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A composite policy tool to measure territorial resilience capacity

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ABSTRACT

The 2007–2008 global recession and consequent slow recovery have revealed considerable heterogeneity in economic performance across countries and regions. This study contributes innovatively to existing resilience literature by identifying a life cycle resilience framework and computing a “handy” composite Regional Economic Resilience Indicator. We analyse economic resilience by means of a cluster and exploratory spatial data analysis, revealing well-defined spatial patterns in the EU. National resilience trends dominate in the EU-15, while a more heterogeneous spatial pattern is present in the EU-13. Our findings can support the monitoring of economic resilience at regional level and facilitate a common understanding of this complex and dynamic process for policy purposes.

1. Introduction

In the last decade, the European Union (EU) was hit by the probably worst crisis in its history. The roots of this crisis were the combination of a loss of competitiveness and high indebtedness especially of periphery countries in the European Monetary Union (EMU) [14,28]. Competitiveness, generally conceived as the capacity of countries or regions to produce goods and services that meet the challenge of foreign competition, did not satisfy in many EU countries the sustainability of the balance of payments, worsening domestic real income and labour market conditions.[1] Furthermore, high levels of indebtedness, measured by the debt-to-GDP ratio index, hampered adjustments to taxation and expenditure policies and limited the ability to mobilize resources to offset the adverse shock. The consequent instability, which led to unprecedented turbulence on financial markets, raised a great challenge for the EU and the rest of the world.

In response to the crisis, EU agreed upon a common strategy within the 2008 European Economic Recovery Plan (EERP) [27] that essentially proposes a set of measures to direct short-term actions to reinforcing Europe's competitiveness in the long term, i.e., smart investment for capacity building in order to promote efficiency and innovation. These measures have been included in the EU2020 framework with respect to which Cohesion Policy has been shaped. In view of EU2020 strategy, the capacity of the European regions to react to external shocks is of particular interest because it has a direct impact on the outcomes of European Economic Policy [58].

The crisis spread asymmetrically in time, strength, and speed across EU regions [26]. Not all of them experienced economic decline and the territorial impact of the crisis varied greatly also within the same country [29,54]. Similarly, while some regions experienced a swift return to pre-crisis levels of employment and output, the process of recovery has proved much more protracted for many regions entering a period of sustained stagnation.

The analysis of the capacity of regions to cope and react to an exogenous shock, i.e. their resilience capacity, is generally carried out for specific countries, while few studies consider it for the European regions as a whole.[2] The majority of the latter define resilience according to a single dimension, mainly by examining labour market dynamics (see, for example, Lagravinese [48], Di Caro [20] and Fingleton et al. [34]).

A more comprehensive systemic framework is generally applied at country level, with Briguglio et al. [9] among the first to have

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[1] The most commonly used measure of competitiveness is productivity [11,43].

[2] Among the most recent studies centred on a single country, we can list Martin et al. [57] and Kitsos and Bishop [44] for the UK; Di Caro [21], Sedita et al. [74], Faggian et al. [32] for Italy; Giannakis Bruggeman [36], Psycharis et al. [69] for Greece; Diodato and Weterings [23] for the Netherlands; and Cuadrado-Roura and Maroto [16], Angulo et al. [2] for Spain. Davies [18], Brakman et al. [8] and Marelli et al. [53], Tsiapa et al. [78], Sensier et al. [75] and Rizzi et al. [70] analyse regional resilience at EU level.

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computed a composite indicator of economic resilience for 86 countries worldwide. Attempts have been made to define resilience at regional level by Martin [55], Tsiapa et al. [78] and Sensier et al. [75], but these authors do not synthesize their theoretical framework into a single indicator. On the other hand, Rizzi et al. [70] develop a synthetic regional resilience indicator for the social, the economic and the environmental dimensions, but they do not clearly define a theoretical framework for the variables selection.

In this context, accounting for the importance of a balanced territorial development - one of Europe's core priorities both from the Territorial Agenda 2020 [76] and Europe 2020 strategy - we present a composite policy tool to identify regional economic resilience at EU level.

Focusing on the economic domain of regional resilience, we extend the approach of Martin and Sunley [56] by grouping together into a synthetic indicator three different dimensions of key economic variables, namely GDP per capita, employment, and productivity (Shapley decomposition [81]).

Compared with previous research, we contribute to the current literature because we: i) set up an innovative, systemic resilience framework, ii) identify the main dimensions of regional economic resilience and synthesize them into a single simple indicator, ii) categorise the resilience degree of EU regions, iii) analyse the spatial patterns using various methodological tools, iv) suggest a potential instrument to draw policy implications.

The paper is structured as follows. The theoretical framework is introduced in Section 2. Section 3 discusses data and methodological issues concerning the weighting and aggregation procedures of the composite indicator. Our results are reported in Section 4 and, finally, Section 5 concludes.

2. The resilience framework

Since resilience is a concept used in multiple fields, it has multiple definitions.[3] In the economic field, Briguglio et al. [9] distinguish between economic vulnerability and economic resilience. They define the former concept as the exposure of an economy to exogenous shocks, which depends on permanent or quasi-permanent inherent structural characteristics over which policy makers can exercise limited control. Resilience, instead, is defined as the policy-induced capacity of an economy to withstand or recover from the effects of such negative shocks.

At regional level, Martin [55] identifies four main dimensions of resilience: (i) resistance, which is the sensitivity of regional output and employment to exogenous shock and determines the demand for public policies; (ii) recovery, which measures how fast the region bounces back from a negative shock; (iii) reorientation, which concerns the extent to which a region changes after a shock by switching for example its economic sectoral composition; and (iv) renewal, which is the ability of a regional economy to renew its growth path.

These dimensions are then all covered by Martin and Sunley [56], Diodato and Weterings [23] and Manca et al. [52], who define resilience as the multidimensional capacity of a regional and local economy to absorb shocks, adapt or transit to new sustainable development path.

2.1. The life cycle of economic resilience

Our theoretical framework is closely related to the one developed by Martin and Sunley [55], who first provided a survey of different definitions and elements that constitute regional economic resilience, which is understood as a process. We extend their conceptualization by characterizing resilience as a complex process with a properly defined life cycle and operationalize it using a composite index. We assume that resilient systems develop through stages of a growth path so that their intrinsic characteristics become progressively trapped within a precise

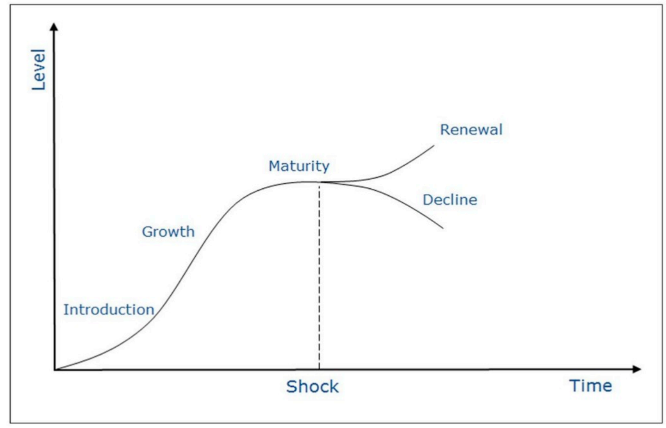

Fig. 1. The life cycle of Resilience.

structure. Differently from the approach of Alessi et al. [1] and Fratesi and Perucca [35], who focus on some individually selected phases of resilience, namely the impact of the crisis, the recovery, the medium-run, and the 'bouncing forward', we build our composite indicator by investigating resilience as a whole system.

We borrowed the product life cycle theory first developed by Raymond Vernon in 1966 [79] in order to conceptualize our framework.

This theory identified four stages, each with its own characteristics crucial for businesses that are trying to manage the life cycle of their particular products. In Fig. 1, we identify and characterize the different steps of a resilience capacity building process following the product life cycle theory's four stages:

- *Introduction Stage* – This stage of the cycle is characterized by a process of learning-by-doing that entails increasing returns to scale for the economy: a proportionate increase in the usual production inputs (labour and capital) gives rise to more than proportionate gains in output [4,51,71,72]. It requires active participation by diverse actors to earn enough in terms of capital accumulation and capacity building to escape from the spiralling mechanism of the so-called 'poverty trap' and accumulate resilience capacity. According to Sachs [73], many factors can contribute to stagnation in a poverty trap, including limited access to credit and capital markets, poor infrastructure, lack of public services and corrupt governance, extreme environmental degradation, etc. Public interventions can help to reverse the vicious cycle.
- *Growth Stage* – The growth stage is typically characterized by a strong growth that benefits from economies of scale. Innovation processes and spill-overs that increase over time, enhancing skill and productivity levels throughout the economy, determine the speed of the growth process and then the slope of the curve of the resilience capacity-building process [47]. During this phase, catching up and falling behind mechanisms operate, giving rise to different levels of development and resilience.
- *Maturity Stage* – During the maturity stage, the growth and capacity building process is close to its steady-state value, and the aim for regional and local authorities is now to maintain the adaptive and coping capacities that they have contributed to building. This stage potentially identifies specific regions with a competitive advantage over others.
- *Decline/Renewal Stage* – Eventually, if a shock hits the economy, two opposite processes may occur. The resilience capacity can start to shrink, and this is what we refer to as the 'decline stage'. This shrinkage may be due to the saturation or inadequacy of that capacity. The alternative can concern the extent to which a regional

[3] See Modica and Reggiani [59] for a review.

economy reacts after a shock and renews its growth path leading to a renewal stage. The capacity to recover built in the first three stages can determine decline, renewal, or eventually a scalloped pattern.

The first three stages (introduction, growth and maturity) are not individually observed, but they pertain to the so-called *slow burning process* [52], which measures the capacity built over time of a region to cope with a shock. During these phases, policy-induced changes can strengthen the resilience capacity of a region. The last stage, decline/renewal, referred to as *shock wave* or *dynamic process*, is based on the immediate exposure to an unexpected shock over which a region can exercise limited control.

2.2. An exploratory investigation

In order to gain a first understanding of the EU NUTS2 regions' pre- and post-crisis performance, we explored the linkages among the growth trends before and after the crisis of some key economic variables i.e., GDP per capita, productivity, defined as GDP per employee and employment rate. GDP per capita “gives important information if we are interested in comparing the economic standard of living across economies with the purpose of implementing distributive policies.” (Paci [66]: 613). The rationale behind our choice of considering productivity is that it provides a general overview of labour productivity, the key factor for lasting growth [46]. The reaction of employment, finally, is claimed by Martin [55] to be one of the more insightful indicators of a regional economy's resilience. If a jobless recovery takes place and continues in the long run, this would determine a mismatch with the output and a persistent inequality.

The three indicators are linked together through the so-called Shapley decomposition method [40,81] to assess the role of each of them in explaining economic growth[4]:

$$\frac{\boldsymbol{Y}}{\boldsymbol{N}} = \frac{\boldsymbol{Y}}{\boldsymbol{E}} \times \frac{\boldsymbol{E}}{\boldsymbol{N}} \tag{1}$$

where $\boldsymbol{Y}$ is GDP, $\boldsymbol{N}$ stands for total population, and $\boldsymbol{E}$ measures number of employees. If full employment is perpetually maintained (i.e., $\boldsymbol{E} = \boldsymbol{N}$) and does not change over time, GDP per capita corresponds to labour productivity.

The time period of the analysis is 2000–2015. Following Crescenzi *et al.* [14], we consider the 2000–2008 interval to compute the trend before the crisis, while the 2009–2015 interval is chosen for the trend after the crisis. Differently from Sensier *et al.* [75], who classify EU regional resilience to several economic shocks since the early 1990s according to per capita GDP and employment measures, we include also productivity because a lasting GDP per capita growth is sustained by labour productivity growth. Conversely, a rising employment rate may hamper GDP per capita growth if not followed by productivity growth.

We classified the 271 NUTS2 regions (see Appendix A for a definition of the European regional system) according to whether they placed above or below the EU average for the three variables.[5] Thus, each of the points in Fig. 2 represents a combination of performance values measured before (x-axis) and after the crisis (y-axis). In order to derive a classification of EU NUTS2 regions with respect to their economic behaviour before and after the 2008 financial and economic crises and the consequent potential for resilience, four different clusters of regions were identified. These quadrants, in anticlockwise order, correspond to:

Fig. 2. Classification of EU NUTS2 over the period 2000–2015.

- Winners (top right) – Regions belonging to this group performed better than the European average before and after the crisis. The crisis hit them, but the economic stability and resilience capacity achieved before the shock occurred helped them to recover rapidly.
- Inefficient process (top left) – The group classifies regions that were unable to recover even if they had experienced a pre-crisis growth trend above the EU average. Many factors can contribute to negatively changing the growth trend e.g., among others inefficient policies, lack of public services, etc. The growth and resilience capacity building process has not reached in the pre-crisis period the critical mass necessary to recover from a negative shock.
- Falling behind (bottom left) – Starting from a position below the European average, these regions were strongly affected by the negative shock and failed to recover.
- Inherent features (bottom right) – Regions in this quadrant were below the European average before the crises, while they were able to react to the crisis efficiently, revealing a post-crisis trend above the European average. We attribute this capacity to recover to some inherent structural characteristics that contributed to changing past trends.

Regarding GDP per capita, regions that performed well before and after the crisis in terms of GDP per capita number 69, around 25% of the total. Only 35 regions are in the “inefficient process” quadrant. Regions are equally distributed in the “falling behind” and “inherent features” quadrants. This means that, of the 167 regions that were declining before the crisis, half of them continued to decline, while half of them experienced growth above the EU average.

Regarding the employment rate, just 39 regions result among the “winners”, while 69 regions, 25%, are in the “inefficient process” quadrant, highlighting that the rise of employment before the crisis was not sustainable. 49 regions belong to the “falling behind” quadrant. 114 regions, around 42%, are placed in the “inherent features” quadrant, showing that the employment trend after the crisis is above the average, while being below it before the crisis.

Regarding productivity, 61 regions continue to register a trend above the average after the crisis, placing them in the “winners” quadrant, while only 30 regions are in the “inefficient process” quadrant. 42% of regions, i.e. 114, appear in the “falling behind” quadrant, highlighting strong issues related to their business structure. There are 66 regions, 25%, in the “inherent features” quadrant.

3. Methodology

Because the resilience of EU regions is a multidimensional complex concept, we propose a composite synthetic regional economic resilience indicator that considers the three variables described above.

[4] The original form of the Shapely decomposition is: $Y/N = Y/E \times E/A \times A/N$, where A is the active population. We used the reduced two-terms decomposition form, i.e. $Y/N = Y/E \times E/N$, because these three variables are generally used to synthetize economic conditions at regional level, and they react rapidly to shocks.

[5] We chose the arithmetic mean as a threshold to split the sample of regions and not the median because outliers were not strongly affecting the distribution so that the arithmetic mean can be used as an adequate position index.

Fig. 3. The Regional Economic Resilience Indicator three-step approach.

To the best of our knowledge, this approach to resilience capacity is innovative since it assesses all the phases of the resilience life cycle in a single indicator.

Weighting and aggregation approaches in composite index construction have been surveyed in detail by Nardo et al. [62]. The Regional Economic Resilience Indicator (RERI) is constructed through a normalization and weight elicitation based on Principal Component Analysis (PCA) that can be applied as a means to reduce dimensionality by transforming the multiple dimensions into a set of a few uncorrelated dimensions. For a robustness check, equal weighting has also been applied. This technique is the approach most commonly adopted, mainly due to the simplicity of the concept, computation and interpretation of selected indicators.

The composite Regional Economic Resilience Indicator to external shocks is defined by two dimensions. The first measures the intrinsic capacity of a region registered over time along its resilient evolutionary path from a base line target point taken as a reference to the measurement period to cope with a crisis and determines its so-called 'slow burning process'. The second dimension, to which we refer as 'shock wave' or 'dynamic' process, enables one to analyse the immediate exposure and reaction capacity to an unexpected shock.

A three-step approach, as illustrated in Fig. 3, was followed to identify regional disparities in the economic resilience capacity to the crisis:

(i) data collection and indicators selection;
(ii) weighting and aggregation;
(iii) clustering and spatial analysis.

3.1. Data collection and indicators selection

This study employs annual data in 2005 constant price euros over the period 2000–2015 from Cambridge Econometrics' European Regional Database (GDP per capita, employment rate and productivity, defined as GDP per employee).

As said, the selection of variables relies on a reduced form of the Shapley decomposition of per capita GDP.

Then, our slow burning and shock wave indicators were selected and built for each variable to match our theoretical framework, as illustrated in Fig. 4 for a hypothetical regional GDP per capita path.[6]

The slow burning indicators cover the evolutionary path towards the first three phases of the resilience life cycle. They are:

- mean over the period 2000–2008 indicates the average level over a particular period of time or in the steady-state behaviour of the system;
- trend over the period before (2000–2008) and after (2009–2015) the crisis[7]: this is the average sustainable rate of growth over a period of time. It is the slope of the line connecting the two points before and after the crisis and measures the steepness of that line and thus the speed of the growth rate The trend over the pre-crisis period, pre-shock dashed line in Fig. 4, is assumed to be the long-run growth trend that a region would have had if the crisis had not occurred. The trend over the post-crisis period - the post-shock dashed line in Fig. 4 - is a proxy for the long-run growth trend as a result of the recovery capacity to the crisis. It considers the growth path towards a renovated resilience life cycle.

The shock dynamic indicators consider the immediate exposure and reaction capacity to an unexpected shock which determine the latest stage of the resilience life cycle. They are:

- the maximum impact of the crisis between 2009 and 2010 compared to 2008 pre-crisis year, as illustrated by the dotted line in Fig. 4, is conceived as the immediate reaction to an unexpected shock;
- the relative change between 2015 and 2008 pre-crisis year, as depicted by the dotted line in Fig. 4, is assumed as the capacity to recover.

The following step consists in the aggregation of the measures created for each variable, GDP per capita, employment and productivity.

3.2. Weighting and aggregation

Two different weighting and aggregation methodologies were used. The first approach relied mainly on Goletsis and Chletsos [37], while the second methodology was based on equally weighting and used, for example, to construct the Regional Competitiveness Index [3].[8]

The first approach consisted of two stages: (a) normalization and (b) weight elicitation.

(a) Normalization of the data helps to i) remove the different scale of each variable, and ii) identify indicators that may be positively correlated with the phenomenon to be measured, whereas others may be negatively correlated with it.[9] There are different methods of normalization, such as ranking, re-scaling (or min-max transformation), standardization (or z-scores) and indicization. As suggested by Goletsis and Chletsos [37], we made use of the min-max transformation. Consider the hth indicator I for region i, I_{hi} is transformed to I_{hi}^{std} taking values within the interval [0,1] according to the following equation:

$$I_{hi}^{std} = \frac{I_{hi} - \min_i(I_{hi})}{\max_i(I_{hi}) - \min_i(I_{hi})} \quad (2)$$

(b) A multivariate method usually applied for space reduction, namely the Principal Component Analysis was used for weight elicitation. PCA, first introduced in 1901 by Karl Pearson [68] in mechanics, was later labelled by Harold Hotelling in the 1930s [42]. PCA has been extensively applied for the creation of synthetic indicators. To recall some influential studies, Noorbakhsh [63] introduced a Modified Human Development Index where weights were determined through PCA. Klasen [45] set up a Composite Deprivation Index accounting for various dimensions and weighting them using PCA. Haq and Zia [41] adopted an analogous approach to construct a composite index of human wellbeing by employing objective and subjective indicators of quality of life for developing countries. Regarding the European context, Annoni *et al.* [3] applied a PCA to build the EU Regional Competitiveness Index v.2016 (RCI), which measures the different dimensions of competitiveness for NUTS2

[6] Table B1 in Appendix B synthesizes definitions and rationales for all the variables used for the indicator construction.

[7] The trend has been computed as follows: i) we regress the time period on the log of the selected variables, and ii) we keep the coefficient associated with the log of the selected variables. If it is positive (negative) and significant, this means that the slope rises (falls). If the coefficient is zero or not significant, the trend is not statistically different from zero.

[8] The weighting scheme of the EU Regional Competitiveness Index (RCI) is more complex because it is based on z-scores normalization procedure and weighted arithmetic mean where the weights are the region's stages of development.

[9] This step is required in order to ensure that an increase in the normalized indicators corresponds to an increase in the composite index.

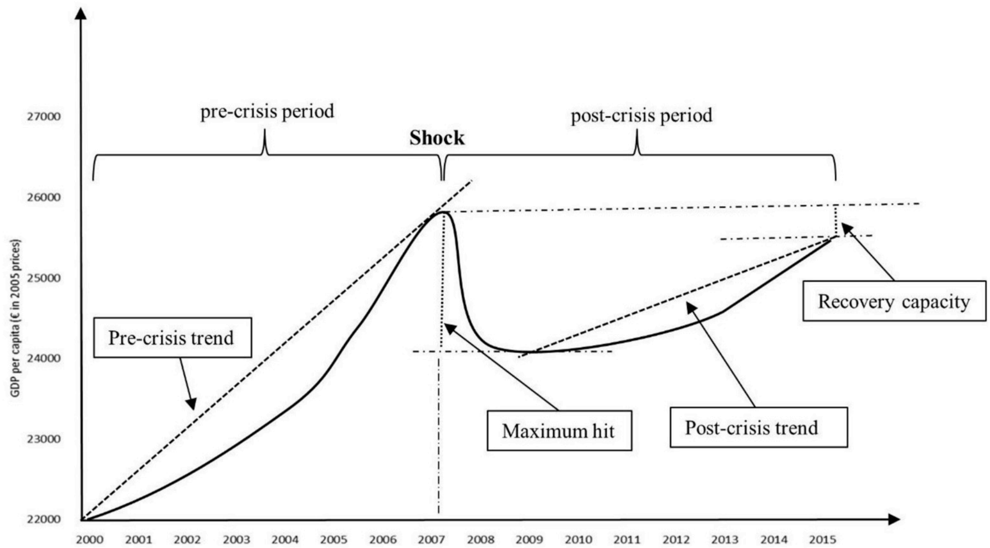

Fig. 4. Components of the Resilience Economic Regional Indicator.

regions. The European Commission [30] has adopted the same approach for the EU Regional Social Progress Index, which captures the society's capacity to fulfil basic human needs, to establish the foundations of well-being, and to create opportunity.

PCA aggregates sub-indicators that are collinear into new ones named 'components', which are able to capture as much of common information of those sub-indicators as possible. PCA determines the set of weights, which explains the largest variation in the original data. Another advantage of PCA is that the largest factor loadings are attributed to the sub-indicators that have the largest variation across countries. Among the disadvantages, it is particularly sensitive to data modification, to the presence of outliers and small-sample issues. Furthermore, correlations do not necessarily track the real influence of the sub-indicators on the phenomenon under analysis [62].

Different criteria can be applied in the selection of components in order to maintain the maximum of information. We kept the components that contribute cumulatively to explain more than 70% of the total variance of the data. The selected components were then used for the aggregating procedure to ensure that the variables used were not correlated.

Weights were estimated as normalized squared loadings (implying the portion of variance of each component explained by each variable). We applied the approach which uses highest loading per variable weighted according to the relative contribution of the respective component to the explanation of the overall variance. The indicator was aggregated through the following weighted additive function:

$$RERI_i = \sum_h w_h I_{hi}^{std} \tag{3}$$

where $RERI_i$ is the Regional Economic Resilience Index for region i, w_h is the weight of indicator h and I_{hi}^{adi} is the adjusted value of indicator I_h for region i.

The alternative equal weights approach, shares the normalization procedure with the first one explained above, while it differs for the weight elicitation. All variables have equal weight, and they are aggregated through an arithmetic mean.

3.3. Clustering and spatial analysis

The overall objective of clustering is to identify regions with shared resilience features and, therefore, strategic geographical and thematic areas of intervention for policy makers.

Hierarchical clustering is applied to a distance matrix computed by using a Euclidean criterion in order to group together regions that share similar resilience capacity. The cluster analysis was performed by following the Ward squared (Ward^2) method proposed by Ref. [61] to identify the clusters of regions that share a similar pattern. The Ward^2 method is hierarchical agglomerative and begins the analysis with as many groups as there are units. Groups are then formed ascendingly from these initial units. At each stage, the two clusters for which there is the smallest increment in the total value of the sum of the squares of the differences within each cluster are grouped. The goal of Ward^2's method is to create homogeneous clusters, i.e. with as little as possible within cluster variability. This hierarchical agglomerative method can be drawn as a dendrogram, a visual tool that helps to identify the groups that best represent the data structure. A general rule of thumb is that clustering is performed where significant gaps exist in the dendrogram.

The second step was to analyse the global and local spatial dependence.

Global spatial dependence was identified by means of Moran's I (*MI*) [60]. This statistic has been widely used in the literature to describe economic phenomena whose distribution in space is not random [17,24,37,48].

The *MI* relates the value of a selected variable with the values of the same variable in the neighbour areas, namely its spatial lag. The intuition is that socio-economic phenomena may be not isolated in space and what is happening in a certain location may be correlated to what is happening in the neighbouring locations. The formal definition of this relation is as follows:

$$MI = \frac{N}{\sum_i \sum_j w_{ij}} \times \left[\frac{\sum_i \sum_j \boldsymbol{w_{ij}(x_i - \bar{x})(x_j - \bar{x})}}{\sum_i \boldsymbol{w_{ij}(x_i - \bar{x})}} \right] \tag{4}$$

where N is the number of regions indexed by i and j, x is the variable of interest; $\bar{x}$ is its mean, and w_{ij} is an element of the spatial weights matrix W, s where each pair of regions are identified by 1 if neighbours, and 0 otherwise. Then, as customary, the matrix is standardized by row.

The calculated *MI* for global autocorrelation, in the case of W standardized by row, varies between -1 and 1. A positive coefficient points to positive spatial autocorrelation, i.e., clusters of similar values can be identified. The reverse represents regimes of negative association, i.e., dissimilar values clustered together in a map. A value close to zero indicates a random spatial pattern.

A precise evaluation and spatial identification of the levels of local spatial autocorrelation are achieved by the Local Moran. The Local

Moran makes it possible to identify the clusters of "spatial outlier regions", i.e., the statistical hotspots and coldspots, the areas with a concentration of regions with high levels and low levels of resilience, respectively. This is possible because the Local Moran is able to identify for each region an indication of significant spatial clustering of similar values around that observation. Furthermore, the sum of the Local Moran for all observations corresponds to the global indicator of spatial association, the Moran's I ([13] p. 71 [49]; p. 129).

The local version of Moran's *I* statistic is a LISA and expressed as follows:

$$I_i = (x_i - \bar{x}) \sum_j w_{ij} (x_j - \bar{x}) \sum_i \sum_j w_{ij} \quad (5)$$

Finally, given that the local Moran I_i is not approximately normally distributed, a conditional randomisation or permutation approach is used to yield empirical pseudo significance levels.

4. Results

4.1. The Regional Economic Resilience Indicator

The RERI for 271 NUTS2 regions was constructed considering the two different aggregation procedures illustrated above. Since the correlation between the two approaches is very high, we only report the results based on the first approach.[10] PCA estimated the weight values for the 15 selected indices.

PCA variance is reported in Table C1, and variable loadings and weights in Table C2 in the Appendix. The identified components account for approximately 77.2% of total variance (last row of Table C1). The weight associated with the slow burning process, in the last column of Table C2, is equal to 0.53 against 0.47 of the shock wave. This means that, in construction of the indicator, these two components have equal significance (see Ref. [64]: 10).[11]

In regard to the relative weights of each component of the Shapley decomposition, the weight of the employment rate, obtained by summing each sub-dimension,[12] is 0.57 and it has the highest value in the pre-crisis and maximum hit axis. GDP per capita has a weight of 0.26, followed by productivity with a weight of 0.17. These results show that employment is the most significant component of the indicator, followed by GDP per capita and then by productivity.

Fig. 4 shows the spatial distribution of the Regional Economic Resilience Indicator by decile. The Regional Economic Resilience indicator has been normalized and varies between 0 and 1, where the smaller values (lighter) represent the less resilient regions, and the higher (darker) values the most resilient regions.

As expected, the consequences of the crisis were not uniform among EU regions.

Evident territorial patterns can be observed:

- Generally, common national trends are observable mainly in the EU-15. Mediterranean countries were characterized by slow growth of the selected indicators before and after the crisis, while Germany and Northern countries experienced strong growth and resilience capacities. Baltic countries were registering rapid growth in the pre-crisis period and, in spite of the economic collapse, they were able to recover;
- Italy, Spain and Belgium show a north/south regional divide that often depends on historical factors[13];
- In the countries where NUTS2 regions have a finer resolution, i.e., Germany, Great Britain, Belgium, Austria, Hungary, Slovakia, Czech Republic and Romania, cities show a resilience higher than that of the surrounding regions. By contrast, Dijkstra et al. [22], conclude that capital metro regions under-performed compared with the national economy in the EU-15 as a consequence of the crisis. The different results can be imputed to the analysis technique, but also to time period sample. Dijkstra et al. [22], in particular, stop the analysis at 2011.

Table 1
Regional Economic Resilience Indicator by country.

Country	Average	Std. Dev.	Country	Average	Std. Dev.
	EU-15			EU-13	
AT	0.585	0.084	BG	0.403	0.179
BE	0.392	0.146	CY	0.281	–
DE	0.658	0.089	CZ	0.610	0.134
DK	0.534	0.128	EE	0.735	–
EL	0.105	0.071	HR	0.265	0.020
ES	0.290	0.131	HU	0.480	0.211
FI	0.528	0.160	LT	0.789	–
FR	0.381	0.080	LV	0.710	–
IE	0.595	0.204	MT	0.652	–
IT	0.307	0.158	PL	0.475	0.108
LU	0.874	–	RO	0.507	0.102
NL	0.564	0.066	SI	0.488	0.108
PT	0.368	0.061	SK	0.603	0.275
SE	0.612	0.082			
UK	0.591	0.078			
EU-15	0.477	0.192	EU-13	0.507	0.167
EU-28	0.483	0.187			

Note: average and std. dev. are based on NUTS-2 data. Std. dev. is not reported for Luxemburg, Cyprus, Latvia, Lithuania, Estonia and Malta because these countries are composed by only one NUTS2 regions.

Table 1 reports average and standard deviation values of the RERI. Countries are grouped into the EU-15 and EU-13, i.e., Member States that joined before and after 2004, respectively, and they are ranked in decreasing order according to their average resilience value. EU-15 countries were relatively less resilient to the crises and exhibited stronger variability from the group average than EU-13.

Regions tend to be centred on national averages in EU-15, with the exception of Italy, Spain and Ireland, while in the EU-13, all countries except Croatia have a quite high variability.

4.2. Clusters and spatial pattern analysis

Fig. 6 shows the results of the cluster analysis; the number of regions belonging to each cluster is reported in brackets. Table C3 in Appendix reports average values of the Regional Economic Resilience Indicator and sub-indexes for each cluster. According to the dendrogram analysis, four clusters can be easily distinguished[14]:

1. 50 regions across Greece, Spain and the South of Italy were the least

[10] The correlation between the two indicators is 94%.

[11] The weights are linked with the significance of each component and not with the relative importance in the indicator [5]. Nardo et al. [62] highlight that weights must be perceived with a compensability logic, and that, in additive aggregations, they have the meaning of substitution rates. Decancq and Lugo [19] provide an interesting overview, in this regard.

[12] mean Employment 2000–08 + trend Employment 2000–08 + trend Employment 2009–15 + fall Employment 2008–10 + recovery Employment 2008–15 = 0.180 + 0.010 + 0.106 + 0.165 + 0.109 = 0.570.

[13] See Federico et al. [33] for Italy, Tirado et al. [77] for Spain, and Buyst [10] for Belgium.

[14] The Cophenetic Correlation Coefficient (CPCC), which computes the correlation between distance values calculated during dendrogram building and the observed distance, is a measure for the quality of the hierarchical structure. A value close to 1 indicates a good fit of hierarchy to the data. CPCC for Ward's^2 method is equal to 0.7309. Compared to other methods, it has the best value (for single linkage the value is 0.5873, for complete linkage 0.6250, for Ward's method 0.5879, for median 0.6323).

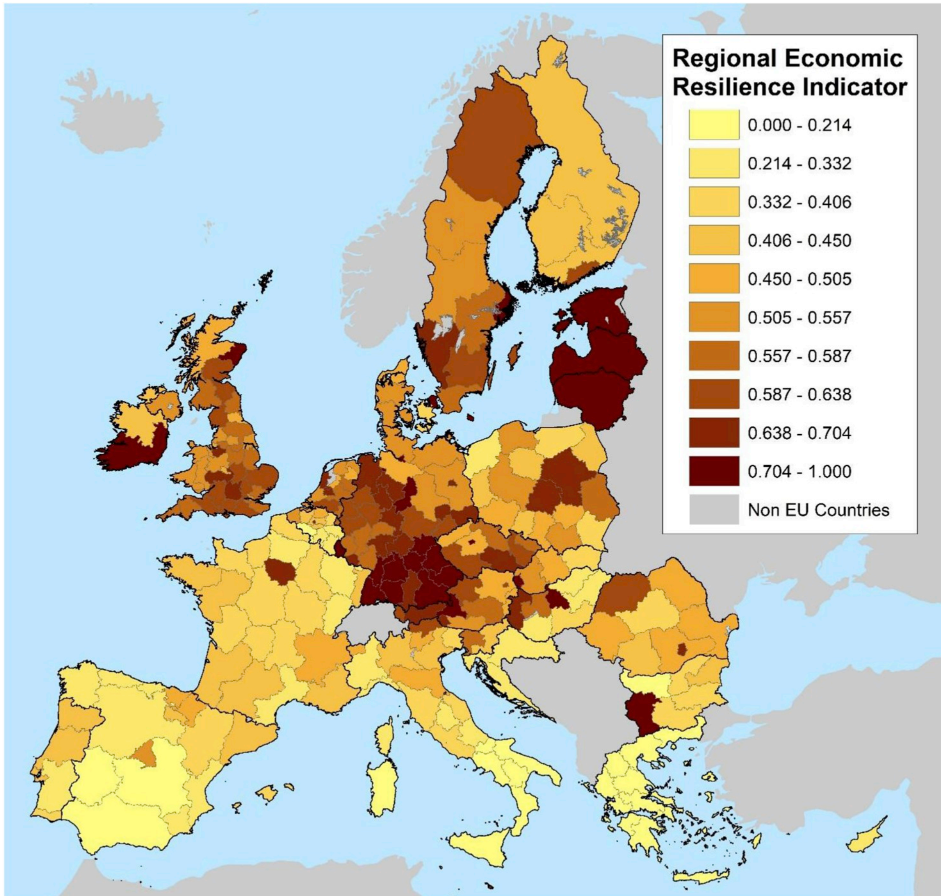

Fig. 5. Regional Economic Resilience Indicator over the period 2000–2015 by NUTS2.

resilient to the crisis (lighter blue). The group was hit strongly by the crisis and had experienced the worst growth in the pre-period crisis which led to the worst recovery. In 2015, the cluster did not recover to pre-2008 levels.

2. 62 regions are characterized by a low ability to cope with the financial crisis. They belong to France, Finland and Eastern countries. The cluster was the second hardest affected by the shock and was still registering a low growth capacity before the crisis. GDP per capita returned to pre-crisis level mainly sustained by productivity growth. Regions belonging to this cluster demonstrated greater efficiency in recovering and overcoming pre-crisis productivity levels.
3. 108 regions, mainly in Germany, Sweden, Great Britain and Eastern countries demonstrated a moderate resilience capacity. The 2008 crisis did not severely impact on the cluster and since it was reaching high levels of growth before the shock, regions in that cluster recovered pre-crisis GDP per capita and productivity levels.
4. 51 regions ranked as the most resilient (darker purple). They are mainly in Germany and the Baltics. The cluster was the one less hit by the 2007–2008 global crisis, and regions belonging to it were on average able to recover in each of the three components examined.

Capital regions tend in general to be more resilient than the overall country to which they belong. A U-shape spatial pattern is also evident in the figure below. In Middle Europe, medium-high resilient regions surround resilient regions in the North-East while medium-low ones form a corridor around non-resilient regions in the South-West. EU-13 exhibits a higher spatial variability than EU-15.

Spatial pattern analysis is based on a row standardized contiguity matrix W, where the four nearest regions are considered neighbours. The results are robust to the specification of other contiguity matrices. Through the mean of the Anselin global Moran's I, which accounts for spatial autocorrelation, we measured the presence of spatial clusters of regions sharing a similar value of economic resilience. The existence of spatial clusters is due to externalities that consist in the influence that a region has on the neighbours as a consequence of various factors such as commuting, share of technology, trade, migration, and a set of intangible assets. A region can gain advantage or disadvantage from the externality if i) it is surrounded by resilient or non-resilient regions and ii) it has the capacity to be permeable to a positive environment and impermeable to a negative one. To be noted is that Moran's I is equal to 0.60. The Moran scatterplot map [39] in Fig. 7 allows us to visualize well-defined and generally homogeneous regional patterns: around 82% of regions are high (low) resilient regions surrounded by high (low) resilient regions. High resilient regions surrounded by high resilient regions are present mainly in Germany, Great Britain, Sweden and the Baltics. Low resilient regions surrounded by low resilient regions pertain to Greece, Spain, Portugal, France and Italy. Regions in EU-13 countries confirm the heterogeneous spatial patterns.

The local Moran significance map in Fig. 8 identifies the statistically significant spatial clusters of resilient and non-resilient regions. The divide within countries shown in Fig. 3 is only partially confirmed, highlighting the importance of using statistical tools to identify clusters.

Southern regions of Italy, Spain and Portugal and Greece belong to the group of 'coldspot' regions. The statistically significant spatial cluster of resilient regions is located in Latvia, Southern Denmark, central and southern Germany, the northern region of Sweden, and around London.

The analysis carried out in this section evidences that, generally, regions belonging to EU-13 countries show greater heterogeneity in their resilience capacity, while EU-15 countries, on the other hand,

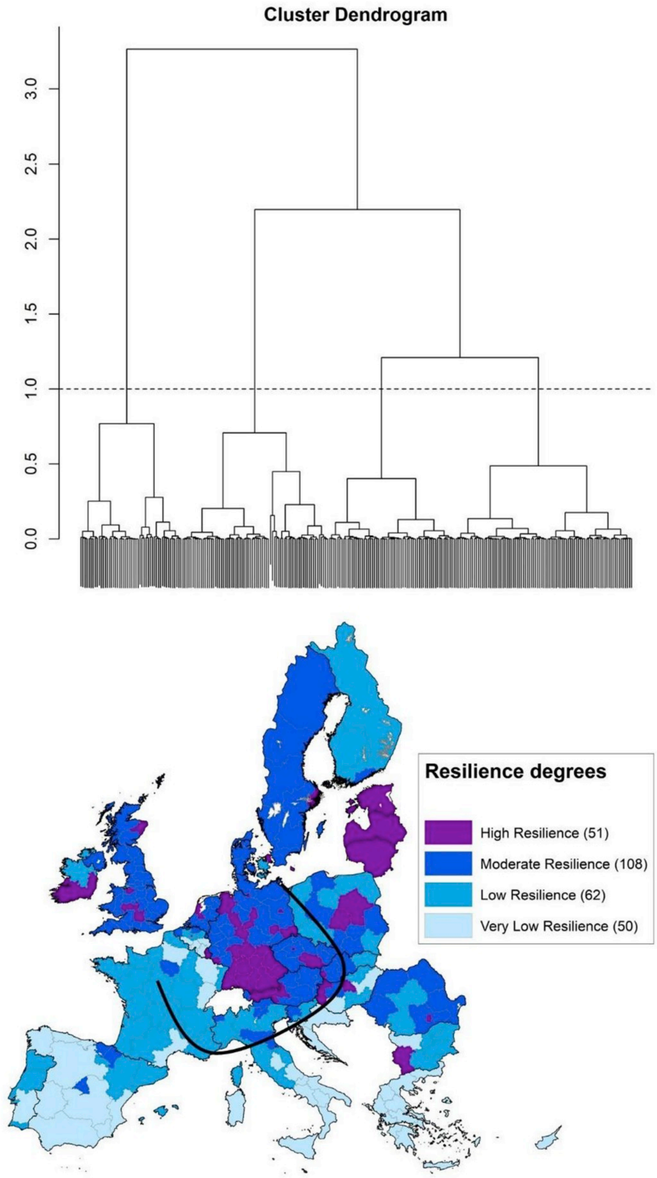

Fig. 6. A four cluster grouping of NUTS2 regions.

present more uniform clusters between moderate and non-resilient regions. In this regard, Moran's I for EU-13 is equal 0.13, and for EU-15 to 0.74. The EU enlargement to New Member States and the convergence process to common living conditions and regulatory framework is at work, but large differences in the economic structure of EU-13 countries compared to EU-15 ones still persist. The structural differences between the two groups are highlighted by Paprotny [67], who stresses that communist states were closest to the West in the 1960s–early 1970s and made little progress thereafter. He observes that, today, the main lag compared with highly developed 'benchmark' states is in GDP per capita, while for other social indicators the lags are lower. Borsi and Metiu [6] confirm this result on analysing 27 EU countries, showing that there is no overall economic convergence and that there is a clear separation between the EU-13 and EU-15 in the long run, with persistent cross-country real income per capita differences. In the EU-13, the territorial heterogeneity does not concern only the Regional Economic Resilience Indicator. EC [30], for example, highlights that the proportion of people at risk of poverty or social exclusion in rural areas and cities is quite similar in the EU-15 (24% and 21%, respectively), while in the EU-13 it is higher in rural areas than in cities: it reaches 34% in the former and 20% in the latter. The same applies to severe material deprivation. These differences are probably rooted in the dynamics of income convergence across regions that, according to Crespo Cuaresma et al. [15], was concentrated in regions with urban agglomerations in the EU-13. This phenomenon has been interpreted by the authors as confirmation of the Williamson hypothesis [80], i.e. in an early stage of development, economic growth is concentrated in few poles corresponding to urban agglomerations.

In EU-15, the spatial homogeneity (see Figs. 5–7) shows that resilience tends to have a national dimension. A region nested in a country moves together with the other regions in that same country. Furthermore, regions in the Mediterranean countries are the least resilient. This goes beyond the core/periphery pattern identified by Dall'erba [17] for GDP per capita in 1989 in the EU-15. Interestingly, while Dall'erba identifies a core/periphery spatial pattern for EU regions, we find it for countries as well. This has important implications in terms of governance because it means that the national context is able profoundly to affect regional performances positively or negatively.

On the other hand, in the EU-13, the spatial autocorrelation is very low, highlighting the regional dimension of resilience. This has mainly an urban dimension for the three measures used in this study: GDP per capita, productivity and employment rate [22].

5. Conclusions

The RERI is a tool that accounts for several components of economy-related resilient capacity and combines them into a comparable, synthetic and easily understandable measure. Compared with the studies examined above, which aimed to provide a useful taxonomy of economic vulnerability and regional resilience and to test the relation between regional performance and crisis-resistance and national macroeconomic conditions, our Regional Economic Resilience Indicator defines the resilience life-cycle and monitors the regional degree of economic resilience capacity. Our approach suggests that the complexity of the resilience framework can be handled by accounting for standard economic variables and adopting a canonical methodology, i.e. the Principal Component Analysis for indicators' construction. Its relative computational simplicity is also chosen to yield broader understanding and allow replicability exercises.

Our main results show that national resilience trends dominate in the EU-15, while in the EU-13, a more heterogeneous spatial pattern is apparent. Capitals are generally more resilient than the surrounding regions. Finally, the analysis shows that the resilience capacity of a region is closely related to that of the surrounding regions. This confirms the limitations of national-level analyses in favour of a more territorially oriented debate.

However, our analysis shows that the national dimension still plays a strong role in shaping regional resilience, because regions tend to be affected by common institutional and legal frameworks, structural policies, etc. Lack of competitiveness, huge debt, heavy borrowing and large exposure to financial markets plunged Greece into a recession deeper than in many other European countries. Similar factors affected with a more smoothed strength the economies of Italy, Portugal and Spain, but the effects were not uniform across regions, with some of them showing much lower resilience. A combination of strong economic activity, more stable public finances, and a favourable political environment helped Germany to recover faster. This is particularly true for the EU-15, where the correlation between our Regional Economic Resilience Indicator and the European Quality of Government Index (EQI) developed by Charron *et al.* [12] reaches 0.70.[15] For the EU-13,

[15] The EQI combines data at regional and national levels regarding services which are generally provided by public institutions (education, health care, etc.). Since EQI is computed at NUTS1 level for Germany, Belgium, Greece, Sweden and Great Britain, we take the average at NUTS1 level for these countries to allow comparability with our RERI.

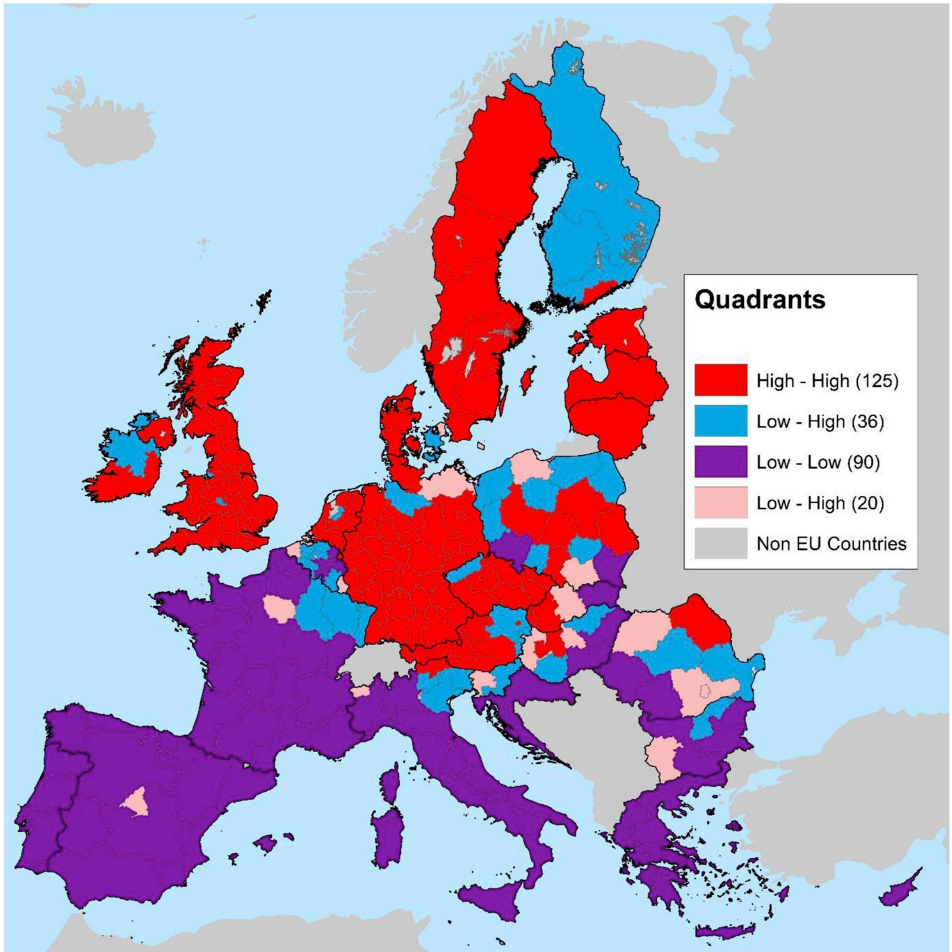

Fig. 7. Moran scatterplot map.

the correlation is 0.20, highlighting that regions at a lower stage of development are probably less affected by institutional factors in their resilience path. Overall, the correlation is 0.36.

The identification of the regionally differentiated effects of the shocks requires explanation of the results in terms of their determinants, including economic, institutional and social factors [56].

Martin [54], Fingleton et al. [34] and ESPON [25], explain the different degrees of regional resilience through several common economic channels, among which the most important are: the sectoral composition of the economy, export-oriented enterprises and their capacity to innovate, and the skills of the workforce. The importance of a favourable business environment is attested by the close correlation with the EU Regional Competitiveness Index v.2016 developed by Annoni et al. [3], which has been computed at around 68% for the whole EU. As regards the EQI, the correlation is higher for the EU-15 than for the EU-13: 0.85 and 0.60, respectively.

Institutional aspects, originally not considered a completely satisfactory explanation for the existence of regional disparities [65], have recently become key explanatory factors [7]. Our results, on the other hand, tend to support the position of Boschma for countries with historical well-grounded territorial development gaps such as Italy, Spain, Portugal and Germany.

Regional social aspects are less correlated with resilience. The correlation with the Social Progress Index, is equal to 48%. As for both the EQI and RCI, the correlation is higher for the EU-15 than for the EU-13: 0.75 and 0.41, respectively.

These findings, in light of the Cohesion Policy centred on a general integrated and inclusive territorial approach, suggest that policy measures to enhance resilience capacity should consider the systemic structure of EU-15 countries where, despite well-targeted interventions in the past, historical gaps persist. In the EU-13, regionally targeted policies should be adopted to deal with the stronger heterogeneous resilience. Moreover, spatial spillovers originating from capital regions, which enhance the competitiveness of the neighbouring regions and entire countries, should be promoted as potential drivers of regional resilience [30].

A natural extension of the proposed Regional Economic Resilience Indicator is its application to crises that occurred in the past to investigate the evolution of regional resilience within the EU. Furthermore, our approach could be applied to other regional contexts. An example is analysis of economic resilience within regions of the USA, which were first and deeply hit by the worldwide crisis. Alternative interesting applications could be to regions of developing countries affected by the end of the raw-materials super cycle. In both cases the RERI could yield intriguing insights by adopting a spatial perspective.

In the EU context, the examination of economic resilience within smaller territorial units, e.g. NUTS3, could be let to future researches. Following Crescenzi et al. [14] and Fratesi and Perucca [35], among others, investigation could be made of the structural characteristics that determine regional resilience in the EU.

Furthermore, we have demonstrated that the resilience cycle as a whole warrants attention. Nevertheless, it is evident that if a single phase of the resilience process is under investigation, the approach of keeping the sub-indicator components separate, and then again decomposing the indicator, may be preferable. Finally, the framework built behind our Regional Economic Resilience Indicator could be applied in diverse territorial contexts making it possible to reorient policy and financial resources to maximize their returns accordingly.

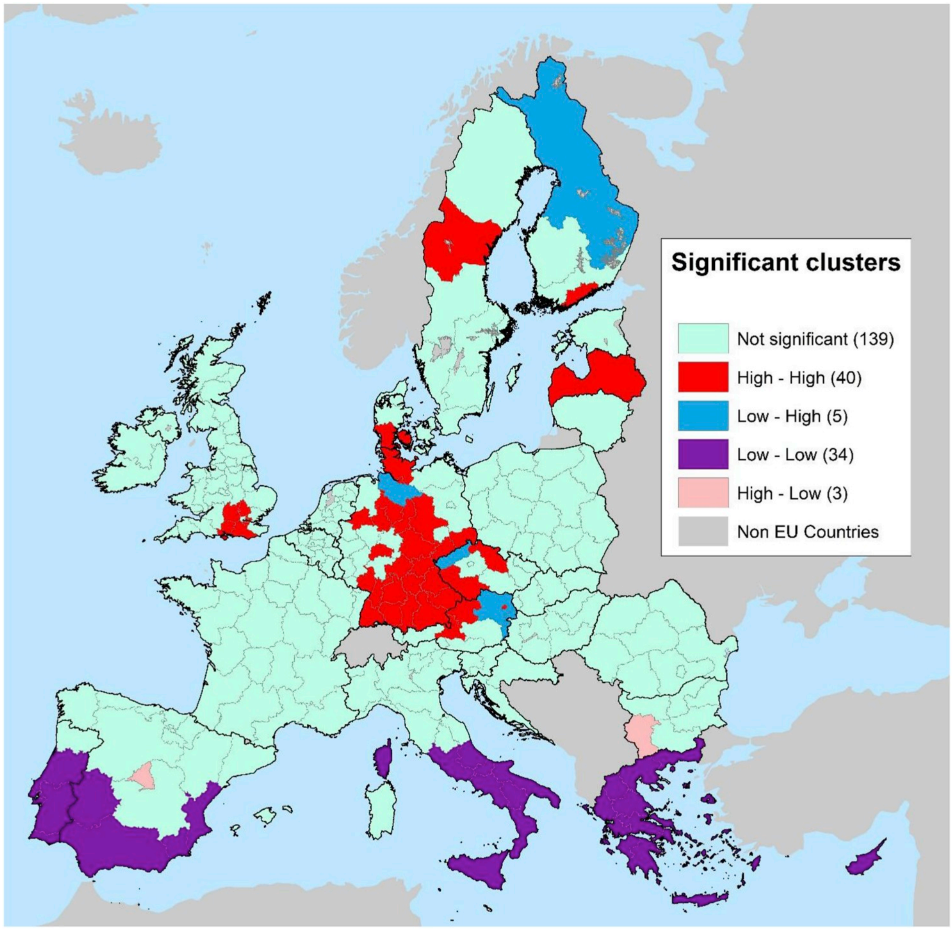

Fig. 8. Moran significance map.

Disclaimer

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

Appendix A. definition of the Nomenclature of Territorial Units for Statistics

The Nomenclature of Territorial Units for Statistics (NUTS) classification was adopted in 2003 by the European Parliament and Council Regulation. For each EU member country, a hierarchy of three NUTS levels, namely NUTS1, NUTS2 and NUTS3, is based primarily on the institutional divisions currently in force in the Member States. NUTS1 level identifies macro areas within each country (i.e. central part, eastern part, southern part, etc.). NUTS2 is linked to regional administrative areas (*länder* in Germany, *régions* in France, *comunidades autonomas* in Spain, *regioni* in Italy, etc.). This level is the basis for the application of regional policies and for the analysis of subnational territorial dynamics by Eurostat and national authorities. The last level, NUTS3, is composed of small regions for specific diagnoses (*kreise* in Germany, *départements* in France, *provincias* in Spain, *provincie* in Italy, etc.).

Because the NUTS classification is based on institutional divisions, regions do not have homogeneous areas. Nevertheless, the NUTS regulation established the minimum and maximum thresholds for the population size of the NUTS regions: NUTS1 between 3 and 7 million, NUTS2 between 800,000 and 3 million, NUTS3 between 150,000 and 800,000. In the smallest EU countries, regions appear at the country and also for NUTS levels 1, 2 and 3, i.e. the same region covers identical territory at the different levels. This is the case of Luxembourg and Cyprus. Countries where NUTS2 corresponds to national boundaries are Latvia, Lithuania, Estonia and Malta. We use NUTS2 version 2013, which provides the most recent data available. The French Départements D'outre-Mer, i.e. Guadalupe, Martinique, La Réunion, Guyane and Mayotte are excluded because of missing data. Tables A1 and A2 provide the number of NUTS per country and some descriptive statistics regarding area and population, respectively.

Table A1
Number of NUTS regions per EU Country.
Source: EU [31].

EU-15				EU-13			
Country	NUTS1	NUTS2	NUTS3	Country	NUTS1	NUTS2	NUTS3
Austria	3	9	15	Bulgaria	2	6	28

(*continued on next page*)

Table A1 (*continued*)

EU-15				EU-13			
Country	NUTS1	NUTS2	NUTS3	Country	NUTS1	NUTS2	NUTS3
Belgium	3	11	22	Croatia	1	2	21
Denmark	1	5	11	Cyprus	1	1	1
Finland	2	5	19	Czech Republic	1	8	14
France	9	27	101	Estonia	1	1	5
Germany	16	38	402	Hungary	3	7	20
Great Britain	12	40	173	Latvia	1	1	6
Greece	4	13	52	Lithuania	1	1	10
Ireland	1	2	8	Malta	1	1	2
Italy	5	21	110	Poland	6	16	72
Luxemburg	1	1	1	Romania	4	8	42
Netherland	4	12	40	Slovakia	1	4	8
Portugal	3	7	25	Slovenia	1	2	12
Spain	7	19	59				
Sweden	3	8	21				

Table A2
Area and population of NUTS regions per EU Country.
Source: EU [31].

	Area (km^2)			Population, year 2014 (1000)		
	Average	Min.	Max.	Average	Min.	Max.
EU-15						
AT	9320	415	19,186	945	287	1766
BE	2775	161	4440	1019	279	1809
DE	9399	419	29,486	2125	519	5089
DK	8583	2553	13,006	1125	581	1749
ES	26,631	13	94,226	2448	84	8389
FI	67,687	1580	226,785	1090	29	1585
FR	24,340	1128	83,534	2532	250	12,005
GR	10,151	2307	19,147	839	198	3856
IE	34,899	33,252	36,545	2303	1233	3373
IT	14,384	3261	25,832	2894	129	9973
LU	2586	2586	2586	550	550	550
NL	3462	1449	5749	1402	381	3577
PT	13,173	80,131	6053	1490	247	3644
SE	54,822	6779	164,078	1206	369	2163
UK	6716	328	41,960	1738	567	5118
EU-13						
BG	18,483	14,645	22,323	1208	810	2128
CY	9251	9251	9251	858	858	858
CZ	9858	496	17,617	1314	1125	1680
EE	45,227	45,227	45,227	1316	1316	1316
HR	28,297	24,705	31,889	2123	1406	2841
HU	13,289	6916	18,337	1411	917	2965
LT	65,300	65,300	65,300	2943	2943	2943
LV	64,573	64,573	64,573	2001	2001	2001
MT	316	316	316	425	425	425
PL	19,542	9412	35,558	2376	960	5293
RO	29,799	1821	36,850	2493	1818	3273
SI	10,137	8061	12,212	1031	981	1080
SK	12,259	2053	16,263	1354	618	1837
EU-28	16,410	13	226,785	1863	29	12,005

Appendix B

Table B1
Variables employed for the Regional Economic Resilience Indicator.

Components of the Regional Economic Resilience Indicator	Variables	Definition and time coverage	Rationale
Slow burning process the capacity of a region registered over time along its resilient evolutionary path to cope with a shock	Pre-crisis average level	Mean over the period 2000-2008	The steady-state behaviour of the system.
	Pre-crisis growth trend	Slope of the line over the 2000-2008 period	The long run growth trend, i.e. the predicted growth path as if the crisis did not occur.
	Post-crisis growth trend	Slope of the line over the 2009-2015 period	The renovated long run growth path as a result of the recovery capacity to the crisis.

(*continued on next page*)

Table B1 (*continued*)

Components of the Regional Economic Resilience Indicator	Variables	Definition and time coverage	Rationale
Shock wave or *dynamic process* the immediate exposure of a region and its reaction capacity to an unexpected shock	Maximum hit of the crisis	Difference between the worst level in 2009 and 2010 and pre-crisis year (2008).	The immediate exposure to the crisis.
	Recovery from the crisis	Relative change between the pre-crisis year (2008) and the latest available data covered in the analysis (2015)	The recovery capacity from the crisis.

Appendix C

Table C1
PCA variance by axis.

	Axis 1	Axis 2	Axis 3
Standard deviation	0.353	0.295	0.223
Proportion of variance	0.368	0.257	0.147
Cumulative proportion	0.368	0.625	0.772

Table C2
PCA variable loadings and weights.

		Axis 1	Axis 2	Axis 3	Weights
Slow burning indicators					
Pre-crisis	mean GDP per capita 2000-08	0.019	0.036	0.019	0.016
2000–08	mean Employment 2000-08	0.009	0.065	0.396	0.18
	mean Productivity 2000-08	0.022	0.028	0.002	0.013
	trend GDP per capita 2000-08	0.137	0.038	0.036	0.062
	trend Employment 2000-08	0.000	0.021	0.013	0.010
	trend Productivity 2000-08	0.107	0.005	0.008	0.049
Post-crisis	trend GDP per capita 2009-15	0.144	0.092	0.000	0.065
2009–15	trend Employment 2009-15	0.032	0.233	0.039	0.106
	trend Productivity 2009-15	0.070	0.000	0.019	0.032
Shock wave indicators					
Maximum hit	fall GDP per capita 2008-10	0.120	0.077	0.000	0.055
2008–10	fall Employment 2008-10	0.004	0.035	0.363	0.165
	fall Productivity 2008-10	0.110	0.067	0.006	0.05
Post-to-pre crisis	recovery GDP per capita 2008-15	0.129	0.062	0.000	0.058
2008–2015	recovery Employment 2008-15	0.030	0.239	0.075	0.109
	recovery Productivity 2008-15	0.067	0.001	0.025	0.030

Table C3
Average values per cluster.

Regional Economic Resilience Indicator		Very low Resilience	Low Resilience	Moderate Resilience	High Resilience
		0.188	0.395	0.555	0.727
Slow burning indicators					
	mean GDP per capita	16,696.200	19,371.390	24,839.370	32,833.630
	mean Employment	0.385	0.417	0.462	0.521
Pre-crisis	mean Productivity	43.552	45.963	52.768	61.527
2000–08	GDP per capita trend	0.018	0.021	0.023	0.027
	Employment trend	0.010	0.005	0.004	0.007
	Productivity trend	0.008	0.016	0.019	0.020
Post-crisis	GDP per capita trend	−0.016	0.006	0.010	0.017
2009–15	Employment trend	−0.015	−0.005	0.002	0.005
	Productivity trend	−0.001	0.012	0.008	0.012
Shock wave indicators					
Maximum hit	GDP per capita fall	−0.114	0.016	0.017	0.074
2008–10	Employment fall	−0.099	−0.044	−0.006	0.018
	Productivity fall	−0.017	−0.066	0.024	0.056
Post-to-pre crisis 2008-15	recovery GDP per capita	−0.114	0.014	0.017	0.069
	recovery Employment	−0.099	−0.044	−0.006	0.015
	recovery Productivity	−0.017	0.064	0.025	0.054

Note: all the values are average levels by cluster.

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