A PROPOSAL FOR A COMPOSITE INDEX TO MEASURE DISTRESS IN MARGINALIZED MUNICIPALITIES[1]

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Abstract. Over the years, the scientific community has increasingly emphasized the need to adopt a multidimensional approach to analyse and measure inequalities. This approach recognizes that inequalities are complex and multifaceted phenomena, involving interconnected components that span various dimensions. In the context of the proposed study, thanks to the availability of results from the Permanent Census of Population and Housing and information derived from other Istat sources, comprehensive analyses have been conducted on all municipalities across the national territory, utilizing data collected in the year 2021. These insights covered a range of factors including territorial characteristics, environmental conditions, demographic dynamics, and socio-economic indicators. Additionally, specific attention has been directed towards gender disparities, with the inclusion of variables that shed light on differential experiences and opportunities among diverse groups. Furthermore, some indicators have been tailored to account specific age groups, such as young adults and the elderly. Finally, the composite index Adjusted Mazziotta-Pareto Index (AMPI) and the Chisquared Automatic Interaction Detector (CHAID) have been calculated.
Subsequently, the study has been focused on municipalities that can be considered more disadvantaged in terms of access to basic public services (Inner Areas), in order to determine if similar trends occur throughout the national territory or if belonging to certain geographical areas represents an additional penalizing factor.

1. Introduction

Italy has approximately 7,900 municipalities, of which 5,532 have fewer than 5,000 inhabitants, and of these 2,007 have fewer than 1,000 inhabitants while only 25 municipalities having more than 150,000 inhabitants. The population, which is distributed differently throughout the territory, also has different characteristics: municipalities have extremely varied demographic, social and economic structures, depending on their size and population density too.

[1] Sections are attributed as follows: sections 4, 5, 6 and 7 to Valeria Quondamstefano, sections 1, 2 and 3 to Mariangela Verrascina.

It is well known that the great territorial differentiation in Italy in terms of size of municipalities, altitude zone, degree of urbanisation, presence and accessibility of services leads to forms of discomfort for Italian municipalities and consequently also for the population living there. Smaller and peripheral territories, especially those that have been experiencing depopulation phenomena in recent years, due to the emigration of young people, and the ageing of the resident population, and which therefore have particular demographic structures, are at a disadvantage (Istat, 2024).

This work presents a proposal to measure some disparities in marginal Italian municipalities through a synthesis of some structural measures of the population and some characteristics of the Italian territory in order to identify the level of distress. The demographic and socio-economic characteristics of the resident population in each municipality of the national territory are derived from data collected in the year 2021 by the Permanent Population Census. The other information is derived from statistics that Istat makes available, such as the Areas at risk of landslides[2].

2. Classification of Municipalities based on Inner Areas

When analysing aspects that may show disparities between municipalities, one cannot disregard the classification of the Italian territory according to the Inner Areas geography. This classification first identifies municipalities with characteristics of pole, inter-municipal pole or belt depending on the availability and accessibility of certain essential services (in particular mobility, education and health) or if they are not far from these; the rest of the municipalities are classified as Inner Areas, i.e. territories of the country that are further away from the centres offering the three types of services. The distance to the supply of essential services is calculated in terms of travel time; as travel time increases, so does the potential difficulty in accessing services.

The definition of Inner Areas dates back to 2014, when the Department for Economic Development and Cohesion (DPS), now named Agency for Territorial Cohesion, launched a 'National Strategy for Inner Areas' (SNAI) as part of the strategic options for the programming of 2014-2020 EU funds (Dipartimento per lo sviluppo e la coesione economica, 2014). For the 2021-2027 programming cycle, the 2014 Inner Areas Map was revised, at the end of 2019, to consider the updated presence of services. More advanced and accurate distance calculation techniques have also been introduced (Istat, 2022).

[2] Indicator obtained by processing data from Ispra and Istat. The data come from the IFFI (Inventory of landslide phenomena in Italy) project. For the numerator, data come from the National mosaic Ispra of the Landslide Hazard Areas of the Hydrogeological Structure Plan (PAI). The area of municipalities (surveyed on 1st January of each year) was used for the denominator (source Istat).

In the 'Pole' municipalities and those that form an 'Inter-municipal Pole' all three services considered are present; 'Belt' municipalities are those for which the distance (in road travel minutes) to the nearest pole is less than 27 minutes. Inner areas are subdivided according to the highest travel time: thus, for times between 27 and 41 minutes the municipalities are classified as 'Intermediate', between 41 and 67 minutes as 'Peripheral', above 67 minutes as 'Ultraperipheral'.

The set of Poles, Inter-municipal Poles and Belt municipalities are referred to as 'Centre Areas' or 'Centres', while the set of Intermediate, Peripheral and Ultraperipheral municipalities identify the 'Inner Areas'.

The municipalities in the Inner Areas are 3,834 (48.51 percent) out of the total 7,903 municipalities existing in Italy in 2021 and have less than a quarter of the total population (13,397,431 out of 59,030,133, i.e. 22.69 percent)). Predominantly, the municipalities in the Inner Areas are mountainous or hilly and are characterised by problems of depopulation, demographic ageing and reduced employment. The Inner Areas are also characterised by the high vulnerability of the territory on which they insist, influenced by their geomorphology (Istat, 2020).

3. Individual Indicators

The interpretation of situations of inequality between Italian municipalities is carried out using some simple and non-redundant indicators representing demographic and socio-economic characteristics of the resident population in the municipality. Some indicators are calculated by gender, in order to analyse whether differential experiences and opportunities can lead to results showing disparities. Finally, an indicator on the morphology of the territory was considered, which represents the level of vulnerability/fragility of the municipalities and which may generate disparities. Specifically, the indicators calculated are:

A. *Proportion of population aged 0-17 years (percentage)* calculated as the ratio of the population aged under 18 to the total resident population per hundred inhabitants;
B. *Dependency ratio (percentage)* calculated as the ratio of the sum of the population aged under 20 and over 65 and the working age population (20-64) per hundred inhabitants;
C. *Proportion of the population aged 25-29 with an educational qualification below lower secondary education* calculated as the ratio of the population aged 25-29 with an educational qualification below lower secondary education to the population of that age group per hundred inhabitants (proxy for the school drop-out rate);

D. *Incidence of employed women aged 20-29 on employed men aged 20-29* calculated as the ratio of employed women aged 20-29 to employed men of the same age group per hundred inhabitants;
E. *Share of women aged 20-64 who receive no income or are housewives* calculated as the ratio of the female population aged 20-64 who receive no income or are housewives to all the women of the same age group per hundred inhabitants;
F. *Areas at risk of landslides (percentage)* calculated as the ratio of land areas covered by high and very high risk of landslides to municipal area.

The indicators described are calculated with the results of the 2021 edition of the Permanent Census of Population and Housing (Istat, 2022). The data on the area at risk of landslides have 2020 as a reference period. The territory taken into account refers to the municipalities existing in 2021.

4. Methodology

4.1. Composite indices

The methodology of composite indices in statistics is a technique used to summarize information from multiple variables into a single indicator. This approach is particularly useful in situations where it is necessary to condense a large amount of data into a more manageable and interpretable form. Composite indices are widely used in economics, sociology, epidemiology, and other disciplines to measure complex phenomena such as economic well-being, quality of life, public health, and more (OCSE, 2008).

4.2. Adjusted Mazziotta-Pareto Index

To synthesize individual indicators into a single, cohesive measure, this work used the Adjusted Mazziotta-Pareto Index (AMPI), a partially non-compensatory composite index designed to standardize individual indicators at a reference time point. This standardization process ensures that the indicators are independent of their original units of measure (De Muro *et al.*, 2011). By assigning equal weights to all individual indicators, the AMPI facilitates absolute time comparisons (Mazziotta and Pareto, 2016). The AMPI introduces a re-scaling mechanism for individual indicators, setting them within a range of 70 to 130. This re-scaling is based on two ‘goalposts’: a minimum and a maximum value that define the potential range of each variable across all time periods and units. These goalposts help ensure that the indicators are comparable over time by providing a consistent framework for measurement. While this approach allows for the aggregation of data with different

variabilities, it does come with certain trade-offs. Specifically, aggregating indicators with inherently different variabilities can introduce some level of distortion. However, the normalization process mitigates this issue by aligning the indicators within the same range, thereby reducing variability disparities. As a result, the normalized indicators exhibit much more similar variability compared to their original forms, enhancing the overall reliability and interpretability of the composite index (Mazziotta and Pareto, 2013). Furthermore, the AMPI's methodology supports the creation of a robust and versatile tool for various applications.

4.3. Chi-Squared Automatic Interaction Detector

The method of sorting municipalities by the Adjusted Mazziotta-Pareto Index (AMPI) is indeed intriguing and provides valuable insights into the phenomenon being studied. However, a more systematic approach is necessary to classify municipalities while considering the distress composite indicator in relation to various covariates. In this context, an effective classification method is the Chi-squared Automatic Interaction Detector (CHAID) (Kass, 1980). This multiple tree statistics algorithm allows for the rapid and efficient visualization of data, creating segments and profiles based on the results. CHAID works by repeatedly splitting the dataset into mutually exclusive subgroups that share similar characteristics with respect to the dependent variable, AMPI in this case. It examines the relationships between the dependent variable and each of the independent variables, selecting the best splits based on statistical significance. This process results in a decision tree that highlights the most influential factors and their interactions. Specifically, in this approach, the AMPI serves as the dependent variable. The independent variables include administrative subdivisions (such as Geographical area, Region, Province/Metropolitan City), geographic characteristics (Altitude zone), demographic characteristics (Degree of urbanisation[3]) and National Strategy for Inner Areas. By using CHAID, municipalities can be systematically classified in a way that takes into account the multidimensional nature of disparities and related covariates. This classification can reveal underlying patterns and trends, providing a more nuanced understanding of how various factors contribute to the composite indicator across different municipalities. This approach not only enhances the interpretability of the data but also aids in identifying key areas for targeted interventions and policymaking. In summary, while the AMPI provides a valuable measure for sorting municipalities, incorporating a systematic classification method like CHAID enriches the analysis. By considering administrative, geographic, and demographic variables, CHAID enables a comprehensive understanding of the

[3] For the classification of the Degree of urbanisation, the Eurostat definition is followed (Eurostat, 2019).

factors influencing the distress composite indicator, facilitating informed decision-making and effective policy development.

5. Main results

Table 1 shows the best 10 Italian municipalities according to the AMPI ranking. Nine municipalities of these are in the North-East, in the province of Bolzano/Bozen and one in North-West, in the province of Pavia. These municipalities have AMPI values between 93.45 and 94.21.

Table 1 – *The best 10 Italian municipalities according to the AMPI ranking – Year 2021.*

AREA	REGION	PROVINCE / METROPOLITAN CITY	MUNICIPALITY	AMPI	N°
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Velturno/Feldthurns	93.45	1
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Lauregno/Laurein	93.59	2
North-West	Lombardia	Pavia	Rognano	93.65	3
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Falzes/Pfalzen	93.76	4
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Luson/Lüsen	93.77	5
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Verano/Vöran	93.99	6
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Villandro/Villanders	94.02	7
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Terento/Terenten	94.10	8
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Perca/Percha	94.17	9
North-East	Trentino-Alto Adige / Südtirol	Bolzano/Bozen	Senale-San Felice/Unsere Liebe Frau im Walde-St. Felix	94.21	10

Source: Elaborations on data from Permanent Population Census, Istat

Table 2 shows the 10 worst municipalities according to the AMPI ranking: 7 are in the South, 2 in the North-West and 1 in the Centre. The AMPI values range from 122.83 to 114.81. Between the best (Feldthurns/Feldthurns) and the worst municipality (Bisegna) there are 29.38 AMPI points.

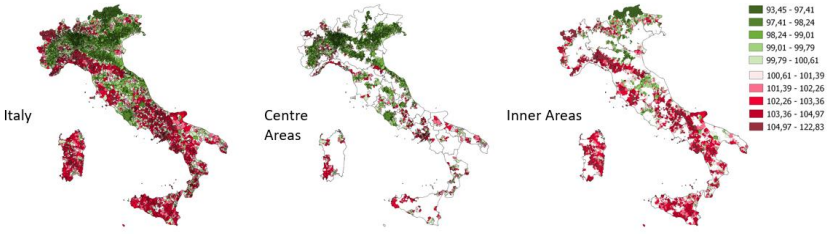
Table 2 – *The worst 10 Italian municipalities according to the AMPI ranking – Year 2021.*

AREA	REGION	PROVINCE / METROPOLITAN CITY	MUNICIPALITY	AMPI	N°
South	Abruzzo	Chieti	Roio del Sangro	122.83	7,903
North-West	Valle d'Aosta/Vallée d'Aoste	Valle d'Aosta/Vallée d'Aoste	Rhêmes-Notre-Dame	118.90	7,902
Centre	Lazio	Roma	Roccagiovine	118.11	7,901
North-West	Valle d'Aosta/Vallée d'Aoste	Valle d'Aosta/Vallée d'Aoste	Ollomont	117.12	7,900
South	Puglia	Foggia	Celle di San Vito	116.71	7,899
South	Campania	Avellino	Montaguto	115.89	7,898
South	Abruzzo	Chieti	Montebello sul Sangro	115.54	7,897
South	Abruzzo	Chieti	Colledimacine	115.11	7,896
South	Campania	Salerno	Cetara	114.82	7,895
South	Abruzzo	L'Aquila	Bisegna	114.81	7,894

Source: Elaborations on data from Permanent Population Census, Istat

Taking Italy as the basis for our composite index, Figure 1 shows the 7,903 Italian municipalities in 2021 ranked according to AMPI values.

Figure 1 – *AMPI ranking of municipalities: Italy, Centre Areas and Inner Areas - Year 2021.*



Source: Elaborations on data from Permanent Population Census, Istat.

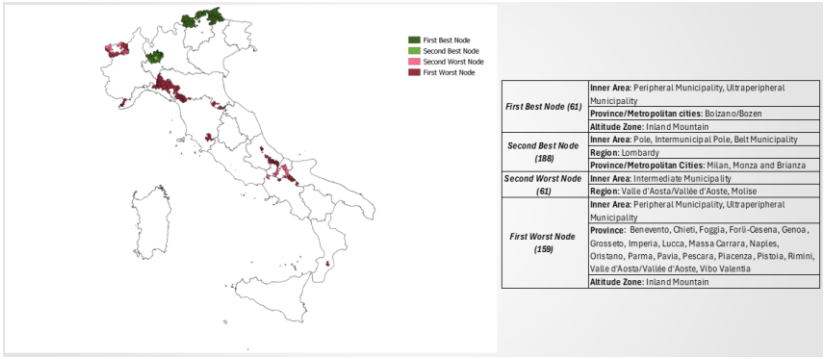
Specifically, the maps refer to Italian municipalities as a whole, municipalities in Centre Areas and municipalities in Inner Areas. The map highlights with a dark green colour those municipalities with a low level of distress. As the intensity of the green colour becomes lighter, the phenomenon increases in intensity, until it changes to shades of red. The darker the colour, the higher the level of distress in those areas. It can be seen that in the Centre Areas there are municipalities with AMPI greater

than 100 (i.e., territories with greater hardship than the Italian average) and in the Inner Areas there are municipalities with AMPI significantly lower than 100 (territories with less hardship than the Italian average). Keeping in mind that the Inner Areas are the most peripheral territories in the country in terms of access to basic public services, one would think that the territories in these areas would be the most critical ones.

The CHAID classification helps to test the veracity, or otherwise, of this idea. As mentioned above, the CHAID, using the composite AMPI index as the dependent variable and some administrative-geographic-demographic indicators as the independent variables, makes possible to identify some groups of municipalities with similar AMPI index values.

Figure 2 shows the results of the best and worst nodes.

Figure 2 – *CHAID: The best and the worst nodes - Year 2021.*



First Best Node (61)	**Inner Area**: Peripheral Municipality, Ultraperipheral Municipality
	Province/Metropolitan cities: Bolzano/Bozen
	Altitude Zone: Inland Mountain
Second Best Node (188)	**Inner Area**: Pole, Intermunicipal Pole, Belt Municipality
	Region: Lombardy
	Province/Metropolitan Cities: Milan, Monza and Brianza
Second Worst Node (61)	**Inner Area**: Intermediate Municipality
	Region: Valle d'Aosta/Vallée d'Aoste, Molise
First Worst Node (159)	**Inner Area**: Peripheral Municipality, Ultraperipheral Municipality
	Province: Benevento, Chieti, Foggia, Forlì-Cesena, Genoa, Grosseto, Imperia, Lucca, Massa Carrara, Naples, Oristano, Parma, Pavia, Pescara, Piacenza, Pistoia, Rimini, Valle d'Aosta/Vallée d'Aoste, Vibo Valentia
	Altitude Zone: Inland Mountain

Source: Elaborations on data from Permanent Population Census, Istat.

The best node is represented by 61 municipalities in the Peripheral and Ultraperipheral Areas of the province of Bolzano/Bozen with Inland Mountain altitude zone. This means that these very edge areas are actually the least deprived in Italy. The evidence from the data, therefore, is contrary to the initial assumptions. But this is unique, in fact if we look at the 2 worst nodes, we see that these are in Peripheral and Ultraperipheral Areas. The analysis at this point must necessarily continue with a focus on Inner Areas.

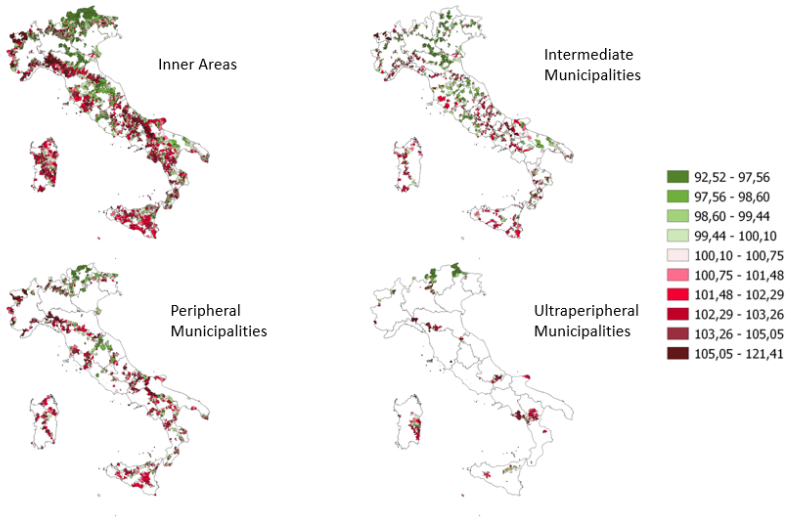
6. Focus on Inner Areas

Given the results generated by the classification trees, a focus was placed on the Inner Areas to understand which municipalities within this classification are actually

the most on the margin. Inner Areas are divided into Intermediate, Peripheral and Ultraperipheral Municipality, according to the distance from a pole that plays the role of a centre of supply of fundamental services relating to education, mobility and health care[4].

Out of the 3,834 municipalities in the Inner Areas, the AMPI was again calculated (in this case the base, set equal to 100, is the average of the values of these municipalities). Figure 3 shows the new AMPI ranking.

Figure 3 – *AMPI ranking of Inner Areas, Intermediate Municipalities, Peripheral Municipalities and Ultraperipheral Municipalities - Year 2021.*



Source: Elaborations on data from Permanent Population Census, Istat.

It can be seen that in all subdivisions of the Inner Areas there are less disadvantaged and more disadvantaged municipalities than the average. In particular, in the Intermediate Municipalities fall 1,928 municipalities, of these 52.54 percent have a higher than average AMPI, indicating a more marginalized situation. In the Peripheral Municipalities there are 1,524 municipalities, of these 70.01 percent have a higher than average AMPI. Finally, 382 municipalities are classified as Ultraperipheral Municipalities, of these 71.99 percent have a higher-than-average AMPI. This shows how, even with exceptions (e.g., some municipalities in the province of Bolzano/Bozen), the farther a municipality is from a Pole, the more it

[4] Intermediate Municipality: if they are between 27 to 41 minutes' travel time away from a centre
Peripheral Municipality: if they are between 41 to 67 minutes' travel
Ultraperipheral Municipality: if they are more than 67 minutes' travel.

will tend to be on the fringes, i.e., at a disadvantage compared to others. Most likely the exceptions are due to better policies in the area (also in terms of tourist attraction), and it is precisely in this direction that politicians should aim.

As the final analysis, the work classified the municipalities in the Inner Areas according to Altitude Zone and Degree of Urbanization (Degurba). Altitude zone derives from the division of the national territory into homogeneous zones resulting from the aggregation of contiguous municipalities based on altimetric threshold values. In particular, the classification includes: Plain, Coastal Hill, Inland Hill, Coastal Mountain and Inland Mountain.

Degree of urbanisation is a classification that indicates the character of an area. Based on the share of the local population living in urban clusters and urban centres, it classifies Local Administrative Units (LAU or municipalities) into three types of area: Cities (densely populated areas), Towns and suburbs (intermediate density areas), Rural areas (thinly populated areas). Table 3 shows the percentage of Municipalities with AMPI >100 in Inner Areas per Altitude Zone and Degree of urbanisation (Degurba). The best situation in Towns and suburbs occurs in correspondence of Intermediate Municipalities on Inland Hill (22.56 percent), the worst in Peripheral Municipalities on Coastal Hill (75.00 percent). In Rural Areas the most critical situation occurs in Ultraperipheral Municipalities on Inland Hill (95.12 percent), while the best in Intermediate Municipalities on Plain (39.60 percent).

Table 3 – *Percentage of Municipalities with AMPI >100, Inner Areas per Altitude Zone and Degurba – Year 2021.*

Inner Areas	Intermediate Municipalities			Peripheral Municipalities			Ultraperipheral Municipalities		
Altitude Zone \ Degurba	Cities	Towns and suburbs	Rural areas	Cities	Towns and suburbs	Rural areas	Cities	Towns and suburbs	Rural areas
Plain	100,00	38,02	39,60	100,00	58,54	44,44	-	-	100,00
Coastal Hill	0,00	49,38	71,72	-	75,00	79,20	-	62,50	85,71
Inland Hill	0,00	22,56	63,45	-	55,10	83,61	-	100,00	95,12
Coastal Mountain	-	60,00	61,11	-	37,50	75,86	-	50,00	88,89
Inland Mountain	-	28,10	58,42	-	45,24	66,53	-	60,00	65,13

Source: Elaborations on data from Permanent Population Census, Istat.

7. Conclusions and Next Steps

The data collected from the Permanent Census of Population and Housing, also integrated with other sources, will allow for the annual analysis of the life histories

of the population and will assist in the planning of specific local policies, facilitating the eventual identification of sub-populations (or territories) which are particularly vulnerable or in difficulty. This integration of the Permanent Census with additional data sources will provide a comprehensive overview of the population's dynamics over time. It will help identify trends and patterns in demographic changes, such as migration, aging, and socio-economic shifts. By understanding these life histories, policymakers can design and implement targeted interventions aimed at addressing specific needs and challenges within local communities. This detailed, data-driven approach ensures that resources are allocated efficiently and effectively to support the most vulnerable groups.

However, the analysis of individual indicators from census data does not provide an overall view. To achieve this, it is necessary to construct a composite indicator to measure multidimensionality and analyse the results. In our work, the analysis of the multidimensional hardship of municipalities indicated a clear surpassing of physical and administrative territorial boundaries: peripheral areas (for example, in the province of Bolzano/Bozen) can be less fragile than others located in centre areas. This means that if good and forward-looking policies are adopted, the situation in these territories can be significantly better than what geomorphological evidence might suggest.

Next steps of the analysis will concern:

- Comparison between the trend of Italians and that of foreigners resident in the area: This involves examining the demographic trends of both native and foreign populations. By comparing these trends, we can gain insights into migration patterns, integration levels, and potential socio-economic disparities. Understanding these differences is crucial for developing inclusive policies that cater to the diverse needs of both groups.
- Expand the set of individual indicators: To enrich the analysis, it is essential to incorporate a broader range of indicators. These could include economic factors (such as employment rates and income levels), social factors (such as education and health outcomes), and environmental factors (such as air quality and green spaces). Expanding the set of indicators provides a more holistic view of the factors influencing population dynamics and helps identify key areas for intervention.
- Study of disparities in Italian municipalities as a function of other spatial classifications (e.g., Local Employment Systems, Ecoregions): This step involves analysing disparities across different municipalities using various spatial classifications. Local Employment Systems and Ecoregions offer additional layers of context, highlighting regional economic and environmental characteristics. By studying these disparities, we can identify

specific local strengths and weaknesses, tailor policies to regional contexts, and promote balanced and sustainable development across the country.

These next steps will enhance our understanding of demographic changes and regional disparities, ultimately supporting the creation of more effective and equitable policies.

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