	0,496
58	FR41	Lorraine	0,721	0,894	0,544	0,788	0,350	0,069	0,040	0,479	0,031	0,937	0,945	0,496
59	DEA3	Münster	0,625	0,741	0,474	0,929	0,462	0,073	0,106	0,507	0,064	0,782	0,971	0,496
60	FR72	Auvergne	0,769	0,823	0,414	0,764	0,382	0,134	0,092	0,473	0,014	0,943	0,929	0,495
61	DED2	Dresden	0,663	0,581	0,398	0,733	0,403	0,238	0,071	0,775	0,024	0,874	0,934	0,494
62	FR21	Champagne-Ardenne	0,702	0,886	0,537	0,752	0,396	0,048	0,016	0,468	0,016	0,957	0,954	0,490
63	DE92	Hannover	0,596	0,627	0,423	0,778	0,527	0,176	0,131	0,428	0,074	0,894	0,949	0,490
64	DE72	Gießen	0,625	0,689	0,510	0,743	0,463	0,165	0,052	0,550	0,040	0,886	0,921	0,489
65	FR61	Aquitaine	0,846	0,866	0,487	0,679	0,413	0,103	0,093	0,341	0,041	0,927	0,865	0,489
66	DEA5	Arnsberg	0,538	0,688	0,330	0,947	0,485	0,114	0,149	0,599	0,069	0,757	0,925	0,487
67	ITH1	Provincia Autonoma di Bolzano/Bozen	0,913	0,815	0,785	0,629	0,632	0,059	0,006	0,508	0,026	0,974	0,261	0,487
68	ITH2	Provincia Autonoma di Trento	0,951	0,793	0,575	0,633	0,516	0,145	0,012	0,506	0,003	0,976	0,505	0,487
69	FR22	Picardie	0,634	0,912	0,602	0,762	0,343	0,078	0,053	0,355	0,046	0,947	0,936	0,485
70	DE94	Weser-Ems	0,606	0,698	0,558	0,732	0,479	0,054	0,065	0,512	0,028	0,910	0,984	0,485
71	ES61	Andalucía	0,721	0,849	0,876	0,884	0,217	0,039	0,078	0,475	0,002	0,963	0,582	0,483
72	FR30	Nord - Pas-de-Calais	0,596	0,909	0,591	0,844	0,382	0,053	0,066	0,354	0,058	0,833	0,926	0,482
73	DEF0	Schleswig-Holstein	0,615	0,688	0,333	0,833	0,442	0,097	0,088	0,540	0,041	0,898	0,977	0,480
74	DE50	Bremen	0,548	0,676	0,387	0,911	0,741	0,278	0,016	0,586	0,013	0,267	0,995	0,480
75	CZ01	Praha	0,596	0,691	0,631	0,819	0,478	0,184	0,016	0,814	0,002	0,359	0,940	0,480
76	PT11	Norte	0,731	0,856	0,727	0,784	0,175	0,042	0,019	0,628	0,086	0,892	0,735	0,479
77	ES41	Castilla y León	0,942	0,775	0,349	0,738	0,294	0,048	0,014	0,606	0,002	0,988	0,872	0,479
78	NL42	Limburg (NL)	0,663	0,834	0,312	0,826	0,500	0,136	0,084	0,453	0,002	0,725	0,966	0,478
79	DE73	Kassel	0,606	0,628	0,476	0,733	0,514	0,135	0,045	0,558	0,037	0,869	0,906	0,478
80	SK01	Bratislavský kraj	0,423	0,724	0,632	0,546	0,532	0,130	0,008	0,633	0,005	0,910	0,964	0,477
81	NL12	Friesland (NL)	0,711	0,868	0,437	0,748	0,405	0,055	0,013	0,293	0,097	0,947	0,995	0,477
82	ES53	Illes Balears	0,827	0,915	0,938	0,753	0,338	0,017	0,007	0,103	0,002	0,927	0,773	0,477
83	FR26	Bourgogne	0,759	0,853	0,356	0,716	0,395	0,060	0,036	0,451	0,014	0,963	0,942	0,476
84	AT12	Niederösterreich	0,663	0,674	0,573	0,614	0,482	0,114	0,083	0,353	0,074	0,951	0,877	0,474
85	DEB1	Koblenz	0,625	0,631	0,438	0,757	0,464	0,049	0,060	0,512	0,148	0,890	0,921	0,474
86	FR81	Languedoc-Roussillon	0,807	0,880	0,510	0,688	0,345	0,132	0,057	0,300	0,022	0,927	0,830	0,473
87	DE24	Oberfranken	0,577	0,591	0,473	0,688	0,509	0,135	0,087	0,496	0,043	0,920	0,907	0,472
88	BE33	Prov. Liège	0,510	0,824	0,600	0,621	0,374	0,093	0,018	0,646	0,101	0,794	0,923	0,472
89	ITF4	Puglia	0,836	0,776	0,655	0,725	0,226	0,032	0,019	0,496	0,078	0,878	0,836	0,471
90	FR63	Limousin	0,740	0,796	0,339	0,786	0,346	0,055	0,009	0,528	0,004	0,943	0,942	0,469
91	FR25	Basse-Normandie	0,769	0,853	0,442	0,738	0,370	0,075	0,026	0,311	0,041	0,918	0,924	0,469
92	FR53	Poitou-Charentes	0,817	0,843	0,377	0,683	0,386	0,055	0,019	0,385	0,026	0,921	0,948	0,468
93	DE40	Brandenburg	0,596	0,631	0,264	0,717	0,379	0,087	0,087	0,668	0,056	0,953	0,989	0,468
94	NL34	Zeeland	0,788	0,839	0,411	0,816	0,455	0,046	0,010	0,206	0,011	0,874	0,973	0,467
95	ES11	Galicia	0,846	0,780	0,420	0,687	0,273	0,038	0,022	0,641	0,002	0,939	0,836	0,466
96	DEB2	Trier	0,644	0,673	0,446	0,674	0,417	0,198	0,019	0,498	0,013	0,894	0,902	0,466
97	ES43	Extremadura	0,788	0,806	0,460	0,775	0,195	0,026	0,004	0,599	0,002	0,988	0,846	0,464
98	DEC0	Saarland	0,538	0,639	0,225	0,963	0,531	0,106	0,034	0,577	0,031	0,753	0,925	0,462
99	DEG0	Thüringen	0,567	0,576	0,313	0,792	0,376	0,122	0,081	0,668	0,002	0,912	0,928	0,461
100	ITH5	Emilia-Romagna	0,875	0,727	0,362	0,647	0,498	0,123	0,181	0,257	0,043	0,876	0,658	0,460
101	CZ06	Jihovýchod	0,519	0,649	0,679	0,607	0,178	0,092	0,014	0,842	0,002	0,929	0,904	0,459
102	ITI4	Lazio	0,827	0,760	0,491	0,726	0,454	0,123	0,067	0,362	0,046	0,874	0,552	0,458
103	ES13	Cantabria	0,846	0,847	0,429	0,788	0,282	0,042	0,005	0,458	0,002	0,949	0,740	0,458

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104	DE93	Lüneburg	0,634	0,675	0,384	0,632	0,360	0,059	0,049	0,543	0,030	0,923	0,987	0,453
105	AT21	Kärnten	0,702	0,659	0,592	0,712	0,495	0,209	0,012	0,473	0,024	0,974	0,339	0,452
106	ITG2	Sardegna	0,836	0,815	0,442	0,705	0,258	0,034	0,005	0,545	0,002	0,951	0,732	0,452
107	PL32	Podkarpackie	0,442	0,631	0,799	0,601	0,063	0,020	0,004	0,962	0,004	0,965	0,883	0,450
108	BE32	Prov. Hainaut	0,433	0,819	0,534	0,647	0,327	0,072	0,018	0,618	0,025	0,843	0,926	0,450
109	AT11	Burgenland (AT)	0,682	0,619	0,553	0,599	0,396	0,053	0,011	0,488	0,011	0,929	0,899	0,450
110	BE35	Prov. Namur	0,500	0,831	0,627	0,394	0,352	0,043	0,009	0,631	0,002	0,953	0,917	0,449
111	DE80	Mecklenburg-Vorpommern	0,558	0,615	0,211	0,765	0,352	0,097	0,020	0,624	0,021	0,957	0,983	0,446
112	ITF5	Basilicata	0,798	0,673	0,628	0,654	0,264	0,024	0,001	0,703	0,002	0,959	0,555	0,446
113	ITF1	Abruzzo	0,827	0,659	0,617	0,683	0,343	0,047	0,011	0,512	0,048	0,931	0,528	0,445
114	CZ03	Jihozápad	0,423	0,653	0,532	0,641	0,164	0,048	0,006	0,860	0,002	0,976	0,918	0,441
115	CZ05	Severovýchod	0,481	0,649	0,600	0,540	0,148	0,040	0,015	0,858	0,002	0,949	0,911	0,438
116	NL13	Drenthe	0,692	0,849	0,347	0,652	0,407	0,045	0,005	0,208	0,040	0,855	0,996	0,437
117	ITI1	Toscana	0,865	0,693	0,320	0,633	0,427	0,084	0,091	0,298	0,103	0,912	0,615	0,437
118	ITH4	Friuli-Venezia Giulia	0,836	0,695	0,210	0,694	0,421	0,098	0,059	0,565	0,010	0,927	0,524	0,436
119	FR83	Corse	0,875	0,873	0,553	0,684	0,375	0,017	0,000	0,279	0,002	1,000	0,440	0,436
120	SK04	Východné Slovensko	0,212	0,726	0,773	0,568	0,098	0,012	0,002	0,918	0,002	0,982	0,864	0,433
121	PL21	Malopolskie	0,452	0,655	0,620	0,717	0,099	0,027	0,023	0,809	0,006	0,933	0,798	0,432
122	ITF2	Molise	0,817	0,580	0,577	0,639	0,254	0,033	0,001	0,639	0,002	0,980	0,540	0,430
123	PL41	Wielkopolskie	0,318	0,746	0,643	0,495	0,134	0,015	0,008	0,801	0,009	0,953	0,982	0,430
124	ES12	Principado de Asturias	0,798	0,709	0,206	0,818	0,271	0,039	0,008	0,481	0,002	0,965	0,725	0,427
125	PL12	Mazowieckie	0,385	0,659	0,550	0,422	0,231	0,058	0,037	0,729	0,019	0,953	0,974	0,427
126	CZ02	Střední Cechy	0,452	0,671	0,636	0,670	0,176	0,066	0,011	0,491	0,002	0,933	0,919	0,426
127	ITF3	Campania	0,644	0,729	0,667	0,917	0,218	0,051	0,025	0,585	0,004	0,818	0,324	0,423
128	PL63	Pomorskie	0,375	0,749	0,543	0,501	0,111	0,022	0,006	0,767	0,002	0,980	0,975	0,423
129	ITI2	Umbria	0,875	0,666	0,496	0,652	0,334	0,045	0,014	0,409	0,021	0,931	0,491	0,422
130	CZ08	Moravskoslezsko	0,327	0,606	0,599	0,636	0,149	0,033	0,005	0,837	0,002	0,910	0,890	0,421
131	BE34	Prov. Luxembourg (BE)	0,577	0,869	0,664	0,228	0,320	0,011	0,003	0,323	0,040	0,969	0,934	0,421
132	ITF6	Calabria	0,788	0,691	0,740	0,803	0,208	0,020	0,006	0,586	0,005	0,918	0,185	0,419
133	PL42	Zachodniopomorskie	0,318	0,660	0,487	0,679	0,089	0,005	0,002	0,758	0,018	0,990	0,981	0,418
134	CZ07	Střední Morava	0,433	0,616	0,625	0,412	0,150	0,036	0,007	0,832	0,002	0,933	0,905	0,418
135	ITC3	Liguria	0,827	0,622	0,084	0,818	0,439	0,089	0,035	0,353	0,002	0,859	0,674	0,416
136	PL61	Kujawsko-Pomorskie	0,337	0,651	0,529	0,541	0,082	0,005	0,001	0,821	0,018	0,974	0,974	0,414
137	PL31	Lubelskie	0,356	0,617	0,670	0,374	0,057	0,009	0,004	0,927	0,004	0,976	0,930	0,412
138	ITG1	Sicilia	0,731	0,704	0,657	0,771	0,218	0,035	0,012	0,498	0,019	0,888	0,309	0,411
139	SK03	Stredné Slovensko	0,212	0,669	0,633	0,484	0,122	0,015	0,002	0,856	0,006	0,984	0,877	0,409
140	ITI3	Marche	0,884	0,682	0,446	0,591	0,372	0,047	0,030	0,471	0,009	0,902	0,316	0,408
141	SK02	Západné Slovensko	0,269	0,656	0,476	0,657	0,153	0,009	0,006	0,733	0,013	0,953	0,901	0,407
142	PL52	Opolskie	0,327	0,595	0,626	0,465	0,086	0,004	0,001	0,810	0,003	0,974	0,950	0,406
143	DEE0	Sachsen-Anhalt	0,490	0,495	0,059	0,662	0,355	0,078	0,029	0,598	0,030	0,925	0,973	0,404
144	PL43	Lubuskie	0,269	0,687	0,609	0,399	0,086	0,004	0,002	0,759	0,006	0,984	0,988	0,402
145	CZ04	Severozápad	0,269	0,617	0,499	0,595	0,127	0,008	0,003	0,799	0,002	0,927	0,928	0,402
146	PL62	Warminsko-Mazurskie	0,289	0,746	0,544	0,389	0,063	0,005	0,000	0,804	0,002	0,986	0,966	0,401
147	PL34	Podlaskie	0,394	0,666	0,569	0,289	0,064	0,009	0,002	0,832	0,006	0,978	0,975	0,401
148	PL51	Dolnoslaskie	0,298	0,632	0,452	0,529	0,141	0,016	0,013	0,717	0,024	0,961	0,934	0,398
149	PL22	Slaskie	0,250	0,615	0,459	0,656	0,126	0,014	0,008	0,766	0,020	0,859	0,931	0,396
150	RO32	Bucuresti - Ilfov	0,250	0,485	0,558	0,599	0,255	0,031	0,009	0,755	0,004	0,729	0,943	0,393
151	PL33	Swietokrzyskie	0,318	0,482	0,501	0,400	0,065	0,005	0,001	0,991	0,005	0,957	0,923	0,389
152	PT15	Algarve	0,644	0,843	0,617	0,373	0,229	0,013	0,000	0,009	0,002	0,898	0,898	0,384
153	BG41	Yugozapaden	0,145	0,263	0,742	0,615	0,099	0,023	0,007	0,718	0,002	0,990	0,900	0,379
154	ITC2	Valle d'Aosta/Vallée d'Aoste	0,721	0,767	0,331	0,555	0,507	0,033	0,002	0,341	0,003	0,970	0,095	0,375
155	RO12	Centru	0,135	0,434	0,601	0,455	0,051	0,001	0,001	0,902	0,006	1,000	0,817	0,368
156	PL11	Lódzkie	0,173	0,607	0,395	0,347	0,104	0,014	0,008	0,738	0,012	0,931	0,971	0,362
157	RO11	Nord-Vest	0,049	0,377	0,647	0,374	0,046	0,004	0,001	0,985	0,006	0,988	0,791	0,357
158	RO41	Sud-Vest Oltenia	0,087	0,192	0,714	0,283	0,022	0,001	0,002	0,947	0,020	0,982	0,870	0,344
159	HU32	Észak-Alföld	0,087	0,472	0,268	0,565	0,045	0,018	0,008	0,712	0,007	0,959	0,955	0,343
160	HU22	Nyugat-Dunántúl	0,231	0,463	0,304	0,485	0,132	0,017	0,004	0,404	0,015	0,961	0,919	0,332
161	BG34	Yugoiztochen	0,020	0,065	0,760	0,491	0,014	0,001	0,001	0,693	0,002	0,996	0,925	0,331
162	BG42	Yuzhen tsentralen	0,068	0,164	0,622	0,448	0,001	0,001	0,000	0,722	0,002	0,998	0,918	0,329
163	RO22	Sud-Est	0,058	0,352	0,523	0,262	0,047	0,000	0,000	0,807	0,002	0,994	0,874	0,328

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164	HU21	Közép-Dunántúl	0,106	0,459	0,161	0,526	0,102	0,025	0,002	0,646	0,008	0,945	0,907	0,327
165	HU31	Észak-Magyarország	0,039	0,377	0,164	0,676	0,049	0,010	0,003	0,728	0,004	0,965	0,885	0,327
166	HU33	Dél-Alföld	0,125	0,380	0,144	0,386	0,058	0,019	0,009	0,740	0,002	0,963	0,962	0,318
167	RO42	Vest	0,039	0,355	0,491	0,000	0,063	0,004	0,002	0,849	0,002	0,994	0,888	0,309
168	BG32	Severen tsentralen	0,001	0,000	0,475	0,527	0,000	0,000	0,000	0,675	0,002	0,996	0,844	0,293
169	HU23	Dél-Dunántúl	0,106	0,459	0,000	0,413	0,049	0,011	0,004	0,646	0,006	0,957	0,830	0,292

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Appendix 2. Ranking according to the CEDI (Source: authors)

			Normalized Variables											
		Weight	0.0833	0.0833	0.0833	0.0833	0.1111	0.1111	0.1111	0.0833	0.0833	0.0833	0.0833	
Rank	**Country code**	**Region**	Growth rate life expectancy 2012/2015	Growth rate diseases of the circulatory system 2012/2015	Growth rate Malignant neoplasms 2012/2015	Growth rate Transport accidents 2012/2015	Growth rate GDP at current market prices 2012/2015 (%)	Growth rate Total intramural R&D expenditure 2011/2013 (%)	Growth rate Total amount of fractional patents inv. per year 2010/2013 (%)	Growth rate waste generated 2010/2011 (%)	Growth waste recycling per inhabitant - composting and digestion 2010/2011 (%)	Growth rate artificial land 2012/2015 (%)	Growth rate estimated soil erosion by water 2000/2012 (%)	**CEDI value**
			(+)	(-)	(-)	(-)	(+)	(+)	(+)	(-)	(+)	(-)	(-)	
1	PL31	Lubelskie	0,848	0,789	0,108	0,894	0,608	0,195	1,000	0,476	0,074	0,899	0,411	0,575
2	RO32	Bucuresti - Ilfov	0,806	0,574	0,316	0,762	0,988	0,095	0,314	0,748	1,000	0,568	0,256	0,574
3	RO22	Sud-Est	0,912	0,497	0,211	0,769	1,000	0,084	0,918	0,645	0,041	0,720	0,270	0,561
4	CZ05	Severovýchod	0,842	0,858	0,564	0,686	0,519	0,213	0,521	0,588	0,041	0,823	0,587	0,555
5	CZ08	Moravskoslezsko	0,709	0,651	0,683	0,776	0,395	0,136	0,785	0,663	0,041	0,796	0,494	0,547
6	CZ06	Jihovýchod	0,794	0,841	0,764	0,591	0,511	0,338	0,315	0,545	0,041	0,709	0,635	0,539
7	BE31	Prov. Brabant Wallon	0,786	0,637	0,596	0,929	0,578	0,373	0,190	0,480	0,046	0,899	0,463	0,530
8	CZ02	Střední Cechy	0,843	0,845	0,594	0,900	0,542	0,363	0,222	0,242	0,041	0,769	0,597	0,528
9	AT11	Burgenland (AT)	0,743	0,689	0,785	0,763	0,611	0,248	0,374	0,184	0,067	0,899	0,523	0,525
10	FR22	Picardie	0,700	0,632	0,506	0,842	0,430	0,236	0,178	1,000	0,017	0,747	0,696	0,522
11	FR30	Nord - Pas-de-Calais	0,836	0,710	0,467	0,678	0,530	0,233	0,192	0,918	0,014	0,805	0,546	0,521
12	BE10	Région de Bruxelles-Capitale	0,834	0,906	0,751	0,914	0,455	0,217	0,094	0,507	0,038	1,000	0,259	0,519
13	CZ01	Praha	0,746	1,000	0,604	0,734	0,433	0,195	0,237	0,497	0,041	0,899	0,541	0,518
14	ES53	Illes Balears	0,738	0,764	0,643	0,747	0,508	0,127	0,334	0,452	0,041	0,839	0,678	0,516
15	FR10	Île de France	0,562	0,771	0,542	0,884	0,494	0,175	0,156	0,929	0,028	0,631	0,730	0,515
16	PL42	Zachodniopomorskie	0,756	0,371	0,216	0,792	0,700	0,141	0,698	0,485	0,076	0,899	0,500	0,512
17	CZ03	Jihozápad	0,568	0,723	0,527	0,839	0,525	0,255	0,334	0,580	0,041	0,782	0,585	0,511
18	HU22	Nyugat-Dunántúl	0,998	0,617	0,764	0,709	0,906	0,250	0,175	0,344	0,056	0,506	0,346	0,510
19	DEB2	Trier	0,257	0,473	0,371	0,500	0,626	1,000	0,286	0,503	0,051	0,711	0,678	0,508
20	HU33	Dél-Alföld	0,667	0,451	0,516	0,631	0,768	0,265	0,214	0,813	0,041	0,899	0,405	0,507
21	AT13	Wien	0,611	0,786	0,771	1,000	0,451	0,173	0,142	0,522	0,042	0,870	0,417	0,503
22	DEB1	Koblenz	0,610	0,657	0,578	0,729	0,625	0,225	0,136	0,494	0,043	0,765	0,837	0,502
23	BE21	Prov. Antwerpen	0,873	0,612	0,605	0,793	0,537	0,190	0,180	0,561	0,038	0,684	0,599	0,498
24	PL34	Podlaskie	0,615	0,459	0,126	0,715	0,648	0,366	0,648	0,524	0,096	0,899	0,321	0,497
25	FR41	Lorraine	0,653	0,631	0,471	0,746	0,519	0,179	0,189	0,881	0,000	0,764	0,638	0,497
26	FR52	Bretagne	0,784	0,785	0,512	0,872	0,525	0,211	0,175	0,386	0,096	0,859	0,457	0,497
27	HU31	Észak-Magyarország	0,865	0,442	0,473	0,794	0,952	0,309	0,084	0,605	0,028	0,594	0,371	0,497
28	CZ04	Severozápad	0,664	0,654	0,595	0,632	0,439	0,280	0,457	0,479	0,041	0,777	0,543	0,496
29	PL12	Mazowieckie	0,847	0,785	0,162	0,853	0,664	0,253	0,197	0,519	0,028	0,819	0,422	0,493
30	ES62	Región de Murcia	0,739	0,786	0,146	0,830	0,500	0,155	0,147	0,840	0,041	0,756	0,710	0,493
31	FR72	Auvergne	0,740	0,614	0,637	0,717	0,518	0,183	0,177	0,691	0,080	0,899	0,357	0,492
32	BE23	Prov. Oost-Vlaanderen	0,742	0,714	0,499	0,739	0,560	0,271	0,117	0,586	0,026	0,772	0,522	0,489
33	DE60	Hamburg	0,565	0,723	0,296	0,903	0,629	0,210	0,124	0,445	0,083	0,887	0,675	0,488
34	BG34	Yugoiztochen	0,670	0,406	0,533	0,617	0,647	0,266	0,364	0,554	0,041	0,709	0,604	0,486
35	NL23	Flevoland	0,829	0,449	0,826	0,651	0,511	0,205	0,360	0,508	0,040	0,705	0,385	0,486
36	ES51	Cataluña	0,736	0,595	0,406	0,786	0,565	0,154	0,125	0,536	0,041	0,851	0,744	0,485
37	DEA3	Münster	0,521	0,656	0,459	0,911	0,573	0,189	0,146	0,478	0,042	0,825	0,707	0,484
38	BE22	Prov. Limburg (BE)	0,871	0,622	0,553	0,764	0,564	0,232	0,061	0,535	0,035	0,846	0,422	0,483
39	ES11	Galicia	0,650	0,878	0,590	0,754	0,528	0,127	0,088	0,548	0,041	0,831	0,484	0,481
40	RO12	Centru	0,715	0,428	0,263	0,807	0,774	0,076	0,428	0,644	0,008	0,899	0,272	0,478
41	PL41	Wielkopolskie	0,616	0,817	0,338	0,828	0,739	0,204	0,095	0,514	0,016	0,819	0,400	0,478
42	DEA5	Arnsberg	0,432	0,671	0,372	0,735	0,591	0,227	0,115	0,477	0,040	0,877	0,879	0,477
43	FR53	Poitou-Charentes	0,651	0,596	0,504	0,669	0,515	0,242	0,133	0,732	0,003	0,784	0,592	0,476

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44	PT15	Algarve	0,699	0,763	0,605	0,781	0,683	0,126	0,084	0,597	0,041	0,653	0,381	0,476
45	PL22	Slaskie	0,759	0,483	0,254	0,863	0,619	0,263	0,232	0,519	0,045	0,899	0,402	0,476
46	DE30	Berlin	0,477	0,617	0,292	0,883	0,617	0,209	0,134	0,443	0,051	0,666	0,996	0,475
47	DE73	Kassel	0,388	0,500	0,432	0,841	0,692	0,227	0,167	0,523	0,039	0,743	0,787	0,475
48	BE25	Prov. West-Vlaanderen	0,652	0,517	0,663	0,706	0,560	0,326	0,156	0,582	0,028	0,666	0,490	0,474
49	ITC3	Liguria	0,651	0,652	0,571	0,765	0,435	0,159	0,239	0,546	0,041	0,632	0,719	0,474
50	ITH5	Emilia-Romagna	0,606	0,776	0,599	0,774	0,471	0,232	0,182	0,550	0,041	0,859	0,302	0,474
51	PL21	Malopolskie	0,797	0,372	0,047	0,907	0,720	0,319	0,380	0,527	0,060	0,769	0,314	0,474
52	RO11	Nord-Vest	0,718	0,596	0,334	0,708	0,919	0,068	0,192	0,928	0,015	0,578	0,199	0,471
53	ITI4	Lazio	0,782	0,747	0,634	0,798	0,260	0,185	0,094	0,549	0,041	0,860	0,516	0,470
54	DEB3	Rheinhessen-Pfalz	0,565	0,582	0,514	0,767	0,572	0,159	0,125	0,508	0,039	0,824	0,697	0,470
55	FR21	Champagne-Ardenne	0,653	0,632	0,429	0,833	0,423	0,177	0,081	0,731	0,011	0,725	0,709	0,469
56	PL11	Lódzkie	0,809	0,871	0,041	0,730	0,675	0,240	0,084	0,433	0,180	0,772	0,464	0,469
57	FR71	Rhône-Alpes	0,649	0,710	0,474	0,824	0,482	0,175	0,149	0,932	0,020	0,792	0,155	0,469
58	PL63	Pomorskie	0,800	0,595	0,244	0,705	0,617	0,369	0,195	0,496	0,041	0,772	0,402	0,469
59	FR62	Midi-Pyrénées	0,649	0,667	0,439	0,716	0,482	0,181	0,120	0,823	0,017	0,819	0,451	0,469
60	DE26	Unterfranken	0,521	0,504	0,445	0,940	0,603	0,198	0,123	0,487	0,041	0,857	0,593	0,468
61	RO41	Sud-Vest Oltenia	0,765	0,514	0,134	0,728	0,710	0,060	0,508	0,734	0,011	0,766	0,256	0,468
62	HU32	Észak-Alföld	0,525	0,387	0,545	0,601	0,628	0,296	0,521	0,547	0,057	0,622	0,400	0,467
63	PL43	Lubuskie	0,664	0,302	0,403	0,781	0,683	0,459	0,097	0,469	0,032	0,760	0,533	0,466
64	CZ07	Střední Morava	0,660	0,783	0,453	0,469	0,563	0,231	0,206	0,542	0,041	0,628	0,680	0,466
65	DE21	Oberbayern	0,564	0,723	0,508	0,743	0,627	0,219	0,130	0,497	0,044	0,814	0,382	0,465
66	DED2	Dresden	0,433	0,577	0,348	0,620	0,691	0,191	0,111	0,505	0,041	0,779	0,948	0,464
67	DEG0	Thüringen	0,477	0,350	0,256	0,806	0,690	0,209	0,095	0,469	0,041	0,847	1,000	0,464
68	FR51	Pays de la Loire	0,563	0,545	0,288	0,806	0,499	0,219	0,125	0,758	0,056	0,899	0,530	0,464
69	NL33	Zuid-Holland	0,741	0,656	0,539	0,794	0,499	0,191	0,149	0,532	0,042	0,701	0,416	0,462
70	FR26	Bourgogne	0,564	0,707	0,234	0,723	0,523	0,163	0,193	0,748	0,012	0,807	0,569	0,461
71	PL51	Dolnoslaskie	0,757	0,679	0,335	0,537	0,619	0,273	0,218	0,537	0,033	0,714	0,459	0,461
72	DEA2	Köln	0,521	0,411	0,516	0,874	0,616	0,175	0,116	0,511	0,042	0,833	0,612	0,461
73	AT12	Niederösterreich	0,654	0,495	0,499	0,775	0,559	0,233	0,185	0,558	0,032	0,821	0,386	0,460
74	FR42	Alsace	0,477	0,589	0,449	0,850	0,518	0,172	0,109	0,824	0,013	0,864	0,385	0,460
75	DE91	Braunschweig	0,388	0,431	0,550	0,931	0,650	0,209	0,131	0,460	0,047	0,645	0,741	0,459
76	PL32	Podkarpackie	0,614	0,151	0,147	0,923	0,694	0,359	0,474	0,464	0,182	0,594	0,397	0,459
77	ES43	Extremadura	0,739	0,553	0,327	0,669	0,500	0,131	0,530	0,659	0,041	0,747	0,220	0,458
78	DE94	Weser-Ems	0,521	0,469	0,482	0,822	0,577	0,216	0,143	0,455	0,046	0,796	0,655	0,458
79	DEA4	Detmold	0,565	0,349	0,743	0,635	0,624	0,222	0,114	0,464	0,045	0,675	0,732	0,457
80	SK04	Východné Slovensko	0,665	0,818	0,143	0,546	0,644	0,243	0,172	0,570	0,041	0,899	0,391	0,457
81	SK01	Bratislavský kraj	0,706	0,556	0,371	0,540	0,619	0,345	0,231	0,556	0,023	0,627	0,499	0,456
82	ITH1	Provincia Autonoma di Bolzano/Bozen	0,606	0,606	1,000	0,736	0,465	0,215	0,118	0,446	0,041	0,786	0,187	0,456
83	NL32	Noord-Holland	0,653	0,606	0,468	0,837	0,638	0,179	0,149	0,509	0,044	0,690	0,372	0,456
84	PT11	Norte	0,830	0,469	0,295	0,695	0,677	0,143	0,142	0,568	0,033	0,855	0,441	0,456
85	FR63	Limousin	0,347	0,757	0,469	0,780	0,518	0,223	0,097	0,742	0,001	0,754	0,493	0,455
86	DE27	Schwaben	0,609	0,676	0,464	0,803	0,615	0,197	0,099	0,501	0,049	0,758	0,384	0,455
87	BG41	Yugozapaden	0,619	0,545	0,727	0,596	0,632	0,258	0,174	0,610	0,041	0,560	0,341	0,455
88	PL61	Kujawsko-Pomorskie	0,943	0,240	0,457	0,925	0,676	0,259	0,051	0,498	0,052	0,665	0,360	0,454
89	HU21	Közép-Dunántúl	0,525	0,180	0,350	0,758	0,832	0,528	0,052	0,530	0,062	0,750	0,411	0,454
90	NL22	Gelderland	0,741	0,570	0,546	0,813	0,516	0,189	0,108	0,503	0,039	0,843	0,304	0,454
91	DEA1	Düsseldorf	0,477	0,498	0,572	0,737	0,580	0,148	0,116	0,477	0,039	0,870	0,648	0,454
92	AT34	Vorarlberg	0,564	0,278	0,671	0,962	0,618	0,262	0,215	0,497	0,041	0,843	0,123	0,453
93	ES52	Comunidad Valenciana	0,651	0,620	0,369	0,653	0,573	0,155	0,113	0,554	0,041	0,751	0,678	0,453
94	ES61	Andalucía	0,697	0,489	0,573	0,776	0,480	0,124	0,145	0,630	0,041	0,807	0,426	0,453
95	DE72	Gießen	0,433	0,407	0,302	0,733	0,619	0,240	0,155	0,474	0,043	0,899	0,788	0,452
96	FR25	Basse-Normandie	0,696	0,497	0,446	0,712	0,473	0,187	0,131	0,780	0,034	0,788	0,421	0,452
97	DE40	Brandenburg	0,477	0,491	0,226	0,714	0,675	0,167	0,182	0,476	0,050	0,819	0,807	0,452
98	BE24	Prov. Vlaams-Brabant	0,739	0,401	0,589	0,569	0,555	0,229	0,154	0,556	0,021	0,899	0,399	0,452
99	ITC4	Lombardia	0,649	0,562	0,613	0,822	0,412	0,174	0,132	0,551	0,041	0,872	0,340	0,451
100	ITF6	Calabria	0,608	0,372	0,559	0,855	0,399	0,244	0,284	0,557	0,041	0,844	0,328	0,450
101	BE35	Prov. Namur	0,749	0,892	0,360	0,934	0,464	0,027	0,181	0,473	0,041	0,645	0,400	0,449
102	FR43	Franche-Comté	0,608	0,660	0,505	0,819	0,544	0,137	0,097	0,427	0,098	0,819	0,416	0,449
103	ITI1	Toscana	0,563	0,605	0,584	0,725	0,429	0,199	0,174	0,580	0,041	0,899	0,290	0,446

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104	DE11	Stuttgart	0,477	0,608	0,329	0,757	0,651	0,181	0,099	0,439	0,052	0,772	0,662	0,445
105	FR82	Provence-Alpes-Côte d'Azur	0,520	0,635	0,372	0,790	0,422	0,287	0,148	0,825	0,006	0,899	0,140	0,444
106	SK02	Západné Slovensko	0,711	0,442	0,209	0,936	0,506	0,168	0,244	0,508	0,054	0,734	0,508	0,444
107	DEC0	Saarland	0,343	0,574	0,282	0,938	0,625	0,169	0,072	0,570	0,046	0,536	0,874	0,443
108	ES12	Principado de Asturias	0,739	0,315	0,580	0,880	0,455	0,108	0,200	0,571	0,041	0,899	0,269	0,443
109	BE32	Prov. Hainaut	0,660	0,924	0,440	0,787	0,493	0,142	0,034	0,465	0,043	0,500	0,580	0,441
110	BG42	Yuzhen tsentralen	0,429	0,465	0,537	0,589	0,642	0,217	0,003	0,781	0,041	0,899	0,396	0,441
111	FR81	Languedoc-Roussillon	0,651	0,723	0,451	0,802	0,438	0,197	0,127	0,418	0,040	0,899	0,272	0,439
112	ITH4	Friuli-Venezia Giulia	0,607	0,441	0,620	0,773	0,460	0,167	0,208	0,573	0,041	0,777	0,304	0,437
113	DE24	Oberfranken	0,477	0,593	0,414	0,707	0,651	0,220	0,138	0,493	0,044	0,726	0,444	0,437
114	ITH3	Veneto	0,606	0,532	0,623	0,783	0,458	0,202	0,130	0,564	0,041	0,839	0,201	0,437
115	DE80	Mecklenburg-Vorpommern	0,567	0,349	0,117	0,756	0,656	0,142	0,118	0,463	0,055	0,814	0,889	0,436
116	RO42	Vest	0,573	0,416	0,089	0,686	0,731	0,309	0,317	0,767	0,041	0,518	0,321	0,435
117	AT32	Salzburg	0,607	0,518	0,481	0,950	0,506	0,273	0,083	0,527	0,032	0,817	0,125	0,434
118	DE12	Karlsruhe	0,433	0,475	0,412	0,771	0,597	0,201	0,118	0,479	0,044	0,671	0,693	0,433
119	DE71	Darmstadt	0,433	0,495	0,377	0,656	0,615	0,156	0,119	0,503	0,041	0,796	0,710	0,433
120	ES23	La Rioja	0,778	0,554	0,629	0,245	0,546	0,067	0,084	0,556	0,041	0,899	0,562	0,433
121	DE93	Lüneburg	0,610	0,558	0,448	0,662	0,571	0,241	0,063	0,463	0,047	0,588	0,640	0,432
122	DE14	Tübingen	0,608	0,549	0,389	0,662	0,647	0,186	0,118	0,474	0,045	0,668	0,514	0,431
123	PL33	Swietokrzyskie	0,616	0,000	0,174	0,844	0,586	0,159	0,528	0,529	0,265	0,530	0,521	0,431
124	ITC1	Piemonte	0,520	0,449	0,487	0,793	0,445	0,193	0,142	0,560	0,041	0,854	0,424	0,431
125	ITF4	Puglia	0,520	0,452	0,452	0,768	0,407	0,245	0,191	0,546	0,041	0,775	0,485	0,430
126	DE50	Bremen	0,432	0,617	0,440	0,810	0,604	0,195	0,094	0,486	0,045	0,500	0,639	0,430
127	FR61	Aquitaine	0,650	0,739	0,208	0,754	0,446	0,212	0,160	0,487	0,033	0,839	0,360	0,430
128	ITI2	Umbria	0,606	0,605	0,853	0,626	0,377	0,145	0,182	0,589	0,041	0,634	0,256	0,429
129	ES22	Comunidad Foral de Navarra	0,562	0,763	0,297	0,650	0,553	0,097	0,036	0,522	0,041	0,801	0,583	0,428
130	BE33	Prov. Liège	0,567	0,656	0,413	0,723	0,479	0,184	0,076	0,470	0,050	0,821	0,446	0,428
131	BE34	Prov. Luxembourg (BE)	0,792	0,899	0,410	0,747	0,479	0,000	0,019	0,500	0,043	0,689	0,370	0,426
132	PL62	Warminsko-Mazurskie	0,757	0,453	0,173	0,698	0,647	0,082	0,123	0,512	0,066	0,899	0,418	0,426
133	NL13	Drenthe	0,654	0,524	0,569	0,659	0,516	0,143	0,123	0,498	0,047	0,556	0,542	0,424
134	NL34	Zeeland	0,651	0,610	0,656	0,274	0,527	0,487	0,328	0,514	0,044	0,000	0,556	0,424
135	ITG1	Sicilia	0,609	0,577	0,504	0,714	0,356	0,215	0,163	0,529	0,041	0,766	0,364	0,423
136	AT33	Tirol	0,564	0,515	0,368	0,814	0,582	0,270	0,180	0,644	0,035	0,760	0,000	0,423
137	NL41	Noord-Brabant	0,565	0,481	0,322	0,632	0,529	0,209	0,206	0,520	0,041	0,841	0,409	0,422
138	NL42	Limburg (NL)	0,565	0,493	0,215	0,657	0,597	0,140	0,234	0,526	0,041	0,776	0,489	0,421
139	ES41	Castilla y León	0,648	0,422	0,481	0,759	0,478	0,144	0,159	0,443	0,041	0,747	0,464	0,421
140	FR23	Haute-Normandie	0,565	0,320	0,237	0,777	0,461	0,233	0,175	0,693	0,068	0,669	0,540	0,419
141	ES24	Aragón	0,477	0,300	0,435	0,883	0,532	0,143	0,089	0,509	0,041	0,747	0,609	0,418
142	NL11	Groningen	0,789	0,623	0,656	0,605	0,000	0,192	0,149	0,515	0,046	0,736	0,591	0,418
143	SK03	Stredné Slovensko	0,713	0,500	0,396	0,478	0,635	0,340	0,142	0,552	0,047	0,442	0,392	0,417
144	NL12	Friesland (NL)	0,697	0,674	0,508	0,414	0,436	0,203	0,119	0,526	0,043	0,825	0,278	0,415
145	ITG2	Sardegna	0,694	0,580	0,396	0,794	0,319	0,154	0,121	0,555	0,041	0,821	0,286	0,413
146	PL52	Opolskie	0,662	0,202	0,576	0,721	0,669	0,144	0,000	0,516	0,200	0,665	0,311	0,411
147	AT31	Oberösterreich	0,477	0,441	0,620	0,737	0,561	0,316	0,134	0,421	0,059	0,747	0,072	0,410
148	DE13	Freiburg	0,477	0,409	0,369	0,576	0,654	0,173	0,137	0,458	0,047	0,814	0,482	0,410
149	BG32	Severen tsentralen	0,622	0,609	0,083	0,227	0,680	0,283	0,086	0,546	0,041	0,709	0,682	0,410
150	ITI3	Marche	0,434	0,383	0,693	0,682	0,460	0,196	0,113	0,537	0,041	0,802	0,303	0,408
151	ES21	País Vasco	0,649	0,552	0,304	0,759	0,540	0,153	0,103	0,553	0,041	0,589	0,383	0,407
152	DEF0	Schleswig-Holstein	0,521	0,734	0,000	0,641	0,579	0,219	0,120	0,466	0,047	0,756	0,499	0,407
153	DE92	Hannover	0,344	0,343	0,420	0,638	0,544	0,202	0,147	0,466	0,044	0,711	0,723	0,407
154	DE25	Mittelfranken	0,389	0,443	0,361	0,582	0,619	0,225	0,141	0,477	0,044	0,736	0,529	0,406
155	DEE0	Sachsen-Anhalt	0,387	0,343	0,216	0,669	0,572	0,187	0,076	0,486	0,048	0,650	0,947	0,405
156	NL21	Overijssel	0,609	0,443	0,368	0,879	0,532	0,063	0,132	0,518	0,044	0,634	0,388	0,404
157	ITF1	Abruzzo	0,520	0,499	0,452	0,791	0,430	0,192	0,098	0,545	0,041	0,837	0,197	0,403
158	ITF5	Basilicata	0,391	0,407	0,333	0,823	0,499	0,166	0,133	0,516	0,041	0,812	0,363	0,396
159	ITH2	Provincia Autonoma di Trento	0,520	0,430	0,719	0,641	0,440	0,198	0,189	0,537	0,041	0,518	0,219	0,394
160	ITF3	Campania	0,477	0,252	0,488	0,733	0,372	0,230	0,144	0,572	0,041	0,870	0,269	0,391
161	NL31	Utrecht	0,564	0,369	0,556	0,601	0,489	0,241	0,166	0,513	0,042	0,603	0,232	0,390
162	AT21	Kärnten	0,565	0,310	0,555	0,878	0,543	0,198	0,051	0,261	0,073	0,786	0,139	0,385
163	ES13	Cantabria	0,520	0,694	0,377	0,522	0,459	0,077	0,189	0,523	0,041	0,823	0,132	0,383

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164	FR83	Corse	0,520	0,602	0,547	0,725	0,417	0,097	0,347	0,000	0,041	0,681	0,296	0,380
165	HU23	Dél-Dunántúl	0,620	0,626	0,128	0,359	0,586	0,294	0,123	0,608	0,036	0,423	0,375	0,376
166	AT22	Steiermark	0,389	0,412	0,572	0,591	0,535	0,264	0,111	0,432	0,050	0,828	0,002	0,374
167	ITF2	Molise	0,434	0,180	0,229	0,462	0,293	0,436	0,183	0,505	0,041	0,484	0,477	0,336
168	ES30	Comunidad de Madrid	0,604	0,158	0,480	0,000	0,520	0,134	0,091	0,577	0,041	0,748	0,287	0,324
169	ITC2	Valle d'Aosta/Vallée d'Aoste	0,002	0,375	0,140	0,555	0,274	0,051	0,143	0,535	0,041	0,681	0,597	0,296

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Figure 1. Map of European regions according to the CESI performances (Source: authors).

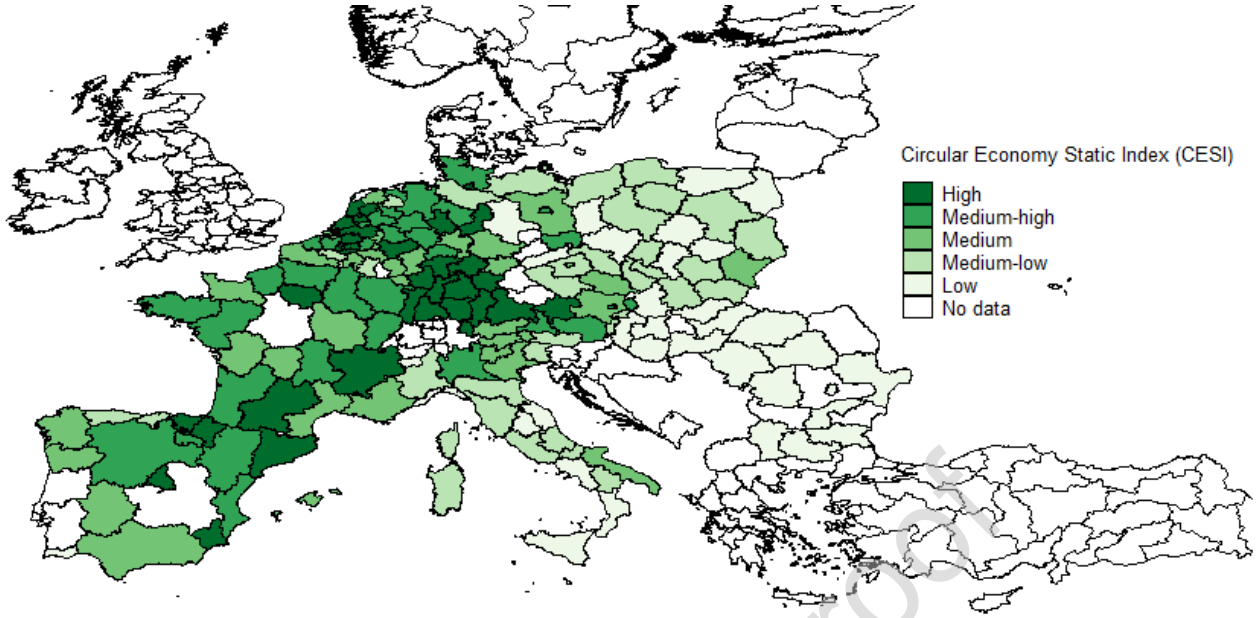

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Figure 2 - Comparison between *Regional green economic performance* (ESPON EU) and CESI performance. (Source: authors).

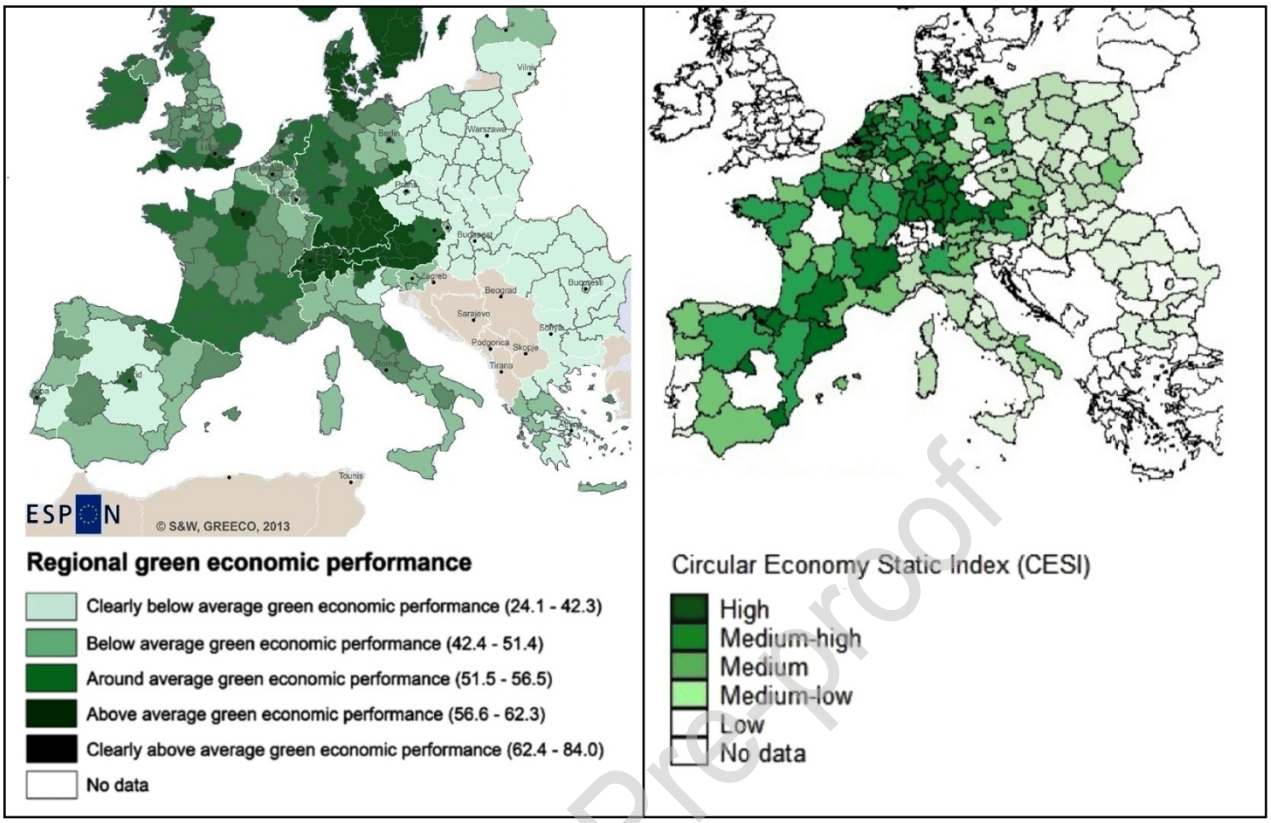

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Figure 3. Map of European regions according to the CEDI performances. (Source: authors).

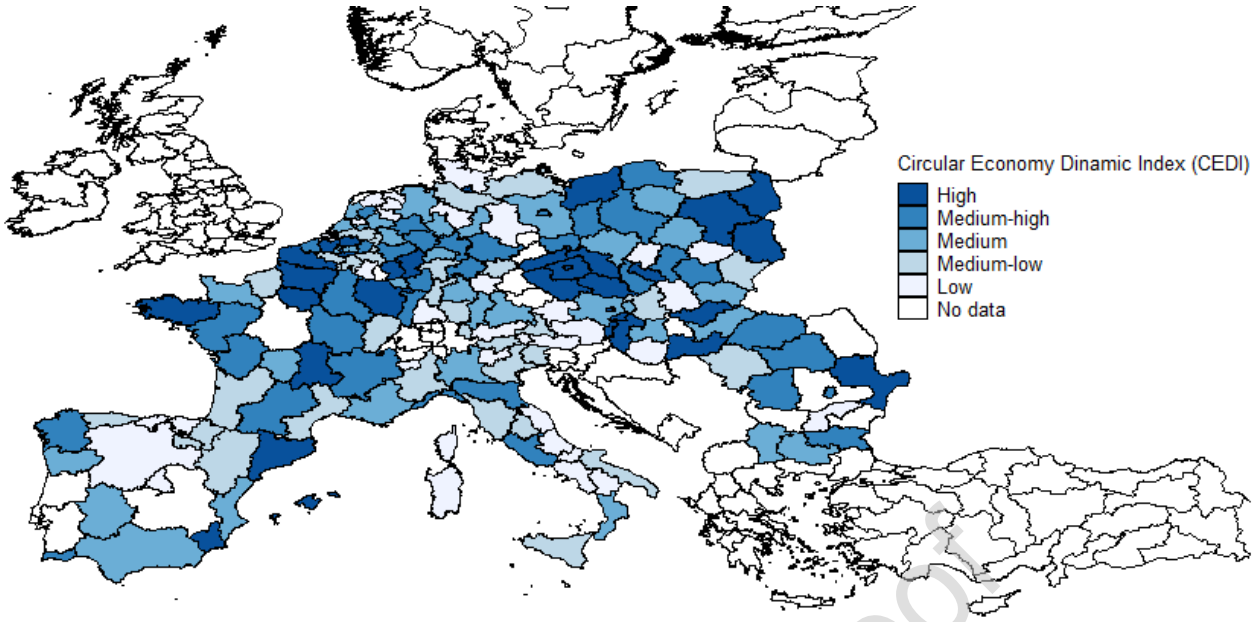

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Figure 4. Comparison between Structural Funds 2007-2013 (Regional Competiveness and Employment Objective) and CESI performance. (Source: authors).

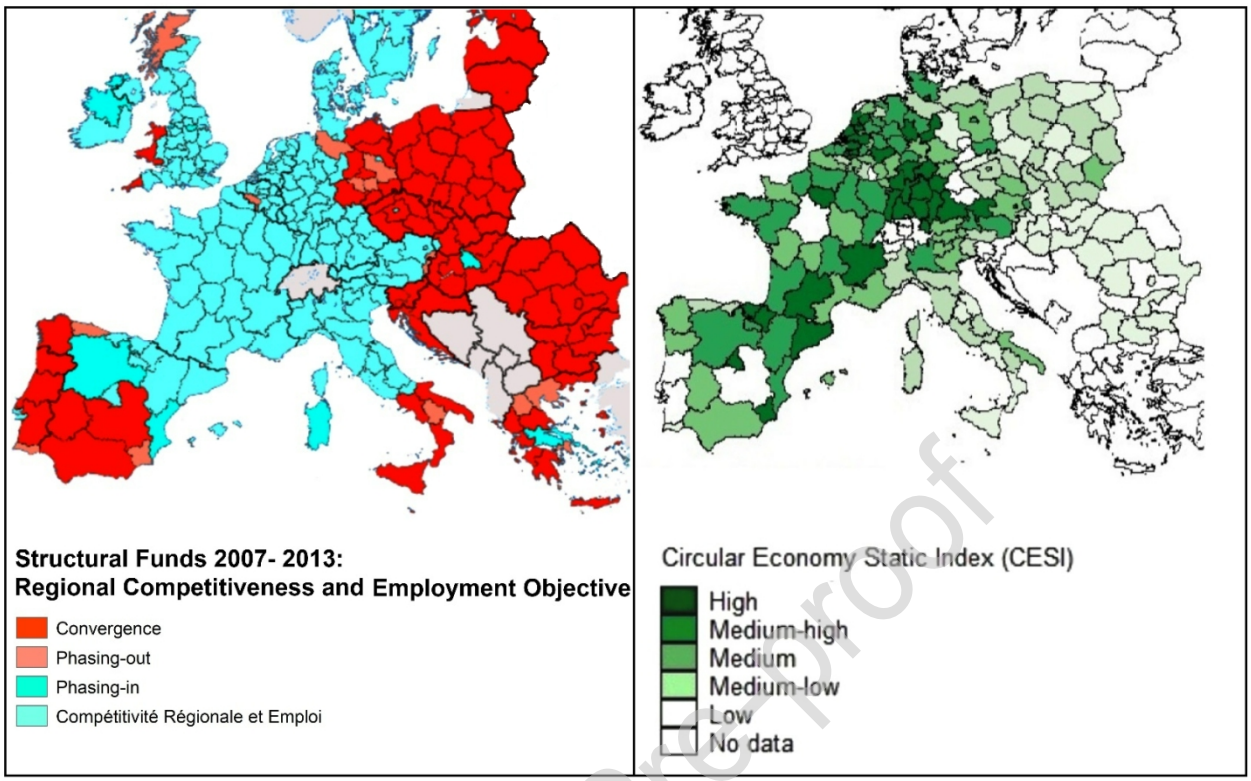

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Figure 5. Comparison between Structural Funds 2007-2013 (Regional Competiveness and Employment Objective) and CEDI performance. (Source: authors).

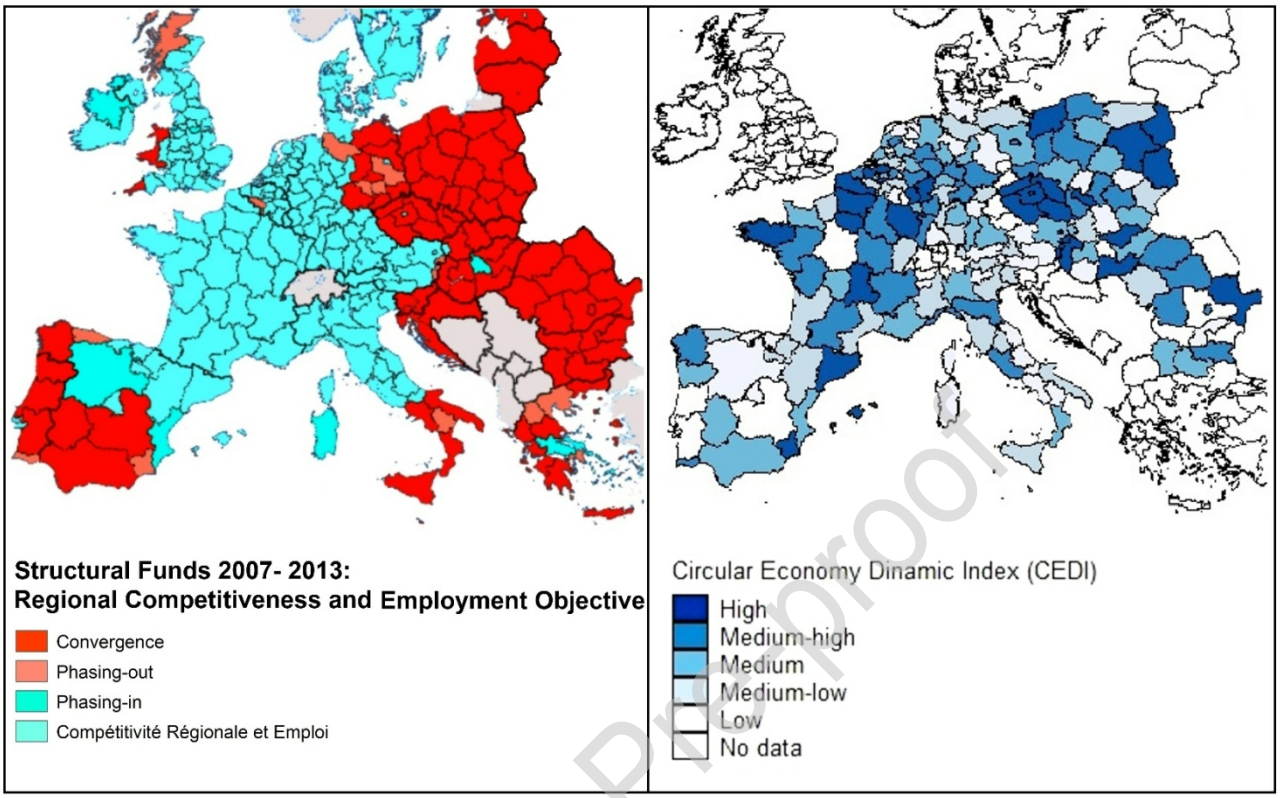

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Figure 6. Diagram of the European regions according to CESI and CEDI performance (Source: authors)

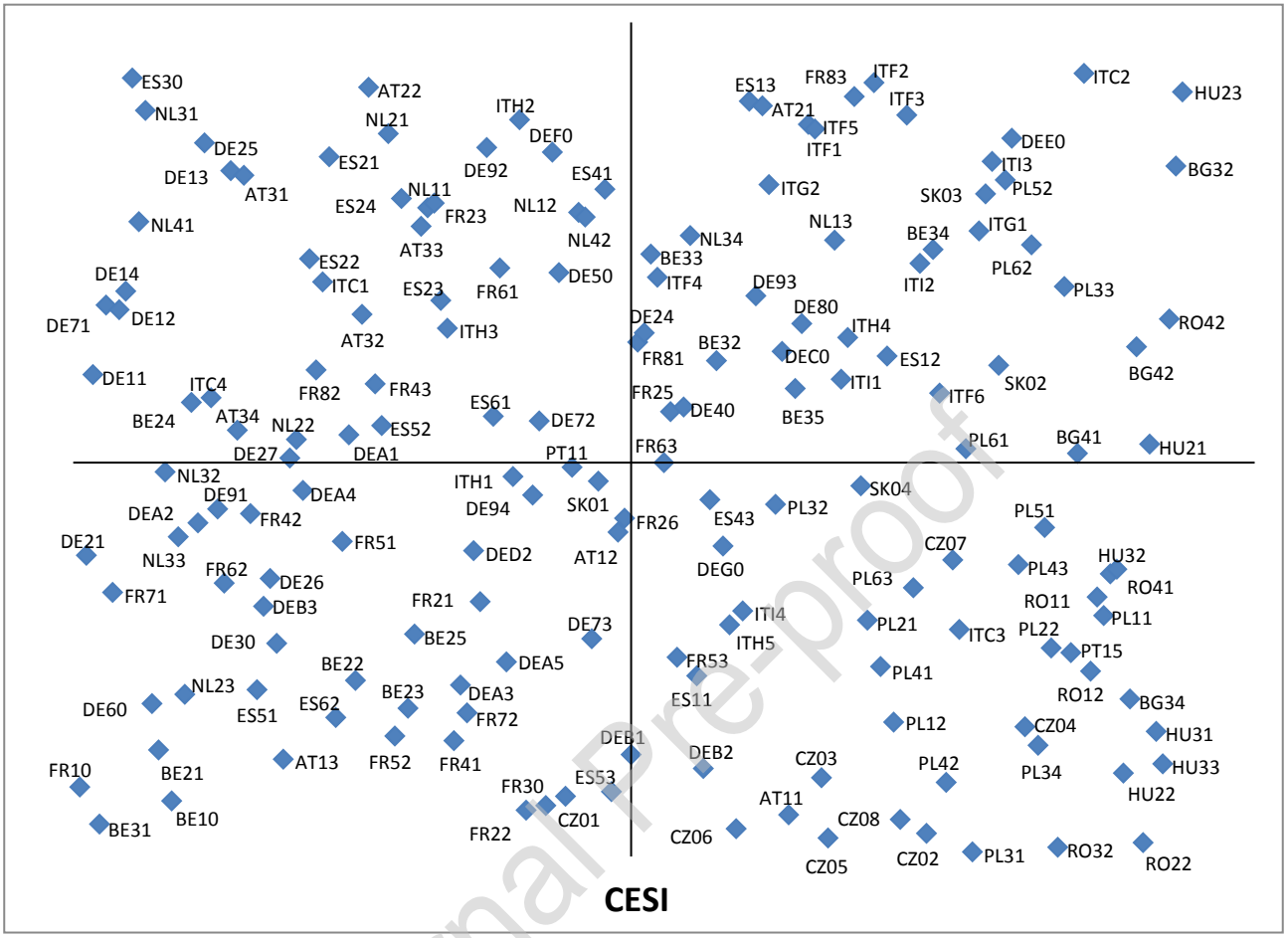

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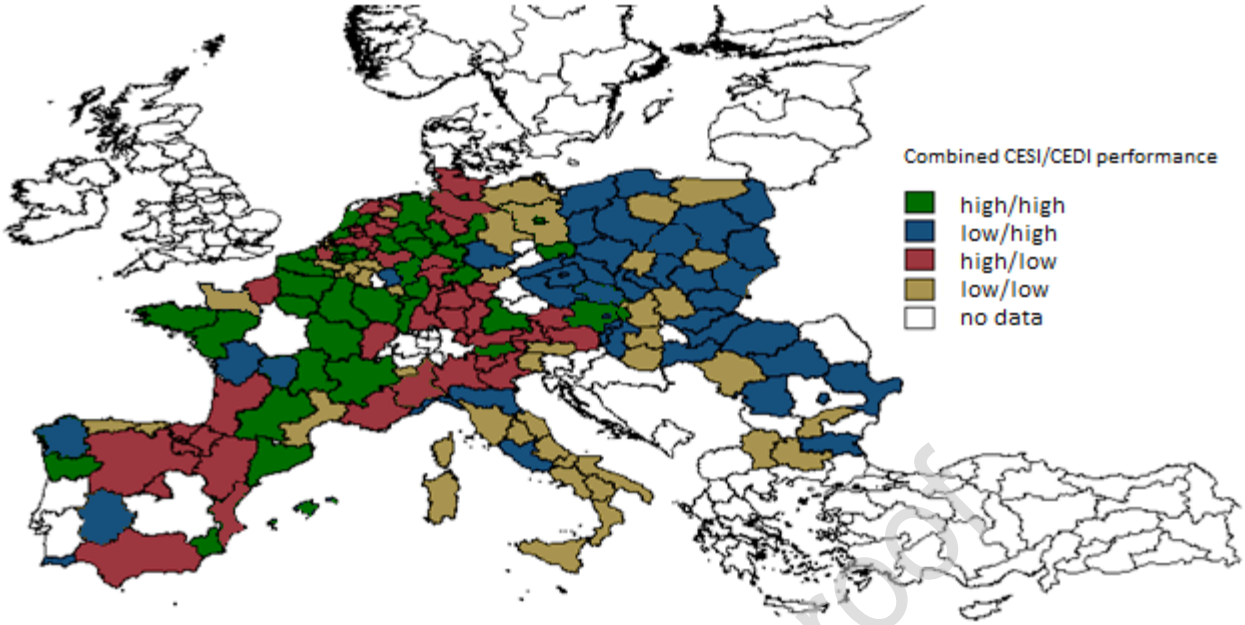
Figure 7. Combined CESI/CEDI performance (Source: authors)



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Regional development of Circular Economy in the European Union: a multidimensional analysis

Francesco Silvestri, Francesca Spigarelli, Mattia Tassinari

Highlights

- How European Regions differ in terms of adoption and implementation of Circular Economy (CE).
- Construction of two composite indicators for a static and a dynamic reading of CE: the Circular Economy Static Index (CESI) and the Circular Economy Dynamic Index (CEDI).
- Classification of the European regions according to four groups.
- The "Never give up" group is characterized by above-median performance for both Indexes (including, e.g., French Île de France, Belgian Brabant Wallon, German Berlin and Hamburg).
- The group of "Satiated and sleepy regions" includes regions where CESI is performing well and CEDI shows low values (e.g., German Freiburg and Spanish Comunidad de Madrid).
- The "The best is yet to come" group is characterized by regions with low values for CESI and a high performance in CEDI (it mostly gathers regions from Eastern Europe).
- The "We don't mind" group is composed by the regions with modest value of both indexes.

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Table 1 – Variables of the proposed *Circular Economy Indexes*

		SUSTAINABILITY DIMENSIONS		
		SOCIO-HEALTH DIMENSION	**ECONOMIC DIMENSION**	**ENVIRONMENTAL DIMENSION**
CIRCULAR ECONOMY DEFINITION	**RECYCLING**			Waste recycling - composting and digestion (tonnes per inhabitant)
	WASTE MINIMIZATION			Waste generated (tonnes per inhabitant)
	LOW CARBON	Life expectancy		
		Transport accidents (rate)		
		Malignant neoplasm (rate)		
		Diseases of the circulatory system (rate)		
	RESOURCE EFFICIENCY			Artificial land (percentage)
				Estimated soil erosion by water (Tonnes per hectare)
	COMPETITIVENESS		Total intramural R&D expenditure (Euro per inhabitant)	
			Total amount of fractional patents inv. per year	
			GDP at current market prices (euro per inhabitant)	

Source: Authors

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Table 2 – Variables of the *Circular Economy Static Index (CESI)* – Weights and contribution in the calculation of the Index

Variables included in each CE dimension	Contribution in the calculation of the Index
SOCIO-HEALTH DIMENSION (weight 1/3)	
Life expectancy 2015	(+)
Diseases of the circulatory system (rate) 2015	(-)
Malignant neoplasms (rate) 2015	(-)
Transport accidents (rate) 2015	(-)
ECONOMIC DIMENSION (weight 1/3)	
GDP at current market prices (euro per inhabitant) 2015	(+)
Total intramural R&D expenditure (euro per inhabitant) 2013	(+)
Total amount of fractional patents inv. per year 2013	(+)
ENVIRONMENTAL DIMENSION (weight 1/3)	
Waste generated (tonnes per inhabitant) 2011	(-)
Waste recycling - composting and digestion (tonnes per inhabitant) 2011	(+)
Artificial land (percentage) 2015	(-)
Estimated soil erosion by water (tonnes per hectare) 2012	(-)

Source: Authors

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Table 3 – Variables of the *Circular Economy Dynamic Index (CEDI)* – Weights and contribution in the calculation of the Index

Variables included in each CE dimension	Contribution in the calculation of the Index
SOCIO-HEALTH DIMENSION (weight 1/3)	
Growth rate life expectancy 2012/2015 (%)	(+)
Growth rate diseases of the circulatory system 2012/2015 (%)	(-)
Growth rate Malignant neoplasm 2012/2015 (%)	(-)
Growth rate Transport accidents 2012/2015 (%)	(-)
ECONOMIC DIMENSION (weight 1/3)	
Growth rate GDP at current market prices 2012/2015 (%)	(+)
Growth rate Total intramural R&D expenditure 2011/2013 (%)	(+)
Growth rate Total amount of fractional patents inv. per year 2010/2013 (%)	(+)
ENVIRONMENTAL DIMENSION (weight 1/3)	
Growth rate waste generated 2010/2011 (%)	(-)
Growth waste recycling per inhabitant - composting and digestion 2010/2011 (%)	(+)
Growth rate artificial land 2012/2015 (%)	(-)
Growth rate estimated soil erosion by water 2000/2012 (%)	(-)

Source: Authors

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Table 4 - Top 15 European regions according to the CESI

CESI Rank	Country code	Region	CESI value
1	FR10	Île de France	0,773
2	DE21	Oberbayern	0,693
3	DE11	Stuttgart	0,680
4	BE31	Prov. Brabant Wallon	0,635
5	DE71	Darmstadt	0,612
6	FR71	Rhône-Alpes	0,603
7	DE12	Karlsruhe	0,592
8	DE14	Tübingen	0,590
9	ES30	Comunidad de Madrid	0,589
10	NL41	Noord-Brabant	0,588
11	NL31	Utrecht	0,579
12	DE60	Hamburg	0,578
13	BE21	Prov. Antwerpen	0,572
14	NL32	Noord-Holland	0,571
15	BE10	Région de Bruxelles-Capitale	0,568

Source: Authors

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Table 5. Top 15 European regions according to the CEDI

CEDI Rank	Country code	Region	CEDI value
1	PL31	Lubelskie	0,575
2	RO32	Bucuresti - Ilfov	0,574
3	RO22	Sud-Est	0,561
4	CZ05	Severovýchod	0,555
5	CZ08	Moravskoslezsko	0,547
6	CZ06	Jihovýchod	0,539
7	BE31	Prov. Brabant Wallon	0,530
8	CZ02	Střední Cechy	0,528
9	AT11	Burgenland (AT)	0,525
10	FR22	Picardie	0,522
11	FR30	Nord - Pas-de-Calais	0,521
12	BE10	Région de Bruxelles-Capitale	0,519
13	CZ01	Praha	0,518
14	ES53	Illes Balears	0,516
15	FR10	Île de France	0,515

Source: Authors

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