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Measuring Regional Competitiveness: New Insights Based on the RCI *

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Abstract: The design of a comprehensive measure of regional competitiveness has attracted much attention, with the Regional Competitiveness Index (RCI) as a benchmark. We contribute from two different perspectives. On the one hand, we test the robustness of the RCI results by modifying the dimensionality reduction technique. On the other hand, we explore the importance of two factors in the analysis of regional competitiveness: geographical distance to potential competitors (by correcting the index with the introduction of several distance measures) and technological specialization (by making a prior selection of the regions that are expected to compete mostly either in high-tech sectors or in medium- or low-tech sectors, and recalculating the index accordingly). The results show that the RCI indicator is robust to the variable reduction methods employed. Moreover, including geographical distance substantially modifies the degree of competitiveness of many regions, which we believe cannot be neglected since competition tends to be fiercer the shorter the distance between the regions involved. Finally, if regions are categorized into two groups based on their technology level, some changes in RCI rankings are very noticeable.
Keywords: competitiveness; European regions; DP2 index; distance; technology
JEL Codes: C43, R10

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1. INTRODUCTION

Competitiveness is one of the most frequently used terms in economics. However, the notion of competitiveness is often fuzzy. As a result, it is defined in many ways (see, for example, Budd and Hirmis, 2004; Kitson et al., 2004). As in this paper, when a macroeconomic approach is adopted, and the focus is on the competitiveness of a territory, some authors (e.g., Krugman, 1998; Boschma, 2004) even doubt the relevance of the concept of "territorial competitiveness" due, among other reasons, to the difficulties in measuring competitiveness

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when moving from the traditional micro context to the macro one. Nevertheless, our opinion in this respect, in line with authors such as Porter (2000), Camagni (2002), Villaverde (2007), and Szabó (2019) is that the complications innate to its measurement should not, in any case, prevent the study of such a substantive issue.

Territorial competitiveness is a sound concept from a theoretical perspective and interesting from an applied or economic policy approach. As Camagni (2002) points out, "the roles and responsibilities of local development policies and spatial planning widen (in a *globalized world*), facing new political and cultural challenges." Regions compete with each other on the degree of efficiency of their enterprises and their institutional qualities, social and cultural factors, physical infrastructures, human capital, innovation capacity, externalities, and so on. According to the European Commission (EC), territorial competitiveness is "the ability to produce goods and services which meet the test of international markets, while at the same time maintaining high and sustainable levels of income or, more generally, the ability of companies, industries, regions, nations and supra-national regions to generate, while being exposed to international competition, relatively high income and employment levels" (European Commission, Directorate-General for Regional and Urban Policy (1999), p. 75), which seems applicable to the approach carried out in this paper.

Further evidence that inter-territorial competitiveness should not be overlooked is that the study of competitiveness at national and regional levels has recently flourished. We provide only a few recent references for further reading (Amato, 2023; Halásková and Bednář, 2023; Le Clech, 2023; Mourão and Popescu, 2023; Cuestas et al., 2024). Indeed, work dealing with this issue at the regional level is becoming increasingly common since, as indicated by Huggins et al. (2013, 2014), country-level studies fail to reveal regional trends and performance breaks between regions. Regional studies have arisen, among other reasons, from the need to formulate workable strategies in terms of competitiveness from a regional policy point of view, which requires a good and reliable measure that brings to light the relative strengths and weaknesses of each region.[1]

In this regard, the publication of a regular report on the measurement of competitiveness of European regions by the EC has also undoubtedly contributed to the development of this branch of the literature, so this report should be deemed, as indicated by several works (e.g., Chrobocińska, 2021; Borsekova et al., 2022), a reference in the field. The well-known Regional Competitiveness Index (*RCI*) proposed by the EC (Annoni and Dijkstra, 2019), which in the version we use examines the year 2019,[2] employs 74 partial indicators/variables, grouped into 11 pillars/dimensions, which are grouped into three sub-indices to finally merge into the *RCI*. For this purpose, data for 268 NUTS2 (based on the 2016 definition) regions are managed.[3] This is, as can be inferred from the above-mentioned breakdown, a comprehensive

[1]As Camagni (2002) and Malecki (2004) argue, in the current context, with the increasing integration of economies around the world—especially through trade and territorial financial flows—weak and lagging regions are at greater risk of being left behind and entering a decline from which they have to find a way out.

[2]However, the data employed rarely correspond to that year. Due to the statistical lag, data from 2016 to 2018 were mostly used.

[3]Administrative regions are therefore used. However, the results may differ if, for example, metropolitan regions based on more economic criteria are used (e.g., Maza and Villaverde, 2011). This paper will use the same sample of regions as the EC.

index which, for example, from an economic policy point of view, could be pretty useful. As Mulatu (2016) points out, policies to create an enabling environment for business need to provide modern physical infrastructure, effective political institutions (such as the rule of law), good healthcare, basic education, efficient capital markets, efficient (business-related) regulations, and quality higher education and science institutions. The information the *RCI* provides can help prioritize all these factors, which is not a trivial point. Anyhow, it is important to admit that some issues are absolutely outside the scope of any measure of competitiveness; the index is not useful in deciding, for example, the type of policies to implement (facilitative or proactive), or it is blind to the policy-making capacity of each government, which is linked to its specificity.

Against this backdrop, this paper aims, using the same data made public by the EC, to deepen, albeit modestly, the understanding of regional competitiveness in Europe. In a way, we follow the call of Barkley (2008), who urged regional scientists to enhance the quality and relevance of the information that policymakers can use to design public policies. We do so from two different but complementary perspectives. We first test the robustness of the results to the variable reduction method used in the construction of the index. Instead of the well-known Principal Component Analysis (*PCA*) technique, we use the Pena's Distance (*DP2*) method (Pena, 1977), which has some advantages detailed below. This is an essential point since if, as Camagni (2002), indicates, "In an era of globalization, the issue of territorial competitiveness is of increasingly central importance for regional development policies", regional scientists need to be confident about the reliability of the information they are providing for the design of such policies focused on improving the competitive capacity of a region/group of regions. Put differently, if the results were to change drastically, the whole premise would be questionable. As we will see below, our findings support the use of the *RCI*, as the changes are not very significant.

Still, while we are sometimes interested in overall competitiveness, there are occasions when a subset of regions may be of particular interest. A recent reference that underscores the need that frequently exists to adapt a global index to a specific group of regions is Tighsazzadeh and MalekpourAsl (2023) in their study on poverty. On this account, refining an index may involve changing the group of territories considered, which is expected to have substantial effects on the results. Hence, the parameters of an index, including modifications, must be intentionally identified and recognized. It may also be time to use different indices or permutations. All these adjustments may be important in addressing policy needs, as in some cases, a region may be interested in fostering its comparative advantage vis-à-vis a specific type of region with which it is fighting for a well-defined market niche or perhaps to attract FDI. Along these lines, the second part of this paper is framed. Starting from the premise that not all regions compete with each other so that a global index can be modified to suit the target groups better, the present paper qualifies the conclusions drawn from the *RCI* from two standpoints. On the one hand, the distance factor and the fact that regions compete to a greater extent with nearby territories than distant ones. The main reason for undertaking this analysis is that the *RCI* results show, as we will see below that regions tend to be geographically concentrated in terms of competitiveness. On the other hand, the technological factor, some regions compete mainly in high-technology sectors, while others compete basically in low-technology sectors via prices. In this case, we decided to focus the study on the technological level, which is not the only source of competitive advantage. The construction of the *RCI* makes it much easier to consider this factor than others. More specifically, we highlight technology as an example of a form of focus/refinement, which has particular salience given the make-up of the *RCI*.

The structure of the paper is as follows. In the second section, after reviewing the computation of the *RCI*, we offer a re-computation of the index with emphasis on the variable reduction method employed; as indicated, we use the *DP2* method. In the third section, we include in the calculation of the competitiveness index factors that can cause considerable changes in the assessment of the competitive capacity of each region: distance and technological level. The main conclusions of the article are summarised in the final section.

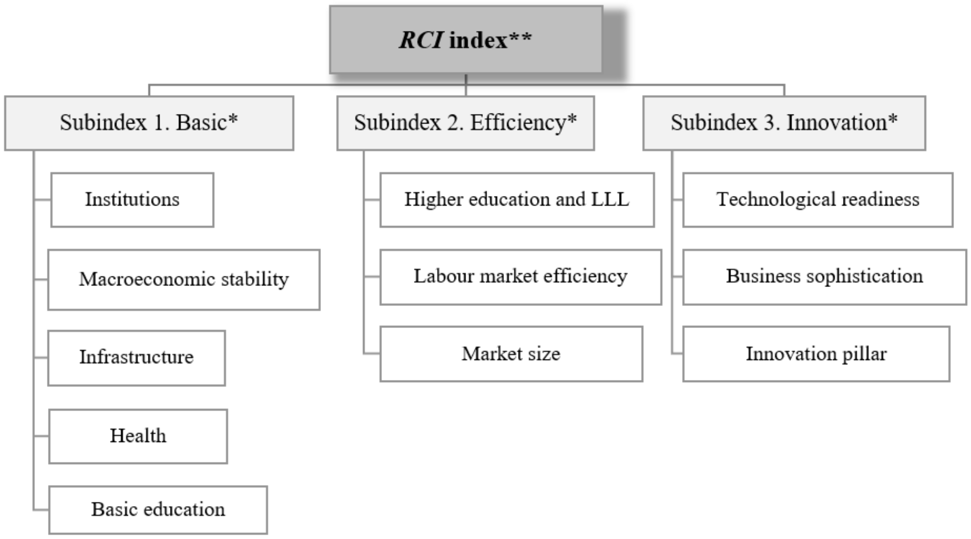
2. RE-COMPUTING THE *RCI*. A NEW AGGREGATION TECHNIQUE

As indicated in the Introduction and shown in Figure 1, the *RCI* is based on more than 70 partial indicators that cannot be considered separately (the list of variables is included in Appendix A), which are grouped into 11 pillars ((1) Institutions, (2) Macroeconomic stability, (3) Infrastructure, (4) Health, (5) Basic education, (6) Higher education and lifelong learning, (7) Labour market efficiency, (8) Market size, (9) Technological readiness, (10) Business sophistication, and (11) Innovation). The aggregation method used is *PCA*. These 11 pillars or dimensions are grouped into three sub-indices: Basic (simple average of the first five pillars), Efficiency (simple average of pillars 6-8), and Innovation (simple average of pillars 9-11). Finally, the degree of development of each region (measured by its GDP per capita in PPS) is taken into account in the calculation of the *RCI* so that it is obtained as the weighted average of the three sub-indices. Specifically, the weights are as follows: If GDP per capita is below 50% of the European average, 35% for Basic, 50% for Efficiency and 15% for Innovation; if between 50% and 75%, the percentages are 31.25%, 50% and 18.75%; if between 75% and 90%, the percentages are 27.50%, 50% and 22.50%; if between 90% and 110%, the percentages are 23.75%, 50% and 26.25%; and if above 110%, 20%, 50% and 30%.

In this section, what we do is to take as a reference the procedure followed for the calculation of the *RCI*, using even the same data, but we make a significant change in the variable reduction method, which allows us to test the sensitivity of the results to this important decision. More specifically, for the computation of each pillar we employ, instead of *PCA*, the popular *DP2* method, which has been extensively applied in the literature to address a wide range of issues (e.g. Somarriba and Pena (2009); Montero et al. (2010); Zarzosa (2012); Rodríguez et al. (2013); Zarzosa and Somarriba (2013); Ivaldi et al. (2017); Ivaldi et al. (2018); Penco et al. (2020); Ciacci et al. (2021)). For the remaining steps (sub-indices as simple averages of the corresponding pillars and the final index as a weighted average depending on the degree of regional development), we strictly follow the *RCI* calculation procedure.

The idea behind the DP2 index (and what gives it its name) is to aggregate the information contained in each variable by distances to a reference corresponding to the theoretical area that reaches the lowest value of the variable in the set of units of analysis (regions here). Therefore, the first step is to make sure that all the partial indicators used can be interpreted in the same way, i.e., that their increases constitute, in all cases, an improvement

Figure 1: *RCI* computation



Note:(*) Each sub-index is built as the simple average of its pillars; (**) The weight of the three sub-indices depends on the level of development (measured by the per capita GDP) of each region (see the main text).

(or worsening, as the case may be) of the situation. As seen in Appendix A, for most of the partial indicators, an increase is associated with an improvement in competitiveness, so we chose to give all the indicators a positive polarity. Thus, for those where the interpretation is the opposite (marked in shading in the Appendix), a simple linear transformation has been applied as follows:

$$x'_{ij} = \max\{x_{ij}\} - x_{ij} \tag{1}$$

where i denotes the region (i = 1, ... , n) and j refers to the indicator that needs to be inverted so that its interpretation is in line with what we have just indicated, i.e., the higher the value the more competitive; as can also be seen in Appendix A (shaded), 19 indicators are in that situation (thus, j = 1, ... , 19 in this case).

Then, for all indicators (raw and reversed ones), the distance to the minimum value (the reference value that, in this case, and according to the previous paragraph, is the 'undesired' value) is computed:

$$d_{ij} = |x_{ij} - \min\{x_{ij}\}| \tag{2}$$

In the next step, we express all indicators (j = 1, ... , m) in comparable abstract units. For this, we use the Frechet Distance ($DF_i = \sum_{j=1}^{m} \frac{d_{ij}}{\sigma_j}$), which summarises additively all indicators in each region i, where σ_j is the standard deviation of the partial indicator/variable j. Hence, the contribution of each indicator d_{ij} to the global/overall indicator is weighted by its standard deviation. More precisely, that contribution is inversely proportional to the variability of each indicator, measured by the standard deviation.

The problem linked to the use of the DF index is that it does not eliminate the duplicated information that always exists when merging several variables or indicators. In other words, it would only be valid when each indicator collects unique information and, consequently, all are uncorrelated. As this is not the case, it is necessary to eliminate the redundant information collected in the battery of indicators used. Consequently, we have the DP2 index expressed as:

$$DP2_i = \sum_{j=1}^{m} \frac{d_{ij}}{\sigma_j} \left(1 - R^2_{j.j-1,j-2,\ldots,1}\right) \tag{3}$$

where $R^2_{j.j-1,j-2,\ldots,1}$ is the coefficient of determination of the linear regression of each indicator j on the remaining ones $(j-1, j-2, \ldots, 1)$. *DF* should be interpreted as the maximum value of *DP2* when all indicators are uncorrelated. Thus, the higher the correlation between the variables, the greater the difference between the two indexes. Consequently, $(1-R^2_{j.j-1,j-2,\ldots,1})$ is set as a correction factor that eliminates redundant information by taking away the proportion of the variance of the observed values that is explained by the linear dependence, since $R^2_{j.j-1,j-2,\ldots,1}$ refers to the proportion of the variance of each indicator that is linearly explained by the rest of indicators.

In view of that, when calculating the *DP2* index, the ranking of the indicators must be established. In other words, it is obligatory to decide which one is used first, second, and so on. The logical decision is to consider the correlation of each indicator with *DF*, so that the most correlated is the first and so on. Consequently, that first indicator contributes all its information to the global index ($\frac{d_1}{\sigma_1}$), the second one contributes the part of its variance that is not correlated with the first indicator ($\frac{d_2}{\sigma_2}(1 - R^2_{2.1})$), ..., and the last indicator contributes only the part of its variance that is not correlated with the remaining ones ($\frac{d_j}{\sigma_j}(1-R^2_{j.j-1,\ldots,1})$). This approach efficiently eliminates duplicate information in the partial indicators.

After explaining its computation, it is significant to note that the DP2 index possesses quite a few advantages over *PCA* (e.g., Montero et al., 2010; Podgorna et al., 2020). First, by weighting according to the inverse standard deviation, arbitrary weighting is avoided, and the problem of heterogeneity (when dealing with variables expressed in different units of measurement) is sorted out. Second, it allows direct comparison between results since it takes the same "state" for the units of analysis as a reference. Third, it is a complete indicator and not just an aggregation mechanism. Given the procedure to reduce duplication explained above, it allows a large number of variables to be included (as is done in the *RCI*) to the extent that the greater the number of variables, the more comprehensive the result is.

Turning now to the findings. Table 1 lists the top 20 regions and the bottom 20 regions, as well as the value of the 'new' competitiveness index, which we call the Modified Regional Competitiveness Index (hereafter, *MRCI*). Compared with the original results, the table also shows the ranking of the *RCI*; we do not report the values of this index, however, as they are not comparable with those obtained in this paper.

As can be seen, the results obtained for the *MRCI* coincide to a large extent with those of the *RCI*, demonstrating the robustness of the latter. This does not exclusively apply to the more or less competitive regions, the only ones shown in the table for reasons of space, since the correlation coefficient between the full results for *MRCI* and *RCI* is 0.985. In the

Table 1: *MRCI*. Comparison with the original one

Top Regions			Bottom Regions		
RCI	***MRCI***	**Value**	***RCI***	***MRCI***	**Value**
SE11	UK00	11.646	EL41	RO22	3.473
UK00	UKJ1	11.269	RO22	RO21	3.476
NL31	SE11	11.241	FRY3	RO41	3.901
UKJ1	NL31	11.186	EL51	BG31	3.905
UKJ2	DK01	11.185	FRY5	RO12	3.997
DK01	UKJ2	11.119	EL53	RO31	4.017
LU00	FR10	10.822	EL63	EL64	4.090
DE21	DE21	10.596	ES64	EL63	4.102
NL00	FI1B	10.506	BG31	EL51	4.117
FI1B	NL00	10.445	EL42	EL65	4.125
FR10	LU00	10.394	EL65	EL53	4.225
DE60	NL33	10.199	RO21	RO11	4.275
DE71	DE60	10.181	EL62	EL41	4.300
NL33	UKD6	10.138	EL64	BG34	4.353
UKJ3	DE71	10.122	RO41	FRY3	4.431
DE12	UKJ3	10.100	PT20	EL61	4.501
UKD6	DE12	10.057	EL61	ITG1	4.510
DE11	DE11	10.037	EL54	EL42	4.568
DEA2	SE22	9.948	EL43	BG32	4.616
NL41	NL41	9.941	RO12	ITF6	4.670

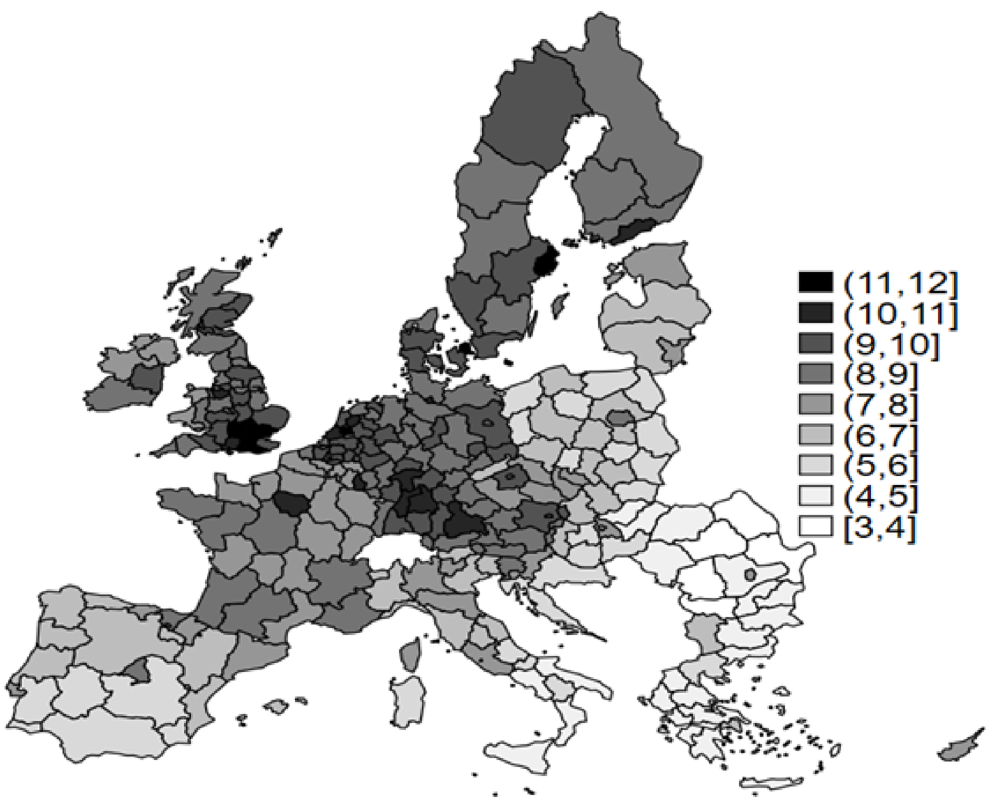
Note: The list of regions, along with the NUTS2 nomenclature, is included in Appendix B.

top regions, almost all of the differences are in the ranking (as 19 out of 20 regions match). The most competitive region is now London and its commuting area (UK00), displacing Stockholm (SE11), while regions such as Île de France (FR10) and Cheshire (UKD6), move up. In contrast, others, such as Luxembourg (LU00), lose positions. As for the bottom regions, where there are changes in the names apart from their ordering. Basically, the eastern, Bulgarian (BG32- Severen tsentralen and BG34- Yugoiztochen) and Romanian (RO11- Nord-Vest and RO31- Sud-Muntenia) regions replace the southern, mainly Greek regions (EL43- Kriti, EL54- Ipeiros and EL62- Ionia Nisia). In any case, the changes cannot be considered quite remarkable. Our results largely reinforce those obtained in the *RCI* published by the EC.

Moreover, by looking more at the values than the ranking, the new *MRCI* allows us to highlight the substantial differences in competitiveness between European regions. Going to extremes, it turns out that London's degree of competitiveness is more than three times higher than that of Sud-Est (RO22). If the 20 top and 20 bottom regions are averaged, the differences are still striking (2.5 times in this case).

Figure 2 displays a thorough overview of the results, from which several relevant conclusions can be drawn. First, there is a distinct spatial dependence in the distribution, i.e., regions with relatively high (low) levels of competitiveness tend to be geographically concentrated. Second, the least competitive regions are in southern Europe, with many Greek, Italian, Spanish, and Portuguese regions standing out. Third, the most competitive regions are located in central and northern Europe and the British Isles. Fourth, and notwithstanding the above, we could underline the existence of some outliers, i.e., regions with a degree of competitiveness quite discordant with the majority in their geographical area.

Figure 2: *MRCI*



Note: Peripheral regions are not included.

3. NOT ALL REGIONS COMPETE WITH EACH OTHER. SOME PRELIMINARY BUT IMPORTANT INSIGHTS

This section aims to deepen our understanding of the competitive capacity of European regions from two different perspectives. On the one hand, the inclusion of distance, as it seems to be the general case, that foremost rivals in competitive terms are usually the closest ones. On the other hand, a very simple approximation to the technological level, as a potential source of competitive advantage for the reasons explained in the Introduction, in which each region competes mostly. In this sense, we group regions according to their technological level to assess their degree of competitiveness in each group subsequently. These two approaches are complementary to the general competitiveness index and may provide additional information that, depending on the case, could help policy-making.

3.1. Distance: Local competitiveness

In the previous section, the level of competitiveness of each region seems, with some exceptions, to be fairly in line with that of its neighboring regions. This result is meaningful and confirms, as has been alluded to in many contexts (e.g., Maza and Villaverde, 2009 on income convergence, or Fingleton et al., 2015 in discussing the feasibility of EMU as a single currency area), that 'space matters'. Suppose we add to this the fact that the main competitors of a given region are, in many cases, the geographically closest regions. In other words, we consider that, although competition is increasingly global in scale, the closest regions continue, in many cases, to compete with each other for scarce resources more than they compete with distant regions. In that case, introducing distance into the analysis is very relevant.

In any event, the role played by distance is certainly debatable. Our view is that, in general terms, neighboring regions compete for investment, labor, knowledge, the establishment of new firms, and so on. The conclusions of several theoretical and empirical papers support this idea. As indicated, for instance, by Griffith and Jones (1980) and LeSage and Llano-Verduras (2014), the commodity flows associated with a destination increase or decrease depending on the attractiveness of its neighboring destinations. In the same vein, dealing with FDI, Villaverde and Maza (2012) state that "regions do compete for FDI flows and that an improvement in any one of these two factors (FDI *attraction factors*) in a region would decrease the flow of FDI in its neighboring regions" (p. 729). From a different perspective, the distance-decay effect is well-accepted when considering agglomeration economies and spillover effects (see, e.g., Altomonte and Békés, 2016) so that they occur predominantly within the same region. For example, Amiti and Cameron (2007) adopt the theoretical framework developed by Fujita et al. (1999) to calculate agglomeration benefits from vertical linkages between firms, showing that positive externalities are highly localized and occur at a ratio of about 100 km. Rosenthal and Strange (2008) conclude that agglomeration externalities decrease sharply with distance, with 75% of them occurring within 25 km. Andersson et al. (2009) and Lychagin et al. (2016), on knowledge spillovers, obtain similar results. All in all, our view is that, while nothing prevents us from accepting the fact that globalization drives competition between regions on a more global scale, the role performed by distance remains quite significant.

With this in mind, the proposal is as follows. For each region, we have calculated its spatial lag, defined as the weighted average of the remaining ones, so that we weigh nearby regions more heavily than distant regions. Specifically, the spatial lag takes the following expression:

$$W\_MRCI_i = \sum_{k=1}^{n} w_{ik} MRCI_k \tag{4}$$

where $MRCI$ denotes our Modified RCI, and w_{ik} are the elements of the distance (spatial weights) matrix W between each region i and the remaining k regions. The role of the distance matrix is to impose a penalty on distance, and its definition can be crucial.

For this reason, and in an attempt to cover the whole spectrum, we propose two somewhat extreme distance matrices. On the one hand, a matrix that considers each of the regions and defines its weights as the inverse of the distance between region i and region k: $w_{ik} = 1/d_{ik}$, where d_{ik} is the Euclidean distance between the two regions considered. On the other hand, a distance matrix with a cutoff that is not too large so that only the regions within it are weighted in the computation of the spatial lag. Specifically, we use a cutoff of 1,000 km ($w_{ik} = 1/d_{ik}$ if $d_{ik} < 1,000km$; 0 otherwise) to limit the number of competitors. In both cases, distance matrices are row-standardized.

In this manner, once the corresponding spatial lags have been computed, we calculate the ratio *MRCI/W_ MRCI* in such a way that we directly compare the degree of competitiveness of each region with that of its neighboring regions (with the nuances inherent to the definition of W used). In doing so, a value greater than 1 indicates the region is more competitive than its neighbors, while a value less than 1 means that its competitive capacity is, in relative terms, lower. Obviously, the further the result is from 1, the greater the competitive strength or weakness, respectively.

In a nutshell, with this metric, we get information on each region's competitiveness level, mainly with respect to the nearest regions. The results are presented in Table 2 (top and bottom 20 regions for both distance matrices) and, for all regions, in Figure 3 (inverse of the distance matrix) and Figure 4 (inverse of the distance but with a 1000 km cutoff). A simple glance at Figures 2-4 shows that the expected results differ when entering the distance (compare Figures 2 and 3) and when a cutoff is introduced (Figures 3 and 4). To avoid being too repetitive, we will focus our comments on the top and bottom 20 regions (Table 2).

With regard to the list of the most competitive regions, it can be noted that the simple inclusion in the calculations of a weighting technique according to geographical distance makes some regions appear (disappear). Like so, capital regions such as AT00- Wien and its commuting area and SK01- Bratislavský Kraj come into view, which shows that, although in general, they do not deserve to be labeled as top performers, they are leading regions within their geographical range. The same applies to some Swedish regions (SE12- Östra Mellansverige and SE23- Västsverige). In contrast, there are Dutch regions (NL33- Zuid-Holland and NL41- Noord-Brabant) and British regions (UKD6- Cheshire and UKJ3- Hampshire and Isle of Wight) which, in a stricter comparison with their surroundings, are no longer leading territories in competitive terms. The most radical changes occur, however, and as expected, when a cutoff point is set in the distance matrix so that, maintaining the distance penalty, only the competitive situation of a region is assessed with the regions that fall within it. In this case, just half of the regions remain, so the first thing we want to stress is that the competitive capacity of some regions could be considered 'global', i.e., with respect to the European regions as a whole, but not 'local', i.e., with respect to their neighbors. We refer, for example, to German regions such as DE11- Stuttgart, DE12- Karlsruhe, and DE71- Darmstadt. As for the regions that replace them, and therefore possess a very high competitive capacity if only compared to geographically close areas, country regions such as CY00- Cyprus and MT00- Malta stand out, joined by country capitals such as RO32- Bucureşti -

Table 2: *MRCI*: Insights from the inclusion of geographical distance

Distance matrix with all regions				Distance matrix with regions in 1,000km			
Top regions	**Value**	**Bottom regions**	**Value**	**Top regions**	**Value**	**Bottom regions**	**Value**
SE11	1.383	RO21	0.489	CY00	1.506	RO21	0.596
DK01	1.354	RO22	0.499	RO32	1.435	RO22	0.643
DE21	1.310	RO41	0.565	EL30	1.417	RO41	0.677
FI1B	1.308	BG31	0.570	MT00	1.344	RO11	0.684
FR10	1.298	RO12	0.573	ES30	1.329	PL43	0.690
NL31	1.275	FRY3	0.574	SE11	1.329	RO12	0.691
UK00	1.273	RO31	0.586	PT17	1.293	RO31	0.694
UKJ1	1.240	RO11	0.601	DK01	1.285	PL62	0.703
LU00	1.232	EL65	0.607	DE21	1.281	BG31	0.706
AT00	1.215	EL51	0.609	BG41	1.258	ITG2	0.709
DE60	1.212	EL64	0.612	FI1B	1.238	PL42	0.714
UKJ2	1.212	EL63	0.612	FR10	1.232	PL61	0.715
SE22	1.205	ITG1	0.618	NL31	1.225	HU31	0.726
DE11	1.201	PT20	0.619	AT00	1.213	HU23	0.726
DE12	1.199	EL53	0.623	SK01	1.208	ITC2	0.732
DE71	1.198	EL41	0.625	UK00	1.207	RO42	0.754
SK01	1.196	ES64	0.626	PL91	1.205	HU32	0.754
NL00	1.193	FRY5	0.638	LU00	1.190	ES64	0.755
SE12	1.191	BG34	0.645	UKJ1	1.175	ITG1	0.768
SE23	1.187	ITF6	0.655	DE60	1.165	PL72	0.776

Note: The list of regions, along with the NUTS2 nomenclature, is included in Appendix B.

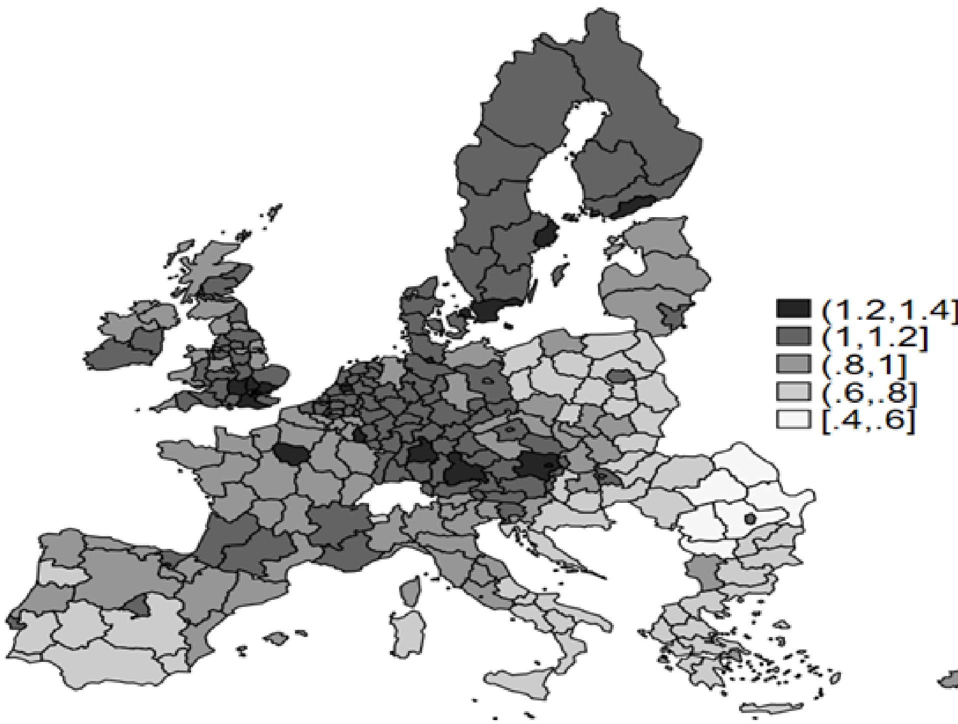
Ilfov, EL30- Attiki, ES30- Madrid, PT17- Área Metr. de Lisboa, BG41- Yugozapaden, and PL91- Warszawski stołeczny.

Concerning the list of bottom regions, the changes are not so intense. When the standard inverse distance matrix is applied, there are no striking adjustments. However, when the cutoff is imposed, some changes are noteworthy. Basically, Bulgarian and Greek regions are replaced by Polish and Hungarian ones, so our approach unveils the existence of 'local' competitive problems in regions such as PL43- Lubuskie, PL62- Warmińsko-mazurskie, HU31- Észak-Magyarország, and HU23- Dél-Dunántúl.

3.2. Technological level: Regions compete based on their strengths

As the introduction indicates, regions tend to specialize and compete in diverse fields/sectors. Thus, we took advantage of the approach for constructing the competitiveness index and focused on technology. Although, as mentioned, there are forms of capital and advantage outside technology, it can be considered one of the most important sources of competitive capability, and the definition of the index itself allows us to easily distinguish, as explained below, two groups of regions. Here, we want to emphasize a fundamental difference between this extension and the previous one. We will now divide the regions into two groups and

Figure 3: Competitiveness by distance. Inverse distance matrix



Note: Peripheral regions are not included.

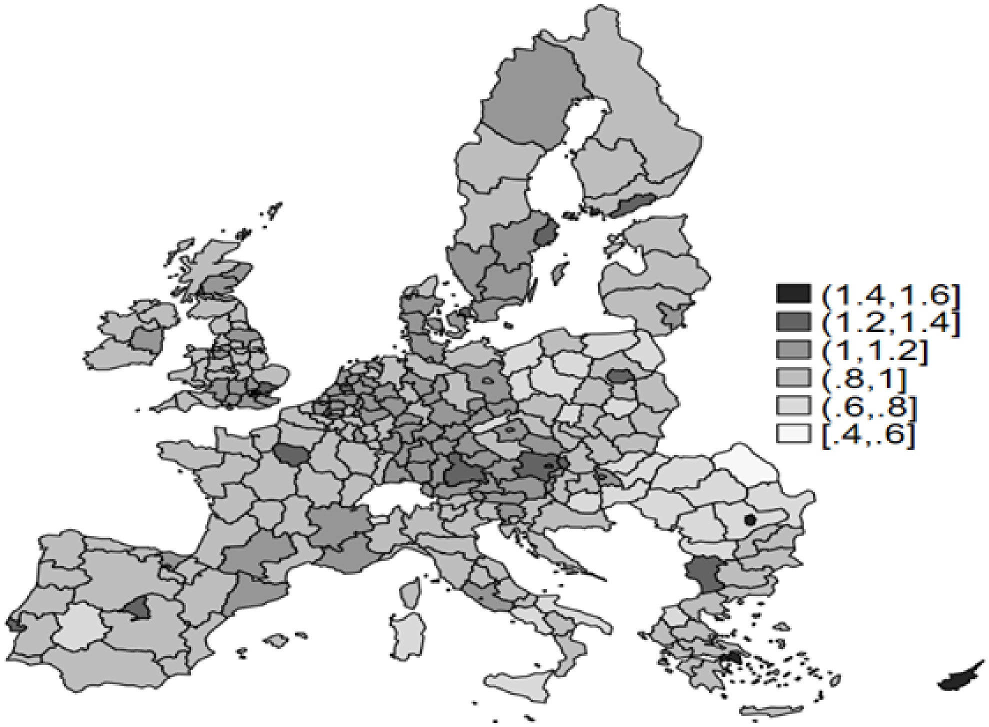
separately compute an index for each group, considering a selection of pillars/variables.

Bearing all these considerations in mind, it can be stated, without a doubt, that only the leading regions in the last two sub-indices of the *RCI* (efficiency and innovation) compete with each other in high-tech sectors. This is because the sectors that constitute the so-called high technology can be defined as those which, given their degree of complexity, require a continuous research effort and a solid technological base; for this, they need, albeit in different proportions depending on the case, both highly skilled workers and state-of-the-art equipment and machinery, as well as synergies between the two. Therefore, for the first group, we have chosen those regions that exceed the average in the last two sub-indices and, exclusively for them, we have constructed a new competitiveness index but only with the indicators included in these two sub-indices.[4] Our idea is to outline a group of regions that are expected to compete with each other given that, most likely, their factor endowments bias their production towards medium-high/high technology products.

In contrast, the rest regions probably compete more in less advanced sectors through prices. Consequently, we have only calculated a new competitiveness index for these regions, but in this case, the partial indicators/pillars are included in the first sub-index. Furthermore, in line with the premise that they compete more in low-tech and labor-intensive

[4]We have considered all indicators at the same time for two reasons. On the one side, our aim is not to compare results with those obtained in the *RCI*. On the other side, we think this is a way of making the most of one of the main advantages of the *DP2* index: omitting potentially redundant information between indicators.

Figure 4: Competitiveness by distance. Inverse distance matrix with cut-off=1,000km



Note: Peripheral regions are not included.

industries, we have added another partial indicator in calculating the competitiveness index: GDP per capita.[5] It is included as a proxy for wages in each region and has been reversed to maintain positive polarity since, in this case, it is understood that modest wages improve the competitiveness of these regions.[6]

Starting with the high-tech group (Table 3), our analysis unmasks the competitive strength of some regions within this group that did not stand out in the more general approach. We refer to quite noteworthy regions in the European context, some German (such as DE14- Tübingen and DE91- Braunschweig), Swedish (SE12- Östra Mellansverige and SE23- Västsverige) and English (UKH1- East Anglia and UKK1- Gloucestershire, Wiltshire and the Bristol/Bath area). More importantly, the list of bottom regions points to the potential competitive problems of, for example, many French regions which, although in principle well equipped to face technological competition, do not seem to be very successful in that task given the capabilities of their potential competitors. The same happens with some Belgian and Spanish regions, among others. The full list of bottom regions is included in Table 3. Being completely new, we preferred not to include names here for the sake of space.

[5]Once again, with all indicators (those included in the first five pillars plus GDP per capita) simultaneously.
[6]This is not to deny that, in a broader assessment, economic objectives may change over time and that, in the long run, lagging regions may have to find room for wage increases that do not undermine their competitiveness.

Table 3: *MRCI*: Insights from the inclusion of technological level

High-technology sectors				Low-technology sectors			
Top regions	**Value**	**Bottom regions**	**Value**	**Top regions**	**Value**	**Bottom regions**	**Value**
UKJ1	45.165	FRI3	17.552	UKN0	21.961	BG31	4.610
SE11	43.687	FRD2	17.890	FRE2	21.486	BG34	6.121
DK01	43.024	FRD1	19.338	BE33	21.064	RO22	6.316
UKJ2	42.730	FRF3	19.404	FRE1	20.822	RO11	6.458
UK00	41.876	ES21	19.921	FRF2	20.196	EL42	6.496
NL31	41.108	BE35	20.803	BE32	19.770	RO41	6.768
DE21	40.998	BE34	20.932	ES24	19.738	EL54	6.815
UKJ3	39.233	FRC2	21.047	ES51	19.546	EL53	6.895
FI1B	39.134	FRB0	21.126	IE04	19.455	EL51	6.913
UKK1	38.603	FRK1	21.180	ES42	18.804	BG33	6.928
DE60	38.290	FRL0	22.405	FRC1	18.026	RO12	6.936
DE12	38.056	FRH0	22.503	FRJ1	17.767	RO42	6.937
DE11	37.781	FRI1	22.924	FRI2	17.493	BG32	7.002
UKD6	37.548	PT17	23.070	ES13	17.491	EL63	7.009
DE14	37.187	FRF1	23.165	PT11	17.119	RO21	7.042
NL00	37.010	ES30	23.491	ES52	16.940	EL43	7.247
DE91	36.165	FRG0	23.627	ES62	16.836	EL65	7.353
SE12	36.043	CZ06	24.280	ES12	16.705	BG42	7.535
SE23	36.036	AT11	24.292	ES22	16.660	EL52	7.753
UKH1	35.793	EE00	24.465	ES41	16.644	EL64	7.772

Note: The list of regions, along with the NUTS2 nomenclature, is included in Appendix B.

Regarding the low-tech group, the most salient fact here concerns the cluster of leading regions, as they all have many competitive shortcomings in the overall indicator. Obviously, in the division we have made, the situation changes, and the results show that these regions would be successful in market segments focused on low-tech and price-competitive sectors. Thus, it is mainly Spanish and French regions that emerge for their relatively high degree of competitiveness. The list can be seen in Table 3.

4. CONCLUSIONS

The competitive capacity of regions has been and will be, in the future, a hot topic in the economic literature. One strand of that main topic is how to measure regional competitiveness. This paper, which takes as a benchmark the *RCI* periodically computed by the EC, has attempted to provide a twofold contribution in this respect. Firstly, by testing the robustness of this index regarding the method of variable aggregation used. Secondly, it includes two factors that play an undeniable role in a region's competitive capacity: geography and technology.

The results show, in relation to the first point, that the changes caused by introducing a possibly more appropriate aggregation method are unnoticeable. In other words, the *RCI* is a robust index, at least from this point of view, which should be considered very important since inaccuracy or imprecision in the measurement of competitiveness and its components could lead to a biased assessment and, consequently, to poor policy design. Notwithstanding the above, there were some relatively minor changes. For instance, London replaced Stockholm as the most competitive region in Europe. Besides, in the new index, the comparative position of several Greek regions improves significantly, in contrast to some eastern European regions.

On the second point, geography and technology bring about significant changes. If we acknowledge that competition intensifies as territories become closer to one another, it's evident that certain regions—like some in the Netherlands and the United Kingdom—experience a decrease in competitive capacity. Conversely, this trend is reversed for others, particularly capital regions. This circumstance can be very relevant and should probably be considered in competitiveness strategies. By way of example, it may happen, especially in some sectors, that competitiveness strategies that, for one region, seem meaningless when considering its situation in general terms become desirable if the focus is limited to relative competitiveness vis-à-vis neighboring regions.

As for the technological level, our approach revealed, among other things, the problems in terms of competitiveness that regions specialized in high-tech sectors (some German, Swedish, and British regions) may have. Similarly, it reveals competitive strengths that went unnoticed in the global index, as there are regions (mainly Spanish and French) that, at least in terms of low-tech sectors and price competition, could find their niche. Once again, the design of a strategy to increase competitive strength should take these issues into account.

We would like to conclude by acknowledging the limitations of this work, particularly on the last point. A search for region-niche market pairs would allow us to be much more precise when referring to competitiveness. On the other hand, this search constitutes a challenging line of future research, as it undoubtedly requires forgetting the *RCI* as a reference, using different data sources, and approaching a new and exciting study from scratch.

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APPENDIX A. INDICATORS USED IN THE COMPUTATION OF THE COMPETITIVENESS INDEX

Pillar	Indicator/Variable	Pillar	Indicator/Variable
Institutions	Quality and accountability of government services	**Higher Education and LLL**	Higher education attainment
	Corruption (*)		Lifelong learning
	Impartiality of government serv.		Early school leavers
	Country-level corruption percept.		Lower-secondary completion only
	Regional-level corruption percept.	**Labour Market Efficiency**	Employment rate (no agriculture)
	Voice and accountability		Long-term unemployment
	Political stability		Unemployment
	Government effectiveness		Labour productivity
	Regulatory quality		Gender balance unemployment
	Rule of law		Gender balance employment
	Control of corruption		Female unemployment
	Ease of doing business index		NEET (not in education, employment or training)
	Property rights		Involuntary part-time/temporary employment
	Intellectual property protection	**Market Size**	Disposable income per capita
	Efficiency of legal framework in settling disputes		Potential market size in GDP
	Efficiency of legal framework in challenging regulations		Potential market size in Population
	Transparency of government policymaking	**Technological Readiness**	Households access to broadband
	Business costs of crime and violence (*)		Individuals buying over the internet
	Organized crime (*)		Households access to internet
	Reliability of police services		Availability of latest technologies
Macroeconomic Stability	Government surplus/deficit		Firm-level technology absorption
	Gross National Savings		FDI and technology transfer
	Government bond yields		Enterprises purchasing online
	Government debt		Enterprises receiving orders online
	NIIP. Net International Investment Position		Enterprises with fixed broadband access
	Road accessibility	**Business Sophistication**	Employment (K-N sectors)
Infrastructure	Railway accessibility		GVA (K-N sectors)
	Passenger flights		Innovative SMEs
	Road fatalities		Marketing organisational innovators

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Table A1 – continued from previous page

Pillar	**Indicator/Variable**	**Pillar**	**Indicator/Variable**
Health	Healthy life expectancy	**Innovation Pillar**	Core creative class employment
	Infant mortality		Knowledge workers
	Cancer disease death rate		Scientific publications
	Heart disease death rate		Total intramural R&D expenditure
	Suicide		Human Resources in S&T
Basic Education	Employer-sponsored training		Employment in technology and knowledge-intensive sectors
	Access to learning info		Exports in medium-high/high-tech manufacturing
	No foreign language		Sales of new to market and new to firm innovation

Source: Own elaboration based on Annoni and Dijkstra (2019). For more information on sources, the unit of measurement and description, and reference year, see Annoni and Dijkstra (2019).
Note: Although its name suggests that it should be reversed, the indicator is already constructed in such a way that the higher the value, the better the situation of the unit of analysis. In shadow, indicators that have been reversed.

APPENDIX B. LIST OF REGIONS

NUTS CODE 2016	NUTS NAME	NUTS CODE 2016	NUTS NAME
AT00 (AT12+AT13)	Wien and its commuting area	FRY2	Martinique
AT11	Burgenland	FRY3	Guyane
AT21	Kärnten	FRY4	La Réunion
AT22	Steiermark	FRY5	Mayotte
AT31	Oberösterreich	HR03	Jadranska Hrvatska
AT32	Salzburg	HR04	Kontinentalna Hrvatska
AT33	Tirol	HU10	Közép-Magyarország
AT34	Vorarlberg	HU21	Közép-Dunántúl
BE00 (BE10+BE24+BE31)	Rég. de Bruxelles-Cap. and its commuting area	HU22	Nyugat-Dunántúl
BE21	Antwerpen	HU23	Dél-Dunántúl
BE22	Limburg	HU31	Észak-Magyarország
BE23	Oost-Vlaanderen	HU32	Észak-Alföld
BE25	West-Vlaanderen	HU33	Dél-Alföld
BE32	Hainaut	IE04	Northern and Western
BE33	Liège	IE05	Southern
BE34	Luxembourg	IE06	Eastern and Midland
BE35	Namur	ITC1	Piemonte
BG31	Severozapaden	ITC2	Valle d'Aosta/Vallée d'Aoste
BG32	Severen tsentralen	ITC3	Liguria
BG33	Severoiztochen	ITC4	Lombardia
BG34	Yugoiztochen	ITF1	Abruzzo
BG41	Yugozapaden	ITF2	Molise
BG42	Yuzhen tsentralen	ITF3	Campania
CY00	Kýpros	ITF4	Puglia
CZ00 (CZ01+CZ02)	Praha and its commuting area	ITF5	Basilicata
CZ03	Jihozápad	ITF6	Calabria
CZ04	Severozápad	ITG1	Sicilia
CZ05	Severovýchod	ITG2	Sardegna
CZ06	Jihovýchod	ITH1	Prov. Autonoma di Bolzano/Bozen
CZ07	Střední Morava	ITH2	Provincia Autonoma di Trento
CZ08	Moravskoslezsko	ITH3	Veneto
DE11	Stuttgart	ITH4	Friuli-Venezia Giulia
DE12	Karlsruhe	ITH5	Emilia-Romagna
DE13	Freiburg	ITI1	Toscana
DE14	Tübingen	ITI2	Umbria
DE21	Oberbayern	ITI3	Marche
DE22	Niederbayern	ITI4	Lazio
DE23	Oberpfalz	LT01	Sostinės regionas
DE24	Oberfranken	LT02	Vidurio ir vakarų Lietuvos regionas
DE25	Mittelfranken	LU00	Luxembourg

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Table A2 – continued from previous page

NUTS CODE 2016	NUTS NAME	NUTS CODE 2016	NUTS NAME
DE26	Unterfranken	LV00	Latvija
DE27	Schwaben	MT00	Malta
DE00 (DE30+DE40)	Berlin and its commuting area	NL00 (NL23+NL32)	Flevoland & Noord-Holland
DE50	Bremen	NL11	Groningen
DE60	Hamburg	NL12	Friesland
DE71	Darmstadt	NL13	Drenthe
DE72	Gießen	NL21	Overijssel
DE73	Kassel	NL22	Gelderland
DE80	Mecklenburg-Vorpommern	NL31	Utrecht
DE91	Braunschweig	NL33	Zuid-Holland
DE92	Hannover	NL34	Zeeland
DE93	Lüneburg	NL41	Noord-Brabant
DE94	Weser-Ems	NL42	Limburg
DEA1	Düsseldorf	PL21	Małopolskie
DEA2	Köln	PL22	Śląskie
DEA3	Münster	PL41	Wielkopolskie
DEA4	Detmold	PL42	Zachodniopomorskie
DEA5	Arnsberg	PL43	Lubuskie
DEB1	Koblenz	PL51	Dolnośląskie
DEB2	Trier	PL52	Opolskie
DEB3	Rheinhessen-Pfalz	PL61	Kujawsko-pomorskie
DEC0	Saarland	PL62	Warmińsko-mazurskie
DED2	Dresden	PL63	Pomorskie
DED4	Chemnitz	PL71	Łódzkie
DED5	Leipzig	PL72	Świętokrzyskie
DEE0	Sachsen-Anhalt	PL81	Lubelskie
DEF0	Schleswig-Holstein	PL82	Podkarpackie
DEG0	Thüringen	PL84	Podlaskie
DK01	Hovedstaden	PL91	Warszawski stołeczny
DK02	Sjælland	PL92	Mazowiecki regionalny
DK03	Syddanmark	PT11	Norte
DK04	Midtjylland	PT15	Algarve
DK05	Nordjylland	PT16	Centro
EE00	Eesti	PT17	Área Metr. de Lisboa
EL30	Attiki	PT18	Alentejo
EL41	Voreio Aigaio	PT20	Região Autónoma dos Açores
EL42	Notio Aigaio	PT30	Região Autónoma da Madeira
EL43	Kriti	RO11	Nord-Vest
EL51	Anatoliki Makedonia, Thraki	RO12	Centru
EL52	Kentriki Makedonia	RO21	Nord-Est
EL53	Dytiki Makedonia	RO22	Sud-Est
EL54	Ipeiros	RO31	Sud - Muntenia
EL61	Thessalia	RO32	Bucureşti - Ilfov
EL62	Ionia Nisia	RO41	Sud-Vest Oltenia
EL63	Dytiki Ellada	RO42	Vest
EL64	Sterea Ellada	SE11	Stockholm

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NUTS CODE 2016	NUTS NAME	NUTS CODE 2016	NUTS NAME
EL65	Peloponnisos	SE12	Östra Mellansverige
ES11	Galicia	SE21	Småland med öarna
ES12	Principado de Asturias	SE22	Sydsverige
ES13	Cantabria	SE23	Västsverige
ES21	País Vasco	SE31	Norra Mellansverige
ES22	Comunidad Foral de Navarra	SE32	Mellersta Norrland
ES23	La Rioja	SE33	Övre Norrland
ES24	Aragón	SI03	Vzhodna Slovenija
ES30	Comunidad de Madrid	SI04	Zahodna Slovenija
ES41	Castilla y León	SK01	Bratislavský kraj
ES42	Castilla-La Mancha	SK02	Západné Slovensko
ES43	Extremadura	SK03	Stredné Slovensko
ES51	Cataluña	SK04	Východné Slovensko
ES52	Comunidad Valenciana	UK00 (UKH2-3+UKI3-7)	London and its commuting area
ES53	Illes Balears	UKC1	Tees Valley and Durham
ES61	Andalucía	UKC2	Northumberland and Tyne and Wear
ES62	Región de Murcia	UKD1	Cumbria
ES63	Ciudad Autónoma de Ceuta	UKD3	Greater Manchester
ES64	Ciudad Autónoma de Melilla	UKD4	Lancashire
ES70	Canarias	UKD6	Cheshire
FI19	Länsi-Suomi	UKD7	Merseyside
FI1B	Helsinki-Uusimaa	UKE1	East Yorkshire and Northern Lincolnshire
FI1C	Etelä-Suomi	UKE2	North Yorkshire
FI1D	Pohjois- ja Itä-Suomi	UKE3	South Yorkshire
FI20	Åland	UKE4	West Yorkshire
FR10	Île de France	UKF1	Derbyshire and Nottinghamshire
FRB0	Centre - Val de Loire	UKF2	Leicestershire, Rutland and Northamptonshire
FRC1	Bourgogne	UKF3	Lincolnshire
FRC2	Franche-Comté	UKG1	Herefordshire, Worcestershire and Warwickshire
FRD1	Basse-Normandie	UKG2	Shropshire and Staffordshire
FRD2	Haute-Normandie	UKG3	West Midlands
FRE1	Nord-Pas de Calais	UKH1	East Anglia
FRE2	Picardie	UKJ1	Berkshire, Buckinghamshire and Oxfordshire
FRF1	Alsace	UKJ2	Surrey, East and West Sussex
FRF2	Champagne-Ardenne	UKJ3	Hampshire and Isle of Wight

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NUTS CODE 2016	NUTS NAME	NUTS CODE 2016	NUTS NAME
FRF3	Lorraine	UKJ4	Kent
FRG0	Pays de la Loire	UKK1	Gloucestershire, Wiltshire and Bristol/Bath area
FRH0	Bretagne	UKK2	Dorset and Somerset
FRI1	Aquitaine	UKK3	Cornwall and Isles of Scilly
FRI2	Limousin	UKK4	Devon
FRI3	Poitou-Charentes	UKL1	West Wales and The Valleys
FRJ1	Languedoc-Roussillon	UKL2	East Wales
FRJ2	Midi-Pyrénées	UKM5	North Eastern Scotland
FRK1	Auvergne	UKM6	Highlands and Islands
FRK2	Rhône-Alpes	UKM7	Eastern Scotland
FRL0	Provence-Alpes-Côte d'Azur	UKM8	West Central Scotland
FRM0	Corse	UKM9	Southern Scotland
FRY1	Guadeloupe	UKN0	Northern Ireland

Source: Own elaboration based on Annoni and Dijkstra (2019).