Spatial dynamics of competitiveness: a comparative analysis of the Blue Banana and emerging EU regions

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Building upon the traditional concept of the "Blue Banana" as Europe's economic core area, this study examines the multifaceted impacts and underlying causes of regional competitiveness disparities across Europe. In particular, it delves into Central and Eastern Europe (CEE), along with the Mediterranean territories of the European Union (EU), analysing the ongoing economic and urban transformations within these areas while also assessing similar patterns in Western and Northern Europe. Leveraging the Nomenclature of Territorial Units for Statistics 2 (NUTS 2) regional breakdown and data sourced from the EU's latest regional competitiveness index (RCI) report, this study conducts a comprehensive analysis of spatial concentrations within the EU. The findings suggest that although some regions of the Blue Banana maintain their relative dominance in regional competitiveness, significant recent developments in other European regions indicate that the concept may be losing relevance. In particular, the CEE regions – especially their capital regions – converged toward the standards set by the Blue Banana. The results of the spatial regression model on the RCI in 2022 substantiate the conclusion that the Blue Banana is no longer a significant territorial concentration. Moreover, the results of the spatial regression model on the changes in RCI scores between 2016 and 2022 indicate that the less affluent CEE and Mediterranean regions have greater development potential than the wealthier western and northern regions, further challenging the traditional notion of the Blue Banana.

Keywords:
Blue Banana,
Central and Eastern Europe,
Mediterranean,
regional competitiveness,
spatial correlation analysis

Online first publication date: 20 January 2026

Introduction

This study explores the current relevance of the "Blue Banana" as Europe's economic backbone, spanning from Northern Italy to Southern England. The study examines the complex interplay between historical context and contemporary economic dynamics within the region, investigating whether recent regional development patterns can undermine its conceptual importance. By tracing the evolution of the Blue Banana concept from its inception to its adaptation in modern discourse, we aim to unravel the intricate factors shaping regional competitiveness in the heart of Europe by employing the latest European Union (EU) regional competitiveness index (RCI) data and econophysics-based tools. To achieve this, a spatial concentration analysis was conducted, employing tools such as the Moran's index (Moran's I) and spatial regression on the data gathered by the latest EU RCI report. The EU RCI assesses a region's competitiveness by taking into account aspects such as human capital, institutional quality, and productivity-related elements, such as research and development (R&D) investments and the NEET (neither in employment nor in education and training) rate (Annoni–Dijkstra 2019). Most notably, the EU RCI definition also incorporates the benefits received by businesses and citizens, focusing on both rather than just the former (Schwab 2012, Porter–Schwab 2008) or the latter (Meyer-Stamer 2008). Additional parameters that contribute to RCI's reliability as a measuring tool include labour market effectiveness, institutional quality, research and technology infrastructure, healthcare, education market size, and macroeconomic stability. Although the RCI does not explicitly incorporate environmental, social, and governance metrics into its core calculation, it considers aspects closely related to these, such as innovation, infrastructure, and quality of life; these factors can indirectly influence a region's attractiveness to sustainable investments, aligning with broader considerations of sustainability and governance principles. This implicit connection offers new opportunities to interpret regional competitiveness through a more integrated lens, consistent with the EU's emphasis on sustainable and inclusive development. At the same time, the sustainability- and governance-related dimensions embedded in the RCI enhance its potential not only as a diagnostic tool for economic performance but also as a framework for assessing how well regions are positioned to meet the broader goals outlined in the current EU strategies (Bilbao-Terol et al. 2017, D'Urso et al. 2022). Regarding the scope of inquiry associated with RCI use, it is crucial to note that such measurement can be impacted by the complex interplay of several variables. Regional competitiveness in the EU is ultimately determined by a wide range of forces along the vertical and horizontal axes of political power, a style of governance that reflects the federalist nature of the EU. Bristow (2010) confirmed that competitiveness cannot be determined solely at the regional level; rather, it requires consideration of local, national, and transnational dimensions.

Beginning with an overview of the Blue Banana area, this study lays the foundation for subsequent economic analysis. In particular, it investigates the economic and

political landscapes of the Eastern Bloc and the Mediterranean, outlining their distinct characteristics as European macroregions. By tracing the key stages resulting in the conceptualization of the Blue Banana, this study places its development within a historical context; it then discusses the underlying statistical tools fundamental to spatial studies, showing the integration of insights from scientific disciplines into social science research. A concise exploration of Moran's I and its applications in analysing EU regional competitiveness is presented in the fourth section, focusing on territorial disparities and the use of spatial and standard regression models. The fifth section focuses on the revised and updated version of the 2022 RCI, while the sixth and final section offers a comparative analysis of the changing RCI scores between 2016 and 2022.

This study contributes to the ongoing debate on the evolving patterns of regional development and competitiveness within the EU. It is important to note that our analysis is limited to regions within the EU owing to data availability constraints. Consequently, Switzerland must be excluded from the spatial analysis, despite its role as an integral component of the continental Western European core area. Therefore, the territorial policy implications of this study are confined to the Nomenclature of Territorial Units for Statistics (NUTS) 2 regions of the EU. Nevertheless, the spatial effects of Switzerland are indirectly discernible in the spatial analysis, as the majority of neighbouring EU regions exhibit high regional competitiveness.

From backbone to Blue Banana: shaping Europe's economic vitality

When considering the development of the notion of the Blue Banana region, Roger Brunet's research should be taken into account. Brunet was the founder of a series of study groups that significantly contributed to the advancement of research on the spatial dynamics of the Blue Banana economic area. In 1989, at the request of the authorities, Brunet and his team embarked on a project to geographically delineate the "backbone of Europe", which is an extraordinary area distinguished by above-average demographic, urban, and economic parameters. Building upon the groundwork laid by France's Interministerial Delegation of Land Planning and Regional Attractiveness (in 1987, Brunet's team identified the European "backbone" as a corridor extending from Northern Italy to Southern England, characterized by a substantial degree of urbanization capable of accommodating approximately 100 million people (Faludi 2015).

This seminal investigation highlighted the region's economic dynamism and underscored the pivotal role of urban centers as catalysts for growth and innovation. It is crucial to emphasize the key attributes of the Blue Banana area in comparison to the Eastern Bloc and Southern Europe. The Blue Banana area has emerged as a densely populated area brimming with industrial hubs, transportation networks, and

cutting-edge telecommunication facilities, reinforcing its dominance in the secondary sector (Hospers 2002). This economic enclave is equally distinguished by its remarkable adaptability to the evolving dynamics of tertiarization within specific industries and the resulting externalities, exemplified by its magnetism for cultural and educational endeavors (Van Dinteren–Meuwissen 1994). This adaptive capacity has positioned the Blue Banana as a leader in the shift toward a knowledge-based economy, further solidifying its prominence in the European economic landscape. Consequently, the Blue Banana plays, and may continue to play – at least in the near future – a leading role in fostering extensive networks of services, transportation, repair facilities, leisure amenities, and communication, with lower unemployment rates and higher per capita incomes than any other European region.

Although the original Blue Banana was centered around the Liverpool–Milan axis, the notion underwent a series of adaptations throughout the 1990s. While the core idea of an urbanized economic powerhouse remained intact, the boundaries of this area became increasingly flexible, including urban centers and regions that were not originally considered by Brunet and his associates (Faludi 2015). During this period, the concept of the "Blue Banana" began to receive its first critique, as it reportedly fostered competition rather than cooperation between EU member states (Kunzmann–Wegener 1991). Over the years, the extraordinary demographic concentration and productive power of this territory have attracted the attention of several scholars eager to discover the reasons behind its development.

As postulated by Nosek–Netrdová (2010), the evolving landscape of market dynamics, globalization, and the assimilation of social and cultural norms aligned with western ideals have been key drivers of income and wage disparities in Central and Eastern Europe (CEE) regions since 1989. In their study, Nosek–Netrdová examined the spatial dynamics of unemployment at the municipal level across Austria, Czech Republic, Germany, and Poland to identify any secondary axes extending from the Blue Banana into Eastern Europe by analysing geosocial divergence patterns. Despite advancements in gender equality driven by stringent EU secondary legislation, disparities in age, education, and health conditions have intensified across the population. Known as "widening countries," states in this region often contend with underdeveloped research infrastructure and weak institutions (Brent 2023).

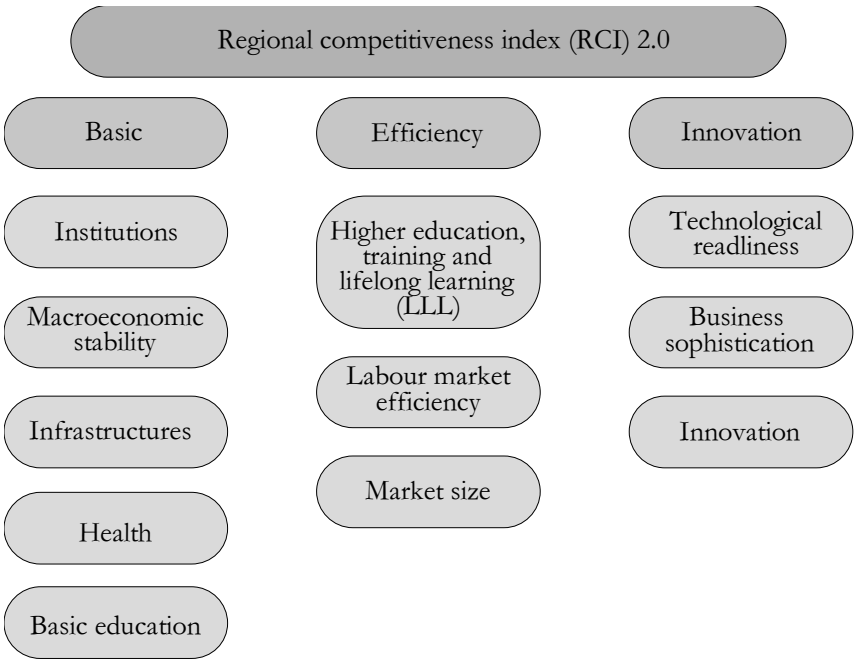
In highlighting the uneven competitiveness levels across different regions of the EU, Umiński–Nazarczuk (2020) argued that globalization has exacerbated pre-existing inequalities, a trend that is unfortunately not limited to the European regions alone. Despite evidence of decreasing *inter*-country inequalities at the global level driven by the convergence of developing regions (above all China and India), *intra*-country inequality is generally rising everywhere. This phenomenon explains why inequality levels within economic regions are increasing despite overall economic growth.

Changing patterns of regional competitiveness in the EU

Regional competitiveness, as defined by Borsekova et al. (2021), represents a region's ability to attract and sustain businesses while simultaneously improving living conditions. Building on the methodological foundation established by the European Commission in the *EU regional competitiveness index 2.0* report (EC 2022), RCI is measured comprehensively through 11 pillars (Figure 1), grouped into three core sub-indices: *basic*, *efficiency*, and *innovation*.

Figure 1

RCI 2.0 foundational methodological structure



Source: EC (2022).

The *basic* sub-index refers to fundamental drivers that either propel a given economic region forward or, if not adequately addressed, hamper its growth. This parameter encompasses several critical dimensions, including the establishment of a robust regulatory framework that ensures stable and predictable long-term growth. Such a framework promotes investment, entrepreneurial spirit, and trust in economic forces, determines the market, facilitates quality infrastructure development, and ensures healthcare and education; these interconnected factors interact to foster the emergence of regional competitiveness.

Similarly, the efficiency sub-index focuses on parameters crucial for the growth of mature regional economies. It delves into the intricacies of labour market dynamics,

examining how efficiently the demand for a skilled workforce can be generated and seamlessly integrated. Such developments are expected to significantly enhance overall economic output efficiency. Lastly, the innovation sub-index scrutinizes the pervasiveness of technology in the socio-economic landscape and its readiness (Dijkstra et al. 2023), by assessing how private households and businesses leverage existing technologies to drive innovation and productivity.

The development of RCI 2.0 provides insights into European regional competitiveness. The framework in Figure 1 acknowledges the impact on each of the three generative areas, each of which evolves alongside the economic development stage. Moreover, the order of relevance within each domain underscores the incremental nature of competitiveness, showing its emergence as a layered construct – evolving through distinct developmental milestones – and highlighting its escalating significance. Foundational elements such as robust infrastructural frameworks and well-functioning labour markets form the basis of competitiveness, while long-term sustainability increasingly depends on technology and innovation. Within this paradigm, the outcome of RCI 2.0 underscores a widespread competitiveness deficiency across the EU eastern regions, with their capitals emerging as exceptions to this trend. Thus, it is possible to appreciate the pivotal role played by potency (particularly in the advanced stages of economic development) and innovation in shaping a region's competitive landscape. Significantly, RCI 2.0 ranks Romania (Sud-Est RO22 and Nord-Est RO21) and Bulgaria (Severozapaden BG31) as the lowest- and second-lowest-performing European regions, particularly in regard to the innovation sub-index. These findings highlight the existing competitiveness gap, as Romania and Bulgaria account for 8 out of the 10 least competitive regions in the EU. Moreover, the Czech Republic and Slovakia display a relative decline in competitiveness compared with the EU average.

Despite the predominant representation of the Nordic regions among the top 10 RCI performers, significant improvements have been observed in widening countries. For instance, notable enhancements in competitiveness have emerged in Lithuania's capital region, which increased by 18 index points, approaching the EU's average. This positive trend is also evident in Slovenia and the Czech Republic,[1] as well as in Portugal's Norte region, Poland's capital region, and Śląskie (Silesia), which saw notable increases in competitiveness of 16, 12, and 14 points, respectively.[2]

To increase competitiveness, CEE countries should prioritize cluster development. Proximity to other businesses and suppliers within a specific industry

[1] LT01 NUTS 2 code is not present in the 2016 Excel document of the Commission; therefore, the comparison here is conducted with respect to 2019. Result obtained from the 2022 value minus the 2019 value of the RCI 2.0 index (114.3 – 94.4 = 19.9).

[2] PL91 NUT2 2 code is not present in the 2016 Excel document of the Commission; therefore, the comparison here is conducted with respect to 2019. Result obtained from the 2022 value minus the 2019 value of the RCI 2.0 index (118.8 – 105.6 = 13.2).

is crucial for enhancing efficiency, fostering additional prospects for innovation in products and processes and simultaneously lowering entry barriers for new businesses. According to Myszkowska (2015), countries with low competitiveness should also focus on establishing stronger business environments to initiate the innovation-driven development stage and sustain the productivity that fuels it. During the launch of the RCI index, Jakub Chełstowski, regional governor of Silesia and member of the European Committee of the Regions, highlighted the crucial role of European funding in regional development, particularly in transitioning from traditional mining industries into modern, clean-tech activities. Moreover, alongside Poland, "catching up" regions in the Baltic states, Croatia, Hungary, and Slovenia are gradually approaching EU standards (Brent 2023). Empirical research by Egri–Tánczos (2018) confirms that between 2004 and 2014, CEE regions exhibited uneven yet consistent convergence toward the Western European core, economically (in terms of gross domestic product [GDP] per capita) and socially (through the human development index [HDI]). However, the gap remained significant in the case of the less favourable regions. In this context, the EU's cohesion and regional convergence policy, along with the effectiveness of structural funds in Central and Eastern European countries, is crucial for reducing regional inequalities, promoting economic and social cohesion, and responding to challenges related to EU enlargement (Frazer et al. 2010, Madanipour et al. 2021, Smetkowski–Wójcik 2012).

The Mediterranean region faces disparities exacerbated by geographical and geopolitical challenges, affecting trade and contributing to the ongoing migration crisis. These issues are compounded by the contrast between Western and Eastern Europe. The only direct gateway from the Mediterranean to global seas within the EU is the port of Algeciras in Spain, where key maritime routes – Gibraltar, the Bosphorus, and the Suez Canal – lie beyond EU jurisdiction. As a result, the EU's inability to exercise its influence in the region translates into a growing dependence on Turkey and Egypt – key partners of the union in the supply of fossil fuels and the "management" of migration flows (Marketos et al. 2022). On the one hand, southern Mediterranean harbours are losing their appeal owing to the Sahara Desert's role in the reduction of transportation links between Northern and sub-Saharan Africa. On the other hand, economic powerhouses in Central and Northern Europe have redirected trade from Genoa and Marseille away from Istanbul, favouring the Rhine axis instead. Frequent tensions erupting among the states located on the east coast of the Mediterranean further contribute to the region's instability. Capasso–Ferragina (2020) observed that the Mediterranean's historical ability to absorb and prevent geopolitical traumas from escalating into full-fledged conflicts has eroded over the last two decades because of the increasing emergence of serious and interrelated regional challenges. The reverb of these shocks reaches all European coasts, albeit to varying degrees, in the form of a migration crisis that, if left unaddressed, could threaten living conditions and safety across the continent. The Mediterranean's

vulnerability to climate change has exacerbated these challenges, and its impact is expected to grow in the coming years.

One of the most notable attempts to address the challenges faced by the Mediterranean region was the establishment of the Euro-Mediterranean Partnership (Marks 1996), following the Euro-Mediterranean Conference of Foreign Affairs Ministers and formalized by 27 states through the Treaty with Declaration in 1995. The primary objective of the Euro-Mediterranean Partnership, as outlined in the Barcelona Declaration (1995), was to "turn the Mediterranean basin into an area of dialogue, exchange and cooperation guaranteeing peace, stability and prosperity" (Council of the European Union 1995), while also pursuing a significant economic goal by establishing a free trade zone in the area through progressive integration. The Euro-Mediterranean Partnership was founded on a set of shared values, including the preservation of the rule of law and the protection of fundamental rights, while also aiming to reduce disparities among countries with direct access to the Mediterranean Sea. In this regard, the French, German, and US governments held different views. Following a heated debate, it was decided that all EU member states would join what later became the Union for the Mediterranean (UfM) to prevent competition with the Blue Banana and other European economic areas.

Exploring spatial autocorrelation in EU RCI 2.0 scores

Moran's index, a pioneering metric introduced by Patrick Alfred Pierce Moran in 1950, is a crucial tool for assessing spatial concentration, shedding light on the intricate dynamics of a quantitative variable across spatially interconnected territories. The term "spatial autocorrelation" denotes the quantification of the interactions between proximate locations in space, and its explanation delves into the extent to which similar or dissimilar values of a given variable group in a geographic space are observable closer together; these spatial patterns may manifest as clusters, dispersion, or random distributions, depending on the set of features. Significantly diverging from its one-dimensional counterpart, the spatial autocorrelation is neither multidimensional nor multidirectional. A key component of its computation is the spatial weight matrix w_{ij}, whose purpose is to identify the neighbouring areas that need to be studied. This matrix plays a critical role in determining Moran's I by regulating spatial autocorrelation and supporting the accurate modelling of spatial relationships.

When conducting a global spatial autocorrelation analysis, a single statistic represents the study area, assuming that the spatial patterns are relatively homogenous across the region; this measure helps to identify whether regions display similar competitiveness scores across the geographic expanse. However, if patterns differ across different locations – meaning competitiveness varies from one region to another – using a single global statistic becomes inadequate. In such cases, the statistics should vary across different subregions to more accurately reflect the spatial

variation. In the absence of global autocorrelation or clustering, local clusters can be identified using local spatial autocorrelation analysis.

Moran's I involves the calculation of cross-products for spatial autocorrelation, forming the basis for a method known as "local indicators of spatial association". Local Moran's I plays a crucial role in this method, measuring the similarity between each spatial unit and its neighbours, identifying statistically significant clusters, and offering a more nuanced understanding of the spatial dynamics of regional competitiveness within the EU.

Building on this foundation, a global Moran's I metric is required to assess the overall spatial autocorrelation across the study area. From the global Moran's I, we obtain the following:

$$I_i = \frac{x_i - \bar{\bar{x}}}{m_2} \sum_{j=1}^{N} w_{ij}(x_j - \bar{\bar{x}}) \quad (1)$$

where:

$$m_2 = \frac{\sum_{i-1}^{N}(x_i - \bar{\bar{x}})^2}{N} \quad (2)$$

- I is the global Moran's I, which measures the global autocorrelation;
- I_i is the local;
- N is the number of analysis units on the map.

From a methodological standpoint, two caveats must be considered before applying Moran's I in any research. First, it should be emphasized that the measure incorporates a spatial distance decay function, in which the influence between two locations diminishes as the distance between them increases. This principle aligns with Tobler's first law of geography, which states that "everything is related to everything else, but close things are more related than far things", (Tobler 1970). Second, islands are not included when computing Moran's I on *neighbourhood-based* spatial weight matrices; this exclusion stems from the statistic's strong reliance on the contiguity of the measured space. Global Moran's I is a measure of the overall clustering of the spatial data and is defined as follows:

$$I = \frac{N}{W} \frac{\Sigma_{i=1}^{N} \Sigma_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\Sigma_{i=1}^{N}(x_i - \bar{x})^2} \quad (3)$$

- N is the total number of spatial units indexed by i and j;
- x is the variable of interest with its average x;
- $\bar{x}$ is the mean of x;
- w_{ij} are the elements of a matrix of spatial weights with zeroes on the diagonal ($w_{ij} = 0$);
- W is the sum of all w_{ij} (i.e., $W = \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}$).

The preceding section provides a mathematical explanation of Moran's I estimate, a vital statistic for determining the mean and variance of the factor under consideration. The calculation begins by subtracting the mean value from each feature value to identify deviation; then, these deviations are multiplied to produce the cross-product for nearby features, which are subsequently summed and integrated into the numerator of Moran's I measure.

The resulting cross-product is positive when neighbouring feature values are either above or below the mean, and negative when one value is below the mean and the other is above the mean. Notably, as the cross-product value increases, the deviation from the mean also increases. A positive Moran's I indicates a tendency toward spatial clustering of values, where high values congregate with other high values, and low values coalesce with other low values. Conversely, a negative Moran's I indicates a proximity between high and low values. When the positive and negative cross-product values are roughly balanced, Moran's I approaches zero. Interpreting the index necessitates consideration of the null hypothesis because the spatial autocorrelation operates inferentially. The null hypothesis for the global Moran's I statistic posits that the distribution of the examined feature across the study area is random, implying that the observed value patterns are a result of spatial randomness.

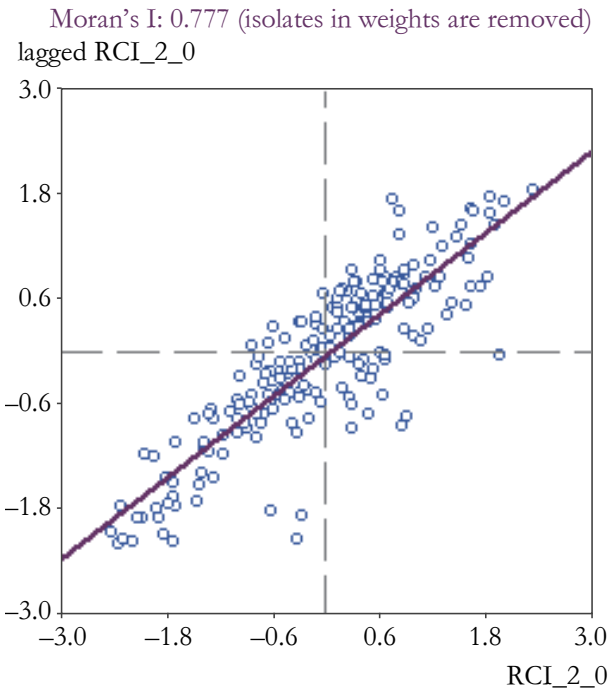
Moran's I has been widely employed in recent European empirical studies to investigate intrastate and cross-country clustering patterns. Among the most popular studies that employ Moran's I, specifically global Moran's I, Shaker's (2015) contribution on the spatial autocorrelation of sustainable development in Europe stands out. At the same time, several studies have linked Moran's I to European regional competitiveness. For instance, Mihaela-Nona et al. (2014) examined the spatial autocorrelation of regional competitiveness in the 42 counties of Romania over the period 2000–2012. Furthermore, Majewska–Truskolaski (2017) explored the spatial autocorrelation of neighbouring states in the EU by analysing the degree of agglomeration of knowledge-intensive services in four Central European countries. A similar attempt to capture cross-country patterns of clustering through Moran's I was made by Arbia–Piras (2004), who investigated trends of GDP per capita convergence in several European regions using spatial correlation methods. This approach was later extended by Smętkowski (2015) regarding regional economic development, and by Vavrek–Benkova (2018) in analysing state economic performance.

One related purpose of this study is to contribute to the existing literature by providing additional evidence on this topic. In applying the model alongside the RCI, we will employ conventional and spatial regression techniques, complemented by quantitative and qualitative analyses, such as descriptive statistics and data visualization. The study focuses on the changes in the RCI 2.0 scores between 2016 and 2022, including its updated version for the year 2023. Notably, RCI 2.0 scores are available exclusively for the NUTS 2 regions of the EU27 (Dijkstra et al. 2023), consequently excluding not only Switzerland, as stated above, but also the United Kingdom from the considered dataset. Furthermore, Cyprus, Ireland, and Malta, being islands, are excluded from the spatial regression analysis to prevent bias in the model outcomes associated with their inclusion in a contiguity-based spatial weight matrix; however, they are included in the descriptive statistics.

The 2022 edition of the RCI 2.0 (EC 2022) highlights significant regional competitiveness disparities across the EU. Annoni–Dijkstra (2019) highlighted a polycentric distribution of competitiveness within the EU, with major metropolitan agglomerations exhibiting robust performance. Nevertheless, significant disparities concerning competitiveness persist between the capital regions and other territorial entities within EU member states. Generally, states with higher competitiveness show lower internal variance levels, with smaller disparities between their capital regions and peripheral areas. In contrast, from 2016 to 2022, states with lower regional competitiveness experienced improvements, whereas transitional regions experienced more pronounced disparities. Notably, advancements primarily occurred in less developed regions, increasingly aligning with the EU average – a trend attributed to the catching up phase observed in developing regions.

Figure 2

Global Moran's I statistics on the spatial concentration of the RCI scores



An analysis of the 2022 RCI 2.0 map of the EU (see in Appendix Figure A1) indicates a concentration of high-scoring regions solely in the northern part of the Blue Banana, with the southern edge of the area (i.e., the Northern Italian regions) lying outside this spatial concentration. Another distinct visible spatial cluster was observed along the Nordic axis, spanning parts of Denmark, Sweden, and Finland. Although several Southern and Eastern European capital regions exhibit high RCI

scores, they remain isolated instances amidst low-scoring regions, in contrast to the larger clusters aforementioned. These observations are corroborated by the local Moran's I statistics (see in Appendix Figure A2), while the global Moran's I statistics (Figure 2) confirm the overall spatial concentration of the RCI scores.[3]

Given the strong interconnection between competitiveness and innovation within the EU, the European Commission, specifically through the Joint Research Center policy reports, has played a crucial role in providing essential insights for identifying the "Current challenges in fostering the European innovation ecosystem" (Nepelski et al. 2017), while also outlining areas where innovation remains a major issue. Therefore, the report identifies as its first priority the "need for an improved innovation performance to boost EU productivity growth", followed by a series of reform proposals in the fields of finance, education, innovation, governance, and social sciences and humanities research.

In reality, the reported lack of productivity growth in several nations and regions can, in large part, be attributed to the stagnation of technological advancement. The modest increase in productivity has been associated with disparities in innovation capacity across EU regions, economic sectors, and businesses within those sectors. It is unrealistic to expect attainment of an equal distribution of innovation across European regions and firms. However, the evident disparities in innovation and productivity performances among regions and firms suggest that new approaches and policy reforms at the national and EU levels will be required to speed up knowledge creation and diffusion and support a wider range of regions and firms.

It is worth noting that the perceptions of R&D initiatives are different across various industries. For instance, in the high- and medium-tech sectors, R&D is often regarded as a crucial competitive advantage. Conversely, in low-tech industries, alternative forms of "non-R&D innovation" (such as capital investments in equipment, which are often spearheaded by high-tech industries) or non-technological innovation (such as marketing and organization changes, as well as social innovation) are frequently the most significant innovation sources.

Nevertheless, irrespective of the industry, the necessity for a robust private research infrastructure can be justified on three grounds. First, it is crucial to sustain Europe's industrial competitiveness and operational efficiency through continuous R&D. Second, a key advantage of R&D lies in its contribution to maintaining and even enhancing the level of educational and practical skills, ensuring stability and averting skill degradation, particularly as technologies evolve and are adopted. Finally, private R&D acts as a vital defence against imminent challenges and disruptions that European society is expected to encounter in the near future. Cohesive responses to challenges in energy, transport, ecological transition, health, social security, and digitalization depend on a solid scientific foundation. This is particularly pertinent

[3] As pointed out earlier in the text, the Moran's I was calculated by excluding some islands because contiguity is crucial in this analysis.

given that these obstacles often present opportunities for further strengthening the European industrial system and creating a community surplus.

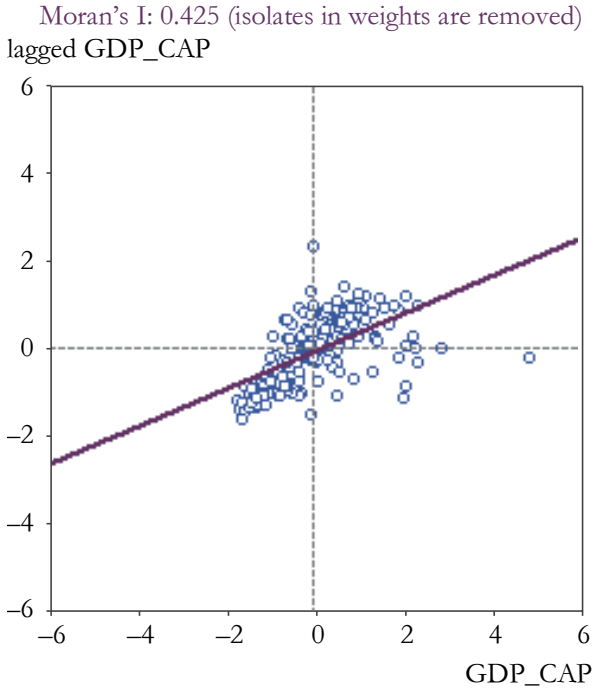
This depiction highlights the significant friction and strain experienced by the border areas of Southern Europe, juxtaposed by a prominent continental ridge cutting through its core. Noteworthy clusters emerge when proximate locations exhibit specific relational dynamics. Although Central Europe plays a pivotal role in the European economy, particularly in trade with the United Kingdom, the southern regions bordering the Mediterranean Sea are characterized by heightened instability; these findings suggest a denser demographic concentration within Continental Europe's Blue Banana.

To delve into the ramifications of these evolving spatial dynamics, standard and spatial regression models are indispensable, with explanatory variables selected based on pertinent literature (as detailed in the subsequent section). When scrutinizing the core correlations of regional competitiveness, two primary factors of production in the global economy – labour and capital – merit consideration. Furthermore, it is valuable to compare these results with the findings of the latest Regional Outlook by the Organization for Economic Co-operation and Development (OECD) (2023), which suggests that disparities between metropolitan and non-metropolitan areas within the member countries account for the most significant portion of regional income inequality. Notably, the report highlights Italy as an exception, "where differences between regions far from midsize/large functional urban areas matter the most".

Although the local spatial concentrations of regional GDP per capita – as the most conventional market economic indicator – show similar patterns to the RCI scores in 2020, as per local Moran's I (see in Appendix Figure A3), the overall concentration is less pronounced (Figure 3). Furthermore, the correlation between the 2020 GDP per capita and the 2022 RCI scores was significantly weaker within the Blue Banana regions than in the rest of the sample (see in Appendix Figure A4). This suggests that the Blue Banana has already reached a high level of GDP per capita, and further growth does not necessarily translate into increased competitiveness. However, it should be noted that this phenomenon is not exclusive to the Blue Banana area. Existing literature shows that the marginal utility of economic growth is diminished in relation to the broader socio-economic performance of countries and regions with high GDP per capita (Abbott et al. 2016, Fuchs et al. 2020, Grasso–Canova 2008, Stewart 2005, Stiglitz et al. 2018). Therefore, it is essential to move beyond the conventional indicators of regional markets and consider other social dimensions to gain a more comprehensive understanding of regional competitiveness. The standard and spatial regression models, which are presented in the following sections, involve proxy explanatory variables aligned with these criteria.

Figure 3

Global Moran's I statistics on the spatial concentration of regional GDP per capita in 2020



Standard and spatial regression modelling on the RCI 2022

After presenting the spatial autocorrelation and some basic correlations of the RCI, we applied regression models to further analyse the determinants of the regional competitiveness scores. Consistent with the findings of Dijkstra et al. (2023) and our earlier observations, the RCI scores display a non-linear (logistic) correlation with regional GDP per capita. Furthermore, there is a linear correlation between the female achievement index (FAI) and employment rates of recent graduates, and a negative linear (or, rather, inversely proportional) correlation with the share of women aged 15–29 who are NEET. For this reason, we also included these (or similar) variables in our model.

To control the independent variables, we included the population size and the employment rate in knowledge-intensive sectors. Additional explanatory variables – included as dummy variables – are the Blue Banana region, the capital region status, and the geographical classification of the regions. As depicted in Appendix Figure A4, the slope of the correlation between RCI and GDP per capita is significantly different

between the Blue Banana regions and the rest of the EU. For this reason, we also include the interaction term as follows:

$$interaction\ term\ =\ regional\ GDP\ per\ capita\ \times BB\ region \quad (4)$$

Table 1 summarizes the variables with supplementary information.

Table 1

Independent variables included in the regression model

Variable	Year	Information	Source
GDP per capita	2020	In PPS, expressed as index (EU27 = 100)	Eurostat
NEET rate	2019–2021 (average)	Share of young people (aged 15–29) not in education, employment, or training; percentage	Eurostat and DG Regional and Urban Policy
Female achievement index	2019–2020 (latest available)	Expressed on a 100-point scale	Norlen et al. (2021)
Population	Latest available	capita	Eurostat
Employment in high tech and knowledge-intensive sectors	2019	Percentage of total employment in NUTS 2 European regions	Eurostat
Blue Banana region	–	Dummy variable	Capoani et al. (2024)
Interaction term	2020	GDP per capita Blue Banana region	Own based on Capoani et al. (2024)
Capital region	–	Dummy variable	own
Western European region	–	NUTS 2 regions of Austria, Belgium, Germany, France, Luxemburg, and the Netherlands; dummy variable and reference category	own
Scandinavian region	–	NUTS 2 regions of Denmark, Finland, and Sweden; dummy variable	own
Mediterranean region	–	NUTS 2 regions of Greece, Italy, Portugal, and Spain; dummy variable	own
CEE region	–	NUTS 2 regions of Bulgaria, Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia; dummy variable	own

The standard model's results (Table 2) indicate that most independent variables are statistically significant, with the exception of the dummy variables of "Scandinavian region", "Capital region", "Blue Banana region", and the interaction term (in the model, "Western European region" serves as the reference category.) These findings imply that the Mediterranean and CEE regions have significantly lower RCI scores than the Western European regions. Moreover, the difference between the Western European and the Scandinavian regions – capital and non-capital regions – and the Blue Banana and non-Blue Banana regions is not statistically significant. Furthermore, the non-significance of the interaction term in the model implies that GDP per capita has not influenced the RCI scores differently in the Blue Banana regions compared with regions outside the area when other control variables are also taken into account. This finding explains the difference between the slopes in Appendix Figure A4, despite the interaction term proving insignificant within the model in Table 2.

Table 2

Standard regression model on the RCI

Variable	Coefficient	Std. error	t-statistics	Probability
Population	1.29949e–06	2.99648e–07	4.33671	0.00002
GDP/cap	0.0862524	0.0295406	2.91979	0.00389
Employment in high-tech sectors	2.22216	0.413064	5.37969	0.00000
NEET	−1.04018	0.12901	−8.06284	0.00000
FAI	0.624316	0.0737973	8.45988	0.00000
Western European region	–	–	–	–
Mediterranean region	−7.74473	1.63295	−4.74279	0.00000
Scandinavian region	−1.41155	2.00044	−0.705619	0.48122
CEE region	−9.9604	1.83205	−5.43676	0.00000
Blue Banana region	6.19356	4.40896	1.40477	0.16158
Interaction term	0.0122351	0.0381889	0.320382	0.74900
Capital region	3.36068	2.07863	1.61678	0.10744
Constant	55.9197	5.36097	10.4309	0.00000

Diagnostics for spatial dependence	Value	Probability
Lagrange multiplier (lag)	17.8884	0.00002
Robust LM (lag)	2.5211	0.11233
Lagrange multiplier (error)	105.1787	0.00000
Robust LM (error)	89.8113	0.00000

The diagnostics for spatial dependence imply that the RCI scores exhibit spatial autocorrelation in the form of spatial error; therefore, the maximum likelihood estimation (MLE) spatial error model may provide better results than the standard model. Similar to the standard model, the MLE spatial error model (Table 3) shows that, in addition to the significant spatial neighbourhood effect, alternative spatial patterns can better explain the territorial concentrations of regional competitiveness outside the Blue Banana area.

Table 3

MLE spatial error model on the RCI

Variable	Coefficient	Std. error	z-value	Probability
Population	1.23221e–06	1.93768e–07	6.35922	0.00000
GDP/cap	0.114196	0.0228759	4.99201	0.00000
Employment in high-tech sectors	2.59748	0.288626	8.99947	0.00000
NEET	−0.695204	0.102653	−6.77238	0.00000
FAI	0.502182	0.0760793	6.60077	0.00000
Western European region	–	–	–	–
Mediterranean region	−6.51205	2.2174	−2.93679	0.00332
Scandinavian region	3.17057	3.66925	0.864092	0.38754
CEE region	−8.38079	2.14413	−3.90872	0.00009
Blue Banana region	4.9846	3.33568	1.49433	0.13509
Interaction term	−0.0237134	0.0260752	−0.909425	0.36313
Capital region	−0.569836	1.42606	−0.399586	0.68946
Lambda	0.819714	0.0355543	23.0553	0.00000
Constant	54.5723	5.12462	10.649	0.00000

Standard and regional correlates of RCI changes between 2016 and 2022

This section of the study investigates the factors influencing changes in the NUTS 2 regional scores between 2016 and 2022, with a particular focus on the correlates of the RCI ratings in 2022. Initially, a baseline model with the same set of variables was used (Table 4). The results show that changes in RCI scores within the Blue Banana area do not substantially differ from those outside the area. Furthermore, variables such as population size, employment rate in high technology and knowledge-intensive sectors, NEET rate, and FAI were found to be non-significant. By contrast, the Mediterranean and CEE regions show notably higher competitiveness growth compared to the Western European regions, whereas the competitiveness scores of the Scandinavian regions have deteriorated considerably. Capital regions have significantly improved their competitiveness scores relative to the non-capital regions. Interestingly, the improvement in competitiveness negatively correlates with GDP per capita, denoting a higher development potential of the less affluent regions compared with the wealthier ones. Nevertheless, this finding does not conclusively indicate the presence of actual regional convergence, a trend likely to be confirmed only by the end of the current decade.

Table 4

Standard regression model on RCI changes between 2016 and 2022

Variable	Coefficient	Std. error	t-statistics	Probability
Population	−7.17668e–08	2.12137e–07	−0.338304	0.73548
GDP/cap	−0.0749841	0.0167379	−4.4799	0.00001
Employment in high-tech sectors	0.168165	0.277235	0.606579	0.54479
NEET	−0.00309764	0.0911961	−0.0339669	0.97288
FAI	0.0157033	0.052045	0.301725	0.76316
Western European region	–	–	–	–
Mediterranean region	11.6018	1.1474	10.1114	0.00000
Scandinavian region	−3.96399	1.4161	−2.79923	0.00560
CEE region	13.4261	1.25977	106.576	0.00000
Blue Banana region	0.47491	0.925498	0.51314	0.60840
Capital region	4.65864	1.47016	3.16879	0.00176
Constant	−1.75867	3.72822	−0.471717	0.63762

Diagnostics for spatial dependence	Value	Probability
Lagrange multiplier (lag)	505.943	0.00000
Robust LM (lag)	7.5710	0.00593
Lagrange multiplier (error)	464.779	0.00000
Robust LM (error)	3.4545	0.06308

Diagnostics of spatial dependence suggest that the MLE spatial lag model yields better results than the standard model. The primary correlations in the spatial model outcomes (Table 5) were almost identical to those in the standard model. However,

it is notable that when accounting for the spatial-lagged scores, the Scandinavian regions did not experience a significantly greater decline in their (relative) competitiveness scores compared with the Western European regions.

Table 5

MLE spatial lag model on RCI changes between 2016 and 2022

Variable	Coefficient	Std. error	z-value	Probability
Population	−3.2873e–08	1.81651e–07	−0.180968	0.85639
GDP/cap	−0.0512023	0.0144718	−3.53807	0.00040
Employment in high-tech sectors	0.266358	0.237402	1.12197	0.26188
NEET	−0.0542209	0.0781125	−0.694139	0.48760
FAI	0.00637212	0.0445856	0.142919	0.88635
Western European region	–	–	–	–
Mediterranean region	7.63519	1.13937	6.70125	0.00000
Scandinavian region	−1.99937	1.25239	−1.59644	0.11039
CEE region	8.26995	1.30961	6.31484	0.00000
Blue Banana region	0.592608	0.802906	0.738079	0.46047
Capital region	2.52607	1.26953	1.98977	0.04662
Spatial lag	0.447494	0.0620533	7.21144	0.00000
Constant	−0.531895	3.19356	−0.166552	0.86772

In summary, standard and spatial regression models suggest a notable improvement in regional competitiveness, particularly evident in certain Mediterranean and CEE regions – notably in some CEE capital regions – over the past few years. This finding aligns with the observations made by Smętkowski (2015) and, more recently, by Dijkstra et al. (2023) regarding the progress of less developed "catching up" regions. Furthermore, it supports the research of Egri–Tánczos (2018) concerning the socio-economic convergence of the CEE regions toward the WE core between 2004 and 2014, as evidenced by GDP per capita and the HDI.

These findings, coupled with the relative decline in RCI scores in the Western and Northern European regions, suggest that the prominence of the Blue Banana area could diminish, especially if the trends observed between 2016 and 2022 persist. However, Northern Italy's Mediterranean location could offer a geographical advantage over the rest of the European Blue Banana, despite its weak performance in employment structure, productivity, competitiveness, and attractiveness (Capoani et al. 2024). The upcoming decade will either confirm or challenge our assessment.

Conclusions

This study aims to provide an overview of the changes and transformations occurring in different EU regions, with a central focus on competitiveness and innovation. Particular attention is given to the Mediterranean and Eastern Europe – two EU macroregions that have faced numerous obstacles to economic prosperity over the modern history of the continent – with a comparative analysis also extending to

patterns in the Western European and Scandinavian regions. In this context, the UfM example offers insight into the steps taken to solve the challenges arising in these complex areas of the globe. This study also examines the factors influencing the recent regional competitiveness scores in a NUTS 2 regional breakdown, as well as the changes observed in the index between 2016 and 2022.

Spatial correlation and regression analysis are subsequently used to investigate patterns and correlates of regional competitiveness in the EU, they are also used to assess whether the traditional Blue Banana area preserves its distinction in terms of geographical variety and economic prosperity within the union. Global Moran's I was used to analyse the overall spatial autocorrelation, which confirmed the strong clustering of competitive regions. The results of the standard and spatial regression models presented in this paper indicate that while the Blue Banana regions still show high regional competitiveness, major advancements in other European regions cast doubt on their sustained dominance.

Furthermore, the paper provides substantial data on EU RCI variation across EU regions. Overall, our findings indicate that most Western European and Scandinavian regions tend to exhibit higher competitiveness levels compared with the Mediterranean and CEE regions. Nevertheless, the recent convergence observed among the NUTS 2 regions of the continental EU over the last decade might gradually undermine the conceptual validity of the Blue Banana. This nuanced analysis sheds light on the multifaceted nature of regional competitiveness and innovation, highlighting the persisting disparities and the emerging opportunities for levelling the economic playing field across the EU. Therefore, policymakers at the regional, national, and EU levels should equally consider the evolving patterns of regional competitiveness to adequately address the socio-economic challenges posed by the restructuring of global economic systems.

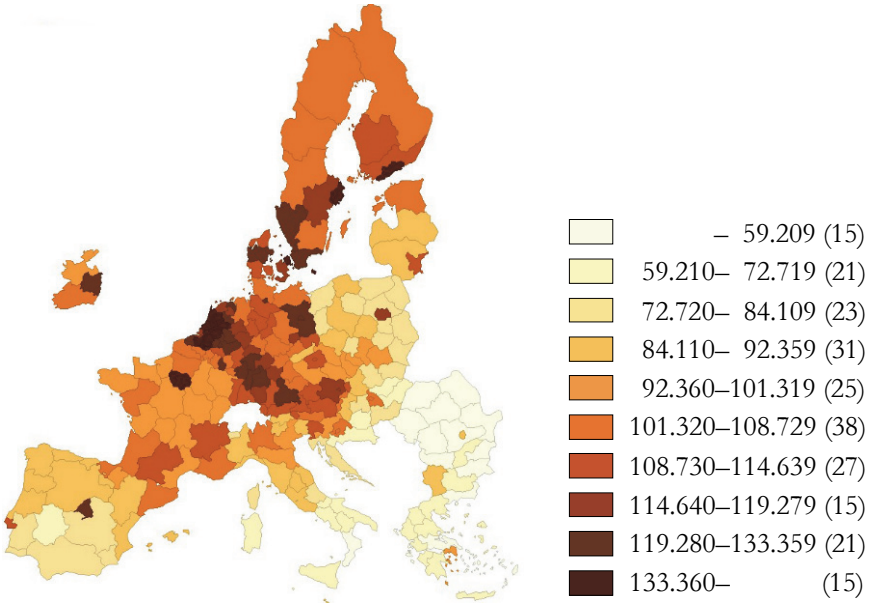
Acknowledgment

This study was funded by the European Union – NextGenerationEU, in the framework of the GRINS – Growing Resilient, Inclusive and Sustainable project (GRINS PE00000018 – CUP H73C22000930001), National Recovery and Resilience Plan (NRRP) – PE9 – Mission 4, C2, Intervention 1.3. The views and opinions expressed are solely those of the authors and do not necessarily reflect those of the EU, nor can the EU be held responsible for them.

Appendix

Figure A1

RCI 2.0 map of the EU27 in 2022



Source: authors' editing based on the EC (2022) data.

Figure A2

Local Moran's I statistics on the spatial concentration of the RCI scores

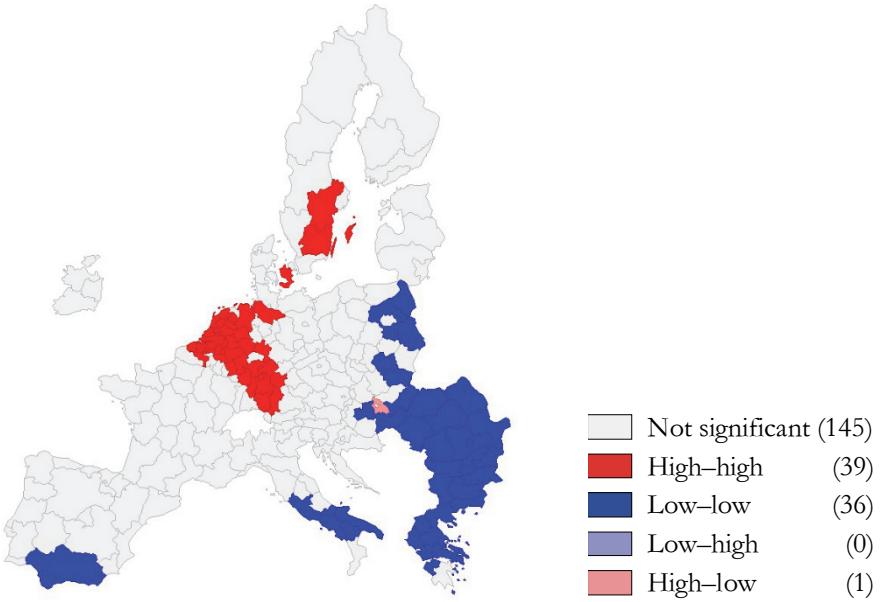


Figure A3

Local Moran's I statistics on the spatial concentration of regional GDP per capita in 2020

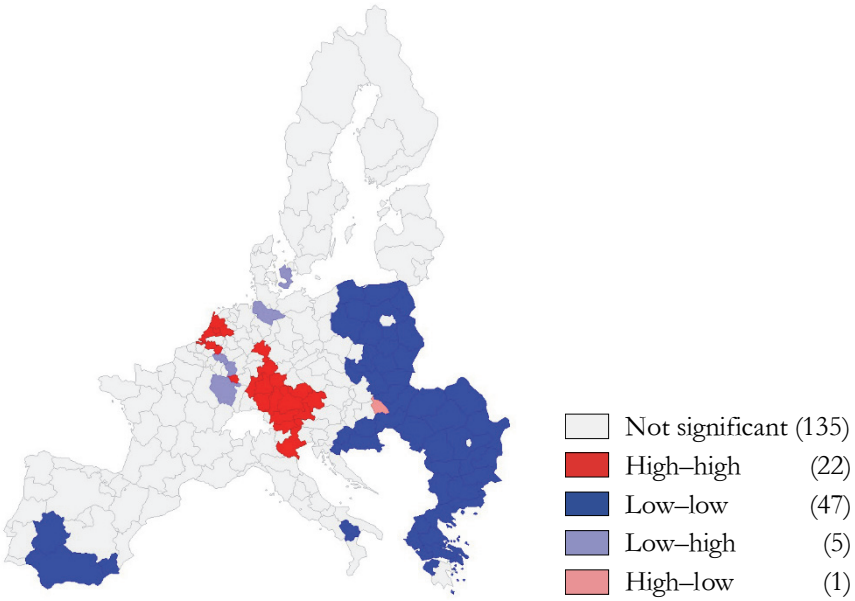
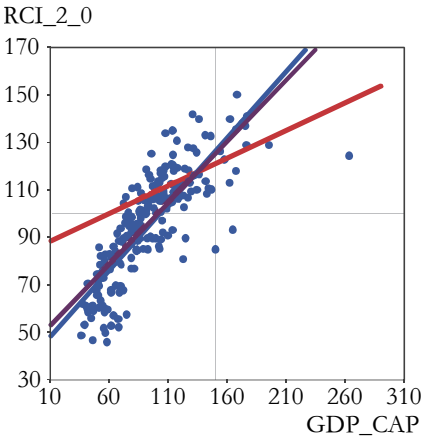


Figure A4

Correlation between RCI and regional GDP per capita among the multitude of 220 continental NUTS 2 regions (in purple), 50 Blue Banana regions (in red), and the rest of the regions (in blue)



	#obs	R^2	const a	std-err a	t-stat a
NUTS 2 regions	220	0.642	48.236	2.621	18.406
Blue Banana regions	50	0.200	86.585	8.180	10.584
Rest of the regions	170	0.716	43.126	2.522	17.103
	p-value a	slope b	std-err b	t-stat b	p-value b
NUTS 2 regions	0.000	0.520	0.026	19.759	0.000
Blue Banana regions	0.000	0.235	0.068	3.468	0.001
Rest of the regions	0.000	0.562	0.027	20.575	0.000

Chow test for sel/unsel regression subsets: distrib = F(2,216), ratio = 20.1404, p-value = 0.000.

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