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Circular Economy in Germany: A Methodology to assess the Circular Economy Performance of NUTS3 Regions

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Abstract: There is currently a massive methodological gap in the spatial analysis of the Circular Economy (CE) performance in general and in Germany particularly. The authors present a methodology to assess this performance in German regions. The methodology consists of 26 indicators in seven dimensions, namely Policy, Innovation, Circular Employment, Consumption and Production, Waste Management, Socio-economic Development, Municipal Sustainability. Data was obtained from different sources and focuses on the base year 2018. The analysis reveals that Germany does not show a clear core-periphery pattern when it comes to regional CE performance. Instead, the pattern is more differentiated with both urban and rural regions of different sizes being able to rank high in CE performance.

Keyword: Circular Economy, Germany, Regional Assessment, Sustainability, NUTS3

JEL: O18, P48, R1, R11

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1. Introduction

"As the 'circular' approach to sustainability begins to gather ground, we humans are finding ourselves within the circle, not without." (Michael Schwarz, 2016)

A sustainable transformation, as currently discussed as a global challenge, must not only look at decarbonisation but also address the production process and its inputs (Wilts, 2021). As claimed by the United Nations: *"Current patterns and processes of production and consumption raise serious questions about the ability of the planetary resource base to meet the material and energy needs of the global economy and human societies"* (UNEP, 2017: 21). On a global level, over 90% of resources do not flow back into a new use cycle after being disposed (Bertelsmann Stiftung, 2019). This is not only a dilemma considering limited resources to be exploited for production and consumption but also in terms of a limited storage capacity of the planet (Blum, 2021). Although the limitations of resources and absorptive capacity of the planet are well known, the global extraction of materials tripled between 1970 and 2017 and keeps growing globally due to an increasing population, rising consumption levels and new consumption patterns such as to-go-packaging or shipment packaging because of e-commerce (Oberle et al., 2019). As about half of global greenhouse gas emissions are related to resource extraction and material processing as well as about 90% of biodiversity loss and water stress, the resource question becomes even more important in light of the recent IPCC report (Deus et al., 2017; Gentil et al., 2009; IPCC, 2021).

For a long time, the emergence of waste was regarded as a necessary side effect of a linear production pattern. However, currently the relevance of resources and their treatment is increasingly highlighted (Wilts & von Griese, 2017; Wilts, 2017). Thereby, addressing these puzzling problems by designing out waste and instead thinking in resource cycles is the main idea of a Circular Economy (CE). The approach includes adding greater value to resources, extending products' operation life, changing consumption patterns, and reducing environmental impacts associated with production and disposal (UNEP, 2017). This approach can be justified (1) ecologically in the context of global boundaries within which humanity can operate safely and which are affected by resource extraction and consumption patterns (Rockström et al., 2009), (2) socially with CE being related to 12 of the 17 UN Sustainable Development Goals (SDGs) (Bertelsmann Stiftung, 2019; UN, 2022), and (3) economically by resource autonomy and enabling a process of continuous economic growth without negative externalities due to externalisation of ecological and social cost (PWC, 2019; CEID, 2021; Wilts, 2021). On European level, the EU Green Deal has recently put the transition from a linear and resource-intensive economy towards a circular, resource-efficient production into focus to establish a climate-neutral Europe and reach the EU goals for emission reduction (CEID, 2021; Dierig, 2020). This trend was further intensified by the COVID-19 pandemic that highlighted the need for regional circularity as opposed to dependency on resource imports (Prognos & INFA, 2020).

Also in Germany, the aspiration to become climate neutral until 2050 or earlier is to be complemented by a perspective that does not exclusively focus on the output side of production, but also the input side of resources used (Agora Energiewende, 2020). The Federal

Ministry of the Environment, Nature Conservation and Nuclear Safety states that: *"In recent years, the circular economy has been recognised throughout the world as an instrument for the sustainable management of ever scarcer resources"* (BMU, 2020: 4). Still, the balance of recent German CE efforts has remained quantitatively limited. The use of secondary resources remained steady between 2010-2014 and no absolute decoupling of economic growth and resource consumption was achieved (CEID, 2021). The former role model country of recycling and waste treatment runs the risk of being outpaced by other actors.

Although CE is an important trend in Europe as well as in Germany, assessment methodologies to quantify the status and to identify development potential remain limited. This is even more true when it comes to an assessment of differentiated regional rather than a general national performance. The authors aim to close this gap by presenting a methodology to assess the regional development status of CE in German regions ("Kreise") which are statistically- comparable to the European NUTS3 level. The relevance of this approach derives from the fact that a high number of regulations in Germany, for instance when it comes to waste treatment, are organised on regional level which will therefore play a crucial role in the transition towards a CE (Prognos & INSA, 2020). Against this backdrop, the paper at hand is organised as follows: Section 2 reviews the concept of CE and its geographical application, before Section 3 focuses on the status of CE in Germany. Section 4 presents the status quo of CE assessment in Germany, presents the new methodology and its underlying data. Section 5 presents the results, and the final Section 6 concludes with an outlook.

2. The Circular Economy Concept

Organising production and consumption in a circular way means that all products should be oriented towards the ambition that no or almost no waste is created after product life. The basic concept of CE originates from industrial ecology and industrial metabolism and goes back to ideas formulated during the 1970s and 1980s. After popularisation during the 1990s, the concept that later was framed as CE involved an alternative to a linear economy by ensuring that economic actions would not exert negative net effects on the environment (D'Amato et al., 2017). In terms of scientific publications, CE took off after just after 2006 with a geographical focus on China, Europe (particularly UK, Netherlands, Italy), the United States and Japan (Yu et al., 2013; Deus et al., 2017).

The focus of CE is resource-oriented, opposed to broader concepts such as green economy or bioeconomy (D'Amato et al., 2017; Walker et al., 2021). Thereby, all stages of resource management are addressed by a CE approach, from resource extraction to design and manufacturing, consumption up to reuse or recycling. As opposed to a closed substance cycle which puts the emphasis on waste management and closing loops at the end of a cycle, CE also includes the first steps of the value chain such as raw material supply, procurement, eco-design, and waste prevention (BMU, 2020). The concept of CE refers to biological cycles which are regarded as an example and role model of perfectly closed material flows (Braungart & McDonough, 2009). In order to "design out" waste, the production process is adapted through a stronger focus on biological ingredients while the consumption process of a product is to be extended by disassembly, refurbishment and reuse (Ellen MacArthur Foundation, 2013). Generally, CE has a strong social and behavioural aspect to it, as illustrated in the "7 Rs" which involve rethink, redesign, repurpose, repair, remanufacture, recycle, and recover. They have replaced the former "3 Rs" of recycling, reuse, and reducing (Bertelsmann Stiftung, 2019; Ellen MacArthur Foundation, 2015).

One of the characteristics of CE is that the basic idea is motivated ecologically but there are also significant economic and social effects. On an environmental level, CE measures not only drive down negative externalities of resource extraction but could lead to an additional annual reduction in greenhouse gas emission of about 440 million tonnes between 2014-2030 by the closure of landfill sites and elevated recycling targets. In combination with other efforts, the annual reduction of Europe's total greenhouse gas emissions could amount to 2-4% (Wilts, 2017). Additionally, the social benefits of CE include macro-economic effects such as additional employment arising from more detailed recycling and new product design efforts (D'Amato et al., 2017). Analyses indicate that CE innovations are positively linked to both employment growth and a company's turnover (Horbach & Rammer, 2019). Economically, resource efficiency decreases the dependency on resource imports which increases the resilience towards trade disruptions and political instability. As about 6-12% of total waste consumption could be saved or avoided through recycling and even 17% when waste avoidance and eco-design are considered, CE has the potential to make a significant difference. While the macro-economic effects are characterised by potentially higher growth rates, the micro-level experiences improved corporate performance, innovativeness, and competitiveness as well as lower consumer prices. Savings in material cost in the EU alone are expected to amount to $630 billion per year which underlines the economic relevance of closing resource cycles (Wilts, 2017).

The magnitude of potential effects on different dimensions is the reason why CE is discussed as broadly as it is today. However, this is also the reason why CE is understood differently depending on the individual perspective (Wilts, 2016a). While institutions such as the EU highlight the potential of CE for economic prosperity and a green transition, others criticise the underlying growth narrative and over-prioritisation of technology in comparison to a undervalues tole of consumers (Hobson & Lynch, 2016). However, the concept of CE remains limited by fundamental laws of thermodynamics and the fact that certain quantitative and qualitative losses are almost unavoidable (Wilts, 2017). A certain level of theoretical diffusion and a depoliticization of sustainable growth are among the critiques on CE (Corvellec et al., 2021).

From a geographical perspective, particularly China plays a major role when it comes to CE, not only as a pioneer of CE but also through recently phasing out waste imports and consequently putting pressure on national recycling systems, particularly in Europe, as there are no alternatives (Schroeder & Jeonghyun, 2019). Apart from Japan, predominantly European countries such as Denmark, Germany, the Netherlands, Scotland, or Sweden see CE gaining traction (Nelles et al., 2016; Ogunmakinde, 2019). With publishing a Circular Economy Action Plan in December 2015, the EU has set the scene for more ambitious and coordinated policy in the future (Wilts, 2017; Wilts 2016a). Moreover, the EU Green Deal provides an additional impetus not only for emission reduction measures but also for the conservation of resources and closing material cycles. In addition, African countries and the United States of America are also beginning to include aspects of circular economy into the consumptive and productive factors. (Babri et al., 2021).

3. State of the Circular Economy in Germany

Germany is regarded as a role model in terms of CE which mainly traces back to early actions in the 1990s. In this context, Mohajan claims that: *"Germany is the first country in the world that tries to implement CE by using technologies of waste and resource management"* (2021: 46). The development of waste management and CE policy in Germany dates to the implementation of the Waste Disposal Act in 1976 which was followed by a packaging law in 1991 which required manufacturers to recycle their packaging material and became a cornerstone of recycling policy. The following years saw the implementation of the "Circular Economy and Waste Management Act" ("Kreislaufwirtschafts- und Abfallgesetz") which was revised and relabelled to "Circular Economy Act" ("Kreislaufwirtschaftsgesetz") in 2012 (Mohajan, 2021; Schroeder & Jeonghyun, 2019). This law implemented a polluter-pays principle, a principle of shared public and private responsibility for waste management as well as a five-tier waste hierarchy (prevention, preparation for reuse, recycling, other forms of recovery, disposal) that gave preference to avoidance of waste through reuse or recycling to limit landfilling (BMU, 2020; Schroeder & Jeonghyun, 2019). By doing so, waste management should be transformed into resource management under the realisation that waste can constitute a source of raw materials and energy (Nelles et al., 2016).

The limited availability of raw materials and the above average consumption of scarce resources were named as the primary motivation for the early adoption of ambitious closed cycle regulation (BMU, 2020). The idea of waste management and sustainable development was also incorporated in the National Strategy for Sustainable Development adopted in 2002 which sets guiding principles for policies across all sectors and helped to scale up the CE concept (Lah, 2016). This CE-related regulation is complemented by the Germany Resource Efficiency Programme (ProGress) which has been updated in 2016 to ProgRess II and since recently operates under the term ProGress III (Mohajan, 2021; Gandenberger, 2021). There is an ongoing discussion whether the Circular Economy Act in Germany counts as adequate CE regulation as, although the name implicated circularity, the focus was exclusively on recycling and waste management without addressing eco-design and other CE aspects. Derived from the holistic approach, the question arises whether Germany, China, or Japan is to be regarded as the CE pioneer is not clearly determinable (Ogunmakinde, 2019).

As a consequence of former regulations, environmental problems related to waste have successfully been reduced in Germany. A waste collection and treatment infrastructure has been implemented and a perspective was established that regards waste as a potential resource for new material cycles. Technical regulation and technologies have made Germany one of the leaders when it comes to the waste management aspect of CE. Significant recycling rates are achieved for almost all relevant waste streams. Increasing energy efficiency and a high product efficiency have led many German actors see waste as a problem which is technically solved (Wilts, 2017; Lah, 2016). According to the OECD, the German role model even underlined that an efficient and low-carbon economy was compatible with economic growth (Lah, 2016).

By now, the CE sector has grown to be a sector with measurable impact in Germany, in economic, ecological, and social terms. Germany has become a global leader when it comes to waste treatment technologies which are exported in almost all countries (Wilts, 2021; Wilts, 2016b). About 27% of firms in Germany have reported CE innovations between 2021-2014 whereby the reduction of energy use per unit of output is the most important innovative activity (Horbach & Rammer, 2019). Although Germany is losing global market share when it comes to waste-related patent applications, it remains the fourth largest location for waste-related patents behind Japan, the United States, and China. Particularly Asian countries have witnessed significant growth between 2010-2017, namely China (+12%), Japan (+3%), or South Korea (+1%) (Prognos & INSA, 2020).

Moreover, waste management alone employs almost 200,000 people in about 3,000 companies in Germany which generate an annual turnover of about €40 billion (Wilts, 2017). When looking at the CE sector in general, the number of employees in Germany rises to more than 310,000 employees in about 11,000 public and private companies in all parts of the value chain which produce an annual turnover of €85 billion and gross value added of about €28 billion (Prognos & INFA, 2020). Other studies estimate the CE sector in Germany to comprise of 270,000 employees in 11,000 companies with an annual turnover of about €70 billion (BMU, 2020). Howbeit, CE is an employment driver: It is expected that a combination of simplified legislation, improved monitoring, and good practice dissemination could create more than 180,000 additional jobs in waste management in Germany by 2030 (Wilts, 2017).

The highest impact of German CE measures on waste is attributed to the Circular Economy Act as well as the Packaging Act whereby the majority of waste management policy in Germany was built on assigning disposal responsibilities to manufacturers and distributors (Nelles et al., 2016; Mohajan, 2021). But also, the regulation of landfilling has generated a measurable impact. Banning the landfilling of untreated biodegradable waste in 2006 has reduced landfill emissions by 77% compared to 1990. While already 65 million tonnes of CO_2 equivalents have been saved annually, landfill gas emissions should still be cut significantly until 2030 (BMU, 2020; Wilts, 2021). It is expected that applying all CE levers to increase the operating life of products in combination with higher recycling and energy efficiency rates would result in a decreased demand for primary resources of 68% until 2050 compared to 2018 (CEID, 2021).

However, one of the major shortcomings of German CE policy remains to be its primary focus on waste and its treatment while failing to address the full concept of CE. The above picture changes when not only waste treatment is addressed since recycling rates stagnate on a high level in Germany while other European countries such as the Netherlands already present higher numbers when it comes to overall reuse or individual sectors such as circular construction (Wilts et al., 2021; Wilts, 2021; Haupt, 2019). About two thirds of waste in

Germany have not been used as a resource in 2013 underlining that recycling rates are of limited value to indicate circularity (Wilts, 2017). Moreover, the rate of waste undergone treatment does not necessarily implicate a high level of circularity as the majority of waste in Germany is treated thermally while the amount of recycled material remains at a low level (Wilts, 2021).

Overall, the amount of waste in Germany continues to increase. The successful relative decoupling of producing a decreasing amount of waste per unit of GDP is primarily traced back to structural and transformation change, such as lower levels of waste volumes from mining activities, rather than to the decrease of waste volumes through avoidance policy. Efficiency gains, for instance through thinner packaging, are over-compensated by a growing demand, for instance of to-go-packaging (Wilts, 2021). The exclusive focus on waste policy has not led to the establishment of a CE or a sustainable solution of the waste problematic. In a nutshell, the CE sector in Germany presents an average economic performance compared to other sustainability-related sectors (Prognos & INSA, 2020). An exceptional role is not observable despite the high significance of recycling and waste treatment in Germany.

Overcoming the gap between intention and actual behaviour would include exploiting the development potential of activities such as preparation for reuse, repair, or extending a product's service life (Wilts, 2017; Wilts et al., 2021). Until now, particularly the European Commission has provided important development impulses and it is to be expected that an updated calculation method will lead to a drop in German recycling figures so that further engagement is required (Wilts et al., 2020; BMU, 2020). The current state of CE transition in Germany is evaluated to be still in an early phase with little momentum (Gandenberger, 2021). This could also be a cause of the many fragmented CE-related activities on regional level (Haupt, 2019; Wilts et al., 2020; Sinigaglia, 2021). A more comprehensive and overall policy in Germany could be worthwhile. However, the regional activities and their assessment in Germany are the focus of this paper and will be further elaborated in the next section. This draws on the appraisal that for regional planning and industrial development the regional level is expected to play a major role for the transition towards a CE (Wilts, 2021; Bertelsmann Stiftung, 2019; Prognos & INSA, 2020).

4. Circular Economy Assessment in German Regions

4.1 Status Quo

Quantifying circularity is a well-established measure on product level to assess recyclability, sustainable sourcing, or reparability and to identify starting points for improvements. Assessments on regional level, on the other hand, are comparably scarce, at least in the European and even more the German context. Among the limitations are (1) outdated data, (2) a focus on national level, or (3) a too narrow definition of CE. An example of analysing CE on a national state has been provided by Avdiushchenko & Zajac (2019) for the case of Poland. However, the transferability and replicability of the Polish indicators is not given due to data restrictions.

In case of Germany, the literature on regional CE assessment is even more scarce. Schlitte & Schulze (2014) have developed an approach to measure waste statistics in German regions based on 2011 data. Recent statistics on certain waste streams are provided by Prognos & INSA (2020) but on national level. A methodology to quantify the anthropogenic stock in Germany was proposed by Schiller et al. (2016). Further assessments focus on individual aspects of a CE such as circular procurement and remain qualitative in their approach (Sinigaglia, 2021). A qualitative approach has also been applied by Kruse & Suenner (2021a; 2021b) to analyse the CE structure in the Hamburg region. The available methodological approaches to quantify the CE in Germany address the national rather than the regional level and therefore do not allow for a spatial differentiation (Prognos & INSA, 2020). The focus of this paper is to cover the research gap in spatial CE analysis by developing and applying a new methodology.

4.2 Data and Methodology

The basic structure of the methodology, which was developed as a modular approach, was developed for the spatial assessment in seven dimensions: Policy, Innovation, Circular Employment, Consumption and Production, Waste Management, Socio-economic Development, and Municipal Sustainability. As focus area of the statistical analysis, the authors applied the German counties ("Kreise und kreisfreie Städte") which is a small-scale regional level comparable to the EU NUTS3 classification. The basic methodology underlines its modular block system and invites other researchers to further develop the approach and apply it in different research settings. The dimensions and indicators used to assess the circular economy in German regions is summarised in Table 1.

Table 1

Methodology for Circular Economy Assessment in German Regions

Dimension	No.	Indicator	Year	Index[1]
Policy	1.1	SDG good practices	2021	(+)
Innovation	2.1	New business formations	2017	(+)
	2.2	Share of employees with academic qualification	2017	(+)
	2.3	Investment per employee	2018	(+)
Circular Employment	3.1	C33 repair and installation of machinery and equipment	2018	(+)
	3.2	E38 waste collection, treatment and disposal activities, materials recovery	2018	(+)
	3.3	E39 employees in remediation activities and other waste management services	2018	(+)
	3.4	G45 wholesale and retail trade and repair of motor vehicles and motorcycles	2018	(+)
	3.5	S95 repair of computers and personal and household goods	2018	(+)
Consumption and Production	4.1	Domestic and bulk waste	2018	(-)
	4.2	Biological and organic waste	2018	(-)
	4.3	Paper and cardboard waste	2018	(-)

	4.4	Glass waste	2018	(-)
	4.5	Lightweight packaging waste	2018	(-)
	4.6	Metal waste	2018	(-)
Waste Management	5.1	Waste treatment plants (without landfill and thermic treatment)	2018	(+)
	5.2	Sewage treatment	2016	(+)
Socio-economic Development	6.1	GDP per capita	2017	(+)
	6.2	Household income	2017	(+)
	6.3	Unemployment rate	2017	(-)
	6.4	Broadband connection	2017	(+)
Municipal Sustainability	7.1	Recreation area per inhabitant	2017	(+)
	7.2	Nearer natural area per inhabitant	2017	(+)
	7.3	Share of settlement and traffic area	2017	(-)
	7.4	Early mortality	2017	(-)

[1] (+) positive, and (-) negative index-effect
Source: HWWI.

The majority of data was obtained from the INKAR database which provides indicators on spatial and city development (INKAR, 2021). Although 2018 was chosen as the base year with the highest data availability, some of the INKAR indicators were only available for 2016 and 2017 (see Table 1). Another deviation from the base year is to be found in the policy dimension. The list of German regional good practices under SDG goal 12 ("ensure sustainable consumption and production patterns") is regularly updated and therefore covers the years after 2018 (SDG Portal, 2021). It is to be recognised that the policy dimension on regional level in Germany is not as considerably backed by different indicators compared to e. g. the analysis of NUTS2 regions. This is because most political strategies on CE either relate to the NUTS2 or the governorate level. However, it can be expected that the increasing relevance of CE as a political target will lead to a possible extension of the methodology in the coming years. The data on employment are taken from the German Federal Employment Agency. The dimensions "consumption and production" and parts of "waste management" are based on an analysis of the annual waste balance reports issues by each governorate for its regions (Bayerisches Landesamt für Umwelt, 2019; Vogt & Ludmann, 2019; MLUL Brandenburg, 2019; Die Bremer Stadtreinigung, 2019; BUE Hamburg, 2019; MUKLV 2019; LUNG Mecklenburg-Vorpommern, 2019; MUEBK Niedersachsen, 2020; MULNV Nordrhein-Westfalen, 2019; MUEEF Rheinland-Pfalz, 2019; MUV Saarland, 2020; LU Sachsen-Anhalt, 2020; Zinkler et al., 2019; LLUR Schleswig-Holstein, 2020; LUBN Thüringen, 2019). The data for regions in Baden-Württemberg relate to the base year 2019 (MUKE Baden-Württemberg, 2020).

The data on consumption and production for Bavarian regions were not available for each region but only for the superior NUTS2-level governorates ("Regierungsbezirke"). To avoid missing data in almost 100 regions the authors applied the average value of the governorates to the subordinate counties. In the dimension consumption and production the two regions "Oberbergischer Kreis" and "Rheinisch-Bergischer Kreis" form the "Bergischer Abfallwirtschaftsverband" that handles waste management and provides data only as an aggregate of both regions. Therefore, the average of the aggregate was applied to both individual regions. Missing data within the different dimensions was handled in that way that one gap (innovation) or two gaps (circular employment, consumption and production, waste management) led to an exclusion of the region from the sub-index analysis to avoid a bias in certain indicators. In the total index, consisting of seven sub-indices, no region presented a gap in more than one sub-index so that no region had to be excluded from the general index.

For the calculation of the index, the authors applied two steps of (1) normalisation of the original data and (2) aggregation of the normalised values to receive a composite measure. The first step was needed due to the different scales and dimensions of the original data from different sources that did not allow for a direct comparison. Each variable was normalised in an interval between 0 and 1 where a value closer to 1 is associated with a superior performance while a value approaching 0 indicates a lower performance.

The normalisation function is given in equation (1.1), where X_{jk} represents the value of the k-th variable for the region j (Silvestri et al., 2020; Avdiushchenko & Zajac, 2019).

$$Y_{jk} = \frac{X_{jk} - \min(X_{1k},\ldots,X_{jk})}{\max(X_{ik},\ldots,X_{Jk}) - \min(X_{1k},\ldots,X_{jk})} \qquad (1.1)$$

Variables with a negative impact on the CE performance were calculated as follows:

$$Y_{jk} = \frac{\max(X_{1k},\ldots,X_{jk}) - X_{jk}}{\max(X_{ik},\ldots,X_{Jk}) - \min(X_{1k},\ldots,X_{jk})} \qquad (1.2)$$

In step 2, the normalised variables were aggregated using an arithmetic average. First, the arithmetic average was calculated for the seven dimensions separately (Policy, Innovation, Circular Employment, Consumption and Production, Waste Management, Socio-economic Development, Municipal Sustainability) which were then combined for the final index. This intermediate step allows for a more detailed view of how the final index is composed. We abstained from applying different weights to the individual variables and dimensions. The function is given in equation (2) whereby a higher Z_j value indicates a stronger CE performance in region j (Silvestri et al., 2020).

$$Z_j = \frac{1}{k} \sum_{k=1}^{K} Y_{jk} \qquad (2)$$

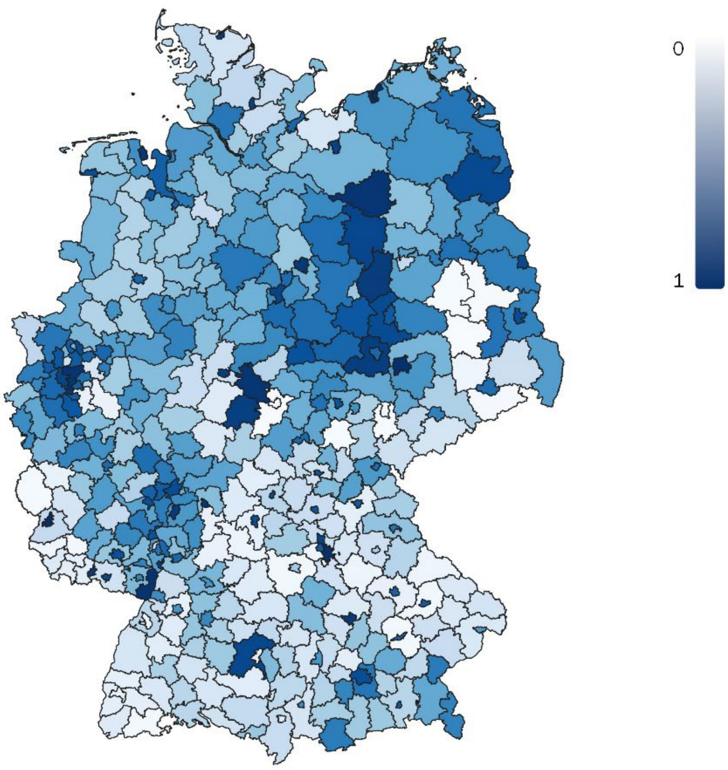
It should be noted that the regional CE assessment methodology throughout this paper cannot provide an absolute measure of CE performance in regions since such a measure would assume that there is a final CE status to be achieved. Instead, the methodology allows for a relative comparison between German regions to identify structural patterns and initiate inter-regional learning to a mutual benefit.

5. Results

The CE assessment in German NUTS3 regions reveals different geographical patterns and spatial characteristics (see Figure 1). One can observe a strong concentration of high CE performance values in Western Germany as well as in the North-West. This is interesting as the economically strong Southern area of Germany ranks relatively low in terms of CE performance while the Ruhr area, as a former location of heavy industry and negative environmental externalities has developed a path towards above-average circularity. Regarding the differences between urban and rural regions, there is no definitive pattern observable. While urban regions and larger cities often appear to be associated with a higher CE performance value there are also examples that contradict a seemingly natural correlation of circularity and urbanism. On the other hand, larger, predominantly rural, regions in Southern Germany tend to rank lower in terms of CE while comparable regions in Northern and North-Western Germany rank particularly high. It becomes clear that there is no obvious region type dominating in terms of CE performance.

Figure 1

Circular Economy Performance in German Regions, 2018



Spatial observations can be derived by looking at the Top-15 regions (see Table 2). The different county and region types indicate that a high ranking in terms of CE performance can be achieved by large cities (type 1), urban districts (type 2), rural districts with concentration tendencies (type 3), and sparsely populated rural areas (type 4). Regarding population density, there appears to be no minimum level that is required for a good CE performance. However, the population density in the Top-15 regions tends to be higher than the average population density implying that a certain level of infrastructure and population is beneficial for the development of CE. The same statistical connection is indicated by accessibility of medium centres which measures the average travel time by car to the next city with medium centre characteristics and the median income. Nevertheless, regions such as "Germersheim" (rank 5, population density of 277), "Prignitz" (rank 6, population density of 36), "Werra-Meißner-Kreis" (rank 8, population density of 99) or "Jerichower Land" (rank 14, population density of 57) underline that also a population density significantly below average does not prohibit a strong circular economy performance. Apparently, highly populated areas with a developed infrastructure and a higher level of income have an advantage when it comes to developing a circular economy, but other factors can compensate these initial conditions. Finally, the share of votes for the green party has been included as an indicator of sensitivity for sustainability in the regions. Table 2 indicates that this factor does not have an influence on the CE performance in a region since the overall average and the Top-15 average are the same. Regions with significantly lower and significantly higher vote shares rank high in the circular economy ranking.

To compare with other research results, the statistical research is in line with previous studies analysing the German waste sector on a regional basis which found that the emergence of certain waste types and treatment infrastructures was associated with the settlement structure (Schlitte & Schulze, 2014). This is partly confirmed by our analysis which includes waste treatment as one of seven dimensions. Also, the geographical CE performance in Germany apparently is less dominated by a core-periphery pattern, as opposed to other European countries. In fact, the CE development pattern in Germany is highly diversified and presents several cores, some with and some without a periphery. This implicates urban regions in Southern and South-Western Germany showing a concentration trend to the disadvantage of surrounding rural areas while the distribution in Northern Germany tends to be more equal. Another observation that can be confirmed is a certain level of East-West divergence with lower per capita waste in Eastern Germany, identified by Schlitte & Schulze (2014), that also applies to CE performance which tends to be stronger in Eastern German regions.

However, it can be argued that that the methodological design favours urban regions by including socio-economic factors such as household income or broadband availability which tend to be higher in urban regions compared to rural, more peripheral regions. Excluding, however, the socio-economic dimension from the index does not change the outcome significantly. Although the order of observed NUTS3 regions is changed slightly, the overall structure persists. A limitation of the methodology is that it does not include production processes. Another research limitation is that the study uses different points in time for the data analysis.

Table 2

Top-15 Regions in Germany in terms of Circular Economy Performance, 2018

Rank	Region	Index Value (2018)	County Type (2017)	Region Type (2017)	Population Density (2017)	Median Income (2017)	Accessibility of Medium Centres (2018)	Share of Votes for the Green Party (2017)
1	Trier, Kreisfreie Stadt	0.5323	1	3	940	3,153	0	12
2	Kreisfreie Stadt Rostock	0.5281	1	3	1,149	2,763	0	7
3	Leipzig, Stadt	0.5177	1	1	1,954	2,807	0	9
4	Nürnberg	0.5028	1	1	2,763	3,470	0	12
5	Germersheim, Landkreis	0.5016	2	1	277	3,836	5	7
6	Prignitz, Landkreis	0.4956	4	3	36	2,239	13	3
7	Mettmann, Kreis	0.4881	2	1	1,192	3,473	0	7
8	Werra-Meißner-Kreis	0.4873	4	2	99	2,821	6	7
9	Wilhelmshaven, Kreisfreie Stadt	0.4495	2	2	713	3,169	0	7
10	Wolfsburg, Kreisfreie Stadt	0.4486	1	2	606	4,622	0	6
11	Aschaffenburg	0.4419	2	3	1,120	3,327	0	11
12	Darmstadt, Kreisfreie Stadt	0.4319	1	1	1,296	4,185	0	18
13	Ingolstadt	0.4305	1	2	1,014	4,635	0	9
14	Jerichower Land, Landkreis	0.4290	4	3	57	2,352	16	3
15	Zweibrücken, Kreisfreie Stadt	0.4283	3	2	485	3,348	0	6
	Average All Regions				525	3,065	7	8
	Average Top-15				913	3,347	3	8

Source: INKAR (2021); HWW

6. Conclusion

The conclusion of the results is clear: A new approach towards resource circularity is useful not only in terms of limited resources but also regarding limited absorptive capacity of the planet and negative externalities of waste disposal. The debate on climate change and a sustainable transition must not exclusively cover the output side (emissions) but also the input side (resources) of production and consumption. One of the solutions for the dilemma of resource consumption is the Circular Economy (CE) which is increasingly mainstreamed, particularly in China and European countries. In this context, Germany has once been a frontrunner when it came to developing waste treatment technologies and introducing regulation schemes. While waste policy constitutes a part of CE, the concept of CE is much larger and involves earlier stages of the value chain, such as sourcing, design, repair, or reuse where Germany drops behind in comparison to other countries. To paint a more detailed picture of CE in Germany that allows for a more differentiated perspective on CE performance, the authors have developed a methodology to assess the CE performance in German regions on NUTS3 level. The approach builds upon a methodology developed for European NUTS2 regions and has been adapted to German characteristics, involving 26 indicators in seven dimensions. The variety of dimensions ensures that CE is covered as a cross-cutting topic which not only involves waste but also policy, employment, consumption and production or municipal sustainability.

The analysis of German counties reveals a geographic concentration of strong CE performances in regions in Western and North-Western Germany. As there are no prior studies on CE on NUTS3 level in Germany, the findings cannot be compared and validated against previous findings. However, the comparison with studies on European level shows that CE in Germany is more differentiated than expected. There is no clear core-periphery pattern that is oriented towards the capital but rather several cores of different sizes. While urban regions appear to be more successful in terms of CE performance than rural regions, there are exceptions, and a spatial pattern cannot be significantly confirmed. Instead, the findings indicate that regions of all types, sizes, and spatial characteristics have the potential to become successful in terms of CE performance. This is interesting particularly for rural regions which have been under-represented in the CE discussion so far. While several cities and their CE activities are mentioned and urban regions and cities dominate the discussion on CE implementation (Bertelsmann Stiftung, 2019), the analysis shows that also rural regions can be successful in CE implementation.

Moreover, since the methodology consists of seven dimensions - here politics, innovation, circular economy, consumption and production, waste management, socio-economic development, municipality sustainability – the circular sustainability approach "completely" reflects the human in the environment and includes the human within the circle.

7. Sources

Agora Energiewende (2020): Klimaneutrales Deutschland: In drei Schritten zu null Treibhaushasen bis 2050 über ein Zwischenziel von -65% im Jahr 2030 als Teil des EU-Green-Deals, Berlin.

Avdiushchenko, A.; Zajac, P. (2019): Circular Economy Indicators as a Supporting Tool for European Regional Development Policies, Sustainability, 2019(11), 3025, doi: 10.3390/su/11113025.

Babri, M.; Corvellec, H.; Stål, H.I. (2021): Material affordances in circular products and business model development: for a relational understanding of human and material agency, Culture and Organization, doi: 10.1080/14759551.2021.1986506.

Bayerisches Landesamt für Umwelt (2019): Hausmüll in Bayern – Bilanzen 2018, Munich.

Behörde für Umwelt und Energie der Freien und Hansestadt Hamburg (BUE Hamburg) (2019): Abfallstatistik Siedlungsabfälle, Hamburg.

Bertelsmann Stiftung (2019): Monitor Nachhaltige Kommune Bericht 2019 Schwerpunktthema Kreislaufwirtschaft, Gütersloh.

Blum, U. (2021): Kreislaufführung von Werkstoffen, Komponenten und Produktion: eine ökonomische Herausforderung, Wirtschaftsdienst, 3, 186-193.

Braungart, M.; McDonough, W. (2009): Cradle to Cradle – Re-Making the way we make things, London: Vintage books.

Circular Economy Initiative Deutschland (CEID) (2021): Circular Economy Roadmap für Deutschland, [online], available at: https://static1.squarespace.com/static/5b52037e4611a0606973bc79/t/60c2018101c5b93b08e45419/1623327119535/Roadmap+DE_Circular+Economy+Roadmap+f%C3%BCr+Deutschland [accessed June 15th, 2021].

Corvellec, H.; Stowell, A.F.; Johansson, N. (2021): Critiques of the circular economy, Journal of Industrial Ecology, doi: 10.111/jiec.13187.

D'Amato, D.; Droste, N.; Allen, B.; Kettunen, M.; Kähtinen, K.; Korhonen, J.; Leskinen, P.; Matthies, B.D.; Toppinen, A. (2017): Green, circular, bio economy: A comparative analysis of sustainability avenues, Journal of Cleaner Production, 168, 716-734.

Deus, R.M.; Savietto, J.P.; Battistelle, R.A.G.; Ometto, A.R. (2017): Trends in publications on the circular economy, Revista Espacios, 38(58), 20.

Die Bremer Stadtreinigung (2019): Abfallbilanz 2018 des öffentlich-rechtlichen Entsorgungsträgers der Stadtgemeinde Bremen, Bremen.

Dierig, C. (2020): Zweimal ignoriert – Deutschland verspielt den Titel des Müll-Weltmeisters, [online], available at: https://www.welt.de/wirtschaft/article211134725/Kreislaufwirtschaft-Deutschland-verpasst-Anschluss-beim-Recycling.html [accessed June 15th, 2021].

Ellen MacArthur Foundation (2013): Towards the Circular Economy: Economic and business rationale for an accelerated transition, https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf [accessed February 17th, 2021].

Ellen MacArthur Foundation (2015): Growth within: a circular economy vision for a competitive Europe, https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthur Foundation_Growth-Within_July15.pdf [accessed February 23rd, 2021].

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) (2020): Waste Management in Germany 2020 – Facts, data, diagrams, Berlin.

Gandenberger, C, (2021): Innovationen für die Circular Economy – Aktueller Stand und Perspektiven – Ein Beitrag zur Weiterentwicklung der deutschen Umweltinnovationspolitik, Umwelt, Innovation, Beschäftigung, 01/2021, Karlsruhe.

Gentil, E.; Clavreul, J.; Christensen, T.H. (2009): Global warming factor of municipal solid waste management in Europe, Waste Management and Research, 27(9), 850-860.

Haupt, B. (2019): The Circular Economy in Southern Germany – Opportunities and Obstacles for Dutch Entrepreneurs in the Infrastructure and Construction Sectors, Study on behalf of the Consulate-General of the Kingdom of the Netherlands in Munich and Netherlands Enterprise Agency, Munich.

Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz (MUKLV) (2019): Abfallmengenbilanz des Landes Hessen für das Land 2019, Wiesbaden.

Hobson, K.; Lynch, N. (2016): Diversifying and de-growing the circular economy: Radical social transformation in a resource-scarce world, Futures, 82, 15-25.

Horbach, J.; Rammer, C. (2019): Circular economy innovations, growth and employment at the firm level – Empirical evidence from Germany, Journal of Industrial Ecology, 24, 615-625.

INKAR (2021): INKAR – Indikatoren und Karten zur Raum- und Stadtentwicklung, Statistische Ämter des Bundes und der Länder, [online], available at: https://www.inkar.de [accessed June 1st, 2021].

Intergovernmental Panel on Climate Change (IPCC) (2021): Climate Change 2021 – The Physical Science Basis, [online], available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf [accessed August 11th, 2021].

Jaeger-Erben, M.; Jensen, C.; Hofmann, F.; Zwiers, J. (2021): There is no sustainable circular economy without a circular society, Resources, Conservation and Recycling, 168, doi: 10.1016/j.resconrec.2021.105476.

Kruse, M.; Suenner, I. (2021a): Local Analysis of the Circular Economy in the Free and Hanseatic City of Hamburg, Report in the scope of Interreg Europe project "REPLACE", [online], available at:

https://www.hwwi.org/fileadmin/hwwi/Publikationen/Studien/Local_Analysis_REPLACE_HWWI.pdf [accessed August 10th, 2021].

Kruse, M.; Suenner, I. (2021b): Kreislaufwirtschaft in Hamburg – Akteure, Trends und Potenziale, HWWI Policy Paper 132, Hamburg.

Lah, O. (2016): Circular Economy Policies and Strategies of Germany, Anbumozhi, V.; Kim, J. (eds.), Towards a Circular Economy: Corporate Management and Policy Pathways, ERIA Report, 2014/44, 59-74.

Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein (LLUR Schleswig-Holstein) (2020): Abfallbilanz 2018 – Siedlungsabfälle, Flintbek.

Landesamt für Umwelt, Bergbau und Naturschutz Freistaat Thüringen (LUBN Thüringen) (2019): Abfallbilanz 2018, Jena.

Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern (LUNG Mecklenburg-Vorpommern) (2019): Daten zur Abfallwirtschaft 2018, Schwerin.

Landesamt für Umweltschutz Sachsen-Anhalt (LU Sachsen-Anhalt) (2020): Abfallbilanz 2018 für das Land Sachsen-Anhalt, Halle (Saale).

Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft des Landes Brandenburg (MLUL Brandenburg) (2019): Daten und Informationen zur Abfallwirtschaft 2019, Potsdam.

Ministerium für Umwelt, Energie, Ernährung und Forsten Rheinland-Pfalz (MUEEF Rheinland-Pfalz) (2019): Landesabfallbilanz Rheinland-Pfalz 2018, Mainz.

Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg (MUKE Baden-Württemberg) (2020): Abfallbilanz 2019, Stuttgart.

Ministerium für Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen (MULNV Nordrhein-Westfalen) (2019): Abfallbilanz Nordrhein-Westfalen für Siedlungsabfälle 2019, Düsseldorf.

Ministerium für Umwelt und Verbraucherschutz Saarland (MUV Saarland) (2020): Abfallbilanz 2018 – Siedlungsabfälle, Saarbrücken.

Mohajan, H.K. (2021): Germany is Ahead to Implement Sustainable Circular Economy, Journal of Economic Development, Environment and People, 10(2), 46-64.

Nelles, M.; Grünes, J.; Morscheck, G. (2016): Waste Management in Germany – Development to a Sustainable Circular Economy?, Procedia Environmental Sciences, 35, 6-14.

Niedersächsisches Ministerium für Umwelt, Energie, Bauen und Klimaschutz (MUEBK Niedersachsen) (2020): Abfallbilanz 2018, Hannover.

Oberle, B.; Bringezu, S.; Hatfield-Dodds, S.; Hellweg, S.; Schandl, H.; Clement, J. (2019): Global Resources Outlook 2019, United Nations Environment Programme.

Ogunmakinde, O.E. (2019): A Review of Circular Economy Development Modes in China, Germany and Japan, Recycling, 4(3), doi: 10.3390/recycling4030027.

Prognos; INFA (2020): Statusbericht der deutschen Kreislaufwirtschaft 2020, Düsseldorf.

PWC (2019): The road to circularity – Why a circular economy is becoming the new normal, Frankfurt am Main.

Rockström, J.; Steffen, W.; Noone, K.; Persson, A.; Chapin, F.S.; Lambin, E.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; Nykist, B.; de Wit, C.A.; Hughes, T.; van der Leeuw, S.; Rodhe, H.; Sörlin, S.; Snyder, P.K.; Costanza, R.; Svedin, U.; Falkenmark, M.; Karlberg, L.; Corell, R.W.; Fabry, V.J.; Hansen, J.; Walker, B.; Livermann, D.; Richardson, K.; Crutzen, P.; Foley, J. (2009): Planetary boundaries: exploring the safe operating space for humanity, Ecology and Society, 14(2), 32.

Schiller, G.; Müller, F.; Ortlepp, R. (2016): Mapping the anthropogenic stock in Germany: Metabolic evidence for a circular economy, Resources, Conservation and Recycling, 123, 93-107.

Schlitte, F.; Schulze, S. (2014): Siedlungsabfallaufkommen in Deutschland, Wirtschaftsdienst, 9/2014, 680-682.

Schroeder, L.; Jeonghyun, K. (2019): Germany's Waste Management Policy Development – A Focus in Municipal Solid Waste, Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (giz), Beijing.

SDG Portal (2021): SDG 12 – Verantwortungsvolle Konsum- und Produktionsmuster, [online], available at: https://sdg-portal.de/de/ueber-das-projekt/17-ziele/verantwortungsvolle-konsum-und-produktionsmuster [accessed June 1st, 2021].

Sinigaglia, A. (2021): Faire Kreislaufwirtschaft – Eine konsequente Weiterentwicklung nachhaltiger öffentlicher Beschaffungspolitik, Studie im Auftrag der Freien Hansestadt Bremen.

United Nations Environment Programme (UNEP) (2017): Resource Efficiency: Potential and Economic Implications, Report of the International Resource Panel, Nairobi.

United Nations (UN) (2022): The 17 Goals, [online], available at: https://sdgs.un.org/goals [accessed January 6th, 2022].

Vogt, R.; Ludmann, S. (2019): Stoffstrom-, Klimagas- und Umweltbilanz für das Jahr 2018 für das Land Berlin, Institut für Energie- und Umweltforschung Heidelberg, Heidelberg.

Walker, A.M.; Opferkuch, K.; Lindgreen, E.R.; Raggi, A.; Simboli, A.; Vermeulen, W.J.V.; Caeiro, S.; Salomone, R. (2021): What is the Relation between Circular Economy and Sustainability? Answers from Frontrunner Companies Engaged with Circular Economy Practices, Circular Economy and Sustainability, doi: 10.1007/s43615-021-00064-7.

Wilts, H. (2016a): Der EU-Aktionsplan zur Kreislaufwirtschaft – Zwischen Ambitionen und Realitäten, Ökologisches Wirtschaften, 2, 12-13.

Wilts, H. (2016b): Deutschland auf dem Weg in die Kreislaufwirtschaft?, WISO Direkt, 15/2016, Bonn.

Wilts, H. (2017): Key Challenges for Transformation Towards a Circular Economy – The Status Quo in Germany, International Journal of Waste Resources, 7(1), 1000262.

Wilts, H. (2021): Zirkuläre Wertschöpfung – Aufbruch in die Kreislaufwirtschaft, Friedrich-Ebert-Stiftung, Bonn.

Wilts, H.; von Gries, N. (2017): Der schwere Weg zur Kreislaufwirtschaft, Gesellschaft, Wirtschaft, Politik (GWP), 66(1), 23-28.

Wilts, H.; Azak, G.; Feder, L.; Galinski, L.; Nicolas, J.; Schinkel, J.; Steger, S.; Jepsen, D.; Rödig, L.; Knappe, F.; Müller, R.; Wagner, J.; Gsell, M.; Beilke, N. (2020): Updating the Waste Prevention Programme: Preparing the foundations for updating the Waste Prevention Programme based in an analysis of the implementation states, Umweltbundesamt, Texte 204/2020, Dessau-Roßlau.

Wilts, H.; Fecke, M.; Zeher, C. (2021): Economics of Waste Prevention: Second-Hand Products in Germany, Economies, 9(74), doi: 10.3390/economies9020074.

Yu, C.; Davis, C.; Dijkema, G.P.J. (2013): Understanding the Evolution of Industrial Symbiosis Research: A Bibliometric and Network Analysis, Journal of Industrial Ecology, 18(2), 280-293.

Zinkler, S.; Winter, D.; Ritscher, M.; Arthen, A. (2019): Siedlungsabfallbilanz 2018, Landesamt für Umwelt, Landwirtschaft und Geologie Freistaat Sachsen, Dresden.

8. Appendix

Appendix 1

Circular Economy Performance in German Counties, 2018

Code	Federal State	County Name	Total Index
01	Schleswig-Holstein		
01001		Flensburg, Kreisfreie Stadt	0.4196
01002		Kiel, Landeshauptstadt, Kreisfreie Stadt	0.3168
01003		Lübeck, Hansestadt, Kreisfreie Stadt	0.3674
01004		Neumünster, Kreisfreie Stadt	0.4167
01051		Dithmarschen, Landkreis	0.3187
01053		Herzogtum Lauenburg, Landkreis	0.3116
01054		Nordfriesland, Landkreis	0.3008
01055		Ostholstein, Landkreis	0.3202
01056		Pinneberg, Landkreis	0.3121
01057		Plön, Landkreis	0.2973
01058		Rendsburg-Eckernförde, Landkreis	0.2991
01059		Schleswig-Flensburg, Landkreis	0.2856
01060		Segeberg, Landkreis	0.2950
01061		Steinburg, Landkreis	0.3591
01062		Stormarn, Landkreis	0.3257
02000	Hamburg	Hamburg	0.3371
03	Lower Saxony		
03101		Braunschweig, Kreisfreie Stadt	0.3654
03102		Salzgitter, Kreisfreie Stadt	0.4118
03103		Wolfsburg, Kreisfreie Stadt	0.4486
03151		Gifhorn, Landkreis	0.3145
03153		Goslar, Landkreis	0.3664
03154		Helmstedt, Landkreis	0.3231
03155		Northeim, Landkreis	0.3289
03157		Peine, Landkreis	0.3468
03158		Wolfenbüttel, Landkreis	0.3442
03159		Göttingen, Landkreis	0.3470
03241		Region Hannover, Landkreis	0.3575
03251		Diepholz, Landkreis	0.3128
03252		Hameln-Pyrmont, Landkreis	0.3301
03254		Hildesheim, Landkreis	0.3268
03255		Holzminden, Landkreis	0.3300
03256		Nienburg (Weser), Landkreis	0.3285
03257		Schaumburg, Landkreis	0.3205
03351		Celle, Landkreis	0.3392
03352		Cuxhaven, Landkreis	0.3382
03353		Harburg, Landkreis	0.3208

03354		Lüchow-Dannenberg, Landkreis	0.3475
03355		Lüneburg, Landkreis	0.3309
03356		Osterholz, Landkreis	0.3290
03357		Rotenburg (Wümme), Landkreis	0.3162
03358		Heidekreis, Landkreis	0.3357
03359		Stade, Landkreis	0.3312
03360		Uelzen, Landkreis	0.3229
03361		Verden, Landkreis	0.2964
03401		Delmenhorst, Kreisfreie Stadt	0.3769
03402		Emden, Kreisfreie Stadt	0.3957
03403		Oldenburg (Oldenburg), Kreisfreie Stadt	0.3913
03404		Osnabrück, Kreisfreie Stadt	0.3698
03405		Wilhelmshaven, Kreisfreie Stadt	0.4495
03451		Ammerland, Landkreis	0.3052
03452		Aurich, Landkreis	0.3159
03453		Cloppenburg, Landkreis	0.3056
03454		Emsland, Landkreis	0.3238
03455		Friesland, Landkreis	0.3441
03456		Grafschaft Bentheim, Landkreis	0.3309
03457		Leer, Landkreis	0.3215
03458		Oldenburg, Landkreis	0.3312
03459		Osnabrück, Landkreis	0.3056
03460		Vechta, Landkreis	0.3194
03461		Wesermarsch, Landkreis	0.3776
03462		Wittmund, Landkreis	0.3164
04	Bremen		
04011		Bremen, Kreisfreie Stadt	0.3551
04012		Bremerhaven, Kreisfreie Stadt	0.3527
05	North Rhine-Westphalia		
05111		Düsseldorf, Kreisfreie Stadt	0.4074
05112		Duisburg, Kreisfreie Stadt	0.3902
05113		Essen, Kreisfreie Stadt	0.3876
05114		Krefeld, Kreisfreie Stadt	0.3855
05116		Mönchengladbach, Kreisfreie Stadt	0.3477
05117		Mülheim an der Ruhr, Kreisfreie Stadt	0.2893
05119		Oberhausen, Kreisfreie Stadt	0.3251
05120		Remscheid, Kreisfreie Stadt	0.3045
05122		Solingen, Kreisfreie Stadt	0.3773
05124		Wuppertal, Kreisfreie Stadt	0.3630
05154		Kleve, Kreis	0.2999
05158		Mettmann, Kreis	0.4881
05162		Rhein-Kreis Neuss	0.3666
05166		Viersen, Kreis	0.3538
05170		Wesel, Kreis	0.3595
05314		Bonn, Kreisfreie Stadt	0.3538
05315		Köln, Kreisfreie Stadt	0.3902
05316		Leverkusen, Kreisfreie Stadt	0.3841

05334		Städteregion Aachen (einschl. Stadt Aachen)	0.3455
05358		Düren, Kreis	0.3325
05362		Rhein-Erft-Kreis	0.3638
05366		Euskirchen, Kreis	0.3219
05370		Heinsberg, Kreis	0.3174
05374		Oberbergischer Kreis	0.3155
05378		Rheinisch-Bergischer Kreis	0.3235
05382		Rhein-Sieg-Kreis	0.3204
05512		Bottrop, Kreisfreie Stadt	0.3841
05513		Gelsenkirchen, Kreisfreie Stadt	0.3991
05515		Münster, Kreisfreie Stadt	0.3422
05554		Borken, Kreis	0.3295
05558		Coesfeld, Kreis	0.3055
05562		Recklinghausen, Kreis	0.3221
05566		Steinfurt, Kreis	0.3097
05570		Warendorf, Kreis	0.3126
05711		Bielefeld, Kreisfreie Stadt	0.3465
05754		Gütersloh, Kreis	0.3444
05758		Herford, Kreis	0.3189
05762		Höxter, Kreis	0.3183
05766		Lippe, Kreis	0.3360
05770		Minden-Lübbecke, Kreis	0.3178
05774		Paderborn, Kreis	0.3510
05911		Bochum, Kreisfreie Stadt	0.3689
05913		Dortmund, Kreisfreie Stadt	0.3680
05914		Hagen, Kreisfreie Stadt	0.3534
05915		Hamm, Kreisfreie Stadt	0.3342
05916		Herne, Kreisfreie Stadt	0.3162
05954		Ennepe-Ruhr-Kreis	0.2821
05958		Hochsauerlandkreis	0.3190
05962		Märkischer Kreis	0.3115
05966		Olpe, Kreis	0.3423
05970		Siegen-Wittgenstein, Kreis	0.3285
05974		Soest, Kreis	0.3373
05978		Unna, Kreis	0.3367
06	Hesse		
06411		Darmstadt, Kreisfreie Stadt	0.4319
06412		Frankfurt am Main, Kreisfreie Stadt	0.3981
06413		Offenbach am Main, Kreisfreie Stadt	0.3222
06414		Wiesbaden, Landeshauptstadt, Kreisfreie Stadt	0.3753
06431		Bergstraße, Landkreis	0.3322
06432		Darmstadt-Dieburg, Landkreis	0.3402
06433		Groß-Gerau, Landkreis	0.3539
06434		Hochtaunuskreis	0.3565
06435		Main-Kinzig-Kreis	0.3349
06436		Main-Taunus-Kreis	0.3786

06437		Odenwaldkreis	0.3438
06438		Offenbach, Landkreis	0.3472
06439		Rheingau-Taunus-Kreis	0.3057
06440		Wetteraukreis	0.3377
06531		Gießen, Landkreis	0.3364
06532		Lahn-Dill-Kreis	0.3185
06533		Limburg-Weilburg, Landkreis	0.3639
06534		Marburg-Biedenkopf, Landkreis	0.3103
06535		Vogelsbergkreis	0.2781
06611		Kassel, Kreisfreie Stadt	0.4222
06631		Fulda, Landkreis	0.3078
06632		Hersfeld-Rotenburg, Landkreis	0.4219
06633		Kassel, Landkreis	0.2910
06634		Schwalm-Eder-Kreis	0.2717
06635		Waldeck-Frankenberg, Landkreis	0.2945
06636		Werra-Meißner-Kreis	0.4873
07	Rhineland-Palatinate		
07111		Koblenz, Kreisfreie Stadt	0.3658
07131		Ahrweiler, Landkreis	0.3497
07132		Altenkirchen (Westerwald), Landkreis	0.3142
07133		Bad Kreuznach, Landkreis	0.2962
07134		Birkenfeld, Landkreis	0.3352
07135		Cochem-Zell, Landkreis	0.3149
07137		Mayen-Koblenz, Landkreis	0.3263
07138		Neuwied, Landkreis	0.3430
07140		Rhein-Hunsrück-Kreis	0.3385
07141		Rhein-Lahn-Kreis	0.3203
07143		Westerwaldkreis	0.3081
07211		Trier, Kreisfreie Stadt	0.5323
07231		Bernkastel-Wittlich, Landkreis	0.2839
07232		Eifelkreis Bitburg-Prüm	0.2080
07233		Vulkaneifel, Landkreis	0.2574
07235		Trier-Saarburg, Landkreis	0.2967
07311		Frankenthal (Pfalz), Kreisfreie Stadt	0.2934
07312		Kaiserslautern, Kreisfreie Stadt	0.3940
07313		Landau in der Pfalz, Kreisfreie Stadt	0.3489
07314		Ludwigshafen am Rhein, Kreisfreie Stadt	0.3623
07315		Mainz, Kreisfreie Stadt	0.3961
07316		Neustadt an der Weinstraße, Kreisfreie Stadt	0.3498
07317		Pirmasens, Kreisfreie Stadt	0.4020
07318		Speyer, Kreisfreie Stadt	0.4218
07319		Worms, Kreisfreie Stadt	0.3930
07320		Zweibrücken, Kreisfreie Stadt	0.4283
07331		Alzey-Worms, Landkreis	0.3570
07332		Bad Dürkheim, Landkreis	0.3217
07333		Donnersbergkreis	0.3474

07334		Germersheim, Landkreis	0.5016
07335		Kaiserslautern, Landkreis	0.3150
07336		Kusel, Landkreis	0.3291
07337		Südliche Weinstraße, Landkreis	0.3217
07338		Rhein-Pfalz-Kreis	0.3353
07339		Mainz-Bingen, Landkreis	0.3346
07340		Südwestpfalz, Landkreis	0.2864
08	Baden-Württemberg		
08111		Stuttgart, Landeshauptstadt, Stadtkreis	0.3478
08115		Böblingen, Landkreis	0.3156
08116		Esslingen, Landkreis	0.3076
08117		Göppingen, Landkreis	0.2903
08118		Ludwigsburg, Landkreis	0.3174
08119		Rems-Murr-Kreis, Landkreis	0.3028
08121		Heilbronn, , Universitätsstadt, Stadtkreis	0.3420
08125		Heilbronn, Landkreis	0.3224
08126		Hohenlohekreis, Landkreis	0.2796
08127		Schwäbisch Hall, Landkreis	0.2690
08128		Main-Tauber-Kreis, Landkreis	0.2482
08135		Heidenheim, Landkreis	0.2975
08136		Ostalbkreis, Landkreis	0.2808
08211		Baden-Baden, Stadtkreis	0.2398
08212		Karlsruhe, Stadtkreis	0.3449
08215		Karlsruhe, Landkreis	0.2922
08216		Rastatt, Landkreis	0.3032
08221		Heidelberg, Stadtkreis	0.3665
08222		Mannheim, Stadtkreis	0.3674
08225		Neckar-Odenwald-Kreis, Landkreis	0.2561
08226		Rhein-Neckar-Kreis, Landkreis	0.3175
08231		Pforzheim, Stadtkreis	0.3407
08235		Calw, Landkreis	0.2701
08236		Enzkreis, Landkreis	0.2643
08237		Freudenstadt, Landkreis	0.2676
08311		Freiburg im Breisgau, Stadtkreis	0.2490
08315		Breisgau-Hochschwarzwald, Landkreis	0.2651
08316		Emmendingen, Landkreis	0.2647
08317		Ortenaukreis, Landkreis	0.2821
08325		Rottweil, Landkreis	0.3075
08326		Schwarzwald-Baar-Kreis, Landkreis	0.2805
08327		Tuttlingen, Landkreis	0.3032
08335		Konstanz, Landkreis	0.3026
08336		Lörrach, Landkreis	0.2724
08337		Waldshut, Landkreis	0.2349
08415		Reutlingen, Landkreis	0.3135
08416		Tübingen, Landkreis	0.3063
08417		Zollernalbkreis, Landkreis	0.2850
08421		Ulm, Stadtkreis	0.2545

08425		Alb-Donau-Kreis, Landkreis	0.4035
08426		Biberach, Landkreis	0.2687
08435		Bodenseekreis, Landkreis	0.2865
08436		Ravensburg, Landkreis	0.2971
08437		Sigmaringen, Landkreis	0.2818
09	Bavaria		
09161		Ingolstadt	0.4305
09162		München, Landeshauptstadt	0.3970
09163		Rosenheim	0.3862
09171		Altötting, Landkreis	0.3553
09172		Berchtesgadener Land, Landkreis	0.3514
09173		Bad Tölz-Wolfratshausen, Landkreis	0.3128
09174		Dachau, Landkreis	0.2655
09175		Ebersberg, Landkreis	0.3052
09176		Eichstätt, Landkreis	0.2728
09177		Erding, Landkreis	0.3296
09178		Freising, Landkreis	0.3174
09179		Fürstenfeldbruck, Landkreis	0.2949
09180		Garmisch-Partenkirchen, Landkreis	0.3549
09181		Landsberg am Lech, Landkreis	0.3047
09182		Miesbach, Landkreis	0.3141
09183		Mühldorf a.Inn, Landkreis	0.2988
09184		München, Landkreis	0.3601
09185		Neuburg-Schrobenhausen, Landkreis	0.2883
09186		Pfaffenhofen a.d.Ilm, Landkreis	0.3162
09187		Rosenheim, Landkreis	0.3033
09188		Starnberg, Landkreis	0.3490
09189		Traunstein, Landkreis	0.3315
09190		Weilheim-Schongau, Landkreis	0.3086
09261		Landshut	0.3705
09262		Passau	0.3396
09263		Straubing	0.3843
09271		Deggendorf, Landkreis	0.2790
09272		Freyung-Grafenau, Landkreis	0.2848
09273		Kelheim, Landkreis	0.2911
09274		Landshut, Landkreis	0.2303
09275		Passau, Landkreis	0.2786
09276		Regen, Landkreis	0.2775
09277		Rottal-Inn, Landkreis	0.2949
09278		Straubing-Bogen, Landkreis	0.2368
09279		Dingolfing-Landau, Landkreis	0.2904
09361		Amberg	0.3086
09362		Regensburg	0.3744
09363		Weiden i.d.OPf.	0.3572
09371		Amberg-Sulzbach, Landkreis	0.2893
09372		Cham, Landkreis	0.2496
09373		Neumarkt i.d.OPf., Landkreis	0.2479

09374	Neustadt a.d.Waldnaab, Landkreis	0.3163
09375	Regensburg, Landkreis	0.2579
09376	Schwandorf, Landkreis	0.3039
09377	Tirschenreuth, Landkreis	0.3089
09461	Bamberg	0.3926
09462	Bayreuth	0.3889
09463	Coburg	0.3904
09464	Hof	0.3636
09471	Bamberg, Landkreis	0.2927
09472	Bayreuth, Landkreis	0.2653
09473	Coburg, Landkreis	0.2857
09474	Forchheim, Landkreis	0.2880
09475	Hof, Landkreis	0.3395
09476	Kronach, Landkreis	0.2973
09477	Kulmbach, Landkreis	0.3361
09478	Lichtenfels, Landkreis	0.3203
09479	Wunsiedel i.Fichtelgebirge, Landkreis	0.3115
09561	Ansbach	0.3124
09562	Erlangen	0.4074
09563	Fürth	0.3878
09564	Nürnberg	0.5028
09565	Schwabach	0.2522
09571	Ansbach, Landkreis	0.2379
09572	Erlangen-Höchstadt, Landkreis	0.2906
09573	Fürth, Landkreis	0.2404
09574	Nürnberger Land, Landkreis	0.2818
09575	Neustadt a.d.Aisch-Bad Windsheim, Landkreis	0.3120
09576	Roth, Landkreis	0.2869
09577	Weißenburg-Gunzenhausen, Landkreis	0.3263
09661	Aschaffenburg	0.4419
09662	Schweinfurt	0.3954
09663	Würzburg	0.3936
09671	Aschaffenburg, Landkreis	0.3194
09672	Bad Kissingen, Landkreis	0.2660
09673	Rhön-Grabfeld, Landkreis	0.2833
09674	Haßberge, Landkreis	0.2950
09675	Kitzingen, Landkreis	0.3011
09676	Miltenberg, Landkreis	0.2547
09677	Main-Spessart, Landkreis	0.2738
09678	Schweinfurt, Landkreis	0.3027
09679	Würzburg, Landkreis	0.2644
09761	Augsburg	0.3406
09762	Kaufbeuren	0.3443
09763	Kempten (Allgäu)	0.2772
09764	Memmingen	0.2749
09771	Aichach-Friedberg, Landkreis	0.2949

09772		Augsburg, Landkreis	0.2816
09773		Dillingen a.d.Donau, Landkreis	0.2839
09774		Günzburg, Landkreis	0.3055
09775		Neu-Ulm, Landkreis	0.3208
09776		Lindau (Bodensee), Landkreis	0.3147
09777		Ostallgäu, Landkreis	0.2842
09778		Unterallgäu, Landkreis	0.3004
09779		Donau-Ries, Landkreis	0.3190
09780		Oberallgäu, Landkreis	0.2952
10	Saarland		
10041		Saarbrücken, Regionalverband	0.2652
10042		Merzig-Wadern, Landkreis	0.2396
10043		Neunkirchen, Landkreis	0.2645
10044		Saarlouis, Landkreis	0.2725
10045		Saarpfalz-Kreis	0.2672
10046		St. Wendel, Landkreis	0.2260
11	Berlin		0.3622
12	Brandenburg		
12051		Brandenburg an der Havel, Kreisfreie Stadt	0.2965
12052		Cottbus, Kreisfreie Stadt	0.3986
12053		Frankfurt (Oder), Kreisfreie Stadt	0.4031
12054		Potsdam, Kreisfreie Stadt	0.3538
12060		Barnim, Landkreis	0.3413
12061		Dahme-Spreewald, Landkreis	0.1815
12062		Elbe-Elster, Landkreis	0.1587
12063		Havelland, Landkreis	0.3243
12064		Märkisch-Oderland, Landkreis	0.3474
12065		Oberhavel, Landkreis	0.3337
12066		Oberspreewald-Lausitz, Landkreis	0.3610
12067		Oder-Spree, Landkreis	0.3529
12068		Ostprignitz-Ruppin, Landkreis	0.3175
12069		Potsdam-Mittelmark, Landkreis	0.3350
12070		Prignitz, Landkreis	0.4956
12071		Spree-Neiße, Landkreis	0.3493
12072		Teltow-Fläming, Landkreis	0.2009
12073		Uckermark, Landkreis	0.4030
13	Mecklenburg-West Pomerania		
13001		Kreisfreie Stadt Greifswald, Hansestadt	0.0410
13002		Kreisfreie Stadt Neubrandenburg, Stadt	0.0000
13003		Kreisfreie Stadt Rostock, Hansestadt	0.5281
13004		Kreisfreie Stadt Schwerin, Landeshauptstadt	0.4213
13071		Landkreis Mecklenburgische Seenplatte	0.3430
13072		Landkreis Rostock	0.3409
13073		Landkreis Vorpommern-Rügen	0.3285
13074		Landkreis Nordwestmecklenburg	0.2825
13075		Landkreis Vorpommern-Greifswald	0.3607
13076		Landkreis Ludwigslust-Parchim	0.3238

14	Saxony		
141		Chemnitz, Regierungsbezirk	
14511		Chemnitz, Stadt	0.3520
14521		Erzgebirgskreis	0.2845
14522		Mittelsachsen, Landkreis	0.3071
14523		Vogtlandkreis	0.2909
14524		Zwickau, Landkreis	0.2993
14612		Dresden, Stadt	0.3642
14625		Bautzen, Landkreis	0.2911
14626		Görlitz, Landkreis	0.3371
14627		Meißen, Landkreis	0.2410
14628		Sächsische Schweiz-Osterzgebirge, Landkreis	0.2241
14713		Leipzig, Stadt	0.5177
14729		Leipzig, Landkreis	0.3412
14730		Nordsachsen, Landkreis	0.3225
15	Saxony-Anhalt		
15001		Dessau-Roßlau, Kreisfreie Stadt	0.3888
15002		Halle (Saale), Kreisfreie Stadt	0.3672
15003		Magdeburg, Kreisfreie Stadt	0.3140
15081		Altmarkkreis Salzwedel	0.3638
15082		Anhalt-Bitterfeld, Landkreis	0.4016
15083		Börde, Landkreis	0.3606
15084		Burgenlandkreis	0.3324
15085		Harz, Landkreis	0.3624
15086		Jerichower Land, Landkreis	0.4290
15087		Mansfeld-Südharz, Landkreis	0.3703
15088		Saalekreis	0.4260
15089		Salzlandkreis	0.3911
15090		Stendal, Landkreis	0.4049
15091		Wittenberg, Landkreis	0.3507
16	Thuringa		
16051		Erfurt, krsfr. Stadt	0.3629
16052		Gera, krsfr. Stadt	0.2365
16053		Jena, krsfr. Stadt	0.3428
16054		Suhl, krsfr. Stadt	0.3665
16055		Weimar, krsfr. Stadt	0.3923
16056		Eisenach, krsfr. Stadt	0.2034
16061		Eichsfeld, Kreis	0.3043
16062		Nordhausen, Kreis	0.3951
16063		Wartburgkreis	0.1440
16064		Unstrut-Hainich-Kreis	0.3275
16065		Kyffhäuserkreis	0.3421
16066		Schmalkalden-Meiningen, Kreis	0.3370
16067		Gotha, Kreis	0.3272
16068		Sömmerda, Kreis	0.3470
16069		Hildburghausen, Kreis	0.2995

16070	Ilm-Kreis	0.3325
16071	Weimarer Land, Kreis	0.3290
16072	Sonneberg, Kreis	0.3258
16073	Saalfeld-Rudolstadt, Kreis	0.1626
16074	Saale-Holzland-Kreis	0.3077
16075	Saale-Orla-Kreis	0.3058
16076	Greiz, Kreis	0.1957
16077	Altenburger Land, Kreis	0.3320

Source: HWWI.

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