# Convergences Versus Gaps. Capital Axiology as a Cognitive Pattern of Territorial Fragility

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**Abstract.** The Italian territory is characterised by significant and persistent disparities. South of Italy is the most backward region in the euro area, having suffered severely from the Great Crisis of 2008 and more recently from the Covid-19 crisis and the ongoing Russian-Ukrainian and Israeli-Palestinian conflicts. Although it is characterised by strong inter-regional disparities, coastal areas and rural or inland areas, it has great potential. It is populated by a third of Italy's population and characterised by a productive fabric that could generate positive effects for the country. The backwardness problem of the Southern Italy has been a national priority, as evidenced by the policies adopted to support the development of these depressed areas. The implementation of a cohesion policy aimed at territorial rebalancing should be based on a systemic vision of the problem, at least at the regional level. A systemic view of the problem can be developed on the basis of appropriate knowledge support. To this end, the study proposes a cognitive model on a regional scale, based on fuzzy clustering, applied to the case study of the region of Sicily, developed in the axiological perspective of the forms of territorial capital, with the aim of identifying gaps and convergences on a regional and infra-regional scale. The region of Sicily is considered in this study as representative of South of Italy. At the regional level, the cognitive model showed less significant gaps for human, economic, natural and environmental capital than for urban capital and, as expected, deep gaps for infrastructural capital.

**Keywords:** Intra-regional gaps · Territorial rebalancing · Fuzzy clustering

## 1 Introduction

The Italian territory is characterised by significant and persistent disparities. The South of Italy (called Mezzogiorno) is the largest backward territory in the European area, which suffered severely from the great crisis of 2008 [1] and, most recently, that related to the Covid-19 crisis and the ongoing Russian-Ukrainian, Israeli-Palestinian conflicts [2]. Although characterised by strong interregional differentiations, coastal areas and

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O. Gervasi et al. (Eds.): ICCSA 2025 Workshops, LNCS 15889, pp. 232–249, 2026.
https://doi.org/10.1007/978-3-031-97603-2_15

rural or inland areas, has great potential. In fact, they are populated by over twenty million inhabitants (one third of the Italian population), and is characterised by a productive system that - although weak and incomplete - could generate positive effects for the country. The issue of the late development of southern Italy has been a national priority, as evidenced by the policies adopted to support the development of these depressed areas, the identification [3] and amount of funding, under the impulse of the cohesion policies and the European Regional Development Fund (ERDF), Cohesion Fund (CF), European Social Fund Plus (ESF+), and the Just Transition Fund (JTF). In Italy, the National Recovery and Resilience Plan, Decree-Law No. 13 was adopted on February 24, 2023, which contains urgent provisions for the implementation of the PNRR and the National Plan of Complementary Investments (PNC), as well as for the implementation of cohesion policies and the common agricultural policy [4–6]. It stipulates that at least 40 per cent of the territorially allocable resources are to be allocated to southern regions [7, 8]. The establishment of a fund to combat deindustrialisation- DPCM November 30, 2021 [9] aimed at contrasting the phenomena of deindustrialisation and impoverishment of the productive and industrial system of various territorial areas. The fund provides for the granting of economic incentives to manufacturing companies that carry out investments to upgrade or redevelop existing production facilities or to install new production activities. The establishment of a Support Fund for Marginalised Municipalities Law No. 178 of December 39, 2020 [10] and DPCM September 30, 2021 [11], the first one established the Fund, the second one provided for the increase of the relative provision, amounting to 90 million euros (30 mln for each year from 2021 to 2023, ex paragraph 65 sexies of the same Law No. 205/2017), for an additional 90 million euros, allocated at the rate of 30 mln for each of the years 2021-2022-2023, for 'disadvantaged municipalities' exposed to the risk of depopulation, suffering from social deprivation, whose population has low income levels (below the first quartile of the distribution of Italian municipalities). The institution of a fund to support the development of municipalities in inland areas [12]. The establishment of a Special Economic Zone for the South - 'ZES unica' covering the territories of the regions of Abruzzo, Basilicata, Calabria, Campania, Molise, Apulia, Sicily, Sardinia [13] is aimed at boosting employment in the South by offering financial and administrative benefits to businesses. The establishment of an SEZ Mission Structure in charge of monitoring and updating the SEZ Strategic Plan, and of managing the resources allocated to the interventions instrumental to the implementation of Mission 5 Component 3 (M5C3) - 'Special Interventions for Territorial Cohesion' of the National Recovery and Resilience Plan (PNRR), intended to support special interventions for territorial cohesion, including investments to combat educational poverty and the strengthening of Special Economic Zones. Cohesion policies and related funds have started to produce their first positive effects even in a difficult context characterised by pandemics, conflicts and strong macroeconomic fluctuations. While there is a slight trend in the narrowing of gaps in the national territory, this trend takes a long time to manifest itself in the infra-regional context. The differences between municipalities on a regional scale are still significant, perhaps as a consequence of the capacity of the strongest and most hegemonic cities to attract capital flows, people and technologies compared to small towns or villages, or because the former start from very different conditions than the latter [14]. Dobrescu et al. 2014 [15] point out that growth

poles can better fulfil their vocation by integrating and implementing innovative collaborative networks in a polycentric territory.Weak territories risk being further weakened even by ad hoc policies and funding, exposing themselves to a gradual and ineluctable loss of their values [16].The implementation of policies aimed at supporting cohesion and aimed at territorial rebalancing should be based on a systemic view of the issue at least on a regional scale [17]. Camagni et al. 2012 and Capello et al. 2013 [18, 19], in this regard, proposed an overview of the main theories of regional development and formalised economic models. They provide the basis to support the development of a coordinated territorial model. With appropriate cognitive support, a systemic view of the problem can be developed. In this regard, the study proposes a knowledge model at regional scale based on fuzzy clustering applied on the Sicily region case study, as a representative region of the southern issue, developed in the axiological perspective of the forms of territorial capital, aimed at detecting divergences and convergences at infra-regional scale. The identification of clusters on a regional scale and infra-regional of convergence areas and gaps could support the identification of the most effective and efficient territorial rebalancing strategies, aimed at enhancing the former and reducing the latter.

## 2 Approaches to the Territorial Gaps

According to economic theories of neoclassical inspiration, territorial inequalities are interpreted following the principles of rationality and market equilibrium, whereby peripheral areas correspond to those areas far from the development centres.In the second half of the 20th century, Francois Perroux developed the theory on industrial polarisation, giving strong support to territorial rebalancing interventions, which were criticised by free market supporters, fuelling a heated debate between supporters of state intervention and supporters of the market as the solver of any dysfunction [20]. Immanuel Wallerstein developed the system-world approach and classified world countries into central, semi-peripheral and peripheral countries, highlighting how this classification to the distribution of power and capitalist-type processes of exploitation. According to this approach, peripheral countries are functional to the economic development of the centre [21]. This structuralist approach provides a justification for corrective interventions aimed at reducing imbalances. An analysis carried out by the World Bank (2009) [22] aimed at surveying the different levels of development on a planetary level, identified the centres of at least 50,000 inhabitants that offer services, host activities and perform important functions, to define all the other localities that are distant from them and cannot access the preconditions of development. Further studies such as those by Czapiewski and Janc 2009 [23] and Franklin 2019 [24] show how the concentration of advanced industrial and tertiary activities in certain locations can significantly increase spatial disparities. The OECD distinguishes between rural and urban areas [25]. Capello et al. 2011 [26], dealing with the issue of peripheral areas have shown that local communities are much more exposed to international events, increasing inequalities and territorial imbalances. Herrschel identified rural areas as areas far from power [27]. Dematteis showed the greater role played by central areas compared to peripheral areas, which in many cases are even lacking [28]. Medeiros [29] taking up the European Spatial

Policy in 2006 [30], proposed to mitigate the imbalances induced by urban polarisation, using a polycentric urban system. Pezzi a Urso [31], have demonstrated how many non-metropolitan areas can become suburbs. Copus et al. in 2017 [32] gave a functionalist interpretation of peripheral areas proposed in the classification developed in the ESPON-funded Profecy project. This interpretation of peripherality associates the concept of spatial peripherality with socio-economic marginality and the distance of an area from the centres offering important services, which to some extent echoes Bock's definition of peripherality, which does not depend on distance but on the lack of connection of political and socio-economic relations [33]. Therefore, even spatially non-peripheral areas could be classified as such, because they do not interact with global economic networks. Some studies on gaps including, those of Chieffallo et al. 2022 highlight the dichotomy between urban (centre) and rural (peripheral) areas [34, 35]. Bignante et al. 2022, pointed out the triggering of imbalances related to the relocation of companies, particularly when they affect areas of less developed countries and neglect peripheral areas of more advanced countries [36]. Bignante et al. 2022 highlight the risk of triggering the brain-drain phenomenon for distant/peripheral centres compared to developed ones and thus suggest corrective interventions [36].

## 3 The Case Study. South of Italy Territorial Gap

There are deep territorial gaps between the South and the Centre-North. These are result of a progressive settling of disadvantageous conditions linked to an asymmetry in the values of the initial configuration and development dynamics. In these weak contexts, the dynamics are often characterised by low or no development of some areas. By a low or absent level of implementation of national policies. In some cases, they are the result of policies that have led to a reduction in services for reasons related to cuts in public spending, or by an unequal distribution of funding for efficient infrastructure provision. And still, from a low level of local governance, cultural backwardness and socio-economic vulnerabilities. A local geography of the gaps shows in some contexts strong differences even on an infra-regional scale. In many regions of Southern Italy, there are differences between coastal territories and peripheral territories, between cities and inland/rural areas; these differences are even more serious if we consider that the strongest local territories are in any case weak territories from the national point of view. ISTAT noted in its report of 25 January 2023 entitled 'The territorial gaps in the PNRR: ten objectives for the South [37] strong regional and infra-regional differences, showing critical contexts, which confirm the classification of areas according to the criteria of geographical peripherality (distance from the Centre-North), and territorial marginality (the so-called 'internal areas'). The report highlighted a low sustainability of gaps, due to the impact on the demographic structure of the south, which in the future prospects appears increasingly fragile. The 'per capita GDP' has been around 55–58% of that of the Centre-North for more than two decades in the South. The level of education in the South confirms a serious backwardness: in 2020, one third (32.8%) of South Italians aged 25–49 had completed at most the third grade of secondary school compared to 24.5% in the Centre-North; 22.6% had a tertiary degree compared to 27.6% in the Centre-North. The entire South has youth employment rates well below the average.

This condition has led to a worrying resurgence of mass emigration. In 2020, the South and the Islands lost as many as 42 young residents (25–34 years old) out of every 100 population movements in extra-regional internal flows (+22 in the Centre-North) and 56 out of every 100 in foreign flows (49 in the Centre-North). This phenomenon is more pronounced in the provinces with low employment and in the 'internal areas'. While the digitisation process has been very rapid in the Centre-North over the last two decades, the South has not yet caught up with the starting gap, as about 60 per cent of residents have limited opportunities to access ultra-wideband.The water network in the South registers losses for about half of the water for civil use, an issue that has become even more critical due to the drought risk to which the entire Italian territory and particularly that of the South is exposed. The endowment of transport infrastructure in the South is lower than in the rest of the country. The density of the railway network, especially the high-speed network, is much lower (0.15 km per 100 km2 of surface area in the South; 0.8 in the North; 0.56 in the Centre). Education outcomes in the South are significantly worse than in the rest of Italy. In the 2021–2022 period, 42.7% of Southern upper V students have 'very weak' competences in mathematics compared to 28.3% in the rest of Italy; and only 6.7% are at a 'very good' level compared to 14.9% in Italy. The supply of childcare services is growing throughout the country, but the gaps are still significant; in fact, for two-thirds of children (0–3 years) in the South the level of supply is below national standards and for the rest the level of supply is very low or null. In the South of Italy - especially in some regions affected by the redirection plans (6 out of 7 in this breakdown) - the contraction of public spending has negatively affected the Essential Levels of Care (LEA), which has led to widespread 'health emigration' to the facilities of the Centre-North. The delays in the South are increasing the risks of an excessive and non-reversible demographic impoverishment. Between 2011 and 2020, the first population decline in the recent history of the South was recorded (−642,000 inhabitants; +335,000 in the Centre-North). With unchanged trends, in 2030 residents will fall below the critical threshold of 20 million for the first time, with a reduction on a ten-year basis of about four times that of the Centre-North (−5.7% and 1.5%). The population loss affects young people. National Institute of Statics has predicted for 2035, an increase in the average age of the population of the South compared to that of the Centre-North. The significance of these phenomena, if not managed, exposes the South to a process of involution, putting its social structure at risk. Sicily is a region in southern Italy where all these issues are detectable. Sicily is the largest region in Italy with an area of 25,832 square kilometres. The population density of Sicily is 194 inhabitants per square kilometre. The resident population, based on the census of 31 December 2022, amounts to 4,814,016 inhabitants, a decrease compared to 2021 (−19,313 persons; −0.4%). This decrease is due to the negative values of the natural balance and internal migration. Sicily has 391 municipalities. More than a quarter of the population (26.3%) lives in the four municipalities with more than 100,000 inhabitants (Palermo, Catania, Messina and Syracuse) and just under a quarter in those with between 20,001 and 50,000 inhabitants (24.3%). The average age will increase from 44.9 to 45.2 years in 2021. Ragusa and Catania are the youngest provinces (44.1 and 44.2 years respectively), while Messina and Enna are the oldest (46.7 and 46.5 years respectively). In Sicily, a new record for the birth rate was reached in 2022, with a decrease of 425 units. The death

rate rose from 12.2 per thousand in 2021 to 12.3 per thousand in 2022 [38]. An analysis of the gaps on an infra-regional scale for Sicily is not available in the literature. One of the objectives of this study is to detect gaps and convergences on an infra-regional scale for Sicily.

## 4 Method

The methodological approach supporting the cognitive model of convergences and gaps for the Region of Sicily is based on the following phases:

- Identification of the forms of territorial capital;
- Construction of a geo-database of indicators characterising the forms of territorial capital;
- Analysis of the territorial clusters based on a fuzzy clustering of the indicators characterising the forms of territorial capital, with the aim of highlighting intra-regional convergences and gaps. Fuzzy clustering is a technique that is part of soft clustering. It allows data to be allocated to clusters in such a way that elements in the same cluster are as similar as possible, while elements in different clusters are as dissimilar as possible. It is an effective tool for identifying the underlying structures of a dataset based on similarity measures. In the context of the proposed research, fuzzy clustering makes it possible to identify indicator clusters for different forms of capital, taking into account the specific characteristics of the data. These are characterised by different degrees of similarity to the clusters, so that hard clustering would reduce the information content of the data, which is best captured by soft clustering.
- Spatial cluster analysis using QGIS to identify convergences and gaps of territorial capital forms at the regional scale, based on clusters number generated (high cluster size corresponds to high divergence at the regional scale, low cluster size corresponds to low divergence or convergence at the regional scale).
- Analysis of the minimum and maximum values and standard deviations of the indicators of territorial Capital forms in order to identify convergences and gaps at the infra-regional level.

### 4.1 The Territorial Capital Forms

Based on the categories introduced by Camagni [39] to classify, six territorial capital forms were identified, namely: human capital (*HC*), urban capital (*UC*), natural capital (*NC*), economic capital (*EC*), environmental capital (*ENVC*) and infrastructure capital (*IC*). For the six territorial capital forms, 13 indicators were identified for human capital, 26 indicators for urban capital, 5 indicators for natural capital, 30 indicators for economic capital and 67 indicators for infrastructure capital. These indicators were selected with reference to the dataset of the Agency for Territorial Cohesion [40] and that of the Council of Ministers [41], based on the territorial capital forms introduced by Camagni [39]. Figure 1 highlights the indicators characterising the different territorial capital forms. The 127 indicators selected to characterise the six forms of territorial capital have been georeferenced. Together they constitute the basic geodatabase to support spatial analyses, instrumental in identifying gaps and convergences.

**Human capital**

**HC1**-Residential population
**HC2**-Population density
**HC3**-Average annual rate of change of resident population
**HC4**-Old-age index
**HC5**-Percentage of foreign population
**HC6**-Incidence of young single-parent families
**HC7**-Incidence of young couples with children
**HC8**-Early exit from the education and training system
**HC9**-Incidence of lone elderly persons
**HC10**-Incidence of mixed couples
**HC11**-Share of pupils at risk of dropping out of secondary school
**HC12**-Share of pupils at risk of dropping out of lower secondary schools
**HC13**-Italian/foreigner school attendance ratio

**Urban capital**

**UC1**-Variation in the building under-utilisation rate
**UC2**-Variation in the under-utilisation index of dwellings
**UC3**-Variation in the under-utilisation rate of dwellings in built-up areas
**UC4**-Index of dwelling dispersion
**UC5**-Index of concentration of building use types
**UC6**-Index of compactness of urban areas
**UC7**-Urban landscape fragmentation index
**UC8**-Under-use of dwellings index
**UC9**-Fixed-site retail trade density
**UC10**-Index of building expansion in urban centres and settlements
**UC11**-Residential attractiveness index
**UC12**-Residential mobility
**UC13**-Population incidence in crowded conditions
**UC14**-Housing crowding index
**UC15**-Rate of building vacancy
**UC16**-Drop-out rate of dwellings in built-up areas
**UC17**-Housing exclusion index
**UC18**-Incidence of residential buildings in a poor state of repair
**UC19**-Index of availability of services in the dwelling
**UC20**-Average age of recent housing stock
**UC21**-Percentage of cars with low environmental impact
**UC22**-Net human density
**UC23**-Incidence of population living in cores and scattered dwellings
**UC24**-Average real estate rent
**UC25**-Average real estate value
**UC26**-Urban (non-agricultural) green area per capita

**Economic capital**

**EC1**-Total Employment in Local Units in the Municipality
**EC2**-Manufacturing employment at Local Units in the municipality
**EC3**-Tourism employment in the local units of the municipality
**EC4**-Manufacturing Sector Employment in Local Units
**EC5**-Employment in tourism sector in local units
**EC6**-Population employed in agriculture in 2001
**EC7**-Utilised agricultural area by location of the enterprise centre
**EC8**-Share of manufacturing employment in local units in the municipality
**EC9**-Share of tourism employment in the local units of the commune
**EC10**-% change in manufacturing employment between 1971 and 2001
**EC11**-% change in employment in the service sector between 1971 and 2001
**EC12**-% change in population employed in agriculture between 1971 and 2001
**EC13**-% change in utilised agricultural area by location of farm centre
**EC14**-Herfindahl-Hirschman concentration index
**EC15**-Change in economic dynamism index
**EC16**-Employment rate
**EC17**-Employment turnover index
**EC18**-Change in unemployment rate
**EC19**-Unemployment Rate
**EC20**-Youth unemployment rate
**EC21**-Incidence of young people out of the labour market and training
**EC22**-Incidence of households with potential economic hardship
**EC23**-Average income
**EC24**-Gini index
**EC25**-Italian/Foreign Employment Ratio
**EC26**-Male/Female employment ratio
**EC27**-Utilised Agricultural Area (UAA) as a percentage of total agricultural area
**EC28**-Percentage of persons employed in ODA and KIBS enterprises
**EC29**-Percentage of APS and KIBS enterprises
**EC30**-Index of Economic Dynamism

**Natural capital**

**NC1**-Area covered by forest
**NC2**-Percentage of forest area
**NC3**-Percentage of municipal protected area
**NC4**-Presence or absence of Natura 2000 network (Sic/ZPS/ZSC)
**NC5**-Average agricultural value

**Infrastructural capital**

**IC1**-Population mobility by private car
**IC2**-Daily mobility for study or work
**IC3**-Commuting index for work
**IC4**-Commuting index within the city
**IC5**-Index of road accessibility to commercial centres
**IC6**-Rail Accessibility Index
**IC7**-Index of accessibility to railway stations
**IC8**-Index of Mobility by Public Transport
**IC9**-Slow Mobility
**IC10**-University presence index
**IC11**-Composite accommodation function rate
**IC12**-Number of State Places of Culture
**IC13**-Number of stadiums
**IC14**-Number of amusement and entertainment hubs
**IC15**-Number of commercial hubs
**IC16**-Number of ordinary hospital beds per 10,000 inhabitants
**IC17**-Index of dynamism of public institutions
**IC18**-Ordinary pharmacies per 10,000 inhabitants
**IC19**-Libraries per 10,000 inhabitants
**IC20**-Drinking water supplied to the municipal network per capita
**IC21**-Percentage of separate waste collection
**IC22**-Density of installed photovoltaic systems
**IC23**-Number of CNR institutes
**IC24**-Number of CNR sites
**IC25**-Number of locations of non-NRC research bodies and institutes
**IC26**-Number of science parks, technological districts and centres of excellence
**IC27**-Number of beds in hospital facilities
**IC28**-Number of hospitals
**IC29**-Number of hospitals with DEA
**IC30**-Number of elderly people enrolled in ASL of the municipality
**IC31**-Number of beds in residential facilities for the elderly
**IC32**-Number of kindergartens
**IC33**-Number of primary school
**IC34**-Number of secondary school
**IC35**-Number of secondary school
**IC36**-Number comprehensive school
**IC37**-Number Permanent Territorial Centre
**IC38**-Number of vocational colleges
**IC39**-Number of technical colleges
**IC40**-Number of higher education institutions
**IC41**-Number of educational establishments
**IC42**-Number of teacher training institutes
**IC43**-Number of Artistic Institutes
**IC44**-Number Classical High School
**IC45**-Number Scientific High School
**IC46**-Number Artistic High School
**IC47**-Number of Academies and Conservatories
**IC48**-Number of boarding schools and teacher training colleges
**IC49**-Number of Territorial Centres Pupils
**IC50**-Number of Vocational Colleges Pupils
**IC51**-Number of Technical Colleges Pupil
**IC52**-Number of pupils at scientific high schools
**IC53**-Number of Primary School Pupils
**IC54**-Number of Secondary School Pupils
**IC55**-Number of pupils master school
**IC56**-Number of pupils art school
**IC57**-Number of pupils secondary school
**IC58**-Number of pupils artistic high school
**IC59**-Number of students in classical high school
**IC60**-Number of stations per municipality
**IC61**-Number of Platinum Type Station
**IC62**-Number of stations of type Gold
**IC63**-Number of stations of type Silver
**IC64**-Number of stations of type Bronze
**IC65**-Share of population without fixed network broadband
**IC66**-Share of population without fixed-line and/or mobile broadband
**IC67**-Precence of a railway station of type at least Silver

**Environmental capital**

**ENVC1**-Seismic risk indicator
**ENVC2**-Class of population exposed to landslide phenomena
**ENVC3**-Standard deviation of altitudes
**ENVC4**-Surface area of land consumed in areas of high and very high seismic hazard
**ENVC5**-Percentage of municipal area at high and very high PAI landslide hazard
**ENVC6**-Resident population at risk in areas of high and very high landslide hazard
**ENVC7**-Surface area of soil consumed in areas with high and very high landslide hazard
**ENVC8**-Percentage of municipal surface area at high hydraulic hazard
**ENVC9**-Resident population at risk in areas of high hydraulic hazard
**ENVC10**-Surface area of soil consumed in high hydraulic hazard areas
**ENVC11**-Total number of establishments with Major Accident Hazard
**ENVC12**-Soil consumed per capita
**ENVC13**-Municipal waste production per capita

**Fig. 1.** Indicators of forms of territorial capital: *HC*, *UC*, *EC*, *NC*, *IC* and *ENVC*

## 5 Results

The indicators for each of the six capital forms were analysed with fuzzy clustering, using NCSS Statistical software [42]. The Kaufman and Rousseeuw algorithm was used for fuzzy clustering. This is a medoid algorithm, which call PAM (Partition Around Medoids). With reference to this approach, the cluster centroid is defined as an element of a cluster whose average dissimilarity with respect to all objects in the cluster is minimal, so that it will be the most central point of a given set of points. The clusters number was selected for each form of capital on the basis of two goodness-of-fit statistics, namely Dunn's normalised partition coefficient and Kaufman's normalised partition coefficient. The criterion used for the selection of the solution, i.e. the number of clusters, is the one that maximises Dunn's normalised partition coefficient and minimises Kaufman's normalised partition coefficient.

Fuzzy clustering for human capital revealed two clusters. In the first cluster fall municipalities with a lower level of human capital endowment and in the second those with a higher endowment. $C_1$ cluster has its centroid in the municipality San Michele di Ganzaria, in the Messina province. $C_2$ cluster has its centroid in the municipality of Comiso, in the Ragusa province. Figure 2 shows the map of $C_1$ and $C_2$ regarding Human Capital.

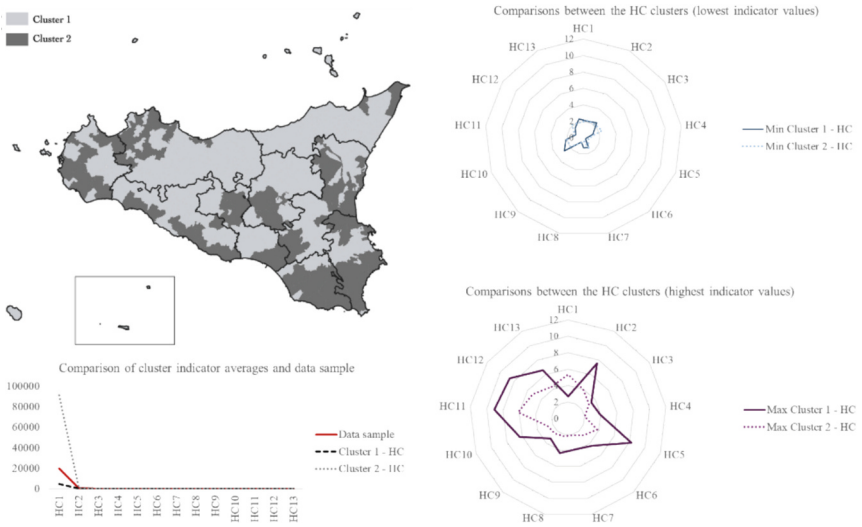



**Fig. 2.** Human Capital distribution in $C_1$ and $C_2$ clusters

$C_1$ includes 81.40% of the municipalities in the Agrigento province, 81.82% in the Caltanissetta province, 63.79% in the Catania province, 90.00% in the Enna province, 97.22% in the Messina province, 90.24% in the Palermo province, 41.67% in the Ragusa province, 74.14% in the Siracusa province, and 70.83% in the Trapani province. $C_2$ includes 18.60% of the municipalities in the Agrigento province, 18.18% in the Caltanissetta province, 36.21% in the Catania province, 10.00% in the Enna province, 2.78% in

the Messina province, 9.76% in the Palermo province, 58.33% in the Ragusa province, 42.86% in the Syracuse province, and 29.17% in the Trapani province. In terms of the minimum and maximum standardised values for the thirteen indicators, municipalities with a higher level of human capital endowment fall into the first cluster rather than the second, as shown in Fig. 3. Indicators average values comparison shows that the values for HC1 - *residential population* and HC2 - *population density* for $C_2$ are higher than the corresponding values for $C_1$, , due to the presence in this cluster of the provincial capitals (Agrigento, Caltanissetta, Catania, Enna, Messina, Palermo, Ragusa, Siracusa and Trapani). $C_2$ is characterised by a higher value of the standard deviation of the indicators, highlighting a greater variability of the human capital endowment within the cluster, and therefore a greater divergence than that of cluster $C_1$, which is characterised by a greater convergence.

Fuzzy clustering for urban capital showed three clusters: $C_1$, $C_2$ and $C_3$.

$C_1$ has its centroid in Mazzarrà Sant'Andrea municipality, in the Messina province. $C_2$ has the centroid in Malvagna municipality, in the Messina province. $C_3$ has its centroid in Paceco municipality, in the Trapani province. Figure 3 shows the map of $C_1$, $C_2$ and $C_3$ regarding Urban Capital. $C_1$ includes 20.93% of the municipalities in the Agrigento province, 59.09% in the Caltanissetta province, 22.41% in the Catania province, 70.00% in the Enna province, 17.59% in the Messina province, 47.56% in the Palermo province, 30.33% in the Ragusa province, 52.33% in the Siracusa province, and 0.00% in the Trapani province.

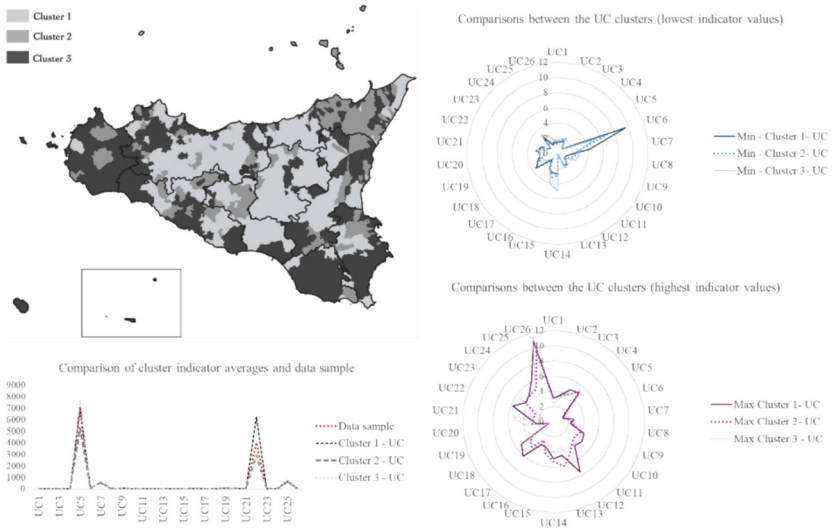



**Fig. 3.** Urban Capital distribution in $C_1$, $C_2$ and $C_3$ clusters

$C_2$ includes 32.56% of the municipalities in the Agrigento province, 13.64% in the Caltanissetta province, 20.69% in the Catania province, 15.00% in the Enna province, 50.00% in the Messina province, 19.51% in the Palermo province, 8.33% in the Ragusa province, 19.05% in the Siracusa province, and 20.83% in the Trapani province. $C_3$

includes 46.51% of the municipalities in the Agrigento province, 27.27% in the Caltanisetta province, 56.90% in the Catania province, 15.00% in the Enna province, 32.41% in the Messina province, 32.93% in the Palermo province, 58.33% in the Ragusa province, 28.57% in the Siracusa province, and 79.17% in the Trapani province. Indicators average values comparison shows higher values for the UC5- *index of concentration of building use types* for $C_1$ compared to $C_2$ and $C_3$, and higher values for the UC22- *net human density* for $C_1$ compared to $C_2$ and comparable to $C_3$. $C_1$ includes the provincial capitals of Catania, Enna, Messina and Palermo, while $C_3$ includes the provincial capitals of Agrigento, Ragusa, Siracusa and Trapani, with Caltanissetta instead in $C_2$. $C_1$ is characterised by a higher value of the standard deviation of the indicators, highlighting a greater variability of the urban capital endowment within the cluster, and therefore a greater divergence, although not as marked as in $C_2$, and more marked than in $C_3$. The latter cluster is characterised by greater convergence.

Fuzzy clustering for Infrastructure Capital determined five clusters $C_1$, $C_2$, $C_3$, $C_4$ and $C_5$. Figure 4 shows the map of $C_1$, $C_2$, $C_3$, $C_4$ and $C_5$ regarding Infrastructural Capital. $C_1$ has its centroid in the municipality Collesano, in the Palermo province. $C_2$ has its centroid in the municipality of Oliveri, in the Messina province. $C_3$ has its centroid in the municipality of Realmonte, in the Agrigento province. $C_4$ has its centroid in the municipality of Butera, in the Caltanissetta province. $C_5$ has its centroid in the municipality of Mascali, in the Catania province. $C_1$ includes 2.23% of the municipalities in the Agrigento province and 100.00% in the Palermo province. $C_2$ includes 97.67% of the municipalities in the Messina province. $C_3$ includes 100.00% of the municipalities in the Siracusa province and 100.00% in the Trapani province. $C_4$ includes 2.27% of the municipalities in the Agrigento province, 100.00% in the Caltanissetta province, 100.00% in the Enna province, 0.93% in Messina province, and 100.00% in the Ragusa province. $C_5$ includes 100% of the municipalities in the Catania province. In this case, the fuzzy clustering showed five clusters, indicating a significant variation in infrastructure capital endowment at the regional level. This classification coincides with the administrative boundaries of the Sicilian provinces. This instance, $C_1$ includes only municipalities in the Palermo province, including the municipality of Palermo; $C_2$ includes only municipalities in the Messina province; $C_3$ includes municipalities in the Agrigento, Trapani and Siracusa province; $C_4$ includes municipalities in the Caltanisetta, Enna and Ragusa province; $C_5$ includes municipalities in the Catania province (Fig. 4). At infra-regional level, based on the maximum standardised values of the sixty-seven indicators, the municipalities with the highest level of infrastructure capital endowment are highlighted in $C_2$ (Fig. 4), followed by $C_1$, $C_5$, $C_3$ and $C_4$. In terms of the minimum standardised values for the sixty-seven indicators, the municipalities with the lowest level of infrastructure capital endowment fall into $C_1$, followed by $C_4$, $C_3$, $C_5$ and $C_2$, as shown in Fig. 4. This shows a more pronounced divergence of the values of this endowment in $C_1$, less pronounced in $C_3$, $C_4$ and $C_5$, and a convergence in $C_2$. The comparison of the average values of the indicators shows higher values of IC31 - *number of beds in residential facilities for the elderly* for $C_1$ compared to $C_5$, $C_2$, $C_3$, $C_4$. $C_4$ is characterised by a higher value of the standard deviation of the indicators, which indicates a greater variability of the infrastructure capital endowment within the cluster, i.e. a greater divergence. The divergences become progressively less marked, again with

reference to the values of the highest standard deviation of the indicators in $C_3$, $C_1$, $C_5$ and less divergence in $C_2$. The latter cluster is characterised by greater convergence.

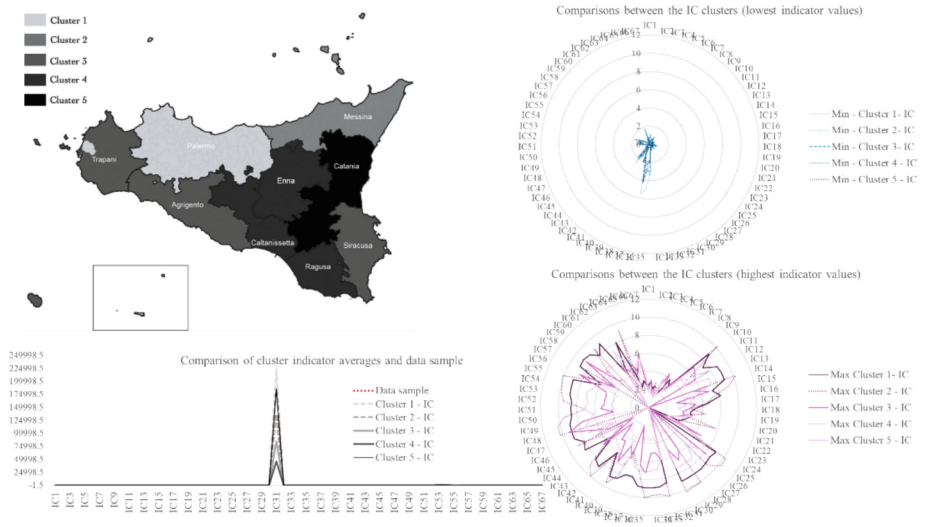



**Fig. 4.** Infrastructure Capital distribution in $C_1$, $C_2$, $C_3$, $C_4$ and $C_5$ clusters

Fuzzy clustering for Economic Capital identified two clusters $C_1$ and $C_2$. $C_1$ has its centroid in the Villafrati municipality, in the Palermo province. $C_2$ has its centroid in the Troina municipality, in the Enna province. $C_1$ includes 74.42% of the municipalities in the Agrigento province, 77.22% in the Caltanissetta province, 75.59% in the Catania province, 35.00% in the Enna province, 93.52% in the Messina province, 76.83% in the Palermo province, 50.00% in the Ragusa province, 61.50% in the Siracusa province, and 62.50% in the Trapani province. $C_2$ includes 25.58% of the municipalities in the Agrigento province, 22.738% in the Caltanissetta province, 22.41% in the Catania province, 65.00% in the Enna province, 6.48% in the Messina province, 23.17% in the Palermo province, 50.00% in the Ragusa province, 38.10% in the Siracusa province, and 37.50% in the Trapani province. Figure 5 shows the map of $C_1$ and $C_2$ regarding Economic Capital. In this case, the fuzzy clustering revealed two clusters, indicating a less significant divergence in economic capital endowment level at regional level. At infra-regional level, the minimum and maximum values of the standardised values of the thirty indicators highlight the municipalities with a higher level of economic capital endowment in $C_1$ than in $C_2$ (Fig. 5). Indicators average values comparison of shows that $C_2$ has higher values for EC1-*Total employment in local units in the municipality*, EC5-*Employment in the tourism sector in local units*, EC7-*Utilised agricultural area by location of the enterprise centre*, compared to $C_1$. $C_2$ is characterised by a higher value of the standard deviation of the indicators, which indicates a greater variability of the economic capital endowment within the cluster, i.e. a greater divergence. The divergences are less pronounced, again with respect to the values of the maximum standard deviation of the economic capital indicators in $C_1$.

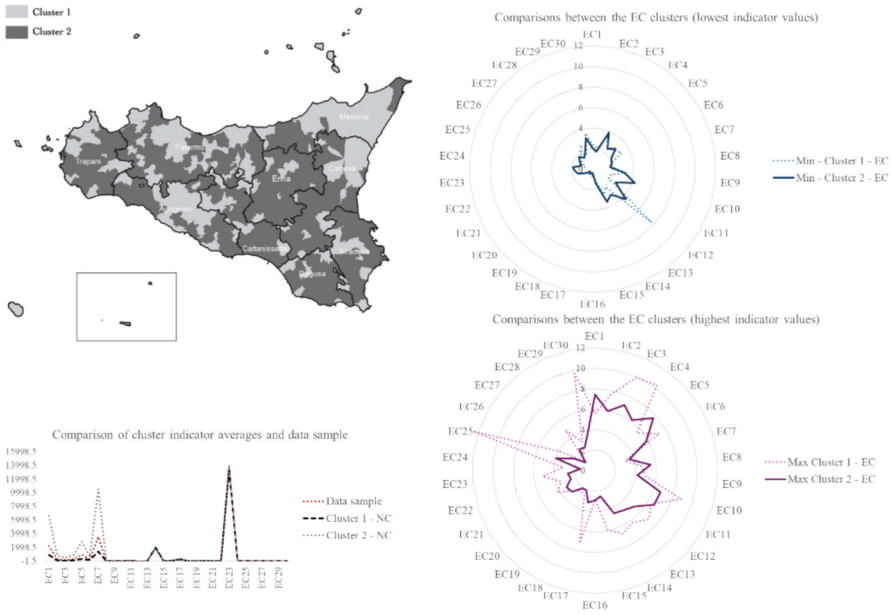



**Fig. 5.** Economic Capital distribution in $C_1$ and $C_2$ clusters

Fuzzy clustering for Natural Capital identified two clusters $C_1$ and $C_2$. $C_1$ has its centroid in Partinico municipality, in the Palermo province. $C_2$ has its centroid in Serradifalco, in the Caltanissetta province. $C_1$ includes 13.95% of municipalities in the Agrigento province, 0.00% in the Caltanissetta and Enna provinces, 67.24% in the Catania province, 67.59% in the Messina province, 36.59% in the Palermo province, 75.00% in the Ragusa province, 76.19% in the Siracusa province and 95.83% in the Trapani province. $C_2$ includes 86.05% of municipalities in the Agrigento province, 100.00% in the Caltanissetta province, 32.76% in the Catania province, 100.00% in the Enna province, 32.41% in the Messina province, 63.41% in the Palermo province, 25.00% in the Ragusa province, 23.81% in the Siracusa province and 4.71% in the Trapani province. Figure 6 shows the map of $C_1$ and $C_2$ regarding Natural Capital.

In this case, the fuzzy clustering revealed two clusters, indicating a less significant variation in natural capital endowment at regional scale. At infra-regional scale, the minimum and maximum values of the standardised values of the five indicators highlight the municipalities with a higher level of natural capital endowment in $C_1$ than in $C_2$ (Fig. 6). Indicators average values comparison of the shows higher values of the indicator NC5-*Average agricultural value* in $C_1$ and higher values of the indicator NC2-*Forest area* in $C_2$. $C_2$ is characterised by a higher value of the standard deviation of the indicators, indicating a higher variability of the natural capital endowment within the cluster, i.e. a greater divergence. Less pronounced divergences, again in relation to the values of the maximum standard deviation of the natural capital indicators in $C_1$.

Fuzzy clustering for Environmental Capital identified two clusters $C_1$ and $C_2$. $C_1$ has its centroid in Raccuja municipality, in the Messina province. $C_2$ has its centroid

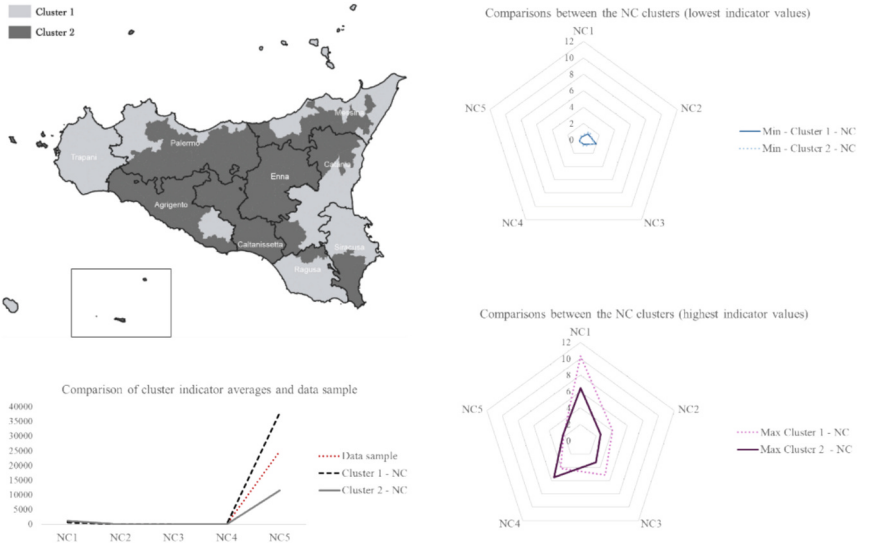



**Fig. 6.** Natural Capital distribution in $C_1$ and $C_2$ clusters

in Camporotondo Etneo municipality, in the Catania province. $C_1$ includes 32.56% of municipalities in the Agrigento province, 27.27% in the Caltanissetta province, 24.14% in the Catania province, 50.0.0% in the Enna province, 38.89% in the Messina province, 36.59% in the Palermo province, 91.67% in the Ragusa province, 57.14% in the Siracusa province and 50.00% in the Trapani province. $C_2$ includes 67.44% of municipalities in the Agrigento province, 68.18% in the Caltanissetta province, 75.86% in the Catania province, 50.00% in the Enna province, 61.11% in the Messina province, 63.41% in the Palermo province, 8.330% in the Ragusa province, 42.86% in the Siracusa province and 50.00% in the Trapani province. Figure 7 shows the map of $C_1$ and $C_2$ regarding Environmental Capital.

In this case, fuzzy clustering showed two clusters, indicating less significant variation in environmental capital endowment at the regional level. The environmental capital indicators provide information on the exposure of municipalities to different environmental risks. At infra-regional scale, the minimum and maximum values of the standardised values for the thirteen indicators highlight the municipalities with a higher level of environmental risk in $C_1$ than in $C_2$ (Fig. 7). Indicators average values comparison shows that $C_1$ has higher values for the indicators ENV4-*Surface area used in areas of high and very high seismic hazard*, ENV6-*Population at risk in areas of high and very high landslide hazard*, ENV9-*Population at risk in areas of high hydraulic hazard*, ENV12-*Soil consumption per capita*, ENV13-*Municipal waste production per capita.* $C_1$ is characterised by a higher value of the standard deviation of the indicators, indicating a greater variability of environmental risk within the cluster, and therefore a greater divergence. The divergence is less marked, again with respect to the values of the highest standard deviation of the environmental capital indicators in $C_2$, i.e. less variability of environmental risk within the cluster.

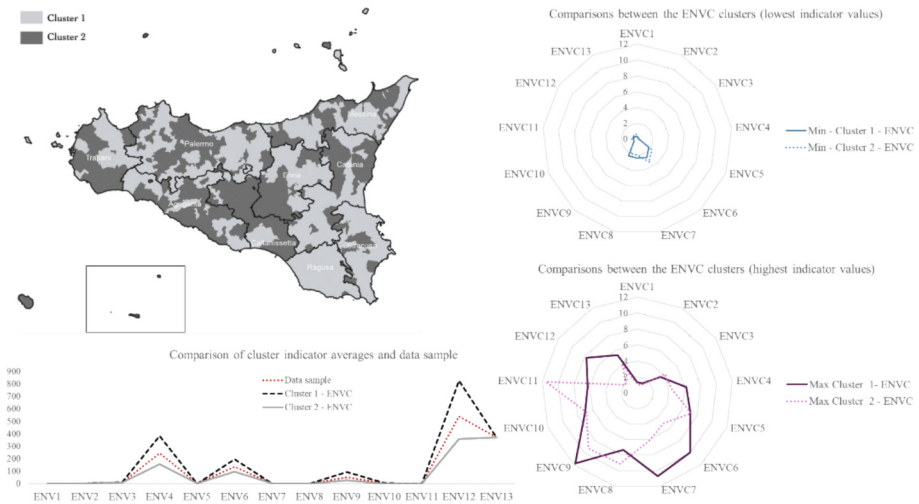



**Fig. 7.** Environmental Capital distribution in $C_1$ and $C_2$ clusters

## 6 Conclusion and Discussion

The cognitive model proposed, developed in the axiological perspective of the forms of territorial capital, aimed at highlighting divergences and convergences at the regional and infra-regional scale, applied to the region of Sicily, representative of the Southern Italy or weak areas with respect to the national territory, has highlighted:

- Less marked divergence at regional scale for human, economic, natural and environmental capital.
- More marked divergences at regional scale for urban capital.
- Strong divergences at regional scale for infrastructure capital.
- Divergences in human capital values for the two clusters identified, and significant divergences within cluster $C_2$ on the infra-regional scale.
- Divergences in urban capital values for the three clusters identified and divergences are significant within cluster $C_1$, which includes the provincial capitals of Catania, Enna, Messina and Palermo, and less marked for cluster $C_2$, which includes the provincial capitals of Agrigento, Ragusa and Siracusa, and greater convergence for $C_3$, even though it includes the provincial capitals of Trapani and Caltanissetta, as regards the infra-regional scale.
- Divergences in infrastructure capital values for the five clusters identified, which in most cases coincide with the administrative boundaries of the nine Sicilian provinces. Intra-regional divergences are more pronounced with different values of the level of infrastructural capital endowment, the variability being accentuated for cluster $C_1$ and less accentuated for clusters $C_3$, $C_4$ and $C_5$. There is a low convergence in cluster $C_2$. The divergences observed in terms of infrastructure endowment highlight a strong criticality, not only in terms of distribution, but also in terms of the general level of endowment at regional level, which is already low compared to the national level. In fact, the areas characterised by higher values of territorial capital endowment

in the estimated classification, with reference to the regional scale, have a lower level of infrastructure capital endowment than the areas in the centre-north. Thus, in this classification, the areas characterised by lower values of infrastructure capital endowment show very marked disparities compared with those in the Centre-North; divergences with regard to the infra-regional scale in the economic capital values for the two clusters identified. With regard to the infra-regional scale, there are more significant divergences for cluster $C_2$, which includes both coastal and inland areas. This is mainly due to the fact that the nine provincial capitals of Sicily are included in cluster $C_2$. Less significant divergences in economic capital values for cluster $C_1$.

- Divergences in natural capital infra-regional scale values for the two clusters identified are due to their different distribution in the territory of Sicily. With regard to the infra-regional scale, there are more significant divergences for cluster $C_2$, due to a greater variability of natural capital endowment, and less for cluster $C_1$. Cluster $C_1$ is characterised by the higher value of the indicator NC5-*Average agricultural value* in cluster $C_1$, while cluster $C_2$ is characterised by the higher value of the indicator NC2-*Percentage of forest area* in cluster $C_2$.
- Divergences with regard environmental capital values in infra-regional scale, in this case representative of the exposure of municipalities to different environmental risks for the two clusters identified. The municipalities with the highest risk of environmental damage are those belonging to cluster $C_1$, which is characterised by the highest values of the indicators ENV4-*Surface area of land consumed in areas of high and very high seismic hazard*, ENV6-*Resident population at risk in areas of high and very high landslide hazard*, ENV9-*Resident population at risk in areas of high hydraulic hazard*, ENV12-*Soil consumed per capit*a, ENV13-*Municipal waste production per capita.* This cluster is characterised by a greater variability in the environmental risk of the municipalities in it than cluster $C_2$. This cluster is characterised by greater variability in the environmental risk of the municipalities within it than cluster $C_2$.

The cognitive model proposed, which aims to highlight convergences and gaps territorial capital endowment at regional and infra-regional levels, might be helpful for decision-makers to identify policies, measures and ad hoc funding to support the development of these areas effectively and efficiently. In particular, analyses of human, urban, infrastructural and economic capital, by highlighting the weakest and strongest areas, might be supportive for policies aimed at territorial rebalancing and the development of measures to reduce gaps and strengthen areas with higher levels of these forms of capital [43, 44]. Natural capital analyses, by highlighting convergences and gaps, might be supportive for the identification of appropriate measures to protect, conserve and enhance the natural heritage. Environmental capital analyses might be supportive for policies development to mitigate environmental risks, which are becoming increasingly severe and recurrent, including those related to climate change. Future developments of this research are aimed at providing a general overview of convergences and gaps for the regions of southern Italy, but it could also be extended to the regions of central and northern Italy. Such a process could provide a complete cognitive picture of convergences and gaps in the Italian territory, on the basis of which targeted and integrated actions could be planned, in compliance with the principle of territorial equity. Future

developments will concern identifying more robust measures about convergences and gaps at regional and infra-regional scales.

**Disclosure of Interests.** The authors have no competing interests to declare that are relevant to the content of this article.

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