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WP3 – Area-Specific Planning

DELIVERABLE 7.3.3

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Executive summary

Scientific reports constitute the third Deliverable (D.7.3.3) of the WP3 (Spoke 7) *Area Specific Planning* and are fully within the actions related to the Target 7.3.1 *Gap Analysis Reports, one for each territorial typology* (M24). The Deliverable is related to the WP 3 objective to identify challenges for the transition towards sustainable, attractive, and smart cities and territories with a focus to specific territorial typologies. These are Metropolitan cities, the so-called "Italy in the middle" (i.e. urban areas including mid-size cities and their wider polycentric and low-density urban systems), Inner regions, and Islands.

The primary activities of the Deliverable, conducted in parallel by the research units of UNIBA, POLIMI, UNINA, UNIBO, UNIVE, UNICA, and UNICT, were necessary to address the following key tasks of WP3:

- Task 7.3.1, Integrate data from WPI with local level data and analysis;
- Task 7.3.2, Identify infrastructures and services digitalization policies to reduce divides between city centers, suburbs, and outskirts;
- Task 7.3.3, Analyze the role of infrastructures and related services on urbanization, residential choices, mobility patterns and choices, firms' relocation decisions and urban economic integration of inner and marginal areas;
- Task 7.3.4, Estimate the additional costs (network infrastructures, energy, transport) due to insularity or peripherality conditions;
- Task 7.3.7, Design of area-specific strategies for gap/vulnerability reduction and equalization policies.

The work conducted by the working groups up to the 24th month is grounded in the analyses and methodologies established at the national level to create the infrastructure and service gap maps developed within WPI. This effort also builds upon certain findings from the local vulnerability maps completed at a national level, as outlined in Deliverable 3.2 of WP3, adapted to various territorial typologies.

Each report is structured around the development targets specified in European and national plans or strategies, along with benchmarks derived from scientific literature, which are then tailored to the unique characteristics of the Italian context. The reports describe and quantify the gaps present in each territorial typology, utilizing specific indicators related to the relevant topics. They also include references to case study examples and any regional or local policies or initiatives aimed at mitigating these gaps.

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1. Spoke 7 Territorial sustainability

1.1. WP3 Area-specific planning

The WP3 aims to identify challenges for transitioning to sustainable and attractive territories, as well as smart cities, focusing on specific territorial typologies such as inner regions, islands, large urban areas, and "Intermediate Italy." To this end, recent trends in living, working, mobility, and tourism have been considered to test their impact on different territorial areas.

The activities were required to address the following main tasks:

- Integrate data from WP1 with local-level data and analysis to define detailed vulnerability maps for specific case studies;
- Identify infrastructures and services digitalization policies to reduce divides between city centers, suburbs and outskirts;
- Analyze the role of infrastructures and related services on urbanization, residential choices, mobility patterns and choices, firms' relocation decisions and urban economic integration of inner and marginal areas;
- Estimate the additional costs (network infrastructures, energy, transport) due to insularity or peripherality conditions;
- Design of area-specific strategies for gap/vulnerability reduction and equalization policies.

The initial part of the work focused on introducing the gap analysis background, which would later be applied to the various topics addressed by each research group for the deliverable.

1.2. Deliverable 3.3 – Scientific reports

This deliverable aims to identify the key gaps hindering the development of specific areas and to propose a strategic vision supported by measurable targets. The document consists of an introductory section followed by four detailed reports, each corresponding to a distinct territorial typology.

The introductory section (par. 1.3) lays the groundwork for the gap analysis, drawing on analyses and methodologies established at the national level. It discusses the creation of infrastructure and service gap maps developed in WP1 and integrates findings from the local vulnerability maps produced nationally, as outlined in Deliverable 3.2 of WP3.

Each report aligns the development targets defined in European and national plans or strategies with benchmarks from the scientific literature, tailoring them to the specific characteristics of the Italian context. The reports identify and quantify gaps, breaking them down by territorial typology and using specific indicators relevant to each topic. They also

include case studies and highlight regional or local policies and initiatives aimed at addressing these gaps.

- **Report A: Gap Analysis for Metropolitan Cities**

Focus areas:

- *Territorial Attractiveness*: Analysis of the capability system, including investments in public utility services, energy resource utilization, and land consumption.
- *Ecological Transition in Transport*: Examination of decarbonization efforts and sustainable mobility, with a focus on high-speed rail and its vulnerability to hydrogeological conditions.
- *Digital Accessibility*: Assessment of access to technological and digital infrastructures, competitiveness of the productive system, and availability of educational services.

- **Report B: Gap Analysis for Intermediate Italy**

Focus areas:

- *Proximity Gaps*: Analysis of educational landscapes and accessibility.
- *Housing Gaps*: Insights into equity and inclusion within the residential domain.
- *Land Use Gaps*: Focus on agricultural landscapes in the context of green and energy infrastructures.

- **Report C: Gap Analysis for Inner Italy**

Focus areas:

- *Essential Services Accessibility*.
- *Ecological Transition in Agriculture*: Enhancing agricultural productivity in marginal areas.
- *Built Heritage and Natural Risks*: Addressing sustainability across economic, social, and environmental dimensions in marginal territories.

- **Report D: Gap Analysis on Insularity**

Focus areas:

- *Structural Economic Disadvantages*: Rooted in geographic isolation, limited market access, and connectivity challenges.
- *Transport Systems and Services*: Unsustainable transport systems, restricted access to essential services, and reliance on tourism or fisheries.
- *Environmental Vulnerability*: Exposure to climate-related risks and dependence on imported energy and water.

The methodology integrates both quantitative and qualitative analyses across three main dimensions: social gaps, environmental gaps, and economic gaps. The overarching goal is to develop replicable policies and interventions that reduce territorial inequalities and promote an inclusive, sustainable development model.

1.3. Gap Analysis background

Introduction to Gap Analysis

Gap Analysis is a strategic assessment tool widely used across disciplines to identify the disparity between current performance and desired outcomes. Initially developed in business

management, its principles have since been applied in diverse contexts, including economics, social development, and environmental conservation.

By systematically evaluating gaps, stakeholders can better prioritize actions, allocate resources, and develop strategies to bridge disparities effectively.

The most critical questions around which the methodology of Gap Analysis resolves are:

1. Evaluate the current state concerning indicators and methods capable of analyzing ongoing phenomena and describing where we stand now.
2. Define the ideal state or the objectives identified as strategic targets in institutional plans and programs, contextualizing where we aim to be based on the current starting conditions of each territory.
3. Identifying the necessary steps to close the gap, through synergy between scenario analyses, which can be envisioned using quantitative and statistical methods, and the territorial vocations and the capacities and aspirations of local actors.

Economic, social and environmental applications

This structured approach enables organizations and policymakers to diagnose issues and design actionable solutions, fostering continuous improvement and alignment with goals.

In the **economic domain**, gap analysis is a cornerstone for planning and policy formulation. Governments and organizations use it to evaluate discrepancies in income distribution, employment rates, market demand, and fiscal policies.

For example: by analyzing income distribution data, policymakers can pinpoint gaps between different socioeconomic groups and design targeted interventions to promote equity. Identifying skill mismatches in the labor market helps develop educational programs and vocational training to align workforce capabilities with market demands. Gap Analysis in trade examines the difference between current export levels and potential capacity, guiding strategies to enhance global market participation.

By addressing these gaps, stakeholders can foster economic resilience, ensure inclusive growth, and optimize resource utilization.

In the **social sphere**, gap analysis is instrumental in identifying and addressing disparities in access to education, healthcare, housing, and other essential services. It supports developing policies and programs to reduce inequalities and promote social welfare. For example: Assessing disparities in school enrollment, literacy rates, and access to quality education highlights the need for targeted investments in underserved regions or demographics. Gap analysis identifies differences in healthcare access, quality, and outcomes, enabling the design of programs to improve public health and reduce mortality rates. Organizations can develop frameworks to promote diversity, equity, and inclusion by evaluating gaps in representation, employment, or legal rights.

The social impact of addressing these gaps extends beyond individuals, contributing to more cohesive and resilient communities.

In **environmental sustainability**, gap analysis plays a crucial role in bridging the divide between current environmental practices and the goals outlined in frameworks such as the Paris Agreement or the United Nations Sustainable Development Goals (SDGs). Key areas include biodiversity conservation, identifying gaps in protected areas or species preservation, and allocating resources to regions or ecosystems requiring immediate attention. Energy transition, assessing the gap between current energy production methods and the adoption

of renewable sources, guides policy decisions to achieve carbon neutrality. Waste management, evaluating gaps in recycling rates, waste reduction targets, and infrastructure availability developing comprehensive strategies for sustainable waste management.

Environmental Gap Analysis thus ensures that conservation efforts are targeted, effective, and aligned with broader global sustainability goals.

Challenges and Opportunities

Despite its widespread utility, Gap Analysis is not without challenges. Despite the allocation of significant public resources, not all local development policies have led to tangible improvements. On the contrary, economic integration processes have often exacerbated development disparities among territories in the global economy. Regions endowed with greater resources have been able to capitalize on the economic globalization process, further strengthening their advantageous positions. Meanwhile, territories with fewer material and immaterial resources have suffered further impoverishment, relegating them to the periphery of the global economy.

The availability and accuracy of data, for instance, are critical for meaningful assessments. Additionally, addressing identified gaps often requires significant resources, collaboration, and time.

However, these challenges also present opportunities for innovation, stakeholder engagement, and the development of dynamic solutions tailored to specific contexts.

Gap Analysis is a versatile tool that transcends disciplinary boundaries, offering valuable insights into economic, social, and environmental challenges. Systematically identifying and addressing disparities empowers stakeholders to drive progress, enhance equity, and contribute to sustainable development. In an increasingly complex world, understanding and bridging gaps is more vital than ever, ensuring that aspirations in all domains are translated into tangible outcomes.

This deliverable aims to analyze the processes of economic, social, ecological, and digital integration, focusing specifically on the structural differences characterizing four distinct territorial typologies: the major urban areas, the "Intermediate Italy", Inner areas, and Islands.

Report A – METROPOLITAN CITIES

1. Gap analysis in the Metropolitan Cities¹

1.1. Introduction

This report examines infrastructure and service provision gaps that hinder metropolitan areas' ability to remain attractive and resilient in the face of significant social, economic, and environmental changes. Utilizing diverse data sources, including georeferenced and real-time data, and developing new indicators to measure territorial attractiveness and resilience, the analysis addresses differentiated aspects that represent the key challenges of digital and sustainable transitions. It also identifies the principal vulnerabilities of Metropolitan Italy within the European context, highlighting geographical disparities between the north and south. The report builds on the analyses and methodologies established at the national level for mapping infrastructure and service gaps, as developed in Work Package 1 (WPI). It also integrates findings from the local vulnerability maps presented in Deliverable 3.2 of Work Package 3 (WP3), adapting these insights to the context of Italy's 14 Metropolitan Cities.

The investigation focuses on three macro-areas critical to the competitiveness, sustainability, and resilience of highly urbanized contexts:

- **Territorial Attractiveness:** Analyzing investments in public utility services, energy resource management, and land use.
- **Ecological Transition in Transport:** Exploring decarbonization strategies and the development of sustainable mobility, with particular attention to high-speed rail (HSR) networks and vulnerabilities related to hydrogeological conditions.
- **Technological and Digital Accessibility:** Assessing the competitiveness of production systems and access to educational services through technological connectivity.

The specific dimensions analyzed in alignment with WP3 include:

1. **Territorial Capacities:** The foundational elements of the socioeconomic development of Metropolitan Cities, categorized into four pillars traditionally used in regional science to assess urban assets across public and private dimensions: social capital, economic capital, human capital, and physical capital.
2. **Public Investments:** Key utility services for large urban areas, including waste management, public transportation, and the maintenance and enhancement of cultural assets and activities.
3. **Energy, Water, and Land Use:** Management and consumption patterns, particularly land use for transport infrastructure.
4. **High-Speed Rail Networks:** Evaluating their role in sustainable mobility and resilience to environmental risks.
5. **Technological Connectivity:** Coverage and accessibility of technological networks and the diversification of advanced digital services, as measures of a city's capacity to foster innovation, development, and social inclusion within the global competitive landscape.

¹ This paragraph was written by the University of Bari "Aldo Moro" _DEMDI research group.

6. **Productive Structure and Internationalization:** The vulnerability of metropolitan business systems to global economic shocks and the extent of economic diversification across sectors and target markets.
7. **Educational and Training Infrastructure:** Accessibility and safety, serving as indicators of metropolitan adaptability to ecological and digital transition challenges.

This report provides an in-depth analysis of these areas to enrich policy discussions and support decision-making processes aimed at enhancing the attractiveness, resilience, and sustainability of Italy's metropolitan areas.

1.2. Socio-economic profiles of the metropolitan cities

Metropolitan cities are "large area territorial bodies" that have replaced the provinces in 10 urban areas of regions with the *ordinary statute* and which have their governing bodies and territories coinciding with those of the former provinces: Rome, Turin, Milan, Venice, Genoa, Bologna, Florence, Bari, Naples, and Reggio Calabria. Added to these are four metropolitan cities in the special statute regions: three in Sicily – Palermo, Catania, Messina – and one in Sardinia – Cagliari.

This section highlights some data from ISTAT (2023) that summarize the socio-demographic aspects and elements of the economic context, including population dynamics, ageing, mortality, settlement choices, the labor market, the level of education, commuting, and the characteristics of the productive fabric. The comparative study of the respective urban territories consisting of the capital municipality (urban hub) and the first and second-level urban belts allows us to observe the dynamics of the evolution of the cities, also highlighting the geographical fragilities mainly linked to anthropic pressure and natural risks.

The 14 Metropolitan Cities include **1,268 municipalities** (16% of Italian municipalities): more than half have fewer than 5,000 inhabitants, one-third have 5,000 to 20,000 inhabitants, 11% have 20,000 to 50,000 inhabitants, and 3.5% have a population exceeding 50,000. The total area covered is 46,637 square kilometers (15.4% of the national surface). The cities are home to 21.3 million people, representing 36.2% of the Italian population (ISTAT, 2023).

The identification of urban hubs and urban belts within the fourteen metropolitan cities reveals the following classification of municipalities:

- **14 urban hubs** represented by the main municipalities, where nearly half of the metropolitan cities' population (43.2%) resides, with an overall density of 2,552 inhabitants per km².
- **177 municipalities** in the first urban belt (14%) with 18.1% of the population.
- **213 municipalities** in the second urban belt (16.8%) with 14.3% of the population.
- **864 municipalities** in the remaining metropolitan territory (68.1%), home to 24.3% of the population.

The "high and medium" degree of urbanization in the metropolitan cities encompasses almost 54% of municipalities, significantly higher than the national average (36%). Based on this

classification, it can be observed that the closer municipalities are to the metropolitan capital, the more urbanized they tend to be. On the other hand, the farther one moves from the capital, the more rural areas emerge, accounting for 15.3% in the first belt and 58% in the outer belt.

Among the metropolitan cities, **Naples** records the highest proportion of highly urbanized municipalities (54.3%), followed by Milan. **Bari** has the highest incidence of municipalities with intermediate density (87.8%), while **Reggio Calabria** shows the highest prevalence of rural areas (74.2%), followed by Messina (70.4%). Similarly, in **Turin**, as in Reggio Calabria and Messina, the degree of “high and medium” urbanization is among the lowest, as the two urban belts surrounding Turin’s capital city have a very small proportion of municipalities (13% of the total) compared to the outermost area, farther from urban centers.

Regarding overall size, the largest metropolitan city is **Turin**, spanning 6,827 km², followed by Rome (5,363 km²) and Palermo (5,009 km²). The smallest are **Cagliari** (1,249 km²) and **Naples** (1,179 km²). Among the capitals, **Rome**, **Venice**, and **Genoa** have the largest territorial extent, while **Florence** and **Cagliari** are the smallest. There are notable differences in metropolitan dimensions: Turin, despite its vast territory, has the smallest impact of its capital on the total area (nearly 2%), while Rome, the second-largest in territorial size, shows the highest proportion of its capital municipality (24% of the total).

Among the indicators describing the relationship between territory and population, the ratio between the resident population and the territorial surface (population density) is useful for assessing the anthropic pressure on the environment and the degree of area congestion.

Naples, with 2,535 inhabitants per km², is the metropolitan city with the highest population density, followed by **Milan** (2,040 inhabitants per km²). Within these territories, classified based on the territorial contiguity of their municipalities, there is a clear concentration of population in the capital cities. Notably, the most densely populated are **Naples** (7,744 inhabitants per km²), **Milan** (7,430 inhabitants per km²), **Turin** (6,526 inhabitants per km²), and **Palermo** (3,957 inhabitants per km²). The least densely populated capital is **Venice** (606 inhabitants per km²).

As is well known, much of Italy’s territory is characterized by significant hydrogeological risk, linked to the nature of the land and human activities that alter its original appearance, affecting natural stability, increasing erosion, and soil instability. In metropolitan cities, the highest incidence of landslide-risk areas as a percentage of total surface is 6.8%, almost two percentage points below the national average. The metropolitan cities with the highest proportions of landslide-risk areas are **Genoa** (25%) and **Florence** (21% of the total), while among the capitals, Genoa leads (31.2%).

Hydrogeological risk areas cover 10.8% of the metropolitan territories’ total surface, roughly aligned with the national average. **Bologna** is the metropolitan city most exposed to flood risk, with 50% of its total area at hydrogeological risk, followed by **Venice** (29.2%). Among the capitals, **Bologna** (57.7%) and **Catania** (50.2%) have the highest levels of hydrogeological risk.

Population distribution: different settlement patterns

As of December 31, 2021, the population of the fourteen metropolitan territories was **21,340,974**, representing a growth of 3.8% compared to 2001, or nearly **786,794 additional residents**. In absolute terms, the most populous metropolitan cities are **Rome** (4.2 million) and **Milan** (3.2

million), while the least populated is **Cagliari** (421,000 inhabitants).

However, observing the population distribution within these territories reveals varying settlement preferences among residents. In the seven metropolitan cities of the **North** and **Center**, plus **Palermo**, the capital municipality acts as an attractive hub compared to the rest of the area, concentrating most of the population. This concentration varies, ranging from **69% in Genoa** and **65.5% in Rome** to **30% in Venice**.

Moving away from the urban hub, particularly in the metropolitan cities of **Turin, Milan, Bologna, Genoa, and Florence**, the second most preferred settlement choice is in the **outermost belt**, followed by the **first belt** (ISTAT, 2023)

The entire country is facing a negative natural change due to low fertility rates, which reduces the population, partially offset by positive migration dynamics. Low fertility inevitably results in a decrease in birth rates, thus contributing negatively to population growth. The demographic trend over the 2001-2021 period shows population growth in metropolitan cities slightly higher than the national average (**3.8% compared to 3.6% for Italy as a whole**), highlighting that metropolitan and more urbanized areas exhibit a degree of attractiveness for population settlement. **669 municipalities** (53% of all municipalities in metropolitan cities) experienced population growth during this period, home to 13 million inhabitants (61% of the total population in the fourteen territories). Meanwhile, the remaining **47% of municipalities** in metropolitan cities recorded a population decline, with only two small municipalities maintaining a stable number of residents.

The geography of demographic changes in the metropolitan areas of Central and Northern Italy shows a population increase, most notably in **Rome (14%)**, **Bologna (10.4%)**, and **Milan (9.4%)**, significantly driven by the arrival of foreign citizens. An exception is **Genoa (-6.8%)**, due in part to an "older" population structure that impacts demographic trends and all related indicators.

There was a slight population increase in the metropolitan cities of **Bari, Catania, and Cagliari** over the same period. Conversely, the population decreased overall in the metropolitan cities of **Messina (-8.8%)**, **Reggio Calabria (-7.3%)**, **Naples (-2.3%)**, and **Palermo (-2.2%)**.

Between 2001 and 2021, the capitals that experienced the highest population growth were **Rome (8%)** and **Milan (7.7%)**, while those that saw the greatest population decline are **Messina (-12.2%)** and **Cagliari (-8.9%)**.

Demographic future in the next decade: a progressive decline

The new population forecasts confirm the persistence of a critical demographic outlook for the country, projecting a population decrease of -1.8% over the next decade. A similar trend is expected for the metropolitan cities, with a decrease in the resident population, though smaller, from 21.3 million on December 31, 2021, to 21.0 million by 2030, representing a change rate of -1.5%. Factors contributing to depopulation at the national level are linked both to the decline in fertility rates, where births are unable to compensate for deaths and to negative migration balances. Although migration flows abroad are positive, they do not offset the negative natural population change.

The negative demographic trend is reflected in the population's demographic indicators. Population aging is one of the most significant factors and has become a major issue for the country. In 2021, the aging index in the metropolitan cities reached a value of **177.5 elderly per 100 children**, continuing to rise over the years (it was **142.4** in 2011), although still much lower

than the national average (**187.6**), confirming the progressive aging of the population across the entire territory: more elderly people in the capital municipality (**192.0**) and in the municipalities of the outermost belt, with a lower incidence in the first two belts.

As of December 31, 2021, there are **1,879,385** foreign residents in the metropolitan cities, accounting for **8.8%** of the total population, slightly above the national average (**8.5%**). The settlement of foreign citizens shows a higher incidence in the capital municipalities (**11.5%** of the total population of the capital municipality). At the same time, the further one moves from the capital, the lower their presence in the territory becomes (**7.3%** in the first belt and **6.5%** in the second). From 2001 to 2021, the share of foreign residents in the metropolitan cities grew from **2.4%** to **8.8%**. This trend is more pronounced in urban centers and milder in the belts but more intense in the North and modest in the South.

Education and labor market participation

Among residents aged 25-64 in metropolitan cities, 43 out of every 100 hold a high school diploma, and 24 out of every 100 have a tertiary education degree (first, second, or third level).

Milan, Bologna, and Rome metropolitan cities have the highest share of tertiary education degrees, ranging from **29% to 31%**. In contrast, the cities with the lowest share are **Catania, Palermo, and Naples**, with values close to **18%** of the population.

The comparison between territories reveals a well-known situation, characterized by a concentration of highly educated populations in the capitals, with an average of **31 people with tertiary qualifications per 100 residents**, compared to areas further away from the more urbanized centers. The municipalities of **Bologna and Milan** exceed the area's average by about 10 percentage points, followed by Cagliari and Florence.

Analyzing the population with at least one secondary qualification (the sum of secondary and tertiary qualifications), the most disadvantaged metropolitan cities and capitals continue to be **Palermo, Naples, and Catania**, where the share of those with at least a high school diploma ranges from **55 to 58 residents per 100 people** of the same age group.

The metropolitan areas, especially in the country's north, are characterized by a higher birth rate and a greater presence of foreigners. All this leads to a larger school population, which is fully served by providing primary and lower secondary schools. The already significant number of schools in metropolitan areas increases when fringe areas are considered. Regarding upper secondary education, metropolitan areas have a large and variegated provision, concentrated mainly in the capital cities and the first belt.

Regarding the system's ability to respond to labor supply, the overall employment rate for the adult population (ages 25-64) in the 14 metropolitan cities is **65%**, two percentage points below the national average.

The metropolitan cities in the North have the highest employment rates, with **Bologna** leading the way (77 employed per 100 people), followed by **Milan and Florence** (76%). In contrast, the metropolitan cities with the lowest rates, indicating labor market fragility and disadvantage, are located in the South: in **Palermo**, only **49%** of the population is employed, followed by **Catania and Naples**, with values close to **50%**.

Also, about employment data, the urban centers show a greater capacity to absorb and employ the available human capital. In fact, in the capital municipalities, just over **66%** of the population is employed. At the same time, as one moves further from the metropolitan center, there is a gradual reduction in employment rates, which average **65%** in the first belt and **62%**

in the second belt. Exceptions include the metropolitan cities of **Bologna, Florence, Turin, Milan,** and **Genoa**, where employment levels in the first and/or second belts are higher or in line with those of the respective capital municipalities (in some cases more than two percentage points higher), and the metropolitan city of **Catania**, where the employment rate in the first belt exceeds that of the capital municipality by five points.

The gradual reduction of gender disparities in active labor market participation is increasingly considered a factor that stimulates economic growth, although it remains a challenge in the national economic system. **Bologna** is the metropolitan city with the highest female employment rate, with **51 women employed per 100**, followed by **Milan** and **Florence**. In contrast, there are still four cities in the South—**Naples, Palermo, Bari,** and **Catania**—with values ranging from **35% to 37%**, where women have the lowest participation in the labor market. However, there are encouraging trends compared to 2011 (ISTAT 2023).

Mobility and economic-productive structure of metropolitan territories

Metropolitan cities have been, for thirty years, the main interest of rail transport policies. With some exceptions, HS is reaching (or will reach by 2026) all urban cores of metropolitan Italy except Reggio Calabria and Sicilian and Sardinian cities. Also, for regional transport, some metropolitan cities were at the center of national and regional policies. Starting in 1998, the concept of suburban service reached Milan and its metropolitan area. It is now a way to design services in most other main metropolitan areas from north to south (interesting the recent systems under the implementation of Palermo, Bari, and Catania).

The resident population that commutes daily for study or work reasons is about **51%** of the total population in metropolitan cities. This figure is broadly in line with the national average and has increased by more than **three percentage points** compared to 2011.

The territorial analysis highlights significant differences, largely explained by employment gaps and the different distribution of work and study locations within the areas. Daily mobility for study or work reasons is highest in **Milan** (about **57%** of the population), followed by **Bologna** and **Florence**. In all Southern metropolitan cities, values are below the area average, with **Palermo, Messina,** and **Reggio Calabria** ranking among the lowest (about **42** people per **100** inhabitants).

Looking at the details of movements within the territory, **intra-municipal mobility** is higher than **inter-municipal mobility**, at **32.6%** versus **18.2%**. This dynamic characterizes all metropolitan cities, with notable differences in **Rome** and **Genoa**, where commuting within the municipality involves more than **40%** of the population, and in some Southern cities, where mobility outside the municipality is relatively limited, not exceeding **12%** (e.g., **Palermo, Reggio Calabria,** and **Messina**).

The analysis within the metropolitan territories confirms a significant prevalence of **intra-municipal mobility** for study or work reasons in the capital municipalities (**46 people per 100 residents**, compared to **five** who commute outside the municipality), attributable to the greater availability of work and study opportunities located in the central areas of the metropolitan city (ISTAT, 2023).

The presence of economic activities in the territory, analyzed through the number of local units relative to the population, helps to provide an initial description of an area's economic structure and entrepreneurial propensity. Overall, the metropolitan cities in 2020, can count on a total of **1,779,620 local units, 83 for every thousand inhabitants**, a value about two points

higher than the national average. The metropolitan city of **Milan**, with 346,509 local units and a ratio of 107 units per thousand inhabitants, shows the highest entrepreneurial density, followed by Florence and Bologna, which are about seven and 13 points lower, respectively. **Palermo** and **Reggio Calabria** (56 and 59 local units per thousand people) are the territories with the lowest availability of economic activities relative to the population, indicating a disadvantage in the area's economic fabric.

Concerning the macro-sectors of economic activity, the highest density of local units in metropolitan territories, over 34 per thousand inhabitants, is found in "**Other services**," which include typical tourism services, financial activities, and professional services. The metropolitan city of **Milan** demonstrates the highest economic potential in this sector, exceeding the area's average by 18 points, reaching 52 local units per thousand inhabitants. In contrast, **Reggio Calabria** (about 19 units per thousand inhabitants) has the lowest density, revealing a certain fragility in the sector. The metropolitan territory of **Florence** is the most industrially-manufacturing oriented (12 units per thousand inhabitants). In contrast, **Bari**, with 25 local units per thousand inhabitants, stands out for its productive specialization in the trade sector, followed by Naples, Cagliari, and Genoa.

The capital municipalities show greater economic vitality and a higher capacity to attract productive units compared to the urban belts, assuming a central role in the overall economy of the territory.

With a density of 102 local units per thousand inhabitants observed for all capitals, **Milan** stands out for its higher entrepreneurial capacity, confirmed by 151 local units per thousand inhabitants in the municipality, followed by Cagliari and Florence, with a gap of 25 and 28 points, respectively. **Reggio Calabria** and **Palermo** do not reach 63 units per thousand inhabitants and are the capital with the lowest local unit density. Within the capitals, the productive specialization reflects what has already been observed for the entire metropolitan area.

The economic structure of the urban belts is generally characterized by a lower production density compared to the capitals, with gaps of about -34 units per thousand inhabitants for the first belts and -37 for the second belts. However, these areas show the highest concentration of activities in the industrial sector.

The joint study of the density of local units and the average per capita income highlights the strong relationship between the two variables. It underscores the key role played by the provincial capitals in entrepreneurial development and income production within their respective metropolitan areas.

Milan stands out for having the highest per capita income, over 23,000 euros, nearly 10,000 euros more than the national average, and for the highest concentration of production units. Higher-than-average values for both indicators are also found in the municipalities of Florence, Bologna, Cagliari, Turin, Rome, Bologna, Genoa, and Venice, while Palermo, Reggio Calabria, and Messina rank below the national average.

Another indicator used to assess a territory's economy's productive structure and potential is the average size of local units, measured in terms of the number of employees. In 2020, the average number of employees per local unit in the metropolitan areas was 3.7, reaching a peak of 4.1 employees in the municipalities of the first urban belts. The highest average size of local units is found in the metropolitan area of **Milan (4.4 employees per local unit)** and its belts, followed by the first belts of Bologna and Florence.

The nominal labor productivity, measured by the value added per employee, is **48.3 thousand**

euros across the metropolitan areas in 2020 (a year marked by the crisis induced by the Covid-19 pandemic), compared to an average national figure of 44.5 thousand euros. The variability of the indicator among the capital cities is very marked: the highest value is observed in **Milan (71.2 thousand euros per employee)** and the lowest in **Messina (29.2 thousand euros per employee)** (ISTAT, 2023).

2. Relevant issues, targets and benchmark²

2.1. Territorial capacities of the metropolitan areas

In line with the framework representing the concept of attractiveness of territories developed in WPI, it was possible to identify a comprehensive set of indicators that enable to detect gaps in critical factors that contribute to the sustainable development of territories (Amaddeo et al., 2024). Following the literature below, there is a description of the specific dimensions mapped through the four territorial capitals:

- *Social capital*: the rules and principles governing interactions and interdependencies among individuals, the institutions they are affiliated with, the relational networks established among different social actors, and the overall cohesion of society (Camagni et al., 2008). This dimension was included to identify development gaps among territories since these social resources play a crucial role in the territorial capacity to mobilize resources and build essential relationships, trust, and rapidly obtain information needed to respond effectively to changes (see, e.g., Tan et al., 2020; Cardoni et al., 2021; Ye et al. 2022).
- *Economic capital*: financial and economic assets and resources that households exploit to sustain their livelihoods and living standards, including income, wealth, as well as savings or credit. Moreover, it encompasses the characteristics of the local market structure. The choice of this dimension is consistent with a large and constantly growing stream of literature, including several indicators about the economic capital as critical factors to assess the resilience of territories and the presence of gaps in terms of development opportunities (see, e.g., Liu et al. 2020; Tan et al., 2020; Lu et al., 2022b).
- *Human Capital* includes skills, knowledge, good health, and the ability to work towards and achieve livelihood objectives. This dimension was considered to assess the heterogeneity in territories' attractiveness levels since human capital serves as a foundational resource, enabling territories to access and fully utilize other capital resources (see, e.g., Liu et al. 2021; Hu et al. 2022; Ye et al. 2022).
- *Physical capital*: basic infrastructure or built environmental features that can help people, households, and businesses to support their livelihoods. This encompasses housing or residential structures, commercial and industrial buildings, infrastructure, and essential lifelines (water, sewer, tourism, and transportation). The inclusion of this dimension is justified by the fact that it includes critical facilities such as tourism accommodation, transportation infrastructures, as well as natural resource stocks that could affect the resilience and attractiveness of territories (see, e.g., Liu et al., 2020; Lu et al. 2022a; Du et al., 2023).

² Paragraphs 2.1 and 2.3 were written by University of Bari_DEMDI research group. Paragraph 2.2 was written by UNINA_DICEA research group.

2.2. Green mobility and high-speed rail (HSR) impact

The European Sustainable Mobility targets in 2030.

With a forecasting view to 2030 concerning the decarbonisation objective, only five Italian cities (Bologna, Florence, Milan, Rome and Turin) adhere to the NetZero2030 "mission" proposed by the European Commission, while the others refer to 2050.

The gap to be filled is assessed about the current state, without considering the interventions already envisaged by the PUMS. Five crucial areas related to sustainable mobility are also considered, with a view to decarbonization by 2030. The assessment indicates which objectives to achieve at the level of the capital municipalities' territories.

The objectives follow:

- An entirely zero-emission local public transport supply, through rail systems (subways/trams), trolleybuses and the complete electrification of bus fleets.
- The development of active mobility through the creation of cycle paths, reaching European level standards, which favor a very significant modal shift towards this type of active mobility.
- Promote the development of electric shared mobility (car, bike, scooter, shared micromobility) and innovative systems such as Mobility as a Service (Maas).
- Promote the reduction of the rate of motorization and the electrification of the private vehicle fleet, also through establishing and developing areas in which the circulation of private combustion vehicles is limited.
- The fifth dimension is somehow the result of the actions carried out on the four previous "levers," namely the modal split.

A "synthetic index" is indicated as the result of the aforementioned dimensions, which immediately indicates the distance cities should bridge to move from today's reality of "unsustainable mobility" to a perspective 2030 of decarbonization and sustainable mobility.

Public Transport

The goal for 2030 is to have zero-emission public transport. Public transport consists of non-polluting networks (metro, tram, trolleybus) and the electrification of road transport. As an indicator, we consider the offer of non-polluting public transport in 2020 (metro, trams, trolleybuses) and the share of electric buses present on the same date. The three metropolitan cities with the smallest gap are **Milan, Naples, and Rome**, with gaps of -19%, -33%, and -38%, respectively, compared to the goal of fully non-polluting public transport. **Palermo, Bari, and Reggio Calabria** are the furthest from the goal, with gaps of -85%, -90%, and -100%.

Active mobility

As an indicator, it is used the density of cycle paths existing in 2020 compared to the number of inhabitants, and as a 2030 target, the reference is to the dossier created by the Clean Cities Campaign in collaboration with Fiab, Kyoto Club, and Legambiente "It's not a country for bikes", which identifies minimum cycle infrastructure thresholds differentiated based on the population of the capital cities:

- 15 km/10,000 inhabitants for cities with less than 500,000 inhabitants;

- 10 km/10.000 inhabitants for cities with a population between 500,000 and 1.5 million inhabitants;
- 5 km/10.000 inhabitants for cities with over 1.5 million inhabitants.

The deficit of cycle paths to date compared to the standards identified is very high in all cities, ranging from -58% in Venice to -98% in Catania, Messina, and Naples.

Shared mobility

The existing shared mobility services are considered, using the overall number of shared vehicles (cars, bicycles, electric scooters, and electric scooters) per inhabitant as an indicator. In this case, the 2030 objective, considered consistent with the decarbonization perspective, takes as an example the situations of European cities where shared mobility has now acquired a significant share of modal trips. As in the case of cycle paths, minimum thresholds of shared mobility services are identified, differentiated based on the population of the capital cities, which favor a very significant modal shift towards this type of sustainable mobility, helping to encourage the reduction of the rate of private motorization:

- 150 vehicles /10,000 inhabitants for cities with less than 500,000 inhabitants;
- 200 vehicles / 10,000 inhabitants for cities with a population between 500,000 and 1.5 million inhabitants;
- 250 vehicles /10,000 inhabitants for cities with over 1.5 million inhabitants).

In some European cities, these targets have already been exceeded, for example, in Helsinki (with more than 300 vehicles/ 10 thousand inhabitants). In Italy, only Florence and Milan are in line with the standards. In all other metropolitan cities, the gap is equal to or greater than - 50%, with Genoa, Catania, and Messina in the last three positions.

Motorization rate

Considering the rate of motorization, and in particular the number of cars per thousand inhabitants, compared with the situation of the most advanced cities, we have indicated as an objective for 2030 that cities should halve (or more) the cars in circulation; a threshold that can constitute an objective - currently very challenging for Italian cities - of vehicle density compatible with a city size characterized by sustainable mobility and high liveability. A single numerical target has not been identified precisely, to consider the profound differences between the various realities in territorial extension, urban density, etc.

On the other hand, verifying how this indication constitutes a challenging but realistic target is possible by verifying the situation in some large European cities is possible. For example, Paris, which in recent years has been strongly engaged in a radical change in travel methods, which is reflected - precisely - in the number of cars in circulation per 1,000 inhabitants, which in 2021 were 450 at a regional level (Ile de France - 12 million of inhabitants), 370 at metropolitan level (Metropole du Grand Paris, 131 municipalities and 7 million inhabitants) and 275 in the city of Paris (2.2 million inhabitants). Other examples of large European cities with high levels of sustainable mobility - especially public transport - are London (Inner London), with 205 cars per 1000 inhabitants; Berlin, with 337 cars per 1000 inhabitants; and the province of Barcelona with 432 cars per 1000 inhabitants.

In this case, the size of the city affects differently – also concerning the specific characteristics of urban development – in large metropolises, such as Berlin, the existence of efficient mass public transport branched out across the territory is crucial, in cities of smaller dimensions much depends – in addition, however, on the presence of efficient public transport services – on the ease of moving around in active ways (by bike or on foot).

In Italy, in this case, there is a very evident gap between the cities of the north and those of the south.

In Italy, there is a very clear gap between the cities of the North and those of the South for this goal.

Modal share

Italian cities have one of the highest motorization rates in Europe, so a significant reduction in these vehicles in circulation is essential (determined by the increase in travel through non-polluting public transport, active and shared mobility).

Taking as reference a study on the topic of ISFORT, which indicates the data relating to the "sustainable mobility rate" in the main European cities (calculated as the sum of the share of journeys on foot + bicycles + public transport on the total), it is identified as an objective standard for modal split, a share of 65% which includes travel by public transport, active mobility and shared mobility.

On the other hand, recent calculations on Google data at a European level – by the Clean Cities Campaign – show that this level has already been reached or exceeded in cities such as Madrid (65%), Amsterdam and Berlin (68%), and Stockholm (69%).

In addition to the data referring to the territory of the metropolitan cities for which we use the information provided by ISFORT – which were collected with homogeneous methodologies and timescales – the areas of the capital municipalities are indicated (for homogeneity with the other mobility components considered), which however are non-homogeneous in terms of survey method and reference year.

Compared to the goal of a 65% modal split with sustainable mobility, Genoa, Turin, Naples, Bari, and Rome are ranked in the top among metropolitan areas. Meanwhile, Palermo, Catania, Messina, and Reggio Calabria are positioned lower in the ranking.

On the other hand, at the level of capital cities, Venice, Milan, Naples, and Bologna occupy the top positions in the ranking. At the same time, Florence, Bari, Palermo, and Catania are in the last positions, respectively.

A "synthetic index" of sustainable mobility

To define a "synthetic index," which indicates through a summary value the "distance" of the 14 cities from the objective of decarbonization and urban liveability through the development of sustainable mobility, the average of the values of the five was calculated dimensions considered to compare the situation of different cities, non-polluting public transport, cycling mobility, shared mobility, motorization rate and modal split.

The result is expressed in the following graph as the average gap indicators 2020–2030 for public transport, active mobility, shared mobility, motorization rate, and modal share:

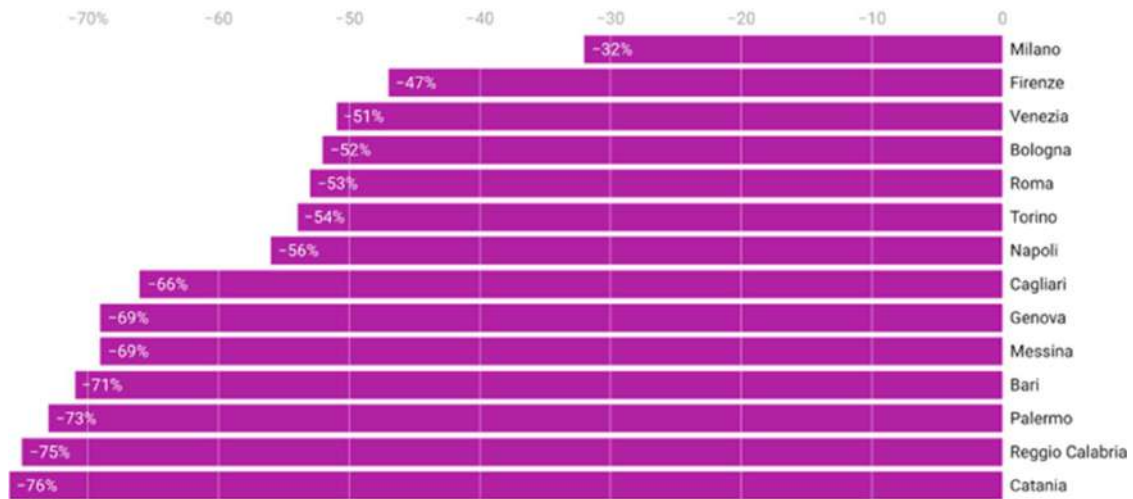


Figure 1: Synthetic index of the gap 2020-2030 compared to the 2023 decarbonization and sustainable mobility target. Source: Kyoto Club elaboration on ISTAT data.

High-Speed Rail development

The story of the HSR network in Italy is a long and controversial. It began in 1975, only 10 years after Japan and before the French TGV, with the construction of the “Direttissima” Rome-Florence line with a design speed of over 250 km/h and to connect two of the leading Italian cities without intermediate stops. The construction of this rail section was completed only in 1992 when the service began. The decision-making and implementation process of the Italian HSR network started in 1986 with the National General Transportation Plan which identified a network of HSR lines as a tool for both relaunching the national rail transport and complying with EU directives. Only in 2005, the second section of the network, the “Naples-Rome” line, became operational, and in 2009 the entire “Turin-Salerno” line was completed. After these interventions, few HSR stations were inaugurated and the section “Milan-Brescia”, 95 kms long, was opened in 2016. Overall, the entire network is 1,467 km long with fourteen HSR stations (Figure 2) and a population of more than 20 million of inhabitants (34% of the total) live within 0.5 h/30 km from an HSR station.

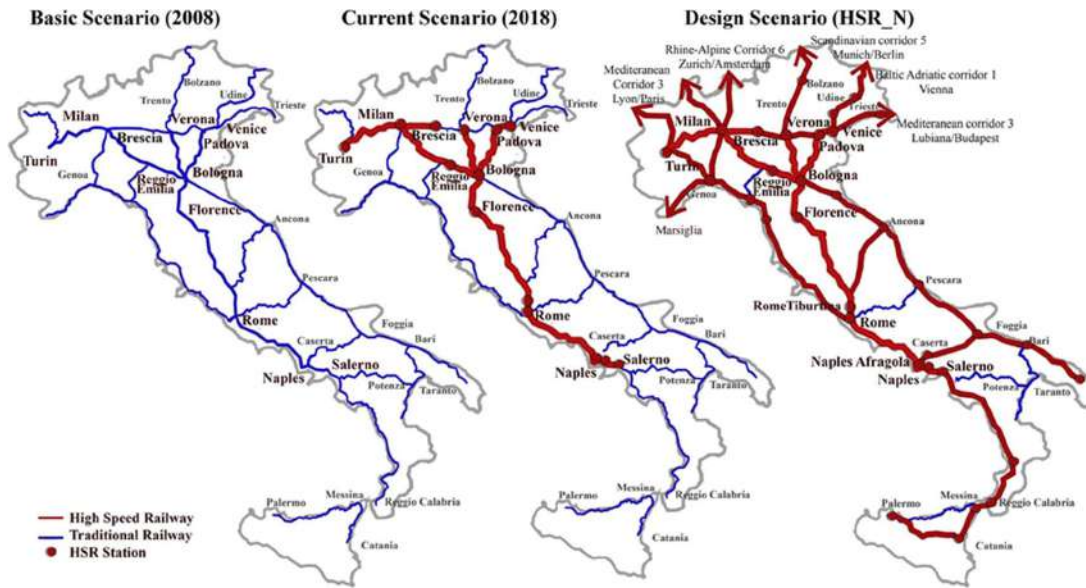


Figure 2: The Italian HSR Network: basic scenario, current scenario and project development (Source: Cascetta et al., 2020).

Today in Italy, there is only an example of in-the-market competition for HSR services. The history of the liberalization of the Italian HSR market starts with the transposition of European directive CEE 440/1991 (implemented in Italy with the acts DPR277/1998, DL146/1999, DL188/2003) aimed at developing the European railways network. The European “First Railway Package” (EU directives 12/2001, 13/2001 and 14/2001) in 2001 regulated the separation between the management of the rail infrastructure and the operation of transport services. In 1997, the rail service company “Italiana Trasporti Ferroviari”, re- named in 2000 into “Trenitalia” was separated from the unique company Ferrovie dello Stato (FS) holding 100% of the shares. In 2001, the Italian government supported the emanation of the “Italian Railway Network” (RFI), a company managing the railway network (supply side) that is held by the Italian State Railways (FSI). In 2007 with the Italian law DL162/2007 (in response to the European “Second Railway Package”), the “National Rail Safety Agency” for controlling/regulating the use of the Italian rail network was established. In 2007, the European “Third Railway Package” was emanated (implemented in Italy with the law 99/2009), which established the rights to use the international passenger rail network. With the opening of the rail market competition, in December 2006 “Nuovo Trasporto Viaggiatori” (NTV) was born with an initial investment of 1 billion Euros by private investors and without any subsidy from the Italian State, becoming Trenitalia’s unique competitor in the HSR market. In February 2007 NTV obtained the railway company license but only in 2012 it started operation of HSR services competing with those provided by the incumbent Trenitalia. By 2018, 213 trains per day are produced by the state rail company Trenitalia and 90 by the private rail company NTV.

In Italy, the HSR services have been integrated with a number of “customers care” features going from a yield management system for tickets proposing a variety of offers for the same trip, on board dedicated personnel, dedicated waiting rooms etc. HSR services are perceived as a real “brand”, the symbol of a comfortable and quality travel. Attention has been dedicated to terminals as well from 2000 onwards new stations have been built, and existing ones have

been substantially renewed following the principle that a station, besides being functional and useful, should be beautiful and comfortable.

2.3. Access to advanced technological infrastructures in the metropolitan areas

Digital infrastructures are essential to guarantee access to different fundamental services, such as healthcare, public administration, and commerce, significantly improving citizens' the quality of life and well-being, especially in rural and remote contexts characterized by underdevelopment. Telemedicine, for example, has shown that it can extend access to medical care even in peripheral regions, reducing health inequalities. Furthermore, technology facilitates access to educational systems (Van Reenen, 2020), as well as supports remote working, which offers greater flexibility to workers and contributes to reducing the environmental impact of transport (Dingel & Neiman, 2020). Finally, a good digital infrastructure can significantly improve the quality and well-being of citizens, especially in rural and remote areas (Kolko, 2012). Among these infrastructures, one of the most crucial to support economic growth and equitable access to services is the broadband network, which enables connectivity to the high-speed internet (Czernich et al., 2011; Edquist et al. 2018). Despite the great importance of this infrastructure and significant progress in its large-scale diffusion, the spatial distribution of broadband remains largely uneven in many territorial areas (European Commission, 2022). Inadequate coverage is mainly observed in rural areas, characterized by inadequate infrastructure investments. The lack of stable and fast connectivity in different peripheral areas prevents equal access to digital opportunities and can intensify pre-existing inequalities, leaving these communities isolated from the global digital economy (Atkinson, 2019; Forman et al., 2012). However, inadequate network coverage is also observed in urbanized contexts characterized by greater economic agglomeration.

Italy, especially when compared to other EU countries, still has minimal levels of digitalization, as confirmed by the data of the Digital Economy and Society Index (DESI) of the European Commission, which places Italy below the European average, with a particular delay in the southern regions (European Commission, 2022). Internally, digitalization highlights the deep regional disparities that represent long-term problems (Felice, 2013). The northern regions have a higher penetration of digital infrastructures than the southern municipalities (Pellegrino & Zingales, 2017; Iammarino et al., 2019).

Generally, the optical fiber distribution in Italy varies significantly from one municipality to another, influenced by economic, demographic, geographic and institutional factors. An ISTAT study found that in some cases the differences in terms of coverage between northern and southern municipalities exceed 30%. This digital inequality is partly determined by the geomorphological characteristics of the Italian territory, with mountainous and rural areas facing greater challenges in implementing high-speed networks. Furthermore, administrative fragmentation and the variability of financial resources available at the local level significantly influence the ability to improve digital infrastructures (Gennaioli et al., 2013).

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3. Mapping and measuring the gaps in Metropolitan cities

3.1. Territorial capacities benchmark of metropolitan areas³

3.1.1. Territorial capacities between metropolitan areas

Comparing the 14 metropolitan areas based on the territorial capital indicators (Amaddeo *et al.*, 2024), reveals different results depending on the capital analyzed. As shown in figures 1-2-3-4, these indicators assess performance on a scale from 1 to 4, where 1 represents the lowest and four the highest performance.

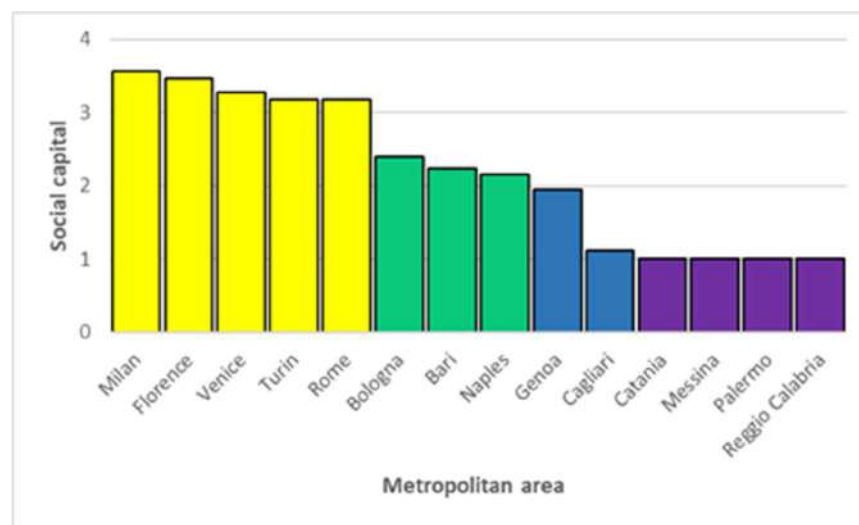


Figure 1: Benchmark of metropolitan areas by composite index of social capital

Starting with social capital, which refers to the social networks, services and resources needed to meet citizens' needs, a two-speed Italy emerges. At the top of the rankings are six metropolitan areas in the North-Central region, including Milan, Florence, Venice, Turin, and Rome, with a social capital score of between three and four points. In contrast, the bottom five positions are occupied exclusively by metropolitan areas in southern Italy, where Cagliari, Messina, Palermo and Reggio Calabria score the lowest of 1. The only negative exception in the Center-North appears to be the metropolitan area of Genoa, which ranks behind Bari and Naples.

³ This paragraph was written by the University of Bari "Aldo Moro" and Politecnico di Milano_DIG research groups.

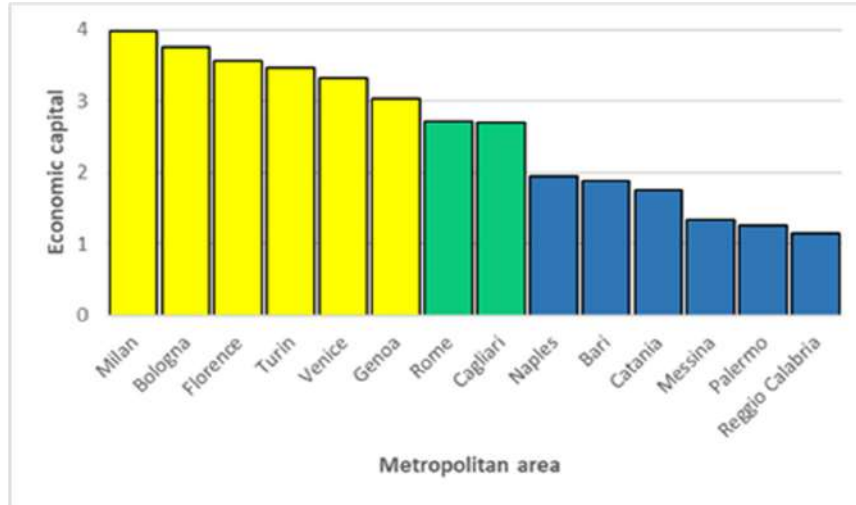


Figure 2: Benchmark of metropolitan areas by composite index of economic capital

A similar result emerges with respect to economic capital, which includes the financial resources people use to support their livelihoods. Again, we observe the metropolitan areas of Milan and Florence among the top three positions in the ranking and an exclusive presence of North Central metropolitan areas cities among the top seven. At the bottom of the ranking, the metropolitan areas of Catania, Messina, Palermo, and Reggio Calabria, in that order, are once again confirmed. Although performing better than the other southern areas, Bari and Naples fail to surpass any North-Center metropolitan areas. An interesting exception is the metropolitan area of Cagliari, which, although underperforming the top six, achieves a result almost on equal level with the metropolitan area of Rome.

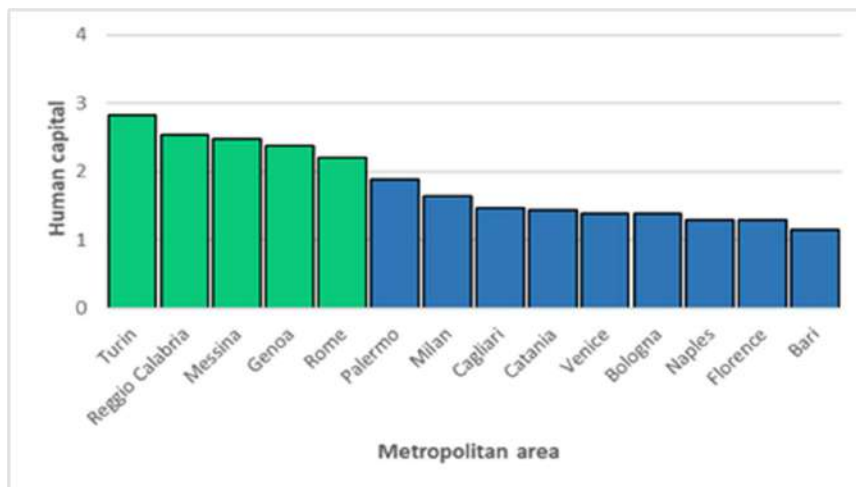


Figure 3: Benchmark of metropolitan areas by composite index of human capital

In the case of human capital, which includes skills, knowledge, health and ability to work, a greater balance is observed compared to other capitals. Although at the top of the ranking is the metropolitan area of Turin, which is confirmed among the top positions, the podium is completed by two metropolitan areas in southern Italy, namely Reggio Calabria and Messina. Interestingly, no metropolitan area scored a 1 or a value between 3 and 4, and the difference

between the first and last ranked is much less marked than in the other capitals. In the last three positions we find the metropolitan area of Florence, which was on the podium in the previous capitals, along with Naples and Bari, which, on the other hand, stood out compared to the other southern areas.

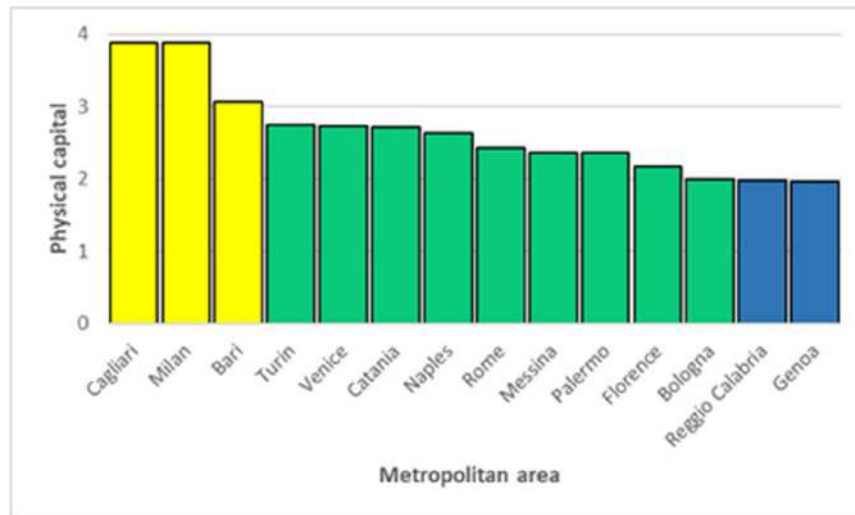


Figure 4: Benchmark of metropolitan areas by composite index of physical capital

As for physical capital, which includes the basic infrastructure that helps households and businesses sustain their livelihoods, the results are completely different from previous ones. In the first two positions are the metropolitan areas of Cagliari and Bari, in addition to the usual presence of Milan. It is also interesting to note that, unlike the previous capitals, the last three positions are two metropolitan cities from the Center, namely Bologna and Genoa. In addition, all metropolitan areas remain almost one point away from the worst performance.

We can identify three distinct groups by including the aggregate index when comparing metropolitan areas. The first group, with performance between three and four points, consists exclusively of metropolitan areas located in the North-Center. In particular, the Milan metropolitan area, ranked first in the social and economic dimensions and second in the physical dimension, ranks first with a score close to the maximum of four points. Next are the metropolitan areas of Turin and Venice, which excelled in the areas of human capital and economic capital, respectively.

The second group, with performance between two and three points, includes the areas of Bologna, Bari, Cagliari, Genoa, and Naples, which showed less consistency in maintaining high performance in multiple dimensions. For example, while ranking first in physical capital, the Cagliari metropolitan area failed to rank among the top seven in the other dimensions.

Finally, in the last place of the ranking, we find exclusively metropolitan areas in the South, namely Catania, Messina, Reggio Calabria, and Palermo. This result highlights how the three metropolitan areas in Sicily performed poorly in the aggregate index. In particular, these three areas performed poorly especially in the dimensions of social capital and economic capital.

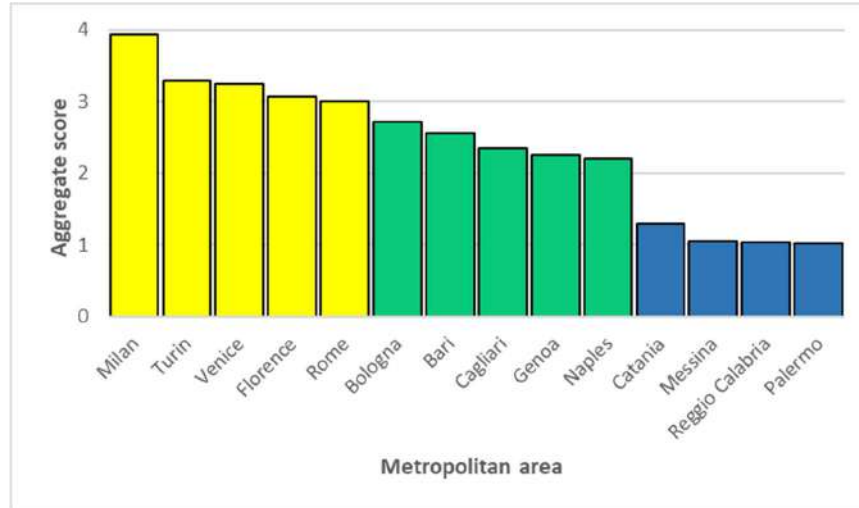


Figure 5: Benchmark of metropolitan areas by aggregate score

3.1.2. Territorial capacities within each metropolitan area

Below is the analysis of the aggregate score distribution for the 14 metropolitan areas based on the national quartile distribution of the indicator. The results confirm a significant territorial gap between northern and southern areas. Different patterns emerge when examining the score distribution within each metropolitan area. In some cases, there is a balanced distribution between the metropolitan city and neighboring municipalities (e.g., Milan). In contrast, in others, the metropolitan city performs better than surrounding areas (e.g., Bologna). Finally, in certain areas, the surrounding municipalities outperform the metropolitan city (e.g., Florence, Bari, Naples).

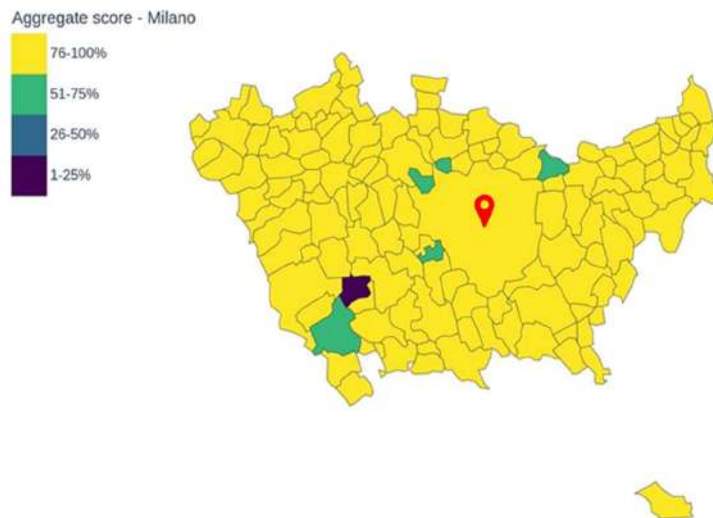


Figure 6: Aggregate score within the metropolitan area of Milan.

The map of the metropolitan area of Milan stands out as the most virtuous among the 14 areas analyzed, with nearly all municipalities falling within the top quartile (76-100%), shown in yellow.

The few exceptions are still positioned in the third quartile (51-75%), depicted in green (Morimondo, Corsico, Pero, Santo Stefano Ticino, and Cologno Monzese). The only isolated case of a municipality with an aggregate score in the lowest quartile is Vermezzo with zero.

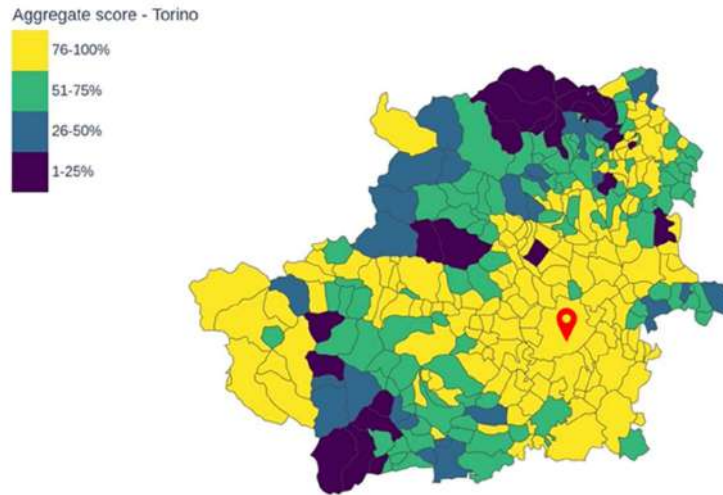


Figure 7: Aggregate score within the metropolitan area of Turin.

The map of the metropolitan area of Turin demonstrates exceptional performance in the central section of the region, where both Turin and its neighboring municipalities are situated within the top quartile (76-100%, highlighted in yellow), showing a high level of territorial resilience and attractiveness. However, as we move toward the northern and southwestern regions of the metropolitan area, there is a noticeable decline in performance. Some municipalities in this area are marked in dark purple, indicating they fall within the lowest quartile (1-25%), including municipalities like Volpiano, Volvera, and Castiglione Torinese. This pattern highlights a more uneven distribution of resilience, with the central urban zone and its surroundings substantially surpassing the performance of more peripheral areas but still presenting a high level of resilience and territorial attractiveness.

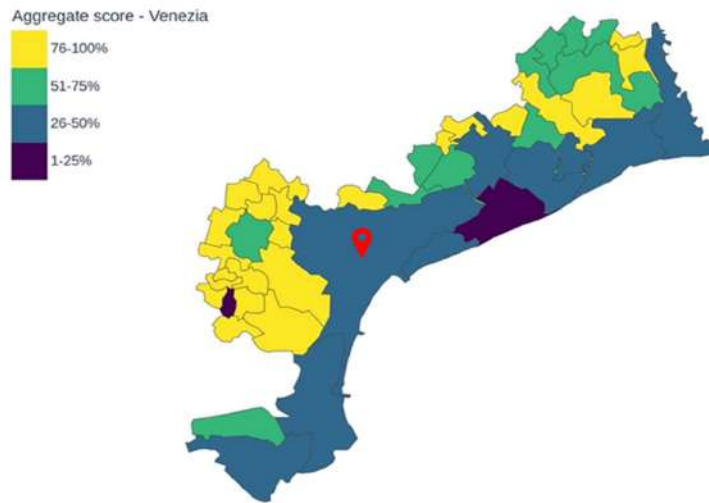


Figure 8: Aggregate score within the metropolitan area of Venice.

The map of the metropolitan area of Venice exhibits a quite uneven distribution of the aggregate indicator scores. Venice itself falls within the second quartile (26-50%), while municipalities to the northwest, such as Campagna Lupia, Mira, and Vigonovo, along with those to the northeast, including San Stino di Livenza, Concordia Sagittaria, and Fossalta di Portogruaro, demonstrate varying performance levels. The only municipality that belongs to the lowest quartile is Jesolo. Overall, the region reflects a moderate level of resilience and attractiveness.

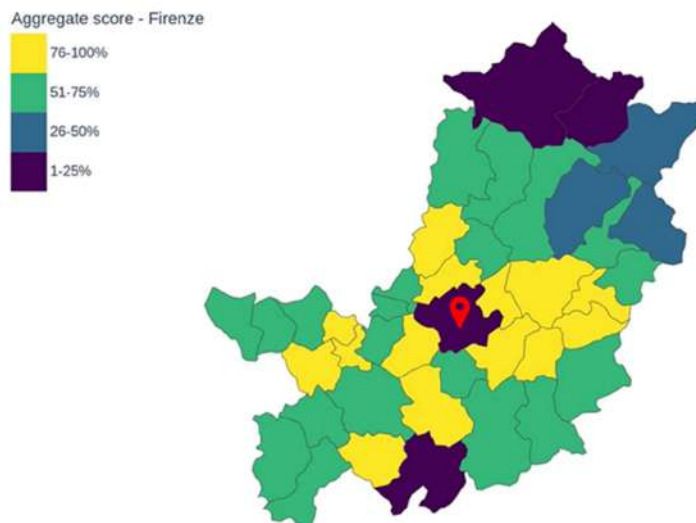


Figure 9: Aggregate score within the metropolitan area of Florence.

The map of the metropolitan area of Florence shows that the city of Florence, together with Firenzuola and Barberino Val d'Elsa, falls within the lowest quartile (1-25%), represented by

dark purple, indicating lower territorial attractiveness and resilience. In contrast, many of the surrounding municipalities score higher, with several cities in the highest quartile (76-100%), shown in yellow (Pontassieve, Fiesole, Bagno a Ripoli, Certaldo, Empoli, Montelupo Fiorentino, Capraia e Limite, Calenzano, Sesto Fiorentino). This suggests a notable disparity between the city center and the surrounding areas, where the latter seems to perform better in terms of overall resilience and attractiveness.

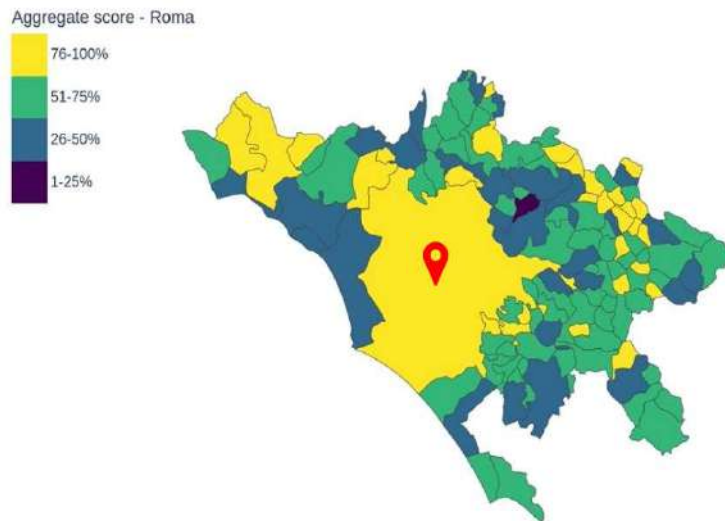


Figure 10: Aggregate score within the metropolitan area of Rome.

The map of the metropolitan area of Rome reveals a high level of territorial attractiveness and resilience, with the central part of Rome standing out in the highest quartile (76-100%), representing strong performance across the four capital dimensions. Surrounding areas, particularly to the north and west, also perform well, mainly in the third quartile (51-75%). However, some pockets to the east and southeast fall into the second quartile (26-50%), indicating disparities in resilience and attractiveness within the broader metropolitan region. Only one municipality, Marcellina, falls within the lowest quartile (1-25%), shown in dark purple. These results highlight the core area's stronger development than some peripheral zones.

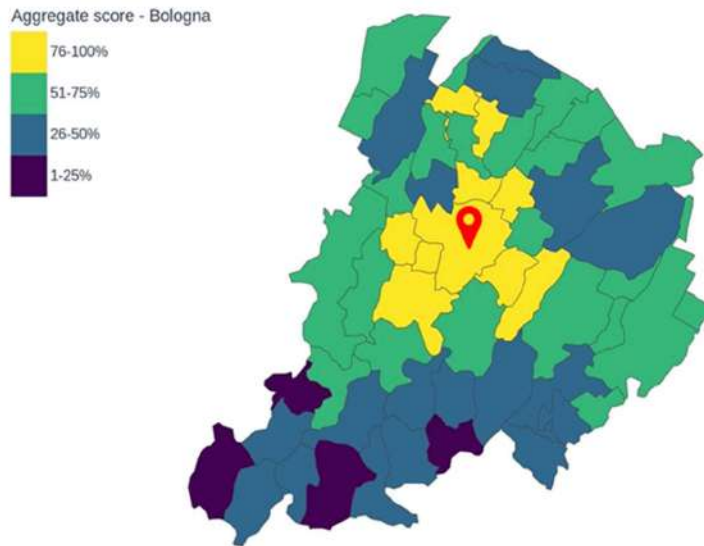


Figure 11: Aggregate score within the metropolitan area of Bologna.

The map of the Bologna metropolitan area shows a strong performance in the central part of the region, where Bologna itself and its surrounding municipalities fall within the highest quartile (76-100%, in yellow). This indicates a high level of territorial resilience and attractiveness, with strong scores across the dimensions of economic, physical, human, and social capital. However, as we move toward the southern and southwestern parts of the metropolitan area, we observe a decline in performance, with several municipalities marked in dark purple, representing the lowest quartile (1-25%), such as Lizzano in Belvedere, Camugnano, Monghidoro and Castel d'Aiano. This suggests a more uneven distribution of resilience, with the core urban area and its neighbors significantly outperforming the more peripheral regions.

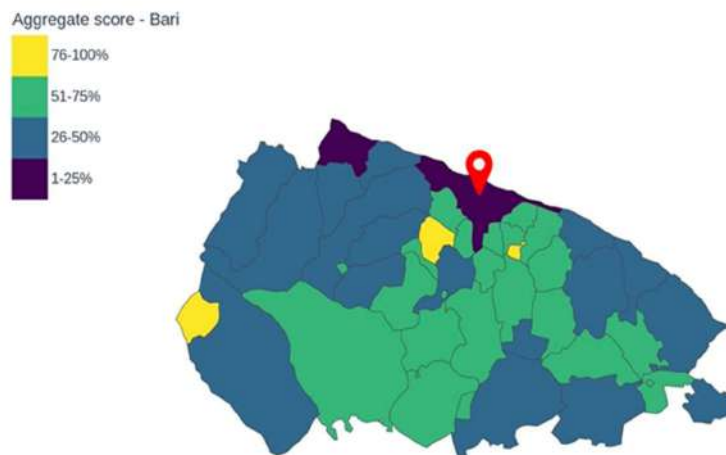


Figure 12: Aggregate score within the metropolitan area of Bari.

The map of the Bari metropolitan area shows a mixed distribution of the territorial resilience

and attractiveness index. The core the city of Bari, marked in dark purple, falls within the 1-25% quartile, indicating a low score in terms of territorial resilience and attractiveness across the aggregate score. This highlights potential challenges for the core urban area. In contrast, some areas to the southwest and a few central municipalities score much higher, with yellow zones indicating the top quartile (76-100%), signaling stronger performance in those municipalities. Overall, the distribution of the aggregate score suggests that Bari lags behind while certain suburban or peripheral areas, in particular Poggiorsini, Bitetto and Capurso, show higher resilience and attractiveness.

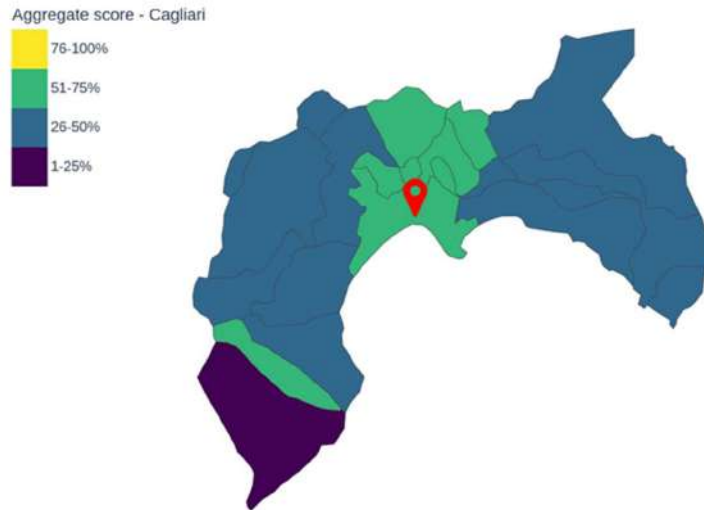


Figure 13: Aggregate score within the metropolitan area of Cagliari.

The map of the Cagliari metropolitan area shows that Cagliari itself, located centrally, falls within the 51-75% quartile (in green), indicating a mid-to-high level of resilience and attractiveness. The surrounding areas show a mix of performances, with a notable area in the southwest (marked in dark purple), corresponding to the municipality of Pula, scoring in the lowest quartile (1-25%), which suggests significant challenges in resilience and attractiveness. Overall, the metropolitan area shows moderate performance, with a few neighboring municipalities also in the 51-75% quartile, but the contrast with weaker areas to the south is evident.

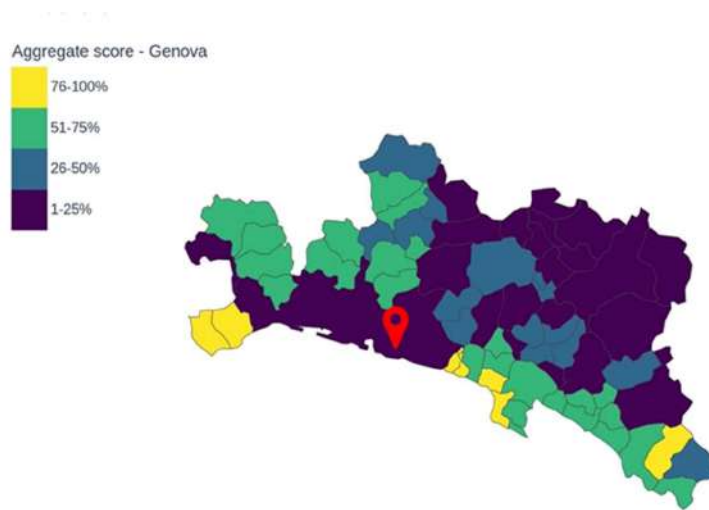


Figure 14: Aggregate score within the metropolitan area of Genoa.

The map of the metropolitan area of Genoa shows that much of the region, including the city of Genoa itself, falls into the lowest quartile (1-25%), represented by dark purple, indicating low levels of territorial attractiveness and resilience. However, there are pockets of higher scores, particularly along the western and eastern coastal areas, where some municipalities are in the highest quartile (76-100%), marked in yellow (Cogoleto, Arenzano, Bogliasco, Pieve Ligure, Recco, Camogli, Casarza Ligure). The central part of the metropolitan area shows some moderate scores in the second and third quartiles (blue and green), but overall, there is a noticeable disparity between the coastal areas and the more inland municipalities.

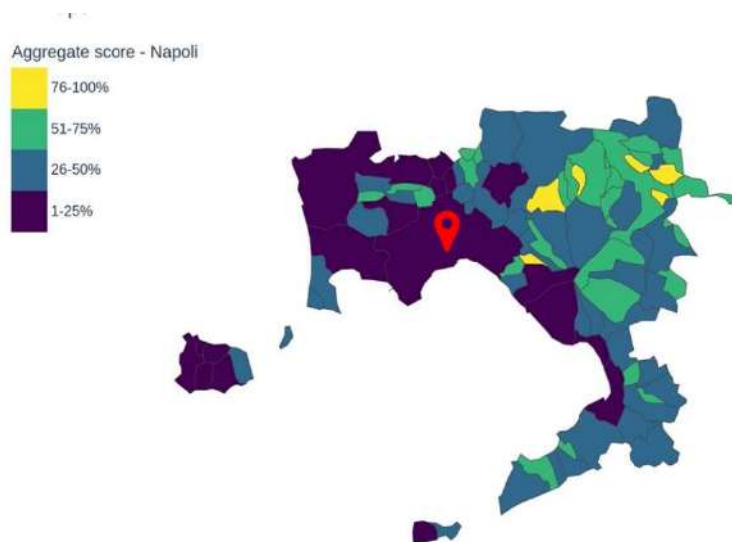


Figure 15: Aggregate score within the metropolitan area of Naples.

The map of the metropolitan area of Naples shows the quartile distribution of territorial attractiveness and resilience for the metropolitan area of Naples. The city itself, located in the

central and western part of the map, falls predominantly in the lowest quartile (1-25%), together with other municipalities such as Pozzuoli, Giugliano, Ercolano and Afragola, indicating weaker performance in economic, physical, human, and social capital dimensions. In contrast, areas to the northeast exhibit stronger resilience and attractiveness, with some zones falling in the highest quartile (76-100%), such as San Paolo Bel Sito, Casamarciano, San Giorgio a Cremano, San Vitaliano. This suggests a significant variation in territorial capital across the metropolitan region.

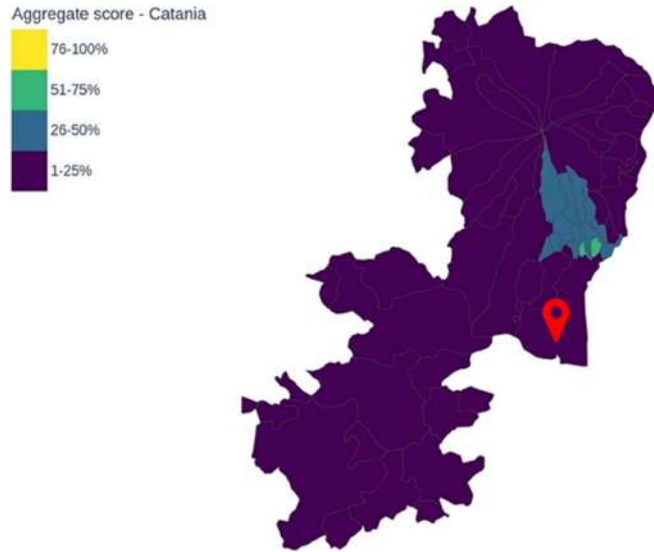


Figure 16: Aggregate score within the metropolitan area of Catania.

The map of the metropolitan area of Catania shows that the entire region, including the city of Catania itself, falls into the lowest quartile (1-25%), represented by dark purple. This indicates that both the city and its surrounding areas have low territorial attractiveness and resilience scores across all dimensions of capital. There are no areas in higher quartiles, suggesting a widespread challenge in terms of development, infrastructure, and overall socio-economic resilience across the metropolitan area. The only part of the metropolitan area of Catania that seems to have a slightly higher aggregate score (second quartile) consists of the group of municipalities located on the slopes of Mount Etna.

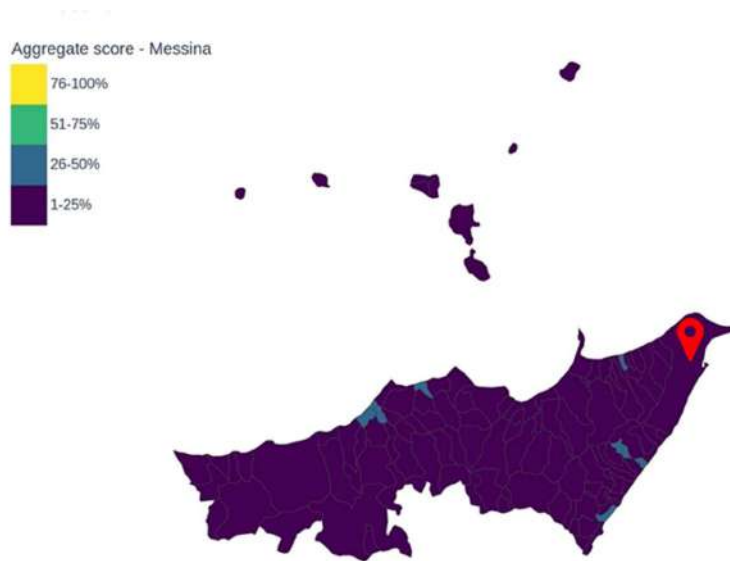


Figure 17: Aggregate score within the metropolitan area of Messina.

The map of the metropolitan area of Messina shows a homogeneous but critical situation among the municipalities included in the area. In fact, compared to the Italian aggregate score, even Messina itself falls into the lowest quartile (1-25%), represented by dark purple, showing very low levels of territorial attractiveness and resilience.

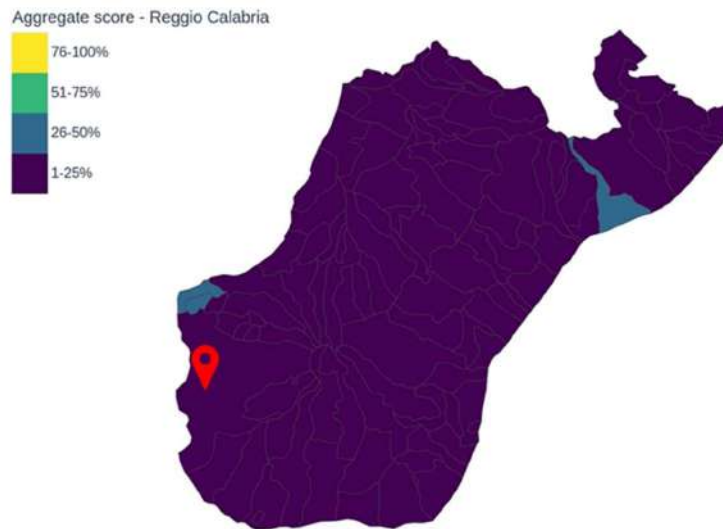


Figure 18: Aggregate score within the metropolitan area of Reggio Calabria.

The map of the metropolitan area of Reggio Calabria shows that the majority of the municipalities, including Reggio Calabria itself, is in the lowest quartile (1-25%) in terms of attractiveness and resilience, reflecting low performance across the economic, physical, human, and social capital dimensions. Only a few areas along the coast stand out, with two small municipalities (Roccella Jonica and Villa San Giovanni) reaching the second quartile

(26-50%). This suggests that Reggio Calabria faces widespread challenges, with limited pockets of stronger resilience and attractiveness, primarily in coastal zones.

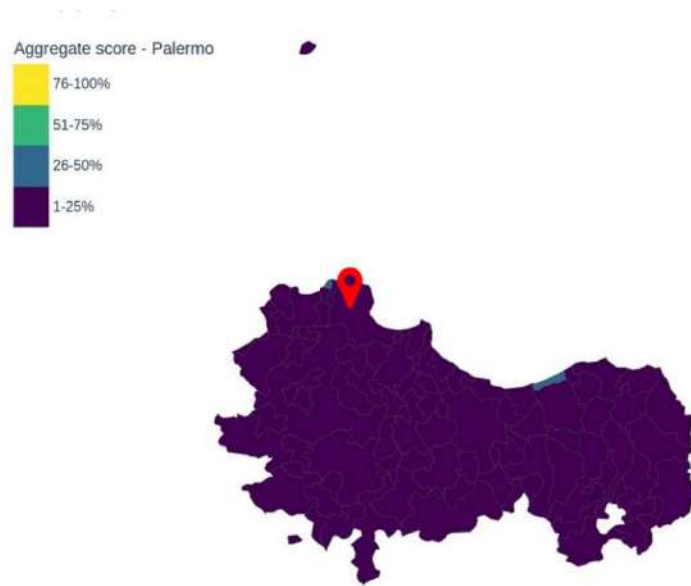


Figure 19: Aggregate score within the metropolitan area of Palermo.

The map of the metropolitan area of Palermo, just like Messina, shows a critical situation among the municipalities included in the area, falling entirely in the lowest quartile (1-25%), represented by dark purple, showing very low levels of territorial attractiveness and resilience.

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3.2. Metropolitan areas capital expenditure gaps⁴

The objective of the analysis will be to evaluate the local expenditure needs in infrastructure, considering the supply and demand factors measuring the existing infrastructural gap. The focus will be on the local transport, culture and environmental (waste management) infrastructure for the Italian municipalities inside the boundaries of the 14 Metropolitan Cities (metropolitan districts): Turin (312 municipalities), Milan (133 municipalities), Venice (44 municipalities), Genoa (67 municipalities), Bologna (55 municipalities), Florence (41 municipalities), Roma Capitale (121 municipalities), Bari (41 municipalities), Naples (92 municipalities), Reggio Calabria (97 municipalities), Palermo (82 municipalities), Catania (58 municipalities), Messina (108 municipalities), Cagliari (17 municipalities), for a total of 1,268 municipalities.

According to fiscal federalism principles, implementing efficient infrastructural equalization, provides that a comparison of the infrastructure service levels with the corresponding service standards should be implemented using appropriate indicators to measure any deviations. The literature provides several contributes about current expenditure connected to local services, but it is hard to find significant proposals for public capital expenditure estimation. The research package will aim to propose a quantitative procedure concerning two objectives: i) the evaluation of the gap between the effective infrastructural endowment and the infrastructure needs deduced from the factors of demand generation; ii) the conversion in monetary terms of this gap.

Regional disparities in infrastructural transport, culture, and waste management endowment could be better grasped by estimates expressed in physical terms. Indeed, sometimes radically diverse topography means that equal investment in money amounts is not equivalent in physical unity across the regions. However, the monetary measurement of public capital c proposed in this analysis certainly has advantages in terms of great uniformity and flexibility, properties of additivity, etc. The estimated monetary differences between expenditure and physical endowment allows us to obtain the representative estimated price/cost of the considered infrastructure.

3.2.1. *Waste management gap and sustainability*

Municipal waste management expenditure has a significant impact on environmental sustainability. Proper waste management practices are essential for reducing the environmental footprint of communities and promoting a healthier planet. When municipalities invest in waste management infrastructure and programs, they can effectively mitigate the negative effects of waste on the environment.

Municipal waste management expenditure plays a critical role in promoting environmental sustainability. Investments in infrastructure, recycling programs, and effective policies can lead to significant environmental benefits, including reduced pollution, resource conservation, and lower greenhouse gas emissions. However, the success of these expenditures hinges on

⁴ This paragraph was written by UNIBA_DEMDI research group

equitable funding distribution, efficient management, and strong policy frameworks. As municipalities continue to grapple with waste management challenges, it is essential to prioritize sustainable practices and ensure that expenditure translates into tangible environmental benefits.

The Waste Management Gap Indicator (WMGI) measures the per capita monetary difference between actual and standard capital expenditures in waste management at the municipal level. The standard is defined as the national average capital expenditure from 2016 to 2022. The indicator is depicted in three panels on a cartogram in *Figure 1*:

- The left panel shows the geographical distribution of the standard capital expenditure per capita, reflecting the infrastructural needs.
- The middle panel displays the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022, when the standard is higher than the actual expenditure.
- The right panel highlights municipalities that reported a gap smaller than in 2016 in real terms in 2022, indicating some progress in bridging the gap.

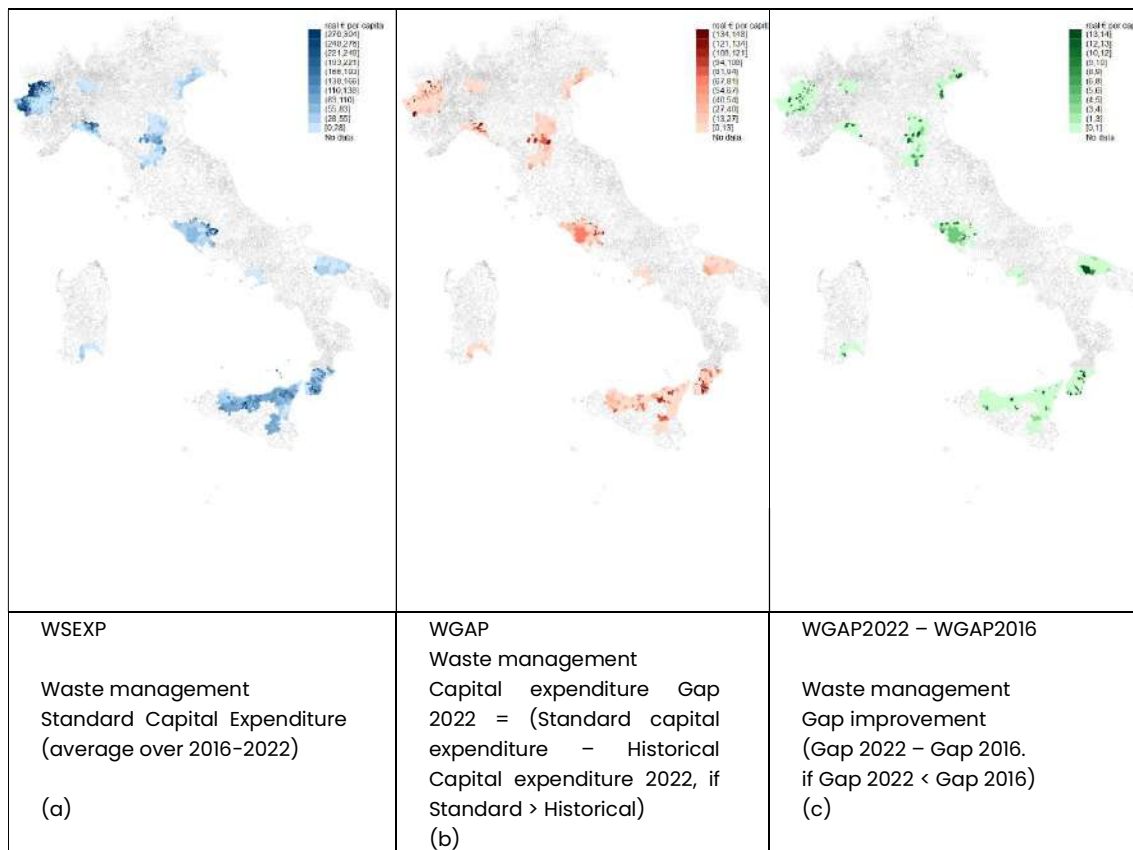


Figure 1: Waste management capital expenditure gap, euro per capita

This indicator provides an estimate of the infrastructural gap in monetary terms for the waste management sector at the municipal level as measured in 2022, considering changes from 2016 to 2022.

The environmental dimension of the infrastructural gap in waste management services measures how inadequacies affect ecological systems. It focuses on aspects like pollution

levels (air and water), waste accumulation (landfill overflow and illegal dumping), resource depletion (recycling rates and waste diversion), and biodiversity impact (habitat disruption and species at risk). This indicator helps governments assess the effectiveness of their waste management systems and guides policy decisions to address infrastructure gaps.

The static dimension of the infrastructural gap in waste management service focuses on the status and characteristics of existing waste management facilities. It typically includes data such as the number and capacity of waste processing and disposal facilities, the geographical distribution of these facilities, and the extent of technological adoption (e.g., advanced recycling processes and waste-to-energy systems). This dimension helps in understanding the baseline infrastructure available and identifies areas lacking sufficient waste management capabilities, crucial for strategic planning and development.

The left panel of *Figure 1* shows the geographical distribution of the per capita standard capital expenditure, reflecting the infrastructural needs based on national averages from 2016 to 2022, which helps identify which metropolitan districts have higher or lower baseline needs in waste management infrastructure. The middle panel of *Figure 1* displays the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022, where the standard exceeds the actual, revealing regions where waste management investment is not meeting the standards, highlighting potentially underfunded areas. The right panel of *Figure 1* indicates municipalities that reported a decrease in their infrastructural gap in real terms from 2016 to 2022, suggesting improvements over time. Torino, with 312 municipalities, shows diverse needs and disparities within the district, where rural areas might lag behind urban centers in receiving adequate funding. Milano, as a major economic hub, likely has higher standard expenditures due to its high population density and industrial activity, and any gaps could significantly impact urban sustainability and public health. Venezia faces unique challenges due to its waterways, which might affect standard expenditure calculations and the practicality of meeting these standards, possibly indicating a larger gap. Regions like Genova, Bologna, and Firenze might show different levels of efficiency in managing waste due to their varied urban and rural compositions, making historical investments and improvements critical to assess. Roma Capitale, with significant tourist influxes, faces unique pressures on its waste management systems, making the gap analysis particularly relevant for balancing tourist impact with sustainability. Southern Districts such as Bari, Napoli, Reggio Calabria, Palermo, Catania, and Messina may struggle with historically lower public infrastructure investments, making the gap analysis crucial for directing future investments to enhance resilience and public health outcomes. Cagliari, with the smallest number of municipalities, focuses on ensuring that even minimal investments are efficiently utilized to meet the waste management needs without overspending, yet closing any critical gaps. *Figure 1* is a vital analytical tool for policymakers, municipal planners, and environmental agencies, providing a clear depiction of where investments in waste management are lacking and where improvements are being made, facilitating targeted interventions to enhance sustainability and efficiency across Italy's metropolitan districts. This gap analysis is essential for understanding the dynamics of waste management needs versus actual expenditures and for planning future initiatives to bridge these gaps effectively.

3.2.2. Local transport infrastructure endowment gap and accessibility

Effective local transport systems are vital for economic development. They facilitate the movement of goods and people, reducing travel time and costs associated with commuting. Improved transport connectivity attracts businesses, boosts local economies, and creates job opportunities. For instance, cities with well-developed public transport networks, such as New York and Tokyo, experience robust economic activity and higher employment rates. Public transit systems also enhance property values as areas with good accessibility become more desirable for residential and commercial investments.

Local transport systems play a crucial role in promoting social inclusion and accessibility. Reliable and affordable public transport ensures that all individuals, including those from low-income backgrounds and people with disabilities, have access to essential services such as healthcare, education, and employment. The extensive bike-sharing programs and pedestrian-friendly infrastructure in cities like Copenhagen exemplify how thoughtful transport planning can enhance accessibility and inclusivity. Improved transport systems reduce social isolation and enable greater participation in community activities, fostering a more cohesive society.

The Local Transport and Roads Gap Indicator (LMGI) measures the per capita monetary difference between actual and standard capital expenditures in local transport and road maintenance at the municipal level. This standard is the national average capital expenditure from 2016 to 2022.

The indicator is depicted in three panels on a cartogram in *Figure 2*:

- The left panel shows the geographical distribution of the standard capital expenditure per capita, reflecting the infrastructural needs.
- The middle panel displays the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022 when the standard is higher than the actual expenditure.
- The right panel highlights municipalities that reported a gap smaller than in 2016 in real terms in 2022, indicating some progress in bridging the gap.

This indicator provides an estimate of the infrastructural gap in monetary terms for the Local Transport and Roads sector at the municipal level as measured in 2022, considering changes from 2016 to 2022.

The accessibility dimension of the indicator for the infrastructural gap in the transport and road maintenance sector for municipalities evaluates how limitations in infrastructure affect transportation efficiency and access. It concentrates on aspects such as road network density (coverage of roads concerning area and population), road condition (percentage of roads in good, fair, and poor condition), public transport availability (frequency and reach of buses, trams, etc.), and connectivity (ease of access to main economic centres and services). This indicator assists local governments in assessing the adequacy of their transportation networks and supports decision-making to enhance mobility and accessibility across municipalities.

The static dimension of an indicator for the infrastructural gap in the local transport and road maintenance sector of municipalities focuses on the status and characteristics of existing

transport infrastructure. It typically includes data such as the length and condition of road networks, the number and types of public transportation facilities (bus stations, tram lines, etc.), the geographical distribution of these assets, and the extent of technological adoption (e.g., smart traffic management systems, electronic toll collection). This dimension aids in understanding the available baseline transport infrastructure and identifies areas lacking sufficient road maintenance and transportation services, which are crucial for strategic planning and urban development.

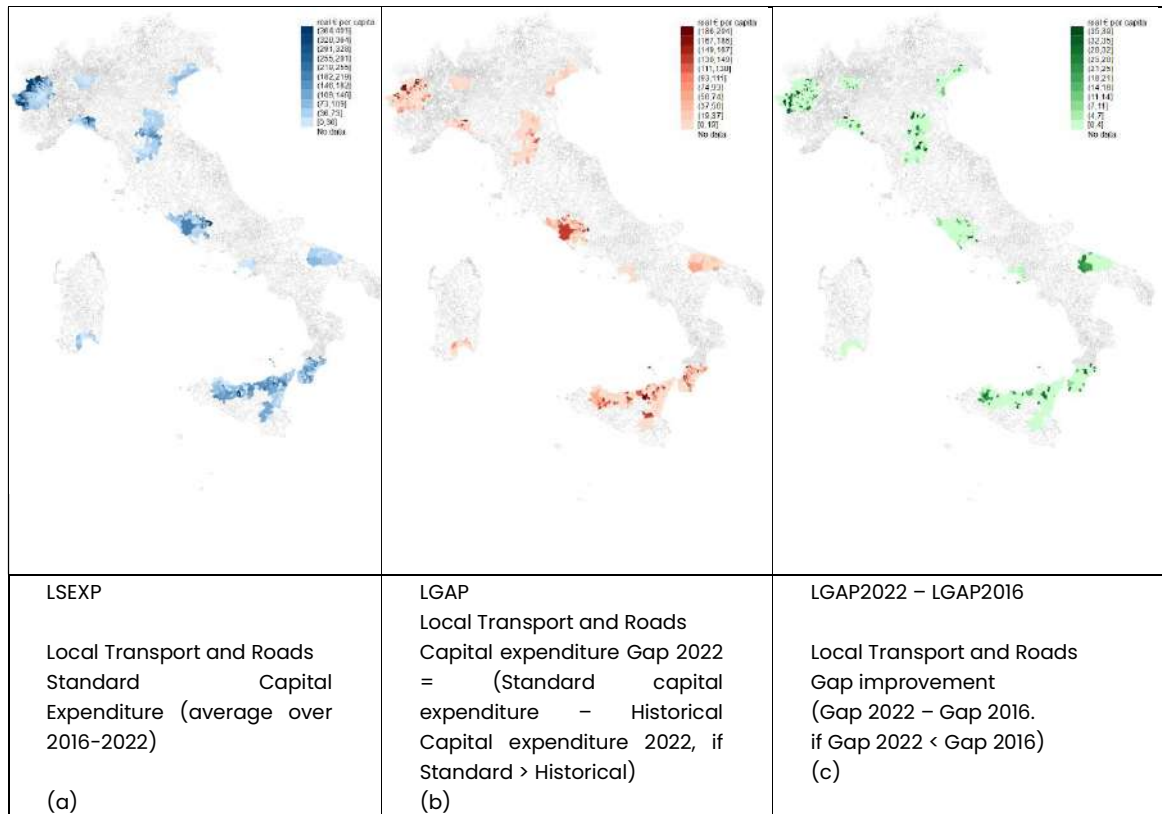


Figure 2: Local Transport and Roads capital expenditure gap, euro per capita

The left panel of *Figure 2* illustrates the geographical distribution of the standard capital expenditure per capita for local transport and roads, indicating the expected infrastructural needs based on national averages from 2016 to 2022, which aids in identifying metropolitan districts with higher or lower baseline transport infrastructure needs. The middle panel of *Figure 2* showcases the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022, highlighting areas where investment in local transport and roads is not meeting the established standards and may be underfunded. The right panel of *Figure 2* shows municipalities that reported a real decrease in their infrastructural gap from 2016 to 2022, indicating positive developments over time. Torino, with its large number of municipalities, may show diverse transport needs, with some rural or peripheral areas potentially underserved compared to the urban center. Milano, as a dense urban environment with heavy daily commutes, likely has high baseline needs for transport infrastructure, and gaps here could significantly impact traffic flow and economic activity. Venezia's unique topology may complicate standard approaches to transport infrastructure,

potentially reflecting larger gaps that require innovative solutions. Cities like Genova, Bologna, and Firenze could display varying efficiency levels in local transport based on their urban-rural mix, where investment histories could illuminate areas needing urgent attention. Roma Capitale may face specific challenges due to its high tourist traffic and historical urban layout, making any transport gaps particularly impactful on both locals and tourists. Southern districts such as Bari, Napoli, Reggio Calabria, Palermo, Catania, and Messina, often dealing with limited funding and infrastructure legacies, highlight the importance of targeted investments to improve connectivity and reduce transport inequities. With fewer municipalities, Cagliari needs focused investment to ensure transport services cover all areas effectively, particularly given its island geography. *Figure 2* provides critical insights for government officials, urban planners, and transport authorities, depicting regions where local transport and road infrastructure investments lag behind needs, facilitating targeted strategies to enhance connectivity and urban mobility across Italy's metropolitan districts. This indicator is crucial for evaluating the adequacy of transport networks and supporting decision-making processes to close infrastructural gaps, improve mobility, and boost economic and social activity in the municipalities.

3.2.3. Local cultural infrastructure endowment gap and attractiveness

Local culture expenditure significantly contributes to the economic vitality of municipalities. Funding cultural events, museums, theatres, and other cultural institutions stimulates the local economy by attracting tourists, generating revenue, and creating jobs. For instance, cities like Edinburgh, known for its renowned festivals, benefit economically from cultural tourism, which supports local businesses and increases tax revenues. Additionally, cultural investments can lead to the regeneration of urban areas, turning neglected neighbourhoods into vibrant cultural districts, thereby attracting further private investment and boosting property values. The cultural life in a municipality is closely linked to the quality of life too. Cultural amenities such as theatres, galleries, music venues, and public art installations enrich residents' lives, providing leisure and educational opportunities. Cities like Paris and Vienna, renowned for their rich cultural offerings, consistently rank high in quality-of-life indices, attracting new residents and businesses. Furthermore, cultural vibrancy makes cities more attractive to skilled professionals and creative industries, fostering an innovative and dynamic urban environment. This, in turn, can lead to a virtuous cycle where increased attractiveness attracts more cultural investments, further enhancing the city's appeal. The Cultural Services Gap Indicator (CMGI) measures the per capita monetary difference between actual and standard capital expenditures in local transport and road maintenance at the municipal level. This standard is the national average capital expenditure from 2016 to 2022.

The indicator is depicted in three panels on a cartogram in *Figure 3*:

- The left panel shows the geographical distribution of the standard capital expenditure per capita, reflecting the infrastructural needs.
- The middle panel displays the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022, when the standard is higher than the actual expenditure.

- The right panel highlights municipalities that reported a gap smaller than in 2016 in real terms in 2022, indicating some progress in bridging the gap.

This indicator provides an estimate of the infrastructural gap in monetary terms for the cultural services sector at the municipal level as measured in 2022, considering changes from 2016 to 2022.

The attractiveness dimension of the indicator for the infrastructural gap in the cultural sector of municipalities measures how inadequacies affect the sector's appeal and vitality. It focuses on aspects like the variety and quality of cultural offerings (performances, exhibitions, workshops), the condition and appeal of cultural facilities (museums, theatres, galleries), community engagement levels, and the economic impact of cultural activities (tourism, local business support). This indicator helps local governments assess the attractiveness and competitiveness of their cultural infrastructure and guides policy decisions to enhance the cultural appeal, drawing both residents and visitors to enrich the local community.

The static dimension of the indicator for the infrastructural gap in the cultural sector of municipalities focuses on the current status and characteristics of existing cultural facilities and services. It typically includes data such as the number and types of cultural institutions (museums, theatres, libraries, etc.), the capacity and utilization rates of these facilities, the geographical distribution across the municipality, and the extent of technological adoption (e.g., digital archives, online access to collections). This dimension aids in understanding the baseline cultural infrastructure available and identifies areas lacking sufficient cultural services, crucial for strategic planning and enhancing cultural accessibility and engagement.

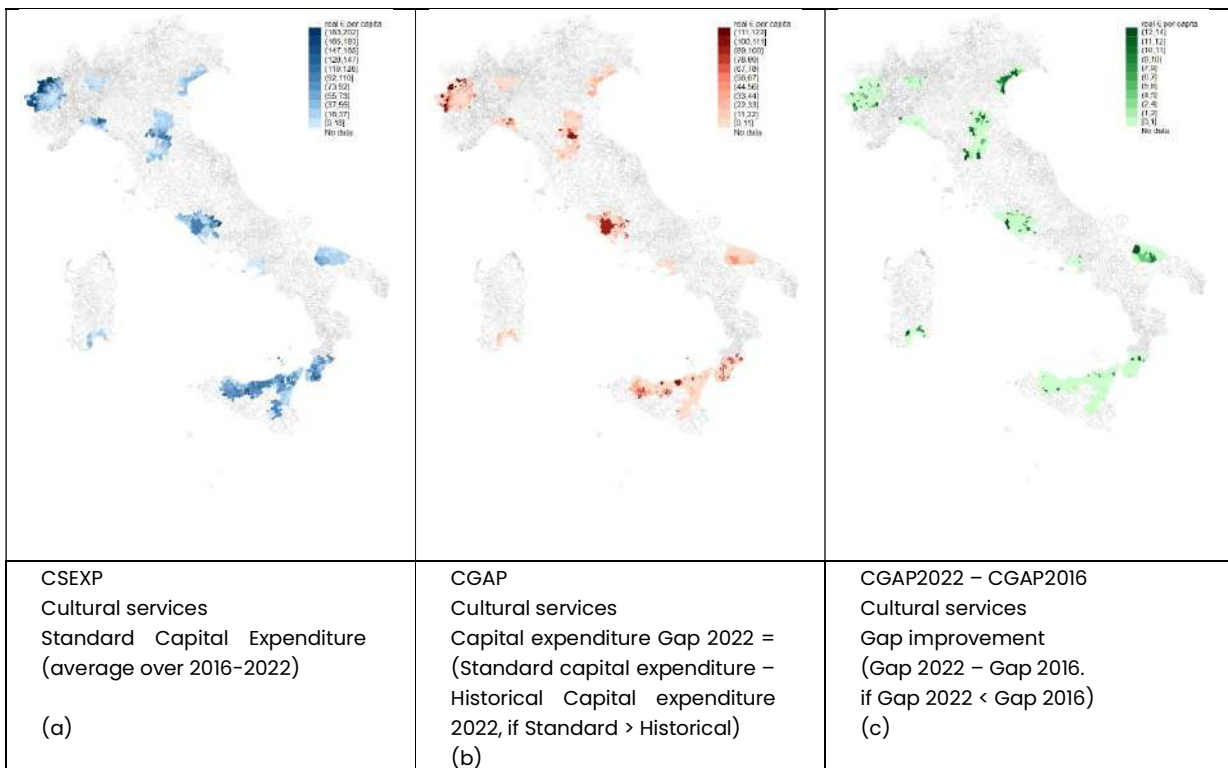


Figure 3: Cultural services capital expenditure gap, euro per capita

The left panel of *Figure 3* shows the geographical distribution of the standard capital expenditure per capita for cultural services, indicating infrastructural needs based on national averages from 2016 to 2022, helping identify metropolitan districts with varying needs for cultural infrastructure. The middle panel of *Figure 3* highlights the infrastructural gap, defined as the difference between the standard and actual capital expenditures in 2022, showcasing areas where cultural infrastructure investment does not meet expected standards, and pointing out potentially underfunded districts. The right panel of *Figure 3* reveals municipalities that reported a real reduction in their infrastructural gap from 2016 to 2022, indicating improvement in cultural infrastructure investment over time. Torino, with a broad array of municipalities, may exhibit diverse cultural needs with potential disparities in cultural service provision between urban and rural areas. Milano, known for its vibrant arts scene, likely has high baseline needs for cultural infrastructure; gaps in this district could significantly affect its cultural vibrancy and economic benefits derived from arts and tourism. With its rich historical and cultural heritage, Venice might face unique challenges in maintaining and expanding its cultural offerings, where gaps could undermine its global cultural status. Cities like Genoa, Bologna, and Florence, each with strong cultural identities, might show different levels of investment efficiency in cultural services which could impact their ability to attract tourists and maintain cultural heritage. Roma Capitale, as a center of historical and cultural significance, faces the challenge of balancing the preservation of its cultural heritage with the need for modern cultural infrastructure, making any identified gaps critical to address for sustaining its cultural and economic vitality. Southern districts such as Bari, Naples, Reggio Calabria, Palermo, Catania, and Messina may require focused investments to enhance cultural services, often constrained by budgetary limitations yet rich in cultural potential that could spur economic development. Despite having fewer municipalities, Cagliari requires efficient use of cultural investments to leverage its unique cultural assets and attract both tourists and local engagement. *Figure 3* is an essential tool for cultural policymakers, city planners, and institutions, illustrating where investments in cultural services are lacking and progress is being made, enabling targeted actions to enrich Italy's metropolitan districts' cultural landscape and economic vitality. This gap analysis is vital for understanding cultural needs versus actual expenditures and planning strategic initiatives to bridge these gaps, enhancing these communities' attractiveness and quality of life.

3.2.4. Total Local Capital Expenditure gap and Local Resilience

Local capital expenditure refers to the funds allocated by municipalities to develop and maintain long-term assets, such as infrastructure, public facilities, and technological systems. These investments are critical for enhancing local resilience, which is the ability of a community to withstand, adapt to, and recover from adverse situations such as economic downturns and social challenges. This essay explores how local capital expenditure influences local resilience, focusing on infrastructure, public services, and technological advancement. Despite the clear benefits, there are challenges associated with capital expenditure. Ensuring equitable distribution of funds and prioritizing projects that offer the most significant resilience benefits can be difficult. Additionally, long-term planning and sustained investment are required to realize the full potential of capital projects, which can be challenging in the face of budget constraints and political changes. Municipalities must also balance immediate needs

with future risks, ensuring that capital expenditure addresses both current vulnerabilities and anticipated challenges.

The Total Services Gap Indicator (TMGI) measures the per capita monetary difference between total actual and standard capital expenditures at the municipal level. This standard is defined as the national average capital expenditure from 2016 to 2022.

The indicator is depicted in three panels on a cartogram in *Figure 4*:

- The left panel shows the geographical distribution of the standard capital expenditure per capita, reflecting the infrastructural needs.
- The middle panel displays the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022, when the standard is higher than the actual expenditure.
- The right panel highlights municipalities that reported a gap smaller than in 2016 in real terms in 2022, indicating some progress in bridging the gap.

This indicator provides an estimate of the infrastructural gap in monetary terms for the all sectors at the municipal level as measured in 2022, considering changes from 2016 to 2022.

The resilience dimension of an indicator for the total capital expenditure in infrastructural services provided by municipalities measures how robustly these services can withstand and adapt to various challenges. It focuses on aspects like the durability and maintenance of infrastructure (roads, bridges, public buildings), the flexibility of systems to adapt to technological advancements and changing needs (upgradable transport systems, modular cultural venues), emergency preparedness levels (flood defenses, earthquake-resistant structures), and the financial sustainability of infrastructure investments (long-term funding strategies, efficient allocation of resources). This indicator helps local governments assess the resilience and long-term viability of their infrastructure across all sectors, guiding policy decisions to bolster resilience, ensure continuity of services, and enhance overall community stability.

The static dimension of the indicator for the total capital in infrastructural services provided by municipalities focuses on the current status and characteristics of existing infrastructure across all sectors. It typically includes data such as the number and types of public facilities (roads, bridges, public buildings, cultural institutions), the capacity and current usage rates of these facilities, the geographical distribution throughout the municipality, and the extent of technological adoption (smart city technologies, digital traffic management systems, online public services). This dimension aids in understanding the baseline infrastructure available and identifies areas lacking sufficient resources, crucial for strategic planning and enhancing service delivery and accessibility across the community.

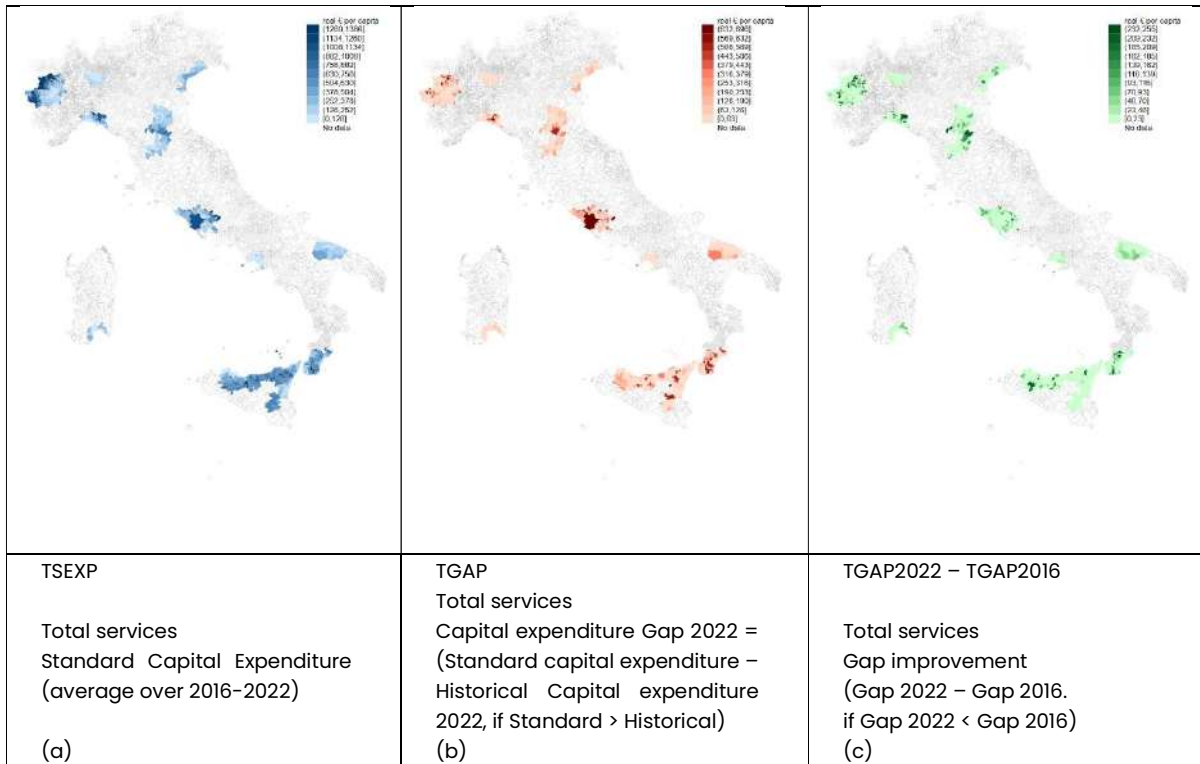


Figure 4: Total capital expenditure gap, euro per capita

The left panel of *Figure 4* displays the geographical distribution of the standard capital expenditure per capita, reflecting the broader infrastructural needs based on national averages from 2016 to 2022, helping to pinpoint metropolitan districts with varying needs for overall infrastructure. The middle panel of *Figure 4* showcases the infrastructural gap, defined as the difference between the standard and the actual capital expenditures in 2022, highlighting areas where overall infrastructure investment does not meet expected standards, pointing out potentially underfunded areas. The right panel of *Figure 4* shows municipalities that reported a reduction in their infrastructural gap from 2016 to 2022 in real terms, indicating improvement in infrastructure investment over time. Torino, encompassing a large number of municipalities, may show varied infrastructure needs across its urban and rural areas, highlighting disparities in infrastructure funding and development. Milan, with its high economic activity and dense population, likely faces significant infrastructure demands; gaps here can impact its economic efficiency and quality of life. Venezia's unique environmental and infrastructural challenges necessitate careful planning and investment to preserve its historical and economic significance while ensuring sustainable development. Smaller cities like Genoa, Bologna, and Florence could exhibit different levels of infrastructure needs based on their historical backgrounds and current economic roles, where strategic investments could enhance their resilience and attractiveness. Roma Capitale requires a balanced approach to infrastructure development, accommodating its vast historical sites with the need for modern infrastructure to support its large population and tourism industry. Southern districts such as Bari, Naples, Reggio Calabria, Palermo, Catania, and Messina often struggle with infrastructure deficits, where targeted funding and projects are crucial for enhancing their economic prospects and living standards. Cagliari, with fewer municipalities

but significant geographical challenges, needs focused infrastructure investment to ensure accessibility and economic growth. *Figure 4* provides critical insight for government officials, urban planners, and infrastructure developers, illustrating where investments in total services are lacking and where improvements are being made, enabling targeted strategies to enhance overall infrastructure across Italy's metropolitan districts. This comprehensive gap analysis is crucial for evaluating the adequacy of infrastructure in supporting economic activities, improving community resilience, and enhancing the quality of life, guiding policy decisions to close infrastructural gaps effectively.

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3.3. Public utilities services' gaps⁵

The analysis considered three public utility service indicators related to the sustainability dimension, included among the target indicators of the Sustainable Development Strategy (Richiedei, A., & Pezzagno, M. (2022)). The analysis specifically focused on comparing the 14 Italian metropolitan areas during the period 2021-2022 and 2023.

Specifically, the indicators include (i) the percentage of potable water loss, (ii) the installed photovoltaic power, and (iii) the difference in energy consumption for domestic use. Currently, the data are provided with a degree of accuracy, which is the most recent available years. The data were collected from ISTAT, TERN, and GSE.

3.3.1. Water losses

Percentage water losses (indicator MIb) are defined as the ratio between the volume of total water losses and the total volume entering the water supply system in the year under consideration. The data were collected from the ISTAT website for the year 2022 for the 14 metropolitan areas. In 2022, the volume of water losses in Italy amounted to XXX. The average water loss among the metropolitan cities was 38%. Among these, the metropolitan city of Reggio Calabria had the highest percentage of water losses (57.4%), while Milan, with 13.4%, was the city with the lowest losses in the network.



Figure 1: Volume of total water losses on the water introduced into the network (2023).

⁵ Paragraphs 3.3.1, 3.3.2 and 3.3.3 were written by UNIBA_DiEF research group, while paragraphs 3.3.4 and 3.3.5 were written by UNIVE_DiE Ca' Foscari University.

The above map shows percentage ratio between the volume of total water losses and the volume of water introduced into the network.

3.3.2. *Installed power energy of a photovoltaic system*

The second indicator is the nominal or installed power of a photovoltaic system. This indicator corresponds to the nominal (or peak) power of its photovoltaic generator, determined by the sum of the electrical power of each module constituting the photovoltaic generator, measured under Standard Test Conditions (radiation of 1,000 W/m² and temperature of 25°C) and weighted by the resident population. The map shows the distribution in the 14 Metropolitan Cities in 2023. The data on installed power were collected from the 2023 statistics section of the Gestore dei Servizi Energetici, while the population data were gathered from the ISTAT website for the same year. Among the metropolitan cities, the one with the highest installed power per capita is Cagliari (1.11 MW per capita), while the city with the lowest installed power is Genoa with 0.06 MW per capita.



Figure 2: Energy installed power of a photovoltaic system (2023).

The above map shows the installed power of photovoltaic systems in 2023, expressed in megawatts (MW) divided by the resident population in 2023 per 1,000 inhabitants.

3.3.3. *Difference in domestic energy consumption*

The third indicator concerns domestic energy consumption in kWh divided by the resident population. The goal is to make domestic energy consumption more responsible by reducing

waste and improving efficiency in choices. This indicator is expected to decrease over the years. It measures domestic energy consumption in kilowatts per capita. The data and corresponding map are based on provincial data and were collected from Terna's energy consumption report, focusing on the difference between 2022 and 2021. The city that recorded the greatest reduction was Bari (-6.49%), while the city with the smallest reduction was Milan with -0.69%.

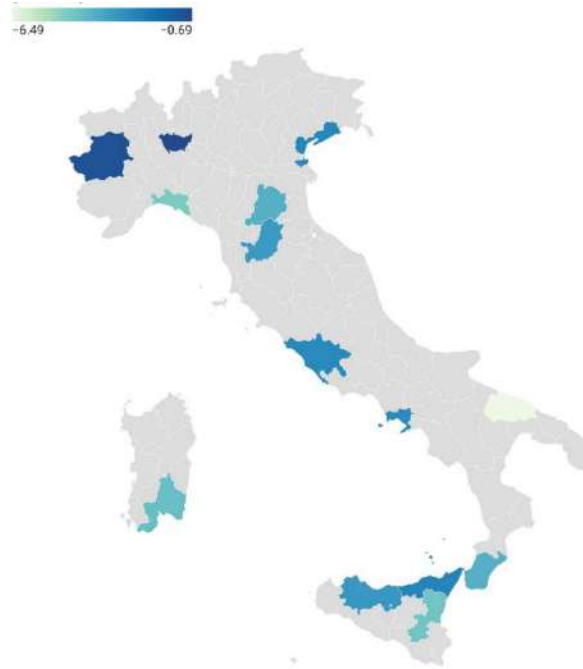


Figure 3: Difference in domestic energy consumption

The above map measures the difference in domestic energy consumption in kilowatts per capita over the last two available years. The data is on a provincial basis and is collected from Terna's energy consumption report, focusing on the difference between 2022 and 2021. This indicator shows the difference in domestic energy consumption between two years (in this case, 2021-2022). It is calculated as domestic energy consumption (kWh) divided by the population.

3.3.4. Land Use Infrastructure Index

The Land Use Infrastructure_Index is an index capable of capturing the concentration of transport infrastructures on a given territory. This is an effective tool for assessing the concentration of transport infrastructures on the Italian territory, offering significant insights into urban and regional development dynamics.

From this analysis, it is possible distinctly note how in more densely populated metropolitan areas such as Milan, Rome and Naples the Land Use Infrastructure Index reaches higher levels. This first observation allows us to determine how urban fabric and density significantly influence infrastructural capillarity: densely populated areas tend to develop denser and more

interconnected transport networks to meet the mobility needs of a concentrated population. At the same time, we can point out that higher levels of infrastructural development are also commonly associated with more efficient industrial development and transport networks. With this in mind, we can therefore consider how emissions associated with transport and industrial activities are higher where the infrastructure network is more articulated; conversely, areas characterised by an inefficient logistics system will see less industrial development and consequently a lower impact in terms of emissions. There is therefore a relationship, also highlighted on a national scale, between infrastructural presence and environmental pollution, where this trend appears extremely marked for areas in northern Italy, found in the metropolitan cities of Venice, Milan, Bologna and Turin.

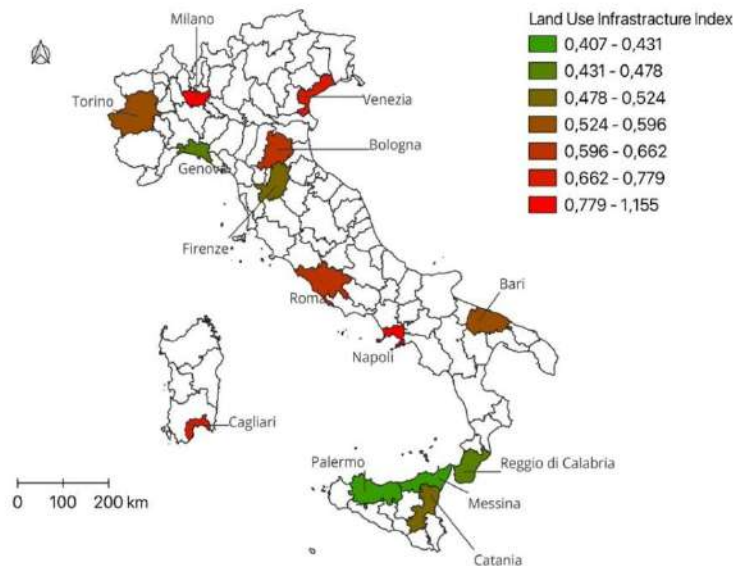


Figure 4: Land use infrastructure Index.

The map shows a marked disparity between North and South, with index values generally higher in the northern and central regions, gradually decreasing towards the South and the islands. This trend probably reflects historical differences in the economic and infrastructural development of the country. It is possible to note how, in particular, the area adjacent to the Strait of Messina, which includes the Metropolitan Cities of Messina and Reggio Calabria, and the nearby Metropolitan Cities of Palermo and Catania are configured as areas where infrastructural development in relation to the index used is particularly weak.

3.3.5. Land Use per Capita

Per capita land consumption in Italian metropolitan cities is a useful indicator for understanding the dynamics of urban development and the environmental challenges faced by the country's large urban areas. Analysis of the thematic map provided reveals a heterogeneous distribution of this phenomenon across the country, offering various elements

for analysis with regard to demographic trends and environmental pressures that characterise the different metropolitan realities.

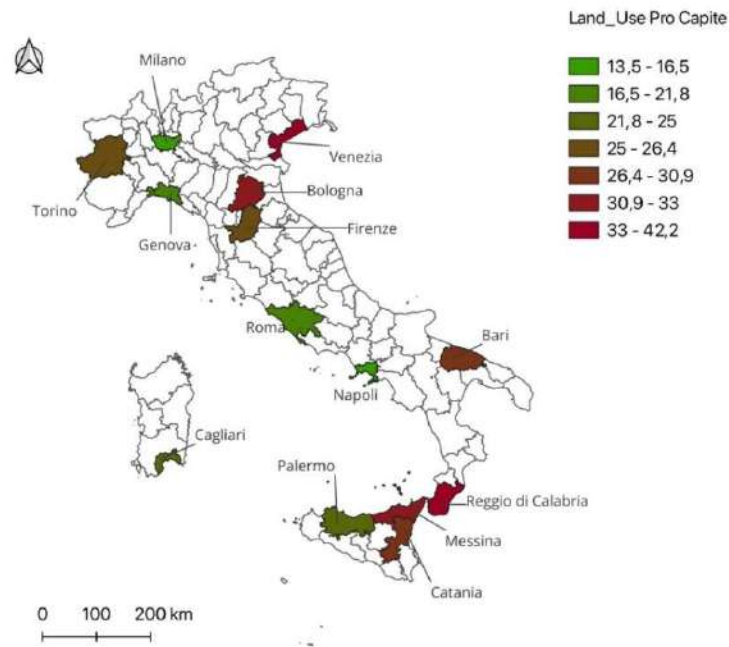


Figure 5: Land use per capita.

The variability observed in per capita land consumption among Italian metropolitan cities reflects a complex interaction of historical, geographical, economic and political factors. Northern Italian cities, such as Turin and Milan, present contrasting situations that show how industrial development and urban planning policies have shaped the urban fabric in different ways, also characterised by extremely different population densities. Turin, with a high per capita land consumption, may reflect the legacy of industrial expansion that favoured a horizontal development of the city. Milan, on the contrary, shows a more contained consumption, suggesting the effectiveness of densification policies, oriented more towards a vertical metropolitan development. The case of Venice emerges as particularly significant, with the highest per capita land consumption among the cities analysed. This datum should be interpreted in the light of the peculiar geographical conformation of the lagoon city, where the limited availability of building land and the need for specific infrastructures for the management of the aquatic environment considerably influence land use. The Venetian situation underlines how the geomorphological characteristics of the territory can play a decisive role in shaping land consumption patterns, imposing unique challenges on urban planning.

In central Italy, Rome has a surprisingly low per capita land consumption for a metropolis of this size. This figure could be the result of urban planning policies oriented towards densification and containment of urban sprawl, as well as the presence of vast green and agricultural areas within the municipal boundaries. Finally, the Metropolitan Cities of Southern Italy and the Islands show considerable variability in per capita land consumption, with Reggio Calabria standing out for particularly high values. This situation could be the result of a

combination of factors, including the geographical conformation of the territory, characterised by hilly and mountainous areas that may require more extensive expansion of urban infrastructure, and possible less regulated urban development dynamics. In contrast, Naples has one of the lowest per capita land consumption, reflecting its historically high population density and compact urban framework.

The observed disparities in per capita land consumption among Italian metropolitan cities raise important questions regarding the sustainability of urban development and spatial planning strategies. Cities with high land consumption face significant challenges in terms of environmental management, energy efficiency and provision of public services. Uncontrolled urban sprawl can lead to a number of negative consequences, including loss of biodiversity, increased hydrogeological risk and fragmentation of ecosystems. On the other hand, cities showing lower land consumption are commonly associated with metropolitan areas that are characterised by high population density, from which problems such as congestion management, the need for adequate green spaces and the maintenance of a high quality of life in high-density contexts can arise.

The analysis of per capita land consumption in Italian metropolitan cities reveals a complex and diverse landscape, reflecting the different urban development trajectories followed by the country's large cities. This indicator offers a significant insight into the challenges and opportunities that Italian metropolitan areas face in pursuing sustainable urban development. The differences observed emphasise the need for tailor-made approaches for each urban reality, which take into account local specificities while within a coherent national framework of policies for sustainability.

Future urban planning strategies will necessarily have to be oriented towards development models that favour urban regeneration, smart densification and the integration of green infrastructure into the city fabric. It will be crucial to promote policies that incentivise the rehabilitation of brownfield sites, limit uncontrolled urban sprawl and encourage a more efficient use of already urbanised land. At the same time, it will be crucial to balance these needs with the need to ensure a high quality of life for citizens through the creation of quality public spaces and the maintenance of an appropriate balance between built-up areas and green spaces.

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3.4. Railways network⁶

3.4.1. High Speed Rail

Several authors have studied the main impacts induced by HSR in Italy. Regarding the transportation system (internal impacts), HSR services have brought a reduction of the travel times between the main cities larger than 30%. The average speed on the Italian HSR lines is around 164 km (including intermediate stopping times), 32% higher than the one observed on the traditional rail network. In addition to an increase in the average speed, the introduction of HSR has increased the services for travellers.

Concerning the prices, the choice among 30 different ticket typologies, has produced an average ticket price reduction of about 40% with respect to the year 2008. This is mainly due, as stated, by the entry in the year 2012 of the NTV private operator in the HSR market, which has started competing with the state operator Trenitalia, with effects comparable to those produced by the low- cost airlines in the air market. By contrast, for the traditional railway services a much more marginal decrease in ticket prices has been observed, quantified in about -15%.

In addition, to the reduced travel times, a significant increase in frequencies has also been observed. For example, between Naples and Rome before HSR, 34 trains per day travelled on an average weekday. Today, 10 years after the introduction of the HSR service, about 94 trains travel on the Rome-Naples section on an average weekday with a frequency in the peak hour of one train every 6 min. Also the HSR demand, as stated, has increased very significantly, passing from 15 millions passengers/ year in 2009 to 45 millions passengers/year in 2018. Of the 43 millions of travellers, 7 millions are estimated as deviated from the traditional railway services, 19 millions have been attracted from other transport modes (private car, buses and air) and 17 millions represent a generated demand (Cascetta et al., 2020).

Average economic growth impacts brought by the HSR in Italy are shown in *Table 1*. HSR services have generated a 2.6% increase of the Italian per capita GDP in 10 years (about 0.3%/year) at a national scale. Furthermore, the HSR impact has grown up to + 5.6% (with maximum values of + 11.8%) for the zones located on the HSR network. Finally, it is interesting to note that also several zones not located within the network of HSR services have shown an increase of per capita GDP, although less significant (about 2.1%). This result is due to the fact that, as stated, also these zones benefit from HSR services (for example, transfers from traditional to HSR services).

Scenario	HSR impact on the Italian per capita GDP(extra growth of per capita GDP in 10 years)		
	Total network	HSR network	Traditional network
current scenario (2018) vs. basic scenario (2008)	Minimum 1.0%	Minimum 2.9%	Minimum 1.0%
	Mean 2.6%	Mean 5.6%	Mean 2.1%
	Maximum 11.8%	Maximum 11.8%	Maximum 6.9%
project scenario (HSR_N) vs. basic scenario (2008)	Mean 6.2%	Mean 15.05%	Mean 3.1%

⁶ Paragraph 3.4.1 was written by UNINA_DICEA research group, while paragraph 3.4.2 was written by UNIBA_DEMDI research group

Table 1: Economic growth impacts induced by the HSR in Italy: current scenario (ex-post) and project scenario (ex-ante). Source: Cascetta et al. (2020)

A horizontal equity analysis has been carried out to evaluate the regional distribution of both the economic and social impacts induced by HSR in Italy. The Lorenz curve and the corresponding Gini index are the most adopted measures of equity in the distribution of an attribute/variable in a population. Both indicators are commonly used in economics as well as in a wide range of disciplines, including transportation planning and accessibility analysis.

The estimation results in terms of both the Lorenz curve and the Gini index are reported in *Figure 1*. Consistently with the zonal aggregation considered, all the Gini indexes estimated are close to zero (0.080–0.177) and the corresponding Lorenz curves are very close to the bisector of the Cartesian plane, meaning an average equal distribution of the attributes considered (per capita GDP and transport accessibility). Estimated Gini indices are significantly lower than those commonly related to individual distributions (e.g. income levels ranging from 0.2 to 0.5) but are to be expected given the distribution of zone aggregated variables.

As for accessibility, the application of the model in equation (1) with negative exponential impedance function⁶ using three different transportation attributes (average rail travel time, ticket price and generalized transport cost) has produced a Gini index equal to 0.16, 0.08 and 0.12 respectively for the basic scenario 2008. These indices grow in the current scenario (2018) to 0.177 and 0.125 for the rail travel time and generalized transport cost attributes respectively, underling a reduction of equity with respect to those parameters. The analyses of the ticket price impact in the current scenario shows an increase in equity (Gini reduction from 0.08 to 0.065).

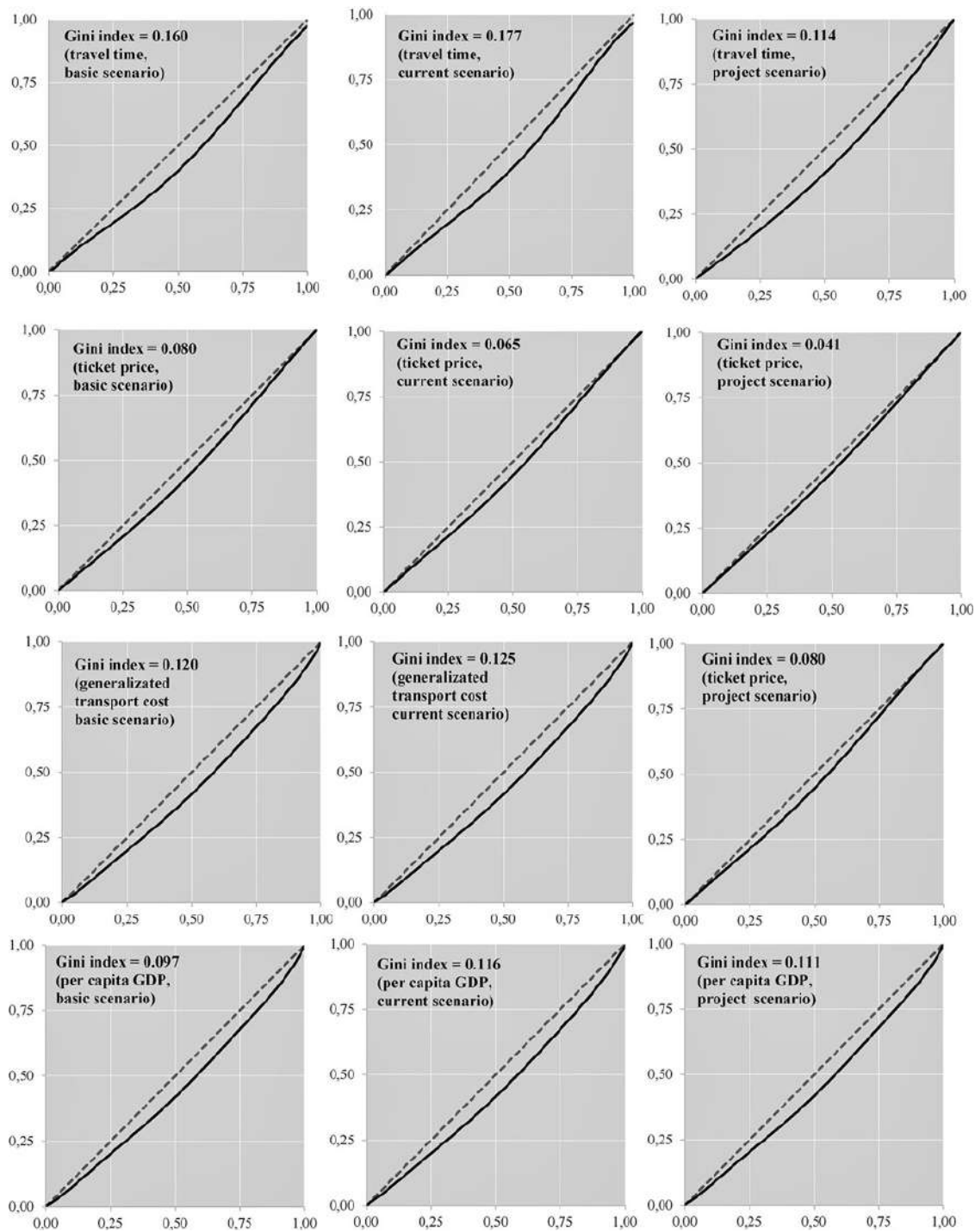


Figure 1: Lorenz curve and the Gini index for different independent variables.

From the tourist point of view, the main attributes defining this product are the ones linked to its attractiveness, to its facilities and to its accessibility, normally provided by an efficient transportation system. Specifically, by attractiveness it is meant the factors generating flows to a given destination. By tourist facilities it is meant those elements, whose absence prevent tourists from travelling to enjoy these attractions. The concept of accessibility is related to the different alternative transport modes available to reach a given tourist destination.

The increase of accessibility to a given tourist destination, thanks to new interventions in the transportation system, represents an important factor for tourism development. The principle that suitable means of transport can change the image of dead centers of tourist interest by transforming them into active places for visitors was highlighted in the paper of Pagliara and Mauriello (2020).

With the advent of new technologies, the transportation system, has experienced a change during the centuries. Specifically rail, thanks to the High Speed Rail (HSR) deployment, was one of sectors mainly affected by their introduction. Several are the projects already realized, others are under construction and more are in the pipeline all over the globe.

It is normal to consider that HSR projects are likely to affect tourist's choices of a given destination.

In the international literature, several studies have analysed the question of the impact of HSR on tourists' behaviour with different approaches, both qualitative and quantitative. However, they have been not able to solve the problem of capturing the spatial variation by fitting a regression model at a local point. The spatial heterogeneity within local models, such as Geographically Weighted (GW) models, provides a better platform allowing exploring the different spatial relationships between HSR and tourism. In the paper by Pagliara and Mauriello (2020), a spatio-temporal analysis has been proposed to evaluate the variables affecting tourists' choices and specifically the impact of HSR on both the Italian and Foreign tourists. The GWPR modelling approach has been proposed, which takes into account the problem of the temporal and spatial autocorrelation in a different way with respect to the Generalized Estimating Equations method.

The different behaviours of Italian and Foreign tourists have been reported, considering the impact of the presence of a HSR service and a second level hub system on them. Specifically in *Figures 2 and 3* the impact of the coefficient of the HSR variable has been presented for both the Italian and Foreign tourists. It is worth noting that HSR has an impact on the five provinces under analysis without considering the tourists' origins. During the years and especially after the year 2012, with the introduction of Nuovo Treno Viaggiatori (NTV), the train frequencies have improved considerably. This effect is evident in 2015 where the impact of HSR on the five provinces is high. In general the competition between the two operators has generated new demand on rail, thanks to the new opportunities supplied. This increase is visible some years later, since the NTV special fares were available only for few number of runs. In 2016, NTV increased the number of convenient runs, after a period of interior crisis of the company, and Trenitalia faced this competition by introducing similar convenient fares for early booking typically chosen by the tourists. Interesting is the case of Napoli, where after a first increase registered between the years 2005 (when the HS section between Napoli and Roma was inaugurated) and 2008, a decrease is present due to the renewal works which the airport undertook. This intervention made the air transport alternative more advantageous

justifying this decrease. The trend then changes again, according to the above considerations.

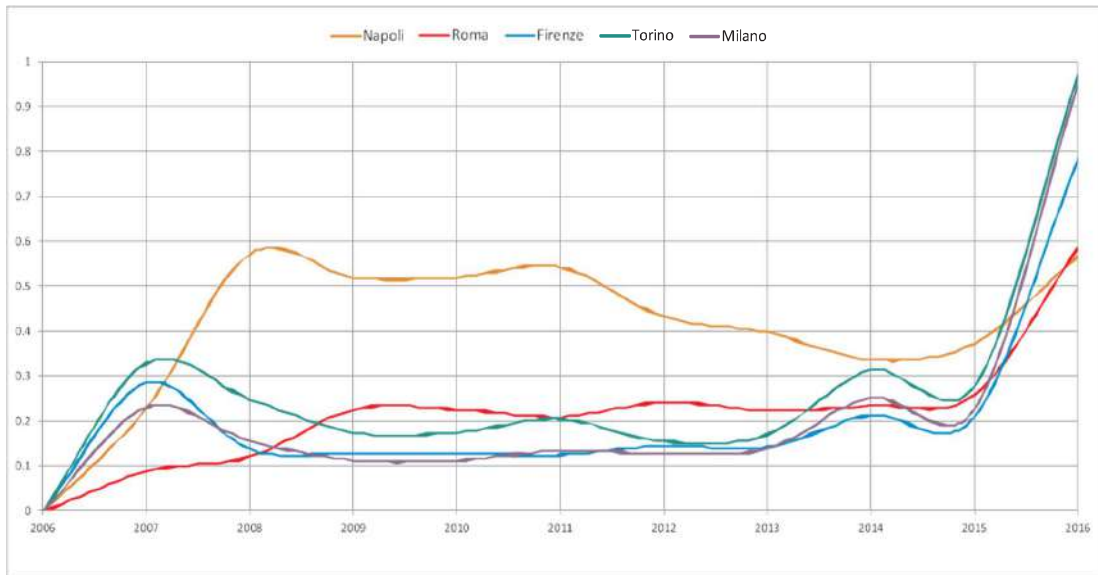


Figure 2. The impact of HSR on five provinces - Italian Tourists.

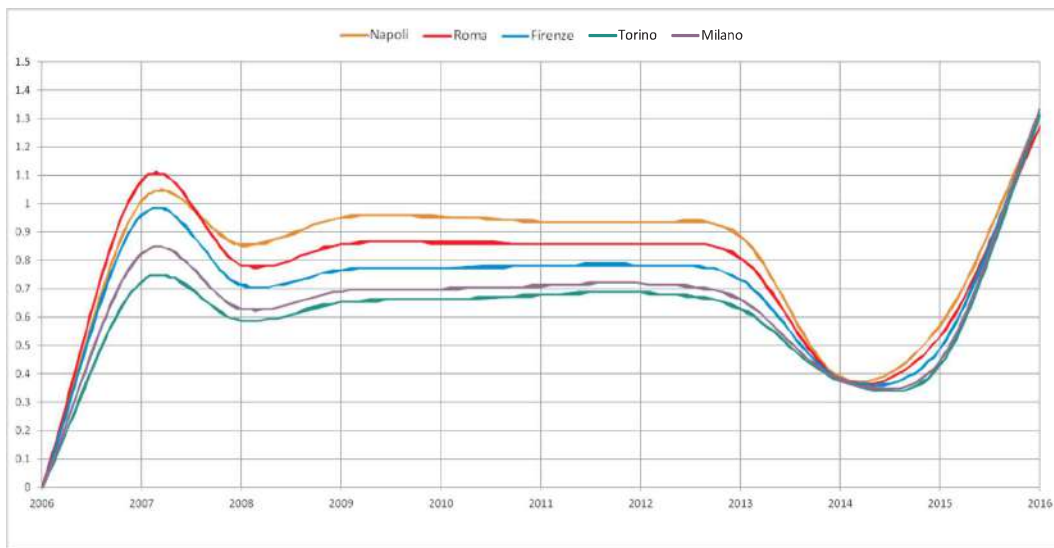


Figure 3. The impact of HSR on five provinces - Foreign Tourists. (Source: Pagliara and Mauriello, 2020)

3.4.2. Vulnerability of the railway transport network

The Italian railway network connecting the country's 14 metropolitan cities (as defined by ISTAT) is increasingly vulnerable to hydrogeological risks, especially floods. The likelihood of such events has increased in recent years, and the spatial exposure across the peninsula has been detailed by ISPRA (2020). In this context, hydrogeological vulnerability of the railway network refers to the risk of service disruptions and resulting loss of network functionality due to such

events (Berdica, 2002; Berche et al., 2009; Mattsson & Jenelius, 2015; Reggiani et al., 2015; Bergantino et al., 2024). Figure 4 presents a graph-based representation of the rail network, while Figure 5 illustrates flood risk levels for main lines in the high-capacity network.

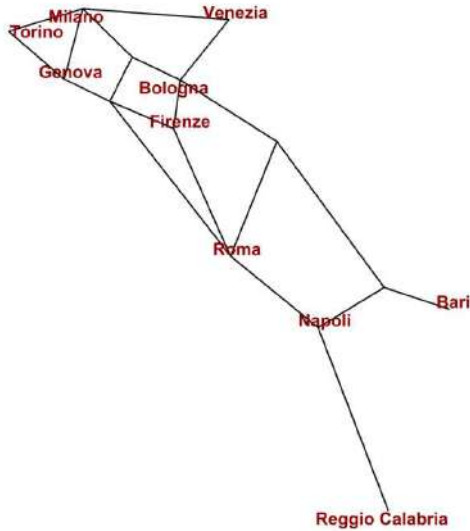


Figure 4: Graph-based network representation of the railway connecting the 10 mainland metropolitan cities.

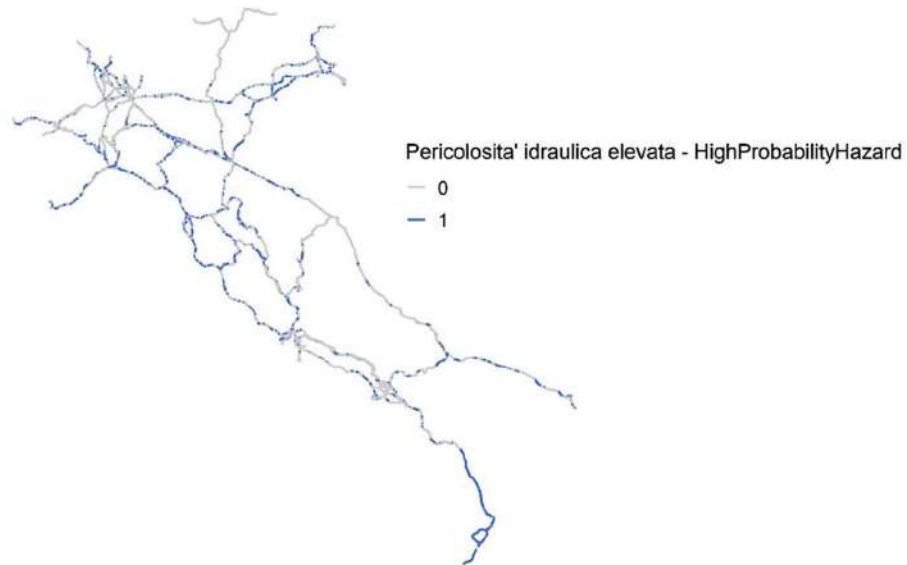


Figure 5: Flood risk of the main mainland rail lines.

At the methodological level, metropolitan areas rail vulnerability to flooding is assessed through an indicator that measures changes in network connectivity following the disruption of critical rail lines. To choose which lines are most critical to flooding, the following index CA_i is utilized:

$$CA_i = PA_i^2 \times E_i$$

where PA_i is the vulnerability to floods at the OD line level at the city level and E_i is the exposure to risk.

Flood vulnerability is the estimated likelihood of occurrence. For this analysis, the High Probability Hazard (HPH) categorization provided by ISPRA divide areas between the ones belonging to a high likelihood of flooding area with return intervals of 20 to 50 years and the one which does not. The geographical intersection of the rail network and the categorized areas (as visualized in Figure 5) defines the vulnerability to hydrogeological hazards at the OD level. To measure risk exposure E_i , potential demand is calculated as the average number of employees at the origin and destination points.

The identified connectivity index of the network is the route efficiency:

$$RE_i = \sum_1^n \left(\frac{d_0(i,j)}{d_1(i,j)} \right) / n$$

Where the route efficiency RE_i is the average of all route efficiencies $\frac{d_0(i,j)}{d_1(i,j)}$ of metropolitan city i towards all other cities j . Shortest paths $d(i,j)$ between nodes i and j are calculated before and after the link removal due to the disruption (Morelli and Cuhna, 2021) and compared to assess loss in efficiency. The parameter ranges from 0 to 1, where 1 indicates that the rail line fully operates despite the disruption, maintaining its 100% performance level in connecting nodes. A value below 1 means that service interruption has increased the distance between nodes, reducing connectivity efficiency.

Based on the index CA, the lines most critical to flood risk per Italian mainland geographical repartitions are:

- 1) Venezia-Bologna (north repartition) (Scenario S1).
- 2) Genova-Roma (central repartition) (Scenario S2).
- 3) Bari-Napoli (south repartition) (Scenario S3).

For the southern repartition, the Napoli-Reggio Calabria line would be the most critical. However, we opted not to create a scenario based on its removal because the only insight would be the disconnection of Reggio Calabria from all the other cities. Based on the chosen scenarios, three sub-networks were created from the base network—one for each scenario. In each sub-network, the corresponding disrupted line was removed from the base network, and the network connectivity indices were recalculated, as detailed in the following section.

The RE indicators spatially shows how the between-metropolitan-cities connectivity change as a result of flood. After identifying the most critical lines through the CA indexes, three scenarios are constructed by removing the critical line from the reference scenario of the high-capacity Italian rail network that connects mainland metropolitan cities. For example, in the northern Italy scenario, the Venezia-Bologna link is removed. The RE indicator quantifies how the average route efficiency between a city and all others changes as a result of this removal, operationalized through the average shortest path length. In the maps, larger and darker dots represent cities that experienced the most significant reductions in efficiency, indicating that the average shortest paths length increase more in such cities compared to

others.

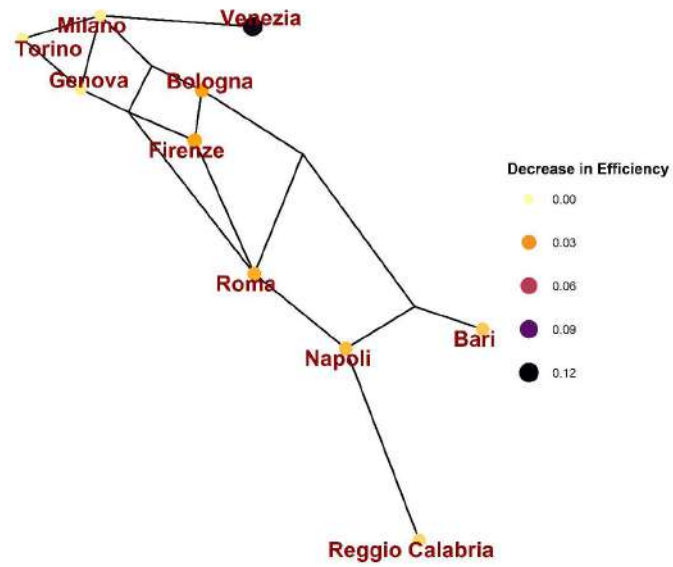


Figure 6: Change in RE in the Venezia-Bologna flood scenario (S1).

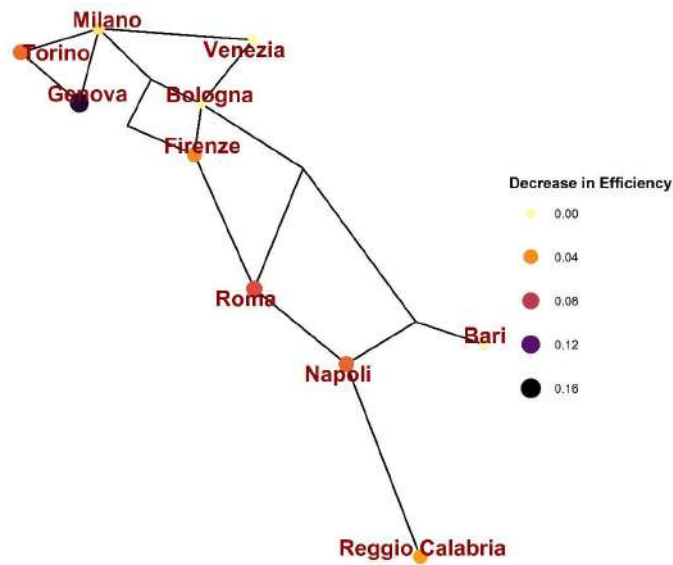


Figure 7: Change in RE in the Genova-Roma flood scenario (S2).

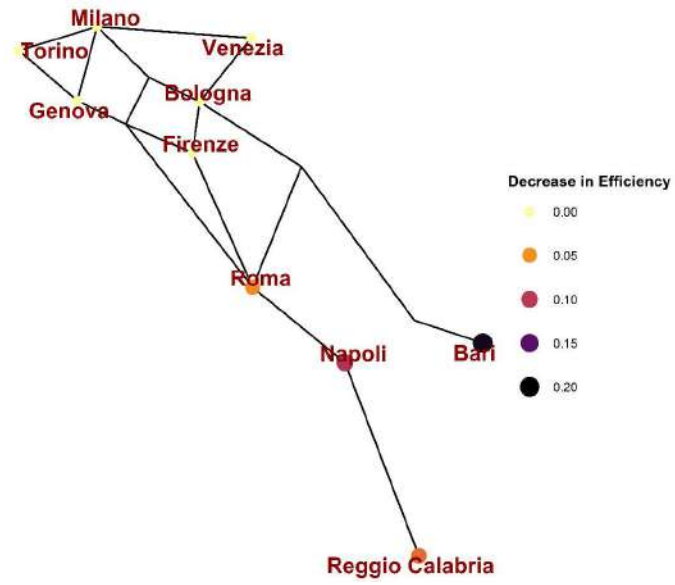


Figure 8: Change in RE in the Bari-Napoli flood scenario (S3)

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3.5. Connectivity to technological infrastructures and diversification of digital services⁷

Technological and digital progress is a primary driver of the transformations shaping contemporary society, redefining communication systems, access to information, and the provision of essential services (Castells, 2011; Brynjolfsson & McAfee, 2014). According to international economic literature, access to advanced technological infrastructures is now a critical factor for ensuring competitiveness, stimulating innovation, and fostering development and social inclusion (van Dijk, 2020).

Numerous studies emphasize the importance of digital infrastructures in driving economic growth (Czernich et al., 2011; Edquist et al., 2018). Acemoglu and Robinson (2012) argue that inclusive institutions and equitable access to technological resources are essential for sustainable economic development. Empirical research has demonstrated that investments in digital infrastructures positively affect firms' productivity, employment, and regional growth (Guiso et al., 2009; Leonardi, 2005). Additionally, the adoption of ICT has been linked to increased innovation and better integration of local economies into global markets (Czernich et al., 2011; Roper & Love, 2006). These studies underscore that digital infrastructures not only enhance operational efficiency for firms but also create new business opportunities and improve regional economic competitiveness (Crescenzi et al., 2016).

However, the literature also highlights that unequal access to technology exacerbates existing socio-economic inequalities. Disparities in access to and the quality of digital infrastructures can create vulnerabilities that disproportionately affect less developed and marginalized areas, as well as specific groups of citizens (Card & Krueger, 1994; Van Deursen & van Dijk, 2014; Bourguignon, 2022; Gal et al., 2019). These inequalities are particularly evident between urban and rural areas, where significant differences exist in broadband diffusion and the availability of advanced digital services (Atkinson, 2019; Forman et al., 2012; Kolko, 2012).

This territorial divide is also visible at the urban scale. Northern Italian cities, such as Milan, Turin, and Bologna, are recognized as centers of technological innovation, characterized by a high concentration of ICT companies and extensive penetration of fiber optic networks (Camagni & Capello, 2015). In contrast, Southern metropolitan cities like Bari, Naples, Palermo, and Reggio Calabria face substantial challenges stemming from insufficient digital infrastructure and lower levels of investment in the technology sector. The limited reach of FTTH networks restricts access to high-speed internet, hampering the growth of technology firms and diminishing local economic competitiveness. Additionally, inadequate digital infrastructure contributes to the "brain drain" phenomenon, with young talents migrating to Northern regions or abroad in search of better job opportunities (Faggian & McCann, 2009).

This report focuses on analyzing digital vulnerability in the distribution and accessibility of broadband infrastructures in Italy's new metropolitan cities (as defined by the Law of April 7, 2014). These metropolitan cities, with their dynamic development and internal agglomeration, provide an ideal framework for examining the interplay between urbanization, technology, and development. The economic literature suggests that targeted interventions in digital infrastructures can significantly enhance local development, improve access to essential services, and promote social inclusion (Aghion et al., 2015; Moretti, 2013).

Specifically, we map the digital vulnerability of Italian municipalities to provide a comprehensive overview of disparities in the distribution and utilization of digital infrastructures. Identifying areas with higher levels of digital vulnerability is critical for planning targeted interventions that can reduce inequalities and foster more equitable and sustainable development. Additionally, we aim to uncover patterns and trends that explain differences in technological progress and well-being between cities in Northern and Southern Italy.

⁷ This paragraph was written by the UNIBA_DEMDI research group.

Ultimately, this report examines metropolitan cities in terms of digital vulnerability, aiming to enrich policy discussions and offer actionable recommendations to stakeholders.

Methodology and construction of indicators

In order to carry out a detailed analysis of the digital vulnerability of the 14 Italian metropolitan cities, a statistical methodology was adopted that is based on the creation of five weighted indicators. Each indicator is specifically designed to examine a critical aspect of connectivity and network coverage, with particular attention to the diffusion of optical fiber at municipal level. These indicators also consider specific socio-economic characteristics of each municipality of the metropolitan cities, thus providing a balanced and comparable assessment of their digital capabilities. This approach allows to study in detail the degree of digitalization and the evolution of infrastructures and therefore the network vulnerability in each analyzed area.

The methodology for the calculation of the weighted municipal indicators is based on a process of normalization and weighting of the collected data. The data were obtained from official sources, such as ISTAT, the Ministry of Economy and Finance and the Italian Telecommunications Authority (AGICOM)⁸. Each indicator has been normalized to take into account economic, demographic and infrastructural variables, such as municipal per capita income, population density, metropolitan municipality surface area and accessibility to railway stations.

Furthermore, in order to provide an accurate and complete synthetic assessment of the digital vulnerability present in the municipalities of the metropolitan cities⁹, we have developed a multidimensional synthetic indicator¹⁰, which combines together the five weighted indicators listed below, since each of them reflects a critical component of the digital infrastructure.

Specifically, the indicators considered are:

1. **Weighted Declared Termination Points:** Measures the availability of fiber optic termination points in Italian municipalities. A high value indicates a low availability of termination points compared to the needs of the population.
2. **Weighted FTTH Coverage:** Represents the percentage of cells covered by fiber to the home (FTTH). A high value indicates insufficient coverage compared to the population and infrastructure of the municipality.
3. **Weighted FTTH Accessibility:** Measures the ease of access to the FTTH network, based on the number of available termination points. A high value indicates poor accessibility to

⁸ All data used refer to the latest available survey. AGICOM data on broadband refer to 03/31/2024. Data on average municipal per capita income, processed by the Ministry of Finance database for 2023, obtained from the declarations of natural persons. Data on population and surfaces for 2023. ISTAT data on Accesses to the highway network for 2023.

⁹ The Metropolitan city is one of the Italian local territorial entities. Established, for the ordinary regions with the Law of 7 April 2014, n. 56, which regulates its establishment in substitution of the Provinces as a large area entity, and with specific Regional Laws for the regions with special statutes. The Metropolitan Cities in Italy are: Turin, Genoa, Milan, Venice, Bologna, Florence, Rome, Naples, Bari, Reggio Calabria, Palermo, Messina, Catania, Cagliari.

¹⁰ The indicators constructed use time-invariant data, in order to represent the state of digital vulnerability at a specific moment in time.

the high-speed network, suggesting that residents have difficulty connecting to the Internet at high speed.

4. **Weighted Connection Diversification:** Evaluates the diversification of Internet connections, based on the number of geographically distinct termination points. A high value suggests low diversification and potential vulnerability to service interruptions.
5. **Weighted FTTC Coverage:** Represents the percentage of cells covered by fiber to the cabinet (FTTC). A high value indicates insufficient FTTC coverage.

The general formula used to calculate each weighted indicator is the following:

$$Weighted_Indicators_{ij} = \frac{Digital\ Indicators_{ij}}{Income_per_cap_j \times Accesses\ to\ the\ highway\ network_j \times \left(\frac{Population}{Surface}\right)_j}$$

Where:

- *Weighted_Indicators_{ij}*: is the value of the weighted indicator for the municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals) and the broadband variable *i*;
- *Digital Variable*: is the value of the broadband variable *i* (e.g., declared termination points, cells covered by FTTH, etc.), for the municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals);
- *Inc_per_cap_{ij}*: is the per capita income for municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals);
- *Accesses to the highway network*: is the number of accesses to the motorway network for municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals);
- $\left(\frac{Population}{Surface}\right)$: is the population density of municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals).

The process of creating the multidimensional digital vulnerability indicator was instead developed through a process of normalization and weighting of each simple weighted indicator. A “min-max scaling” normalization process was used, which allowed each indicator to be scaled so that its values are between 0 and 1. This is useful when the variables have different scales and are not directly comparable. The formula for min-max scaling is:

$$Normalized\ Value_{ij} = \frac{Weighted_Indicators_{ij} - \min(Weighted_Indicators_i)}{\max(Weighted_Indicators_i) - \min(Weighted_Indicators_i)}$$

Where:

- *Normalized Value_{ij}*: is the normalized value of the indicator *i* for the municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals)
- *Weighted_Indicators_{ij}*: is the value of the indicator weighted by the municipality *j* (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals) and the broadband variable *i*

- $\min(\text{Weighted_Indicators}_i)$: is the minimum value of the weighted indicator i among all municipalities (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals)
- $\max(\text{Weighted_Indicators}_i)$: is the maximum value of the weighted indicator i among all municipalities (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals).

After normalizing the individual indicators, we proceed with their integration into an overall indicator that reflects digital vulnerability in metropolitan cities. This synthesis is essential to understand the multiple challenges that influence digitalization and to identify areas that need priority interventions. The general formula for the multidimensional digital vulnerability indicator represents an average of normalized values:

$$\text{Multidimensional_Indicator} = \frac{\sum_{i=1}^n \text{Normalized Value}_{ij}}{n}$$

Where:

- n is the total number of indicators
- $\text{Normalized Value}_{ij}$: is the normalized value of the indicator i for the municipality j (i.e., each individual municipality within the metropolitan cities or the only metropolitan city capitals).

In this process, the weights to the variables were assigned uniformly, in order to obtain a balanced assessment of digital vulnerability, with respect to the different economic, socio-demographic and infrastructural dimensions considered.

Consequently, this methodology allows to precisely identify the areas that show the highest levels of digital vulnerability. For reasons of synthesis, on the maps the digital vulnerability values in each metropolitan city are reported in terms of deciles, with 0-1 representing low vulnerability, 9-10 high vulnerability.

At a practical level, a higher value of the multidimensional indicator indicates a greater digital vulnerability, suggesting that the capital cities and/or the internal municipalities of the metropolitan cities that present high values have a lower availability of connectivity infrastructures compared to their population and infrastructural structure.

Ultimately, this indicator offers a detailed view of the disparities in access to broadband infrastructures.

Results

The analyses on digital vulnerability in broadband access in Italy, reported in this section, highlight significant spatial differences between metropolitan cities in the North and those in the South. In many cases, Northern Cities present significantly lower values of the multidimensional indicator, indicating lower digital vulnerability than Southern cities. In particular, the maps (*Figures 1:4*) and *Tables (1,2)* clearly reflect the disparities in digital vulnerability between different Italian regions.

As a first analysis, we focus only on a comparison between the 14 provincial capitals of the

Italian Metropolitan Cities¹¹.

Figures 1 present heterogeneous levels of digital vulnerability, with high values especially in the municipalities of Southern Italy and in some specific cities in the North. The areas colored with darker shades of pink indicate higher levels of digital vulnerability (between the seventh and tenth decile of the distribution).

At a comparative level, the comparison between the different Italian cities is particularly interesting. Cities in Northern Italy, in particular Milan, Turin, Florence and Bologna, present the lowest levels of vulnerability (between the first and fourth decile, with average values in these cities, reported in *Table 1*, ranging from 0.0061 to 0.0194), highlighting a robust broadband digital infrastructure, which supports a wide variety of technological and connectivity services, also reflecting a solid socio-economic base. On the contrary, cities such as Genoa and Venice, despite being in the North, show higher levels of digital vulnerability, probably due to structural factors such as lower urban agglomeration or difficulty in accessing transport systems, in the case of Venice, and socio-economic issues such as lower incomes, which can influence the distribution and effectiveness of digital infrastructures.

Cities in the island regions and the capital of Calabria, present very high levels of vulnerability (see *Figures 1 and Table 1*), which suggests a greater lack of digital infrastructures.

On the contrary, Naples and Bari show more moderate levels of vulnerability, similar to those of Bologna. These data reflect the development that these cities are consolidating in recent years. However, a special case is Rome, which presents the highest level of vulnerability among Italian metropolitan cities, an outlier that could be due to its complex socio-economic, demographic and geographical structure.

Metropolitan Cities	Weighted Declared Termination Points	Weighted FTTH Coverage	Weighted FTTH Accessibility	Weighted Connection Diversification	Weighted FTTC Coverage	Multidimensional Indicator
Turin	0.2680	0.0244	0.0669	0.0491	0.0282	0.0151
Genoa	1.1758	0.0688	0.2255	0.1424	0.0846	0.0493
Milan	0.0687	0.0104	0.0407	0.0181	0.0040	0.0061
Venice	1.6324	0.1518	0.4805	0.3684	0.1490	0.1005
Bologna	0.3456	0.0286	0.0927	0.0583	0.0372	0.0194
Florence	0.2316	0.0142	0.0398	0.0303	0.0214	0.0100
Rome	2.9952	0.1530	0.3513	0.2946	0.2572	0.1067
Naples	0.3818	0.0291	0.0870	0.0703	0.0262	0.0193
Bari	0.4673	0.0336	0.1150	0.0876	0.0314	0.0240
Reggiocalabria	2.1114	0.1361	0.3745	0.2737	0.1559	0.0895
Palermo	0.7681	0.0484	0.1514	0.1157	0.0405	0.0333
Messina	1.6980	0.1212	0.3386	0.2603	0.0926	0.0760
Catania	1.3106	0.0913	0.3278	0.2610	0.0816	0.0678
Cagliari	1.2489	0.1147	0.2498	0.2284	0.1253	0.0660

¹¹ In this analysis, the attribution of deciles is connected to the destruction of the digital vulnerability indicator of the 14 Metropolitan Cities Capitals.

Table 1: Average Vulnerability Indicators for Metropolitan City Capitals¹². Source: own processing

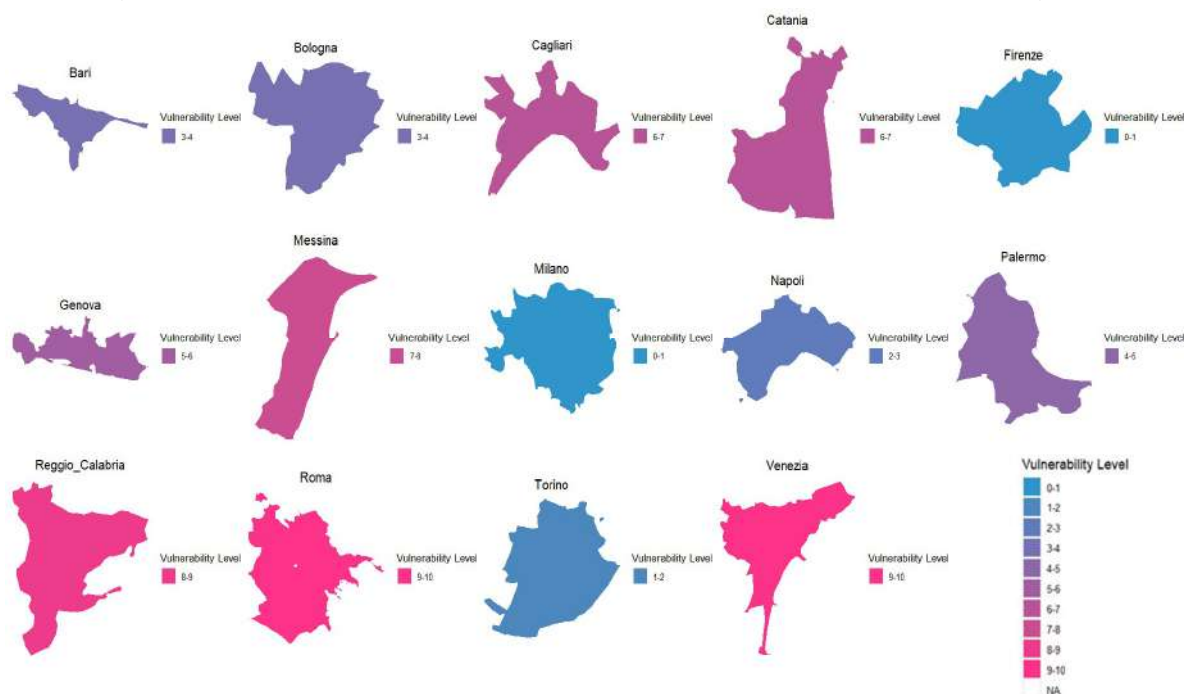


Figure 1: Digital Vulnerability Index of Metropolitan Cities Capitals. Source: own processing

As a second vulnerability analysis, we consider all the municipalities that make up each Italian metropolitan city (formerly NUTS-3 provincial level)¹³. In this case, the presence of a greater number of municipalities for each metropolitan city allows us to study the differences in vulnerability in broadband access, not only between metropolitan cities, but also within them. Also in this case, we observe significant disparities in terms of digital vulnerability between metropolitan cities in the North and South (see the maps in *Figure 2, 3 and Table 2*).

Furthermore, the presence of spatial heterogeneity is also observable within the same metropolitan cities.

For example, in the metropolitan city of Rome, some peripheral municipalities have significantly higher levels of digital vulnerability than the Capital, indicating a non-homogeneous distribution of broadband infrastructures. Although not with the same levels of vulnerability, the presence of higher levels in the capitals of the metropolitan cities can also be found in other areas such as Turin, Genoa, Bologna, Milan, Venice, Reggio Calabria, Naples. Similar trends may be due to the socio-economic structures of municipalities close to cities. In fact, they can benefit from agglomerations and indirect spillovers (for example, faster access to the motorway network or higher income levels), capable of generating advantages compared to cities, which are instead more characterised by the pervasiveness of multidimensional phenomena. Despite this, other metropolitan cities are characterised by

¹² This table does not report the standard deviation for each metropolitan municipality due to the lack of variance in the data.

¹³ In this analysis, the attribution of deciles is connected to the destruction of the digital vulnerability indicator of all the municipalities of the metropolitan cities.

greater homogeneity in terms of intra-municipal digital vulnerability, for example Bari, Palermo, Florence, Messina, Cagliari, Catania. In these areas, vulnerability is spatially distributed. This shows a similar gradient of broadband accessibility in all municipalities of those areas.

Metropolitan Cities	Weighted Declared Termination Points	Weighted FTTH Coverage	Weighted FTTH Accessibility	Weighted Connection Diversification	Weighted FTTC Coverage	Multidimensional Indicator	Total Municipalities per Metropolitan Cities
Torino	0.1750 (0.6699)	0.0160 (0.0285)	0.0227 (0.0429)	0.0223 (0.0424)	0.0293 (0.0120)	0.0129 (0.0073)	310
Genova	0.2188 (0.3211)	0.0082 (0.0141)	0.0150 (0.0330)	0.0131 (0.0248)	0.0344 (0.0176)	0.0083 (0.0061)	64
Milano	0.0795 (0.0689)	0.0034 (0.0049)	0.0136 (0.0205)	0.0055 (0.0086)	0.0084 (0.0092)	0.0035 (0.0031)	133
Venezia	0.3553 (0.4537)	0.0163 (0.0307)	0.0299 (0.0772)	0.0258 (0.0611)	0.0709 (0.0518)	0.0186 (0.0127)	44
Bologna	0.2430 (0.2668)	0.0084 (0.0163)	0.0143 (0.0298)	0.0128 (0.0263)	0.0319 (0.0345)	0.0082 (0.0076)	55
Firenze	0.4127 (0.4201)	0.0141 (0.0240)	0.0283 (0.0485)	0.0246 (0.0413)	0.0557 (0.0500)	0.0141 (0.0126)	41
Roma	0.2845 (0.5367)	0.0088 (0.0210)	0.0206 (0.0461)	0.0181 (0.0395)	0.0503 (0.0235)	0.0150 (0.0079)	121
Napoli	0.1021 (0.1348)	0.0030 (0.0068)	0.0065 (0.0165)	0.0055 (0.0138)	0.0122 (0.0093)	0.0045 (0.0028)	92
Bari	0.7414 (0.7001)	0.0179 (0.0283)	0.0631 (0.1129)	0.0503 (0.0903)	0.0434 (0.0489)	0.0235 (0.0198)	41
Reggio di Calabria	0.3388 (0.4028)	0.0026 (0.0139)	0.0057 (0.0381)	0.0045 (0.0279)	0.0307 (0.0257)	0.0102 (0.0058)	97
Palermo	0.6383 (0.7289)	0.0211 (0.0330)	0.0655 (0.1218)	0.0563 (0.0970)	0.0466 (0.0323)	0.0251 (0.0185)	82
Messina	0.4119 (0.4311)	0.0176 (0.0233)	0.0491 (0.0739)	0.0420 (0.0582)	0.0259 (0.0226)	0.0151 (0.0134)	108

Catania	0.4787 (0.5538)	0.0117 (0.0222)	0.0322 (0.0710)	0.0277 (0.0603)	0.0343 (0.031 8)	0.0159 (0.0119)	58
Cagliari	0.7276 (0.8201)	0.0340 (0.0481)	0.0636 (0.0921)	0.0605 (0.0877)	0.0840 (0.074 8)	0.0283 (0.0243)	17

Table 2. Indicator Analysis for Metropolitan Cities and Their Municipalities. Source: own processing

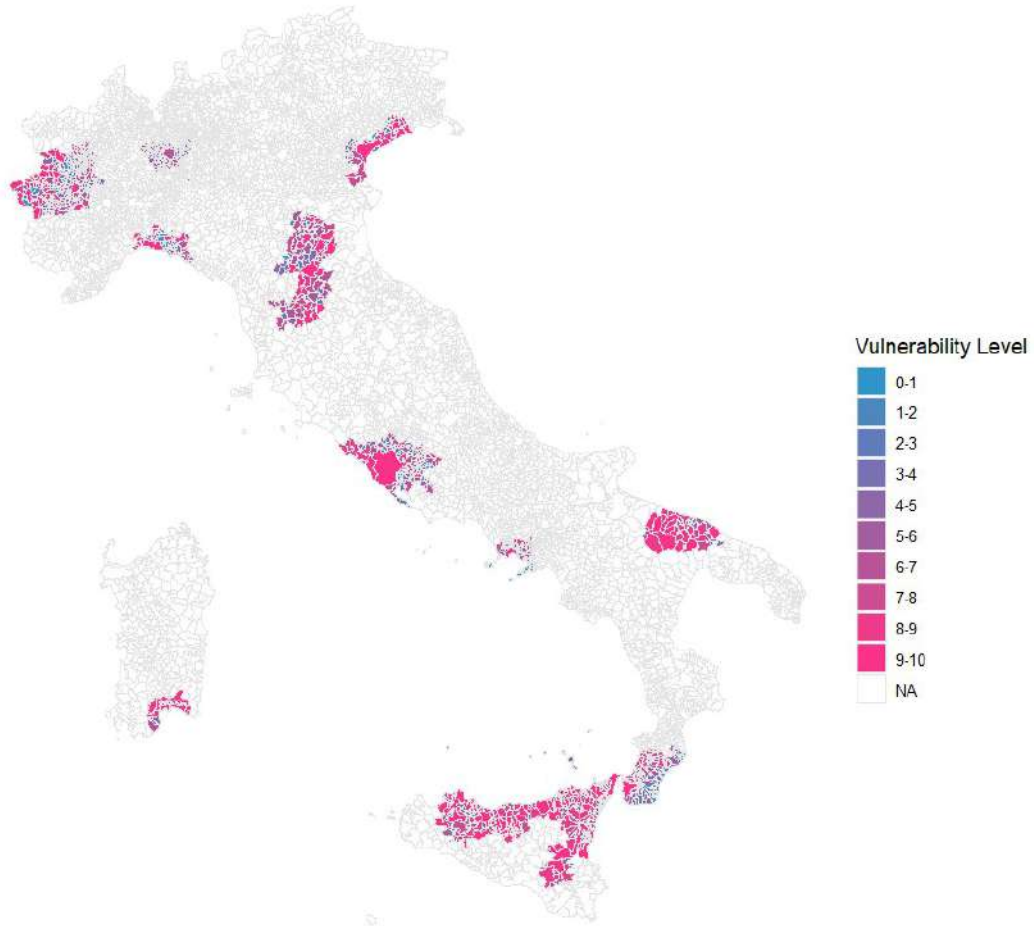


Figure 2. Municipal of Metropolitan Cities Digital Vulnerability. Source: own processing

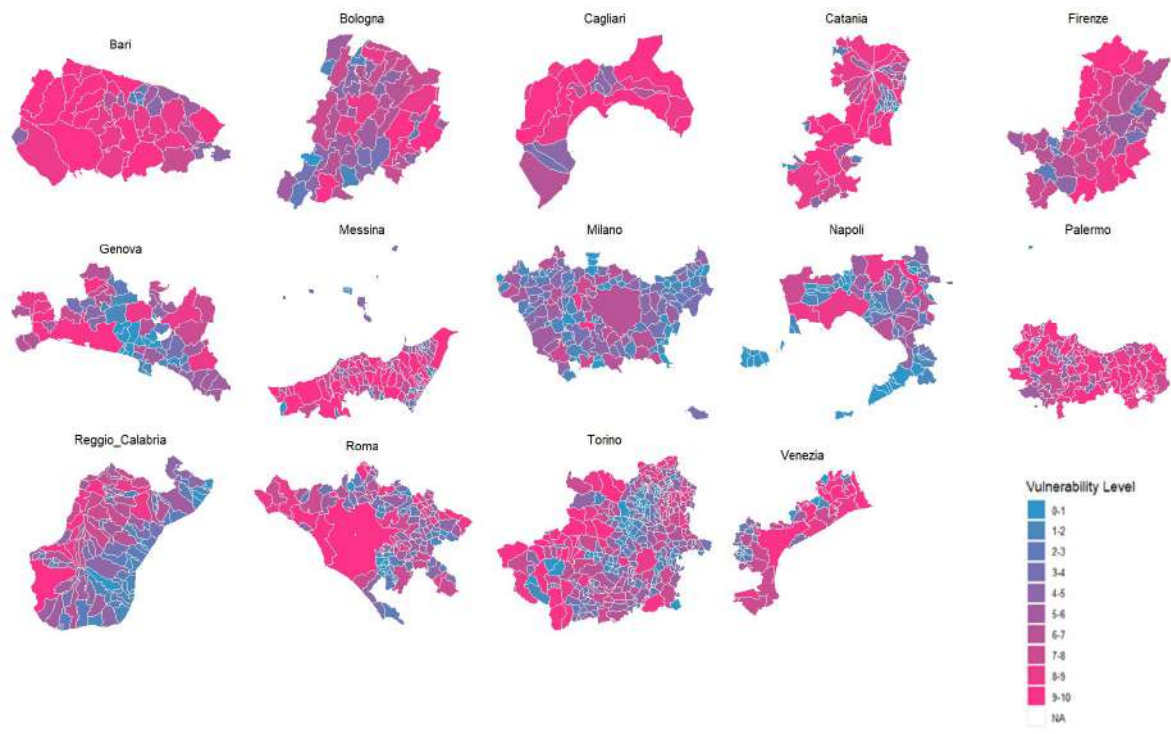


Figure 3. Digital Vulnerability of Metropolitan Cities. Source: own processing

Conclusion

The in-depth analysis of digital vulnerability in Italian metropolitan cities has highlighted marked territorial disparities, which reflect the historical inequalities between the North and the South of the country. The values of the multidimensional indicator of digital vulnerability constructed demonstrate that southern cities face significant challenges in terms of access and quality of broadband infrastructure, especially compared to northern cities, which instead enjoy greater technological integration. Digitalization, in this sense, can play a crucial role in promoting equity, as demonstrated by various studies, which positively correlate technological access with innovation and economic growth. The results obtained clearly show the need for targeted investments and effective policies to overcome the digital divide, not only improving the economic competitiveness of disadvantaged cities but also ensuring an equitable distribution of technological opportunities. Addressing these critical issues requires a concerted effort between stakeholders at various levels, from local to national, and a strategic vision that includes investments in infrastructure, incentives for innovation, and digital skills development programs. This will reduce existing inequalities and promote fair and sustainable development, facilitating access to essential services that can create new job and income opportunities for all citizens, regardless of their geographical location.

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3.6. Diversification of export systems at the metropolitan-level¹⁴

The analysis of vulnerability and diversification of export systems at the metropolitan-level, particularly in the context of global crises, offers valuable insights into how these large urban and economic hubs react to external shocks. Economic vulnerability, as discussed in the literature, can arise from both structural factors (like export concentration and openness) and policy choices, influencing how these territories absorb or recover from crises such as the Global Financial Crisis (GFC) and the COVID-19 pandemic.

The motivation for this analysis is to evaluate how the export stability and diversification of Italy's "metropolitan cities" –which are key drivers of national economic performance–affect their vulnerability to external shocks. Given the importance of exports to Italy's overall economy, the focus on metropolitan areas allows for a more nuanced understanding of sub-national economic resilience, where economic activity is highly concentrated.

3.6.1. Export stability

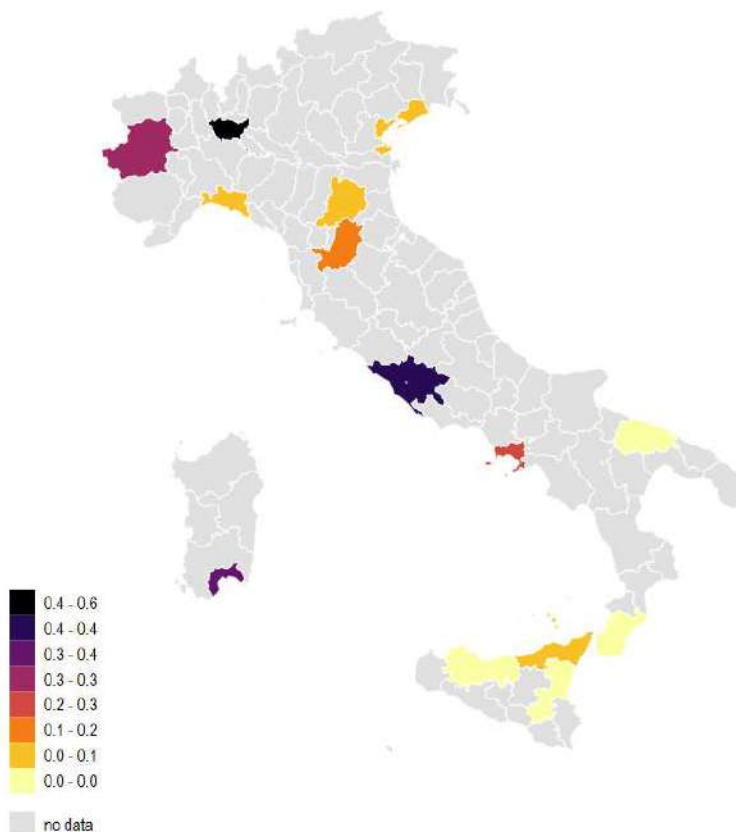


Figure 1: Export stability based on the response to the COVID-19 shock.

¹⁴ Paragraphs 3.6.1 and 3.6.2 were written by UNIVE research group. Paragraph 3.6.3 was written by UNIVE_DiE of Ca' Foscari University.

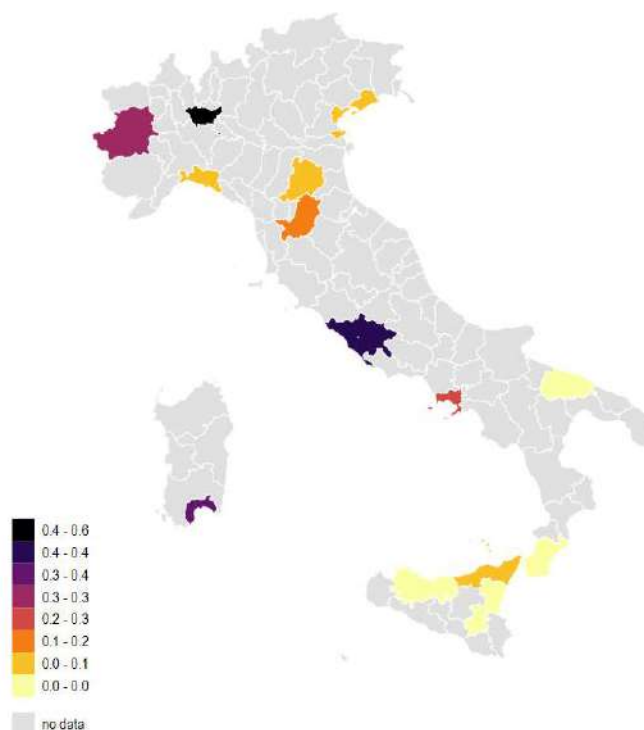


Figure 2: Export stability based on the response to the Global Financial Crisis.

Looking at the metrics like EXP.VULN.COV (for the COVID period) and EXP.VULN.GFC (for the GFC period), we can see a clear variation in how “metropolitan cities” fared during these global crises. Milan, with the highest vulnerability values during both the COVID-19 pandemic (0.613) and the Global Financial Crisis (GFC), 0.291, shows that its export system was highly susceptible to external shocks. This suggests Milan’s economy, while being a powerhouse, might have been highly exposed to specific sectors or markets that were severely impacted by these crises. High levels of economic openness and possibly a concentration of exports in a few high-value sectors, such as finance or high-tech manufacturing, could explain this heightened vulnerability.

3.6.2. Export diversification

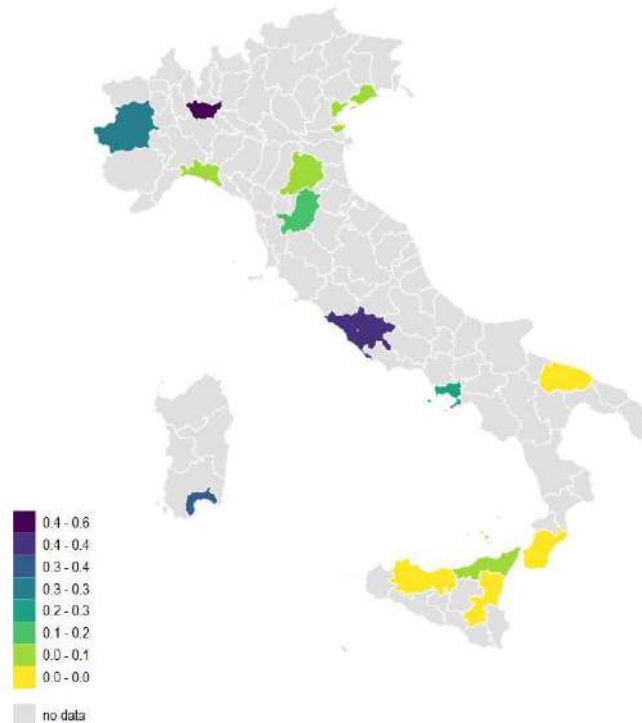


Figure 3: Export diversification in terms of reached destinations in the period 2017-2022.

Despite this, Milan also exhibits the highest export diversification (EXP.VULN.GEODIV at 5.397), indicating that the city's export portfolio is spread across various sectors and regions. This diversification may have cushioned the city from even worse impacts, highlighting the importance of sectoral spread in mitigating external shocks.

On the other hand, Reggio Calabria, with vulnerability scores of 0.005 (COVID) and 0.001 (GFC), shows remarkable stability in export activities. However, this low vulnerability might be more a reflection of lower integration into global export markets rather than an indication of resilience. Its lower values for export diversification metrics (EXP.VULN.GEODIV of 4.842 and EXP.VULN.SETTDIV of 4.633) suggest that Reggio Calabria's export base is more limited, which could leave it vulnerable to future sector-specific shocks. The limited diversification also means fewer opportunities for economic growth, pointing to the challenges smaller or less-developed "metropolitan cities" face in building robust export economies.

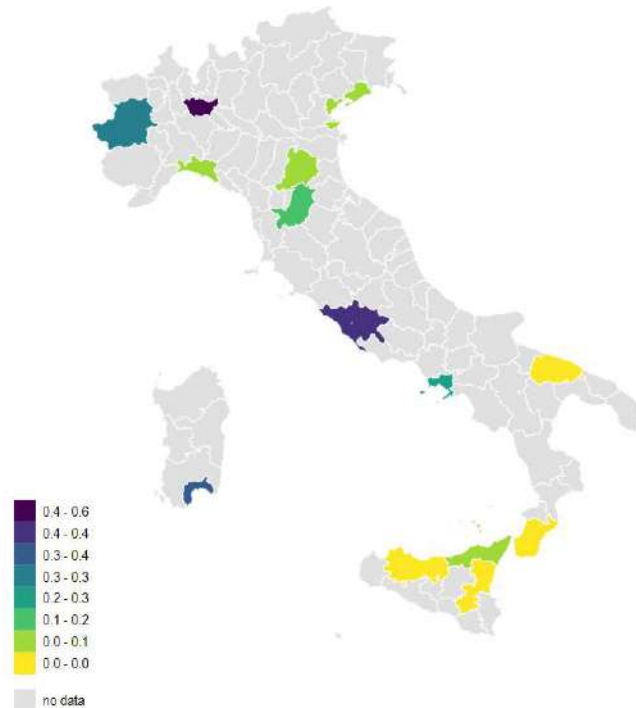


Figure 4: Export diversification in terms of exported sectors in the period 2017-2022.

Rome, Turin and Naples present intermediate cases. These cities exhibit a mix of relatively high vulnerability and good diversification. For example, Rome has a significant vulnerability score of 0.401 (COVID) but a high diversification score (EXP.VULN.GEODIV at 5.348). This suggests that while Rome's exports were hit by external shocks, the variety of sectors and regions it exports to helped buffer the city from even more severe economic consequences. Similarly, Turin shows vulnerability (0.334 for COVID) but with strong diversification, which likely helped soften the impacts.

Conclusions

The “metropolitan cities” represent some of Italy’s most dynamic economic regions, but their exposure to global economic crises varies widely. Given that these metropolitan areas are hubs of international trade and investment, their vulnerability to export volatility is a key factor in assessing Italy’s overall economic resilience. The data shows that larger, more industrialized metropolitan areas like Milano, Roma, and Torino are highly exposed to global shocks but also benefit from greater diversification, which allows them to recover more quickly.

In contrast, smaller or less economically diverse “metropolitan cities” like Reggio Calabria or Messina have lower immediate vulnerability, but this could be deceptive. Their lower exposure to external shocks is largely because they are less integrated into global trade networks, meaning they may not be as resilient in the long term due to the lack of diversified economic activities. This is a critical insight for regional policy development: while larger, more diversified metropolitan areas might weather shocks better, smaller areas may need targeted policies to diversify their economies and reduce future risks.

Furthermore, the fact that these metrics are analyzed at the “metropolitan cities” level is

particularly useful for tailoring policy interventions. Unlike broader regions or provinces, metropolitan areas often concentrate economic activity, and their export profiles can vary dramatically even within the same larger region. This level of observation allows for a granular understanding of how specific urban economies function within the global market. For example, Firenze and Genova display relatively stable export systems with high diversification, reflecting their established roles in sectors like manufacturing, tourism, and maritime trade, respectively. This contrasts with cities like Cagliari, where the economy is more volatile and less diversified, leading to greater vulnerability to shocks (e.g., EXP.VULN.COV of 0.375 and EXP.VULN.GFC of 0.174).

The analysis of export vulnerability at the level of Italy's "metropolitan cities" provides key insights into how these critical economic hubs respond to external crises. While major cities like Milano and Roma show high vulnerability due to their exposure to global markets, their diversified export bases help mitigate the severity of these impacts. On the other hand, smaller metropolitan areas like Reggio Calabria or Messina, with lower current vulnerability, might face significant challenges in the future due to their limited diversification. This underscores the need for policies focused on enhancing export diversification and resilience, particularly in smaller metropolitan areas that are more vulnerable to sector-specific shocks.

This level of analysis is essential because "metropolitan cities" are not just economic engines for their regions but also play a crucial role in the national economy. As such, enhancing the resilience of these areas through diversification and strategic export policies is vital to safeguarding Italy's broader economic stability in the face of global uncertainties.

3.6.3. Trade Emission Index

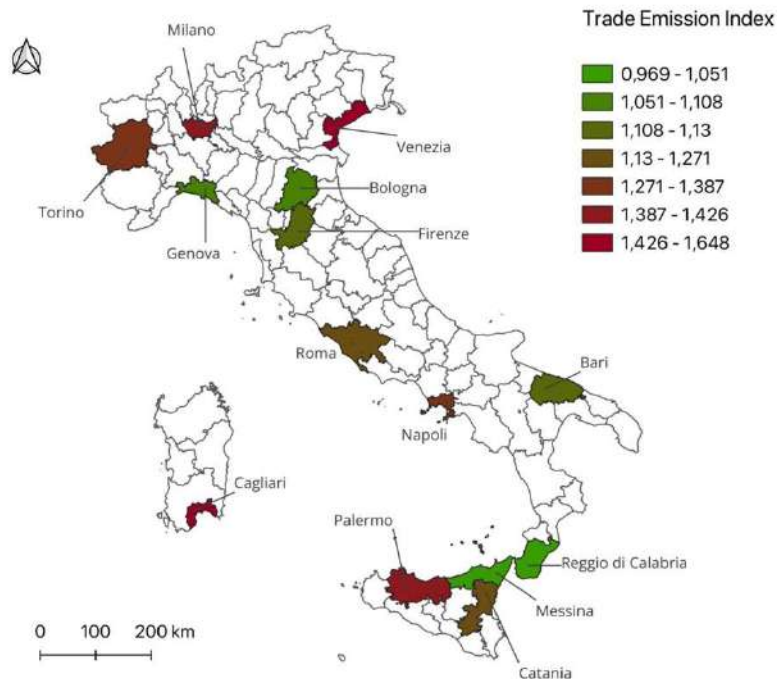


Figure 5: Relationship between emissions and foreign trade (Trade Emission Index)

The Trade Emission Index analysis of metropolitan cities reveals a complex intertwining of economic development and environmental impact, offering significant insights into urban dynamics in relation to sustainability. The index considered is aimed at relating the monetary volumes of imports and exports to the level of particulate matter (PM10) in the air. This premise is useful to understand how areas with high import-export and emission levels will be categorised in the thematic cartography with colours tending towards red and conversely, areas associated with better air quality and lower levels of foreign trade will be coloured green. From the thematic cartography we can therefore see how the Metropolitan Cities of Northern Italy are configured as environmentally critical areas in relation to trade flows, especially with reference to Milan, Venice and Turin. Researchers attribute the presence of pollutants in the area to several economic and geo-morphological factors. From an economic point of view, Northern Italy is characterised by a strong industrialisation of the area, with which high levels of emissions are commonly associated, as also seen on a national scale. This pattern underlines how areas with a strong manufacturing vocation and intense import-export activity are particularly exposed to environmental challenges. Rome's situation, with an intermediate index, instead reflects its more service and administration-oriented economy, highlighting how the composition of the economic fabric significantly influences the environmental footprint of urban areas. Analysing the geo-morphological aspects, we can then observe how the Po Valley is configured as a flat territory bordered by the mountain chain of the Alps, which can complicate the systemic cycle of cleaning fine particles from the air.

Another aspect to highlight is the presence of strategic transport infrastructures, such as ports and freight villages, which emerges as a determining factor in defining emission levels. Metropolitan cities with major port systems, such as Venice, Naples and, to a lesser extent, Genoa, show high indices, highlighting the crucial role of these infrastructures in generating not only economic activity but also a significant environmental impact. This phenomenon, which can be traced not only to emissions produced by ships at berth or in navigation, but also to vehicular traffic induced by related logistic activities, can be deduced from the cartography presented, suggesting a correlation between freight traffic intensity and air pollution levels. In conclusion, the analysis of the Commercial Emission Index in Italian metropolitan cities reveals a complex reality in which economic, infrastructural and geographical factors intersect, leading to diversified emission patterns. This multidimensional understanding underlines the need for integrated approaches in urban environmental management that take into account not only economic activities and infrastructures, but also the geo-morphological peculiarities of each territory. Targeted mitigation and adaptation strategies that balance the needs of economic development with the imperatives of environmental sustainability are therefore essential to address the challenges posed by air pollution in Italian metropolitan areas, with particular urgency for those located in geographically unfavourable contexts such as the Po Valley.

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3.7. Public education system gaps¹⁵

The proper management of the public education system requires a full understanding of two fundamental dimensions, namely the territorial endowment in school infrastructure and the quality and accessibility of the education service.

The depth of the link between material infrastructure endowment and education quality is a matter of common knowledge and encompasses several aspects of the education system, as acknowledged in a dedicated World Bank record (Barrett, P., et al., 2019).

With specific regards to Italy, the quality of education results in being affected by a strong territorial divide (see, e.g. Agasisti T., Vittadini G., 2012) and the students performances seem to be significantly spatially correlated (Donno S., Bagnarol C., Marsili M., 2020); additionally, both infrastructural and territorial variables are needful to explain the achievements of students (see e.g. Bovini G., Sestito P., 2021). This should be encouraging the study of the relationship between school infrastructure and education quality under a thoroughly spatial perspective. To this aim, a significant deal of information is openly available on behalf of the Italian Government itself, thus highlighting the public interest in the availability of school system data.

The main data source regarding the infrastructural state of schools is the School Buildings Database, managed by the Ministry of Education covering several aspects such as the environmental and urban context, the reachability by public or private transport, the presence of safety certifications, the building period, school areas surfaces or buildings volumes or the intended use of physical spaces.

In addition to this database, we deem that also the availability of ultra-broadband connection is a feature worthy of attention. The Plan to provide most schools with the ultra-broadband was approved in 2020 and implied a funding of about 400 mln euros.

About the quality of education services, we mainly rely on the Invalsi scores, which constitute a spatially homogeneous indicator of the students skills. Aggregate scores are published each year both at the municipality and province level.

Given the amount of publicly available data, we developed an R package to retrieve, aggregate and display the main data sources related to the school system (Cefalo, L., Pollice, A., Maranzano, P.). It should be easing the work of any researcher who focuses on these issues. This will be the source of input data which can be considered simple indicators.

In order to gather the information provided by simple indicators, we can define some composite ones, of which here we display a couple of simple examples. The crucial task to build a composite index is finding an adequate set of weights (for a comprehensive view, see e.g. European Union, & Joint Research Centre, 2008). The method we choose to implement is that of Aydin, O., et al., (2022), which is briefly summarised in the specific sections of the composite indicators.

In this report we study the state of school infrastructure in Italy with a specific focus on the fourteen Metropolitan Cities (MCs.), i.e. fourteen provinces (NUTS-3 units) whose capitals are particularly large urban centers. We calculate two composite indexes, the first one (tentatively) summarizing the concept of school accessibility; the other one referring to school buildings

¹⁵ This paragraph was written by UNIBA_DiEF research group.

safety. The choice of variables partially follows a recent report from the Bank of Italy, which proposes composite indicators for infrastructure demand and supply across all Italian municipalities. The analysis has been performed by means of the R package SchoolDataIT, whose version 0.2.1 is available on CRAN.

Motivation of the analysis and results

Mission 4 of Next Generation EU Plan aims at identifying divergences between territories at different scales. To have the possibility to take targeted actions, a focus on municipalities (NUTS-4 level) is of paramount importance. We analyze the quality of the school system at provincial and municipal level. The scope of this analysis is to carry out two indicators that account for the infrastructural endowment, in the first case, and for the vulnerability of school buildings in terms of safety hazard, in the latter case. The indicators summarize a bunch of variables as outlined below. The generative algorithm underlying the construction of the indicators assigns a certain weight to each variable and discards the variables which have a poor explanatory power according to a rule based on the determination coefficient. The results of the analysis show how at a provincial level the southern provinces have marginal infrastructural endowment, with the only exception of the province of Bari. In the case of the second indicator, i.e. the safety hazard, we observe the same tendency as before. In this case, the indicator seems to be driven by the seismic risk which tends to be less incisive in Cagliari, Bari, and in the northern provinces, like Turin and Milan. A more detailed analysis focuses on the fourteen Metropolitan Cities, where the peculiarities of each territorial domain emerge.

Data

We collect data from the Unique School Data Portal (<https://dati.istruzione.it/opendata/opendata/>) and from the Ultra-Broadband project database (<https://bandaultralarga.italia.it/scuole-voucher/progetto-scuole/>). Input data have been scraped and elaborated by means of the SchoolDataIT R package, under version 0.2.2 (available on GitHub at the link: <https://github.com/lcef97/SchoolDataIT>).

The first group of variables we choose is:

- **BB_Activation_status**: Share of schools with ultra-broadband connection by September 1st 2022
- **Belt**: Intermediate municipalities within a travel time of 40'54" from infrastructural poles...
- **Canteen**: Share of schools provided with a canteen
- **Central**: Infrastructural poles (classes A and B of the ISTAT Inner Areas taxonomy)
- **Energy_saving_devices**: Share of schools equipped with energy-saving devices
- **Gymnasium**: Share of schools provided with a gymnasium
- **IT_classrooms**: Share of schools provided with an IT classroom or laboratory
- **Technology_classrooms**: Share of schools provided with technology classrooms other than IT laboratories
- **School_bus**: Share of schools reached by dedicated school buses
 - **Urban_public_transport**: Share of schools within 250 meters of public transport hubs

Higher values in these variables imply better access to schools and better infrastructure endowment. The second group of variables is:

- **Air_pollution_sources_proximity**: Share of schools exposed to air pollution sources
- **Old_building**: Share of schools built before 1976
- **Hydrogeological_restrictions**: Share of school buildings subject to hydrogeological restrictions
- **Seismic_hazard**: Municipality is classified as a medium-high or a high seismicity zone (with peak ground acceleration $\geq 0.15g$)
- **Disturbances**: Share of schools exposed to outdoor disturbances like pollution sources, hazardous industries, or dumps.

To handle missing values at the municipality level, we impute them from the province-level averages.

Since we are not interested in the distinction among school orders, we only keep **Primary**, **Middle** and **High** schools, namely we keep all and only the buildings identifiable as such, then average aggregated data over these three orders. We define the dummy variable **Seismic_hazard** to denote those schools located in high or medium-high seismicity municipalities. Also, due to the high number of high values in school buildings age, we adopt a dummy variable **Old_building**, identifying schools built before 1976. We use this break year due to the adoption of modern seismic design, which was established by Law n.64 of 1974. There is no significant association between school year and seismic design compliance, but we cannot rely on the latter variable either due to the high frequency of missing observations (in some provinces it exceeds 60%). Finally, based on the Inner Areas taxonomy we define two additional variables, i.e. **Central**, denoting whether a municipality is an infrastructural pole and **Belt** denoting whether a municipality is a semi-peripheral one, namely it is not a pole, but is relatively close to the closest pole.

Finally we define the dataframe we will be working on. We scale the **Building_age** to the [0,1] interval to fit to the same range as all other variables.

Composite index calculation

The composite indicator y is a linear combination of a number p of known variables, which we denote X . To build a composite indicator, the target is thus to determine a set of weights W , where $\text{card}(W) = p$. Source code can be found at <https://github.com/olgnaydn/compindexR>. The first step of the algorithm is to define the indicator on the weights. At the first iteration, for a set of weights $W_j^{(1)} \forall j \in [1, p]$ we consider the linear regression of the indicator on single variables as a function of weights:

$$\beta_j(W_j^{(1)}) := (X_j'X_j)^{-1}X_j'XW^{(1)}$$

And so we do with the relevant determination coefficients:

$$R_j^2(W^{(1)}) := 1 - \frac{[XW^{(1)} - \beta_j(W_j^{(1)})X_j]'[XW^{(1)} - \beta_j(W_j^{(1)})X_j]}{[XW^{(1)} - \bar{X}W^{(1)}]'[XW^{(1)} - \bar{X}W^{(1)}]}$$

Now, the weights $W^{(1)}$ are defined to minimise the variability of the R_j^2 coefficients:

$$W^{(1)} := \operatorname{argmin}_W \sum_{j=1}^p \left[\frac{R_j^2(W)}{\sum_{j=1}^p R_j^2(W)} - \frac{1}{p} \right]^2$$

Once $W^{(1)}$ is computed, the algorithm checks whether all the normalised $\frac{R_j^2(W)}{\sum_{j=1}^p R_j^2(W)}$ coefficients lie within an acceptance interval centered around $\frac{1}{p}$. Variables with coefficients outside this interval are dropped. Weights are then re-computed on the $p - 1$ remaining variables. This procedure is repeated until either all the $R_j^2(W)$ lie inside the acceptance interval, or the maximum number of iterations, namely $p - 2$, is reached. We denote by `fields1.in` and `fields2.in` the groups of variables entering the final indicators (i.e. those not dropped).

The weights calculated with the `compindexR` algorithm are shown. These are the weights contributing to the accessibility indicator; as it can be seen, the `Central` binary variable was dropped by the algorithm (in the first iteration, it had a weight of 10^{-4})

And these are the weights contributing to the safety hazard indicator; as before, one variable is not considered necessary to build the algorithm, the variable `Air_pollution_sources_proximity` was dropped by the algorithm, likely due to the overlapping with the more generic `Disturbances` indicator.

Between-provinces comparison

First we observe the average value of these indicators across provinces. Lighter colours correspond to higher values of the first indicator (CI1) and lower values of the second one (CI2), implying either a better infrastructure endowment or a safer environment.

The impression we have is that Southern provinces have a disadvantage in terms of school infrastructure endowment, with the exception of the MC of Bari; Southern provinces have a general disadvantage in terms of recreational spaces and public transport availability, which is especially true in the case of the most vulnerable ones, namely Reggio Calabria and Palermo. The former also displays a strong disadvantage in energy saving devices availability. For what concerns buildings safety, using this set of variables we can detect a particularly vulnerable profile across the three MCs in Sicily and the MC of Reggio Calabria. Most municipalities in these provinces are classified as high or medium-high seismicity areas, other than having a high share of schools exposed to outdoors disturbances. The provinces of Genoa and Venice are not exposed to a high seismic risk, yet they have a relatively high share of schools built under hydrogeological restrictions and of old school buildings.

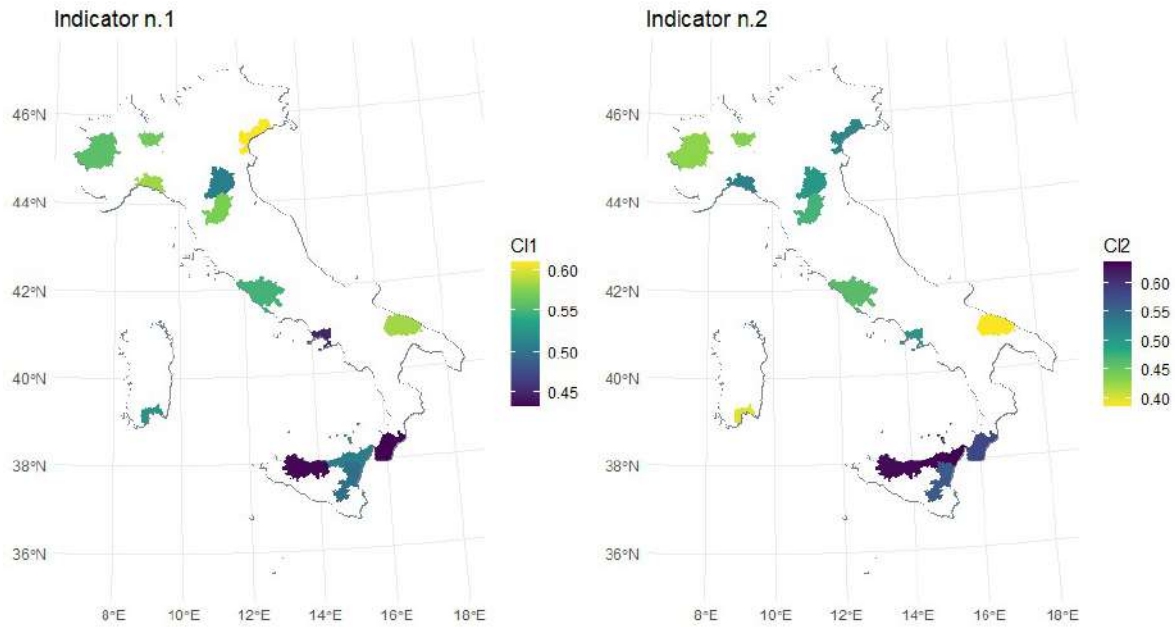


Figure 1: Averaged indicators across provinces

Detailed maps

Here, we insert the province-specific maps of the two indicators, along with some comments. Red dots stand for the provincial capitals.

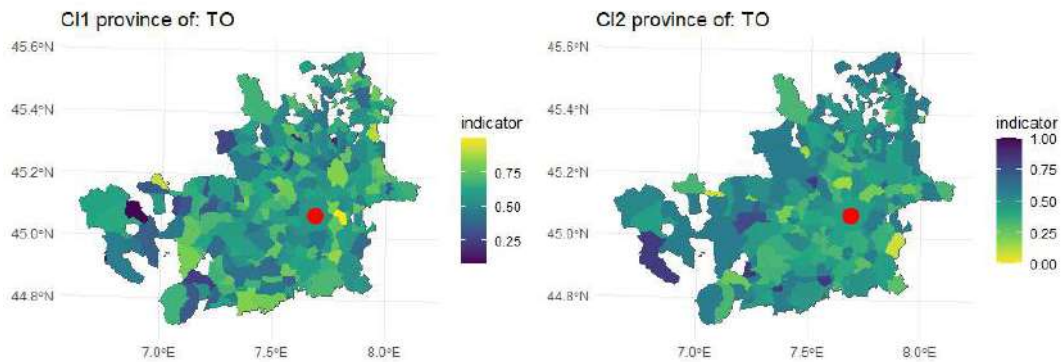


Figure 2: Province of Turin

For the province of Turin, the comparison between the two indicators highlights how the municipality of Turin does not have that solid endowment in terms of school infrastructure and at the same time it has no particularly safe environment of work/study. However, for both the indicators, there is a general tendency to improve as long as we move away from the provincial capital. The mountain Alpine area has a poor performance for both school

infrastructures and safety.

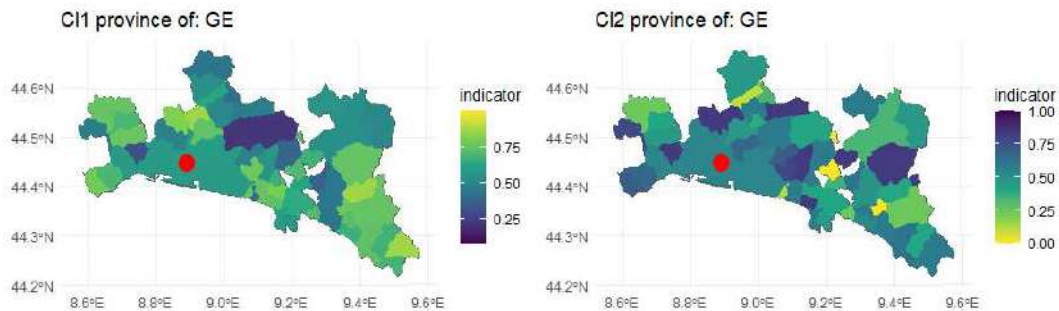


Figure 3:Province of Genoa

It catches the eye how the municipality of Genoa has not the best performances in terms of both the indicators. For the two considered indicators, we can notice how they improve when moving away from the provincial capital, highlighting a sort of centripetal force. However, in the metropolitan area of Genoa, the situation is much better for the school endowment (CI1) than for the safety (CI2), with this latter reaching some peaks in a few municipalities.

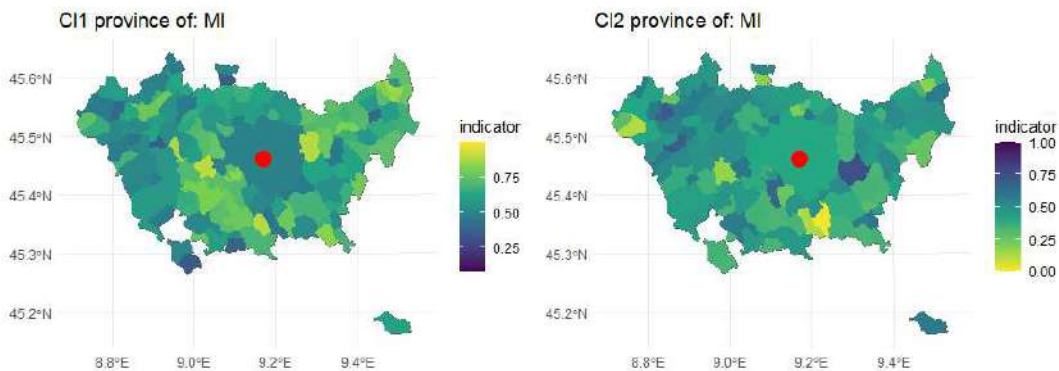


Figure 4: Province of Milan

Again, we observe how for the municipality of Milan we have intermediate values of both the indicators. For the first indicator, the occurrence of the centripetal force in the surrounding area of Milan could be explained, among others, by the congestion which can compromise the school accessibility, while for the second indicator, the situation seems to be much more homogeneous, therefore no evident pattern emerges from a visual inspection of the map of the safety hazard index.

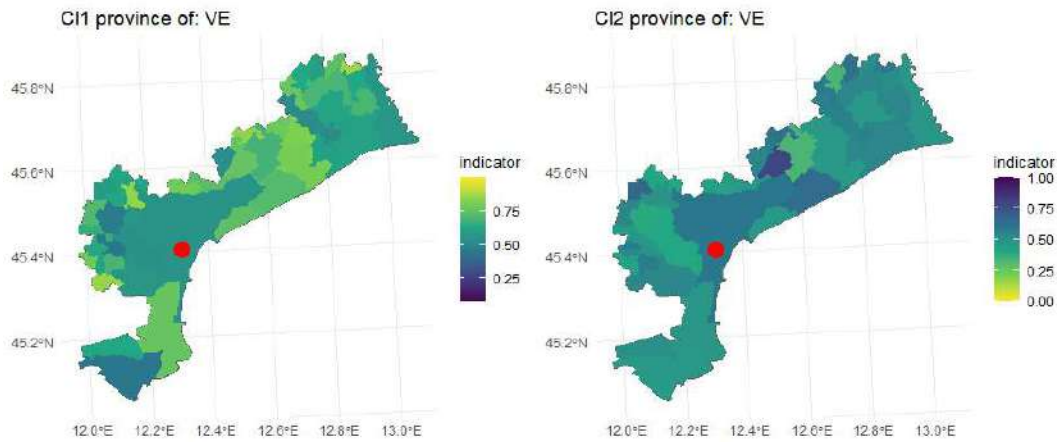


Figure 5: Province of Venice

The Municipality of Venice seems to be not particularly endowed in terms of school infrastructures nor having a safe school environment. Especially for the second indicator (CI2), the Venice lagoon is exposed to sensible hydrogeological risks, indeed the situation looks quite homogeneous for the entire metropolitan area. On the other hand, for the first indicator (CI1), some improvement in terms of school accessibility can be detected in the surrounding area of Venice.

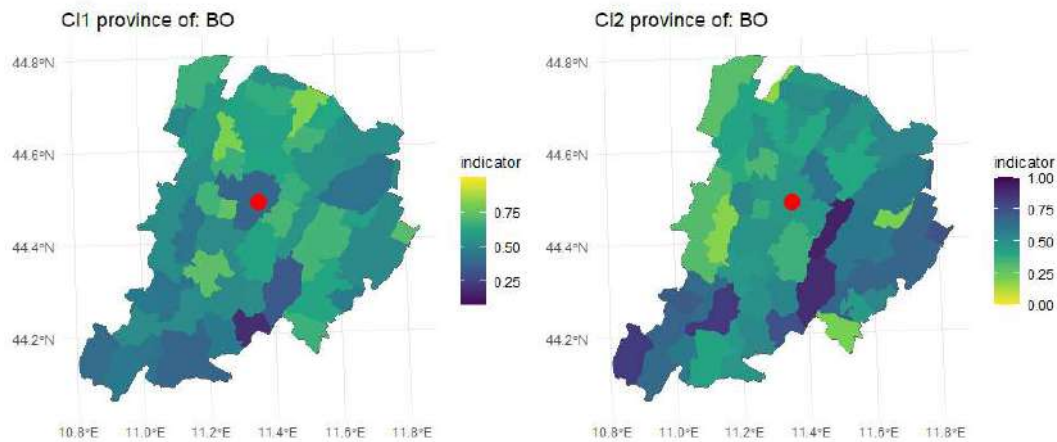


Figure 6: Province of Bologna

The municipality of Bologna shows a scholarly speaking poor endowment, while having an intermediate safety environment. In general, in this peculiar case, the situation seems to be quite homogeneous with a negative tendency for both the indicators, although some rare exceptions occur in the hinterland, despite being not particularly excellent in their values. The Apennine and sub-Apennine area shows the worst performances of both the indicators.

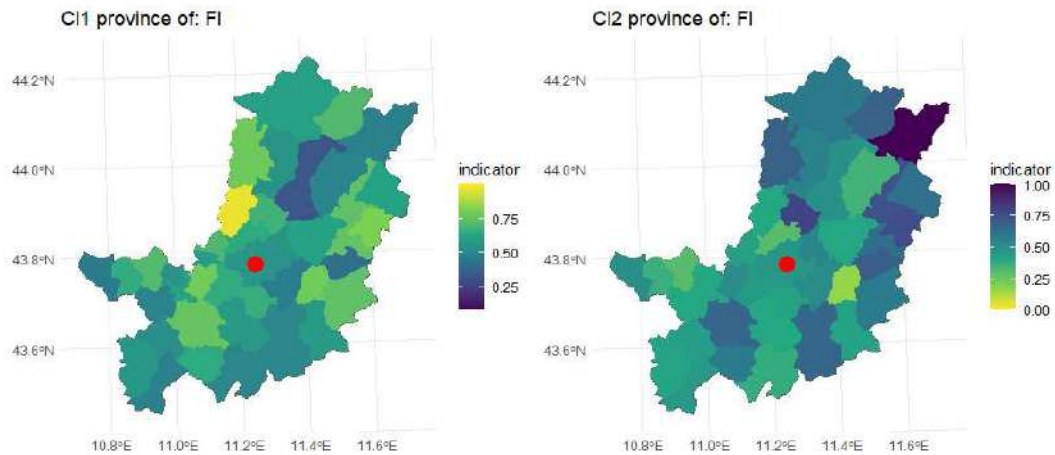


Figure 7: Province of Florence

It is a fact that big urban centers are not that accessible in terms of schools and at the same time nor that much safer, as one may contrarily expect. This is also the case with the municipality of Florence. In this case, the second indicator referring to the safety hazard of schools highlights a quite unsafe environment in the Apennine area, despite the school accessibility seems to be good in that area. The province of Florence has a patchy trend across the territory, with some minor exceptions in the suburbs of Florence for the first indicator.

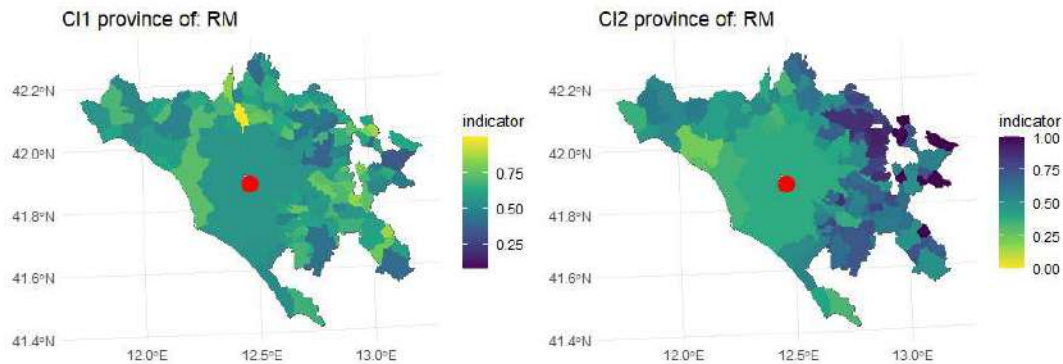


Figure 8: Province of Rome

The Province of Rome is characterized by medium levels of school accessibility across the entire territory and by poor safety environments. In this latter case, the situation is exacerbated when moving towards the Apennine area, where the school buildings look very unsafe, probably due also to the seismic nature of that area. The municipality of Rome has poor school accessibility, probably given by the intrinsic congestion of the capital city, while the school environment is slightly safer. In general, school accessibility is quite homogeneous across the province.

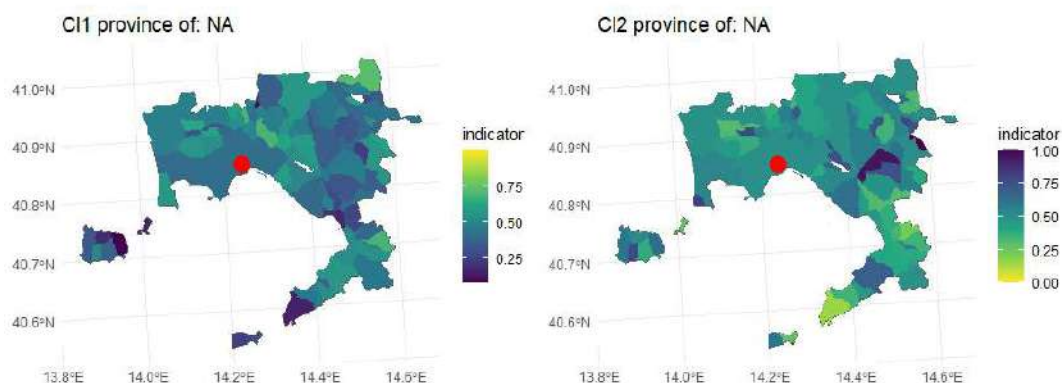


Figure 9: Province of Naples

The municipality of Naples shows poor school accessibility and a medium safety environment of schools. For both indicators, the situation is extended to the whole province. The school accessibility gets worse in the Vesuvian area. Also, the safety hazard indicator tends to assume warning values around Vesuvio Vulcan and in the Pozzuoli area, as one can expect. However, it is surprising to observe that the safety risk is not generalized around the Vulcan and the very seismic area of Pozzuoli, rather it seems to appear a localized risk.

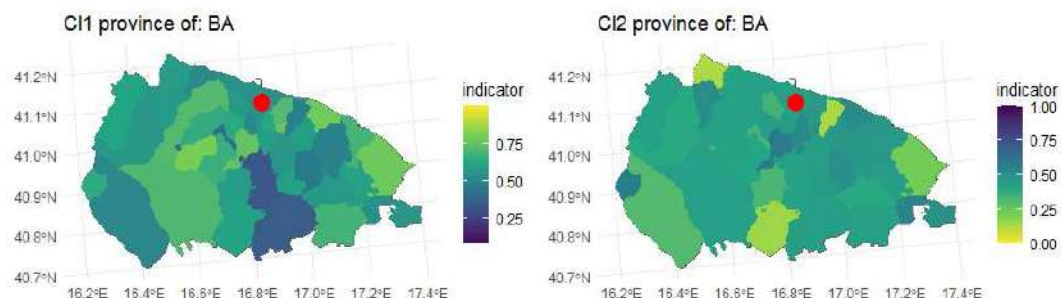


Figure 10: Province of Bari

The city of Bari has medium values of both the indicators. However, for the safety hazard index, the situation appears to be quite homogeneous across the entire province, with some positive exceptions in the peripheral areas of the province. On the other hand, the school accessibility indicator is a bit more variable, with a general tendency to get worse in the sub-Apennine and Highland of Murgia areas. No particular patterns emerge from visual inspection of both maps.

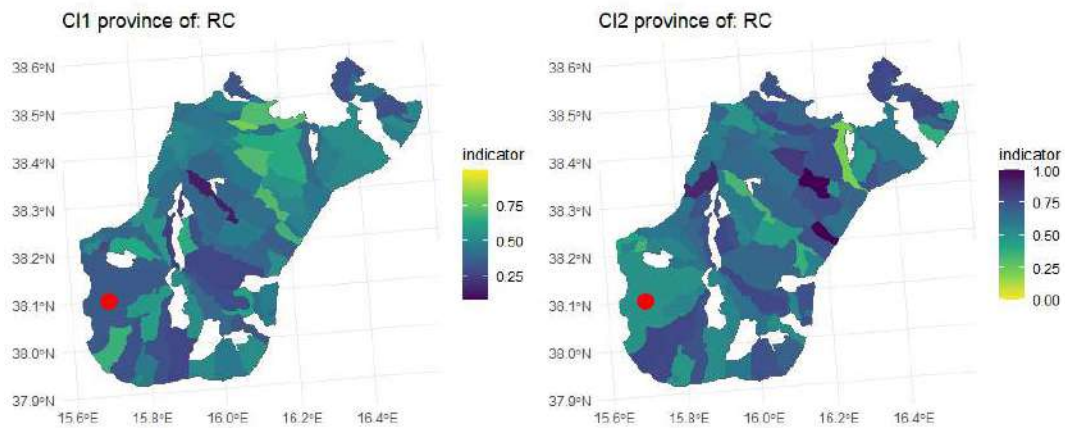


Figure 11: Province of Reggio Calabria

The municipality of Reggio Calabria has poor school accessibility and an intermediate safety environment. However, the poor quality of both indicators extends to the whole provinces. Only for the first indicator, we observe a slight improvement in the northern area of the province. Both maps do not highlight specific patterns.

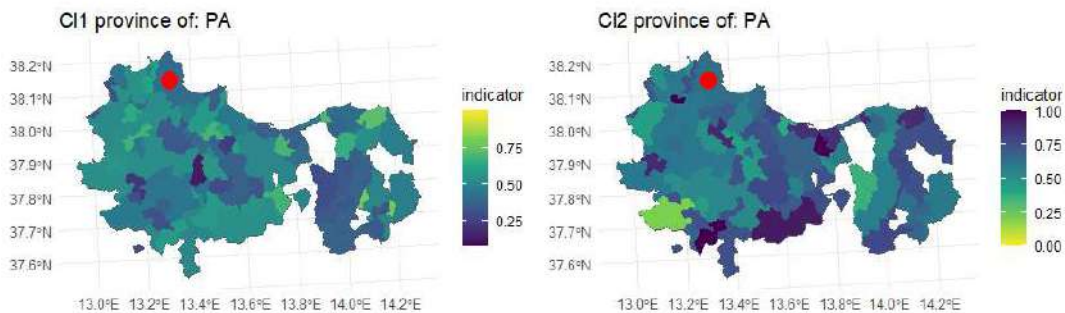


Figure 12: Province of Palermo

The city of Palermo has bad performances in terms of both indicators. The situation of the provincial capital extends to the entire province. However, critical situations emerge especially in the Madonie mountain area with respect to the safety hazard index. There are no peculiarities to highlight in the province, as a negative and homogeneous path characterizes the whole territory.

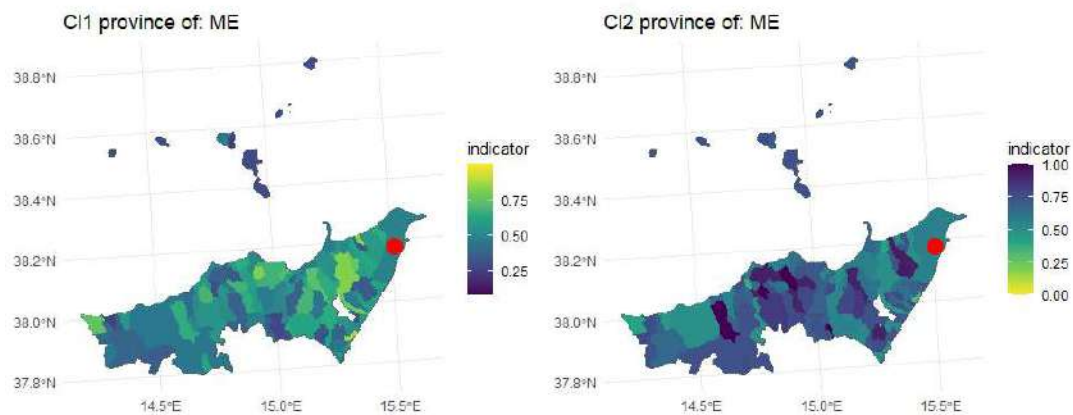


Figure 13: Province of Messina

It is a constant for the metropolitan areas of the south of Italy the fact to observe a generalized and negative infrastructural endowment and safety of schools. The province of Messina does not constitute an exception. However, the first indicator (CI1) shows a better performance compared to the second one (CI2). In general, inner areas of the province of Messina have a very poor safety index.

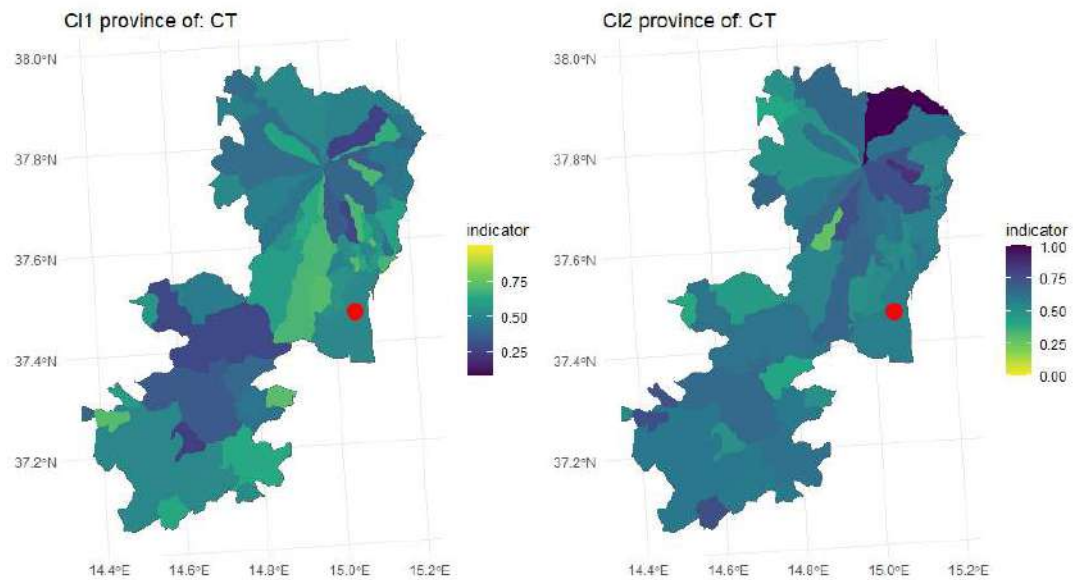


Figure 14: Province of Catania

The three Sicilian metropolitan areas, as defined by the Italian National Institute of Statistics, have almost the same behavior in terms of school accessibility and safety environments. We can reasonably retain that the same situation extends to the whole island in general. However,

for the province of Catania, we highlight the peculiarity of the Etna Vulcan. First, we notice a bad performance of the two indicators in the municipality of Catania, with a slight improvement in the suburbs of the city only for the first indicator. However, the presence of the Etna Vulcan compromises the accessibility and safety of school in the dorsal and surrounding areas. Also, the south of the province is identified as poor in terms of both the indexes.

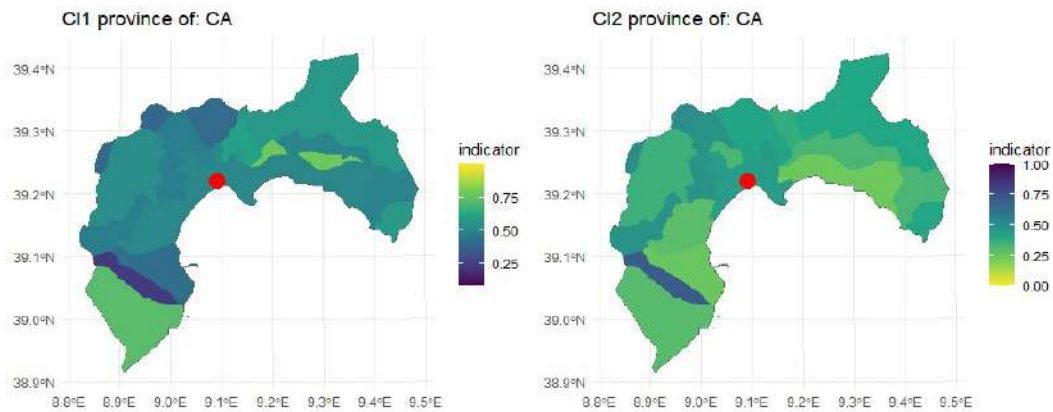


Figure 15: Province of Cagliari

The city of Cagliari is characterized by intermediate levels of school accessibility and safety. It catches the eye how the situation is quite uniform across the entire province, although the two indicators are not that concordant in this case. Indeed, the first indicator (CI1) highlights scarce school accessibility; this could be due to the well-known difficulty in commuting across Sardinia, especially by railway transportation. The second indicator depicts a quite safe school environment, and this can be due to the peculiar characteristic of the Sardinian Island, which is typically free of natural catastrophes.

Conclusions

The scope of the analysis was to identify discrepancies across the fourteen Metropolitan Cities regarding the school system. To this end we implemented a procedure to build up two indicators that we retain of paramount importance in the context of schools. The first indicator focuses on accessibility and more generally on infrastructural endowment, while the second indicator accounts for the frailty of school which is almost entirely conditional on the frailty of territories, as no specific interventions on the school buildings have been done to prevent the possible occurrence of catastrophes like earthquakes, floods, and so on. At a glance, the results of the analysis shed light on the polarization of the school infrastructures between north and south, with only some minor exceptions. More interesting could appear the safety hazard unveiled by the analysis. In particular, the most critical situations belong to the mountain areas, where the risk of landslides is typically high. The same occur for the seismic zones of Central Italy, for the vulnerable areas in correspondence of Vulcans, and for the areas exposed to high hydrogeological risks. All these considerations contribute to giving a picture of the school system in our country.

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Report B - INTERMEDIATE ITALY

1. Gap analysis of the Intermediate Italy

1.1. Introduction

The geography of intermediate Italy, excluding metropolitan and inner regions, is diverse and can be classified into several subclasses, including medium or non-metropolitan capital cities, metropolitan fringes, and urban-rural continuum municipalities. Variations exist within these subclasses, especially among different types of inner municipalities and those in the urban-rural continuum. This classification leverages ISTAT's urbanization and altitude data, distinguishing categories such as sparsely populated and intermediate-density municipalities.

Population trends reveal a slight overall decline in intermediate Italy, with notable regional differences. Rural and less densely populated areas experience the sharpest contraction, while some medium-sized cities in northern regions and select coastal areas show modest growth. Migration patterns vary, with positive balances in central and northern areas but negative ones elsewhere. Birth rates also differ by region, with higher values in parts of northern Italy and segments of the south.

The real estate market is highly variable. Medium-sized cities and metropolitan fringes see more transactions and higher prices, driven by local desirability rather than a clear north-south divide. In contrast, the urban-rural continuum is characterized by slower market activity and general price declines, although some areas remain attractive due to tourism.

Environmentally, intermediate Italy features low-gradient landscapes with extensive agricultural areas, moderate levels of urbanized soil, and significant non-residential land use. However, ecological issues such as soil degradation, pollution, and hydraulic risks present ongoing challenges.

Service provision in intermediate Italy is uneven. Education tends to be polarized, with better availability in denser areas but limited diversity. Rail services, while accessible initially, are often insufficient, characterized by slow and infrequent options that discourage use in favor of private cars.

In summary, intermediate Italy represents a complex interplay of urbanization, demographic trends, real estate dynamics, and environmental concerns. Addressing these challenges requires careful analysis and tailored policies that account for local specificities.

This dossier aims to focus on the infrastructure gaps of Intermediate Italy through three themes:

- I. **Proximity Gaps in Intermediate Italy. A Focus on Educational Landscapes and Accessibility**
- II. **Housing Gap in Intermediate Italy. A Focus on Equity and Inclusion in the Residential Domain**

III. Land Use Gaps in Intermediate Italy. A focus on Agricultural Landscapes in the light of Green and Energy Infrastructures

PART I – Proximity Gaps in Intermediate Italy. A Focus on Educational Landscapes and Accessibility

1. Relevant Issues and Benchmarks

1.1. *Proximity and everyday-life infrastructures*

The concept of (spatial) proximity refers to the physical distance between individuals, services, and resources within urban environments. It plays a pivotal role in shaping daily life by influencing accessibility, social interactions, and overall quality of life. Proximity, therefore, becomes a cornerstone in the design and management of social services and transport infrastructures, integral components of what the Collettivo per l'Economia Fondamentale (2019) describes as "everyday-life infrastructures".

Understanding the relationship between proximity and various urban settings is critical for fostering sustainable transitions and enhancing social equity across diverse contexts. This has significant implications for public action and policymaking, as explored by Renzoni and Savoldi (2019), Mattioli, Renzoni, and Savoldi (2021), and Pucci and Vecchio (2024). However, research across different scales in Europe underscores the challenges of defining benchmarks for proximity in diverse territorial contexts (Papaioannou et al. 2019, Benchmarking accessibility in cities: measuring the impact of proximity and transport performance). These challenges often stem from biases associated with the differing dynamics of small and large cities, complicating efforts to establish universally applicable standards.

What forms of proximity can be identified and analyzed within the differentiated contexts of intermediate territories, which lie between the extremes of metropolitan and rural environments?

This report examines proximity through two key lenses: the educational system, focusing specifically on schools for ages 6–18, and public transport infrastructure, with an emphasis on railway networks. From this dual perspective, the study engages with European, national, regional, and local issues to construct theoretical and operational frameworks. These frameworks critically address and challenge benchmarks such as the 15-minute city, educational poverty, and mobility justice.

1.2. *The x- minutes city*

The concept of the x-minutes city has gained prominence as a transformative urban planning model, aiming to redesign cities so that residents can access essential services within a 15-, 20-, or 30-minute walk or bike ride from their homes (Moreno 2024; Moreno et al. 2021). In recent years – particularly in the aftermath of the COVID-19 pandemic – this model has become a focal point of many European urban policies. Its application spans metropolitan and medium-sized cities, offering a comprehensive vision for sustainable urban mobility, improved public spaces, and a shift in urban planning priorities toward people rather than vehicles (DUT Report 2024 on 15-minute city applications).

Cities like Barcelona and Paris exemplify this approach by integrating active mobility, street redesign, strengthened public transport systems, and enhanced collective services. These measures aim to reduce emissions, improve urban quality of life, and address climate change (Paris ville du quart d'heure, ou le pari de la proximité). Furthermore, the C40 Cities network included the 15-minute city model in its Agenda for a Green and Just Recovery (2020), emphasizing its role in creating equitable and sustainable urban environments.

School infrastructure and public transport systems are central elements in the discourse on chrono-urbanism and the x-minute city model. They serve as pivotal nodes in promoting practical tools aimed at fostering sustainable urban mobility and designing people-centered urban spaces and planning strategies.

In Italy, ministerial recommendations from 1975—largely unmet—propose optimal distances for home-to-school travel: 300 meters for kindergartens (ages 3–5), 500 meters for primary schools (ages 6–10), and 1,000 meters for middle schools (ages 11–13). For secondary schools (ages 14–18), a maximum travel time of 20 minutes by public transport is advised.

The relationship between travel distances and modes of mobility is significant. According to ISTAT data (2023), daily trips to school are made on foot by 33% of children in kindergartens, 36.4% in primary schools, and 41.4% in middle schools, but this figure drops to 18% for secondary school students. Cycling remains minimal, accounting for just 0.7% for kindergarten and primary school students, 2.8% for middle school students, and 4.5% for secondary school students. Use of local public transport (bus or tram) increases with age: 2.1% for kindergartens, 3.2% for primary schools, 6.3% for middle schools, and 18.6% for secondary schools.

The time spent traveling also varies. The proportion of students who reach school within 15 minutes is 78.8% for kindergartens, 81.7% for primary schools, 75.8% for middle schools, and just 35.3% for secondary schools.

In contrast, European cities such as Barcelona and Paris are pursuing ambitious goals to ensure that 90% of students can walk or cycle to school within 15 minutes by 2030. **This raises the question: where does Italy stand in achieving such targets?**

Localization, urban density, and accessibility are critical variables tightly linked to the characteristics of specific local contexts. The concept of the 15-Minute City is predominantly designed for dense urban areas, often neglecting hinterlands where many residents relocate for more affordable housing, commuting daily to urban centers. This focus on dense urban

cores can obscure governance challenges at the metropolitan and regional levels (Eldér et al. 2021). These challenges are particularly evident in Italy (Peverini and Chiaro, 2020), characterized by a plurality of polycentric and urbanized landscapes.

Additionally, the concept raises distinct issues depending on school sizing criteria for small and rural schools (Renzoni, Donadoni, Mattioli 2024) and the specific mobility routines of high school students (Mattioli, Vendemmia 2021). **Achieving proximity targets requires tailoring approaches to diverse territorial contexts and varying educational levels.**

For areas affected by urban sprawl and suburbanization, some cities and metropolitan regions have adapted the 15-Minute City model into variations like the 20-Minute City or the 30-Minute Territory (Poorthuis, Zook 2023). These adaptations emphasize extending accessibility through enhanced public transport, rather than relying solely on walking and cycling, thus expanding the local radius of connectivity while maintaining the core principles of proximity.

1.3. Educational poverty and social justice

Educational poverty refers to the lack of access to quality education, leading to inadequate educational outcomes and reinforcing cycles of disadvantage. This multidimensional concept encompasses not only economic barriers faced by individuals and families but also social, cultural, and institutional factors that restrict access to and success in education.

In Europe, the persistence of educational poverty raises critical questions about social justice, as disparities in educational attainment often mirror and exacerbate broader social inequalities (Hofmarcher 2021). **The European Commission has highlighted educational inequalities as an urgent concern, emphasizing that these disparities can result in long-term socio-economic disadvantages and impede social mobility** (European Commission/EACEA/Eurydice, 2020).

The spatial dimension of educational poverty is particularly significant for EU and national policies, influencing both general and sectoral planning efforts. Addressing these challenges requires a nuanced approach that considers the geographic, social, and institutional contexts in which educational inequalities manifest.

A recent EU resolution on strengthening the European Education Area (EU 2021/C66/01) sets ambitious targets for 2030, addressing various priorities. These include improving student competencies, expanding educational opportunities for children aged 0–6, and reducing early school leaving to below 9%. The resolution also underscores the need for sustainable school infrastructure, emphasizing both environmentally conscious building design and socio-spatial accessibility.

A key focus of the document is ensuring equitable access to education, particularly for individuals from disadvantaged backgrounds and those in peripheral areas. By fostering inclusive, high-quality education, the resolution aims to mitigate social, economic, and cultural inequalities, aligning education policy with broader goals of social cohesion and equity.

Italy presents a distinctive case in terms of educational poverty and social justice, marked by significant disparities across its regions, particularly between the north and south (Save the Children, 2022; Banca d'Italia, 2024; Carlana et al., 2024). Public spending on education in Italy is among the lowest in Europe, representing only 4% of GDP in 2022, compared to the EU average of 4.7%. This financial constraint is compounded by a demographic decline and a low graduation rate. In 2021, only 26.8% of 30–34-year-olds in Italy held a tertiary education degree, a figure well below the EU27 average of 41.6%. The European Union has set a target of 45% for the 25–34 age group by 2030, as outlined in the Council resolution on the “Strategic Framework for European Cooperation in the Field of Education and Training”.

While northern regions of Italy benefit from relatively high levels of educational attainment and access to resources, southern regions face significant challenges, including lower graduation rates, higher dropout rates, and limited educational opportunities. For instance, in Southern Italy, only one in five young people holds a degree, compared to three out of ten in the Center and North (Istat 2021). However, **despite these macro-regional differences, the diversity and specificity of local contexts in Italy call for a more nuanced understanding of these disparities, particularly when considering intermediate territories. These areas, which lie between metropolitan and rural regions, present unique challenges and require tailored approaches to address educational inequalities effectively.**

1.4. Local Public Transport and Mobility Justice

Benchmarking accessibility, particularly in terms of public transport, is a complex task. Per capita metrics, commonly used in other sectors (e.g., hospital beds per inhabitant), such as kilometers of network per inhabitant, are insufficient for comparing cities and, especially, non-urban areas. In fact, accessibility depends not only on the level of supply—which could, in theory, be relatively easy to measure—but also on factors like network structure and land use, particularly the distribution of generators and attractors. Additionally, homogeneous data coverage (such as timetables and the spatial distribution of access points) is lacking in most European countries. Only recently, the widespread adoption of GTFS (General Transit Feed Specification) has begun to make this information available in a more standardized format, offering some progress toward more consistent benchmarking.

A recent study by Poelman et al. (2020), published by DG Regio, represents a significant advancement in public transport benchmarking. It focuses on accessibility via walking, biking, and public transport for the populations of a large selection of urban areas. The study selects areas based on the availability of GTFS data, covering more than 450 urban areas across Europe. What makes this report particularly valuable is that it includes small and mid-sized cities, which are characteristic of the “intermediate Italy” context.

In Table 1, we present a benchmarking analysis based on the average values of key indicators for small and mid-sized European cities in the sample (with populations under 200,000 inhabitants). The averages are provided for all of Europe, as well as for Italy, France, and Germany, to facilitate comparison.

	12-km radius			8-km radius		
	PT performance (%trips up to 45')	Share of accessibility due to walking	Average distance to pop	PT performance (%trips up to 30')	Share of accessibility due to walking	Average distance to pop
Europe	53,4%	7,7%	6.141	44,9%	14,1%	4.068
IT	67,0%	9,5%	5.556	62,4%	16,5%	3.463
FR	43,2%	8,7%	6.417	37,1%	15,9%	4.190
DE	51,2%	6,6%	6.371	43,7%	12,1%	4.201

Table 1. Proximity and public transport indicators for European cities under 200k inhabitants. Source: our elaborations on Poelman et al., 2020.

The key indicators for "PT performance" in this study include the share of the population within reach of trips up to 45 and 30 minutes, either by public transport or walking, within designated radii. As the data shows, cities in Intermediate Italy perform better than their European counterparts, with higher levels of public transport accessibility and walking proximity. However, this advantage is primarily due to the more compact urban fabric of these cities, rather than the efficiency of their public transport networks. In fact, other indicators – such as public transport vehicle kilometers per inhabitant in urban centers (which measures network extension and supply) and the average straight-line speed of bus trips in urban centers (which reflects network efficiency) – are below the continental average.

Location-based accessibility measures, like the one described above, view accessibility as an inherent characteristic of a place (Geurs & Van Wee, 2004), with mobility choices resulting from the desire to minimize travel efforts. However, this perspective has been increasingly challenged by a more recent approach known as person-based accessibility, which falls under the broader concept of transport justice (Martens, 2006; Martens, 2016; Pucci & Vecchio, 2019). In this framework, mobility is seen as an enabling factor that is shaped by an individual's characteristics (e.g., gender) and their specific needs and desires. Mobility policies, from this perspective, are not just about reducing transport costs but are seen as a means to enhance individuals' ability to move and access opportunities, empowering them to navigate and participate in society more effectively.

From an operational perspective, this shift in vision fundamentally changes how we measure accessibility and develop benchmarking. In traditional mobility measures, the focus is on places, assessing how well locations are served by transport options. In contrast, person-based accessibility focuses on user groups and their specific characteristics. For example, simply having public transport supply is not sufficient to ensure access to educational infrastructure. If the transport system's timing is not aligned with the needs of users – such as bus timetables not coordinated with school schedules – or if it doesn't accommodate specific user categories, such as people with disabilities, then access is still limited. This highlights the

importance of considering the needs of all individuals in accessibility planning and benchmarking.

From this perspective, public transport in Intermediate Italy may offer good theoretical spatial coverage, but it can be problematic in terms of quality, reliability, and time coverage. In times of limited public funding for transport subsidies, the tendency is often to maintain a constant level of supply in terms of spatial coverage while progressively reducing performance and continuity. This approach ultimately weakens the effectiveness of the transport system, particularly for the most disadvantaged groups, who rely on reliable and accessible public transport to meet their mobility needs.

2. Overcoming Territorial Gaps

2.1. *School Infrastructure as a Testbed for Proximity in Intermediate Italy*

The general objectives of the x-minutes city and proximity must be carefully adapted to the diverse territorial dimensions of Intermediate Italy's complex and varied contexts. As widely discussed, the x-minutes city model is primarily applied to predominantly metropolitan and medium-to-high-density urban environments. But what happens when a region does not fit neatly into these categories – when there is neither a city nor the idealized 15-minute framework?

The distribution of schools serves as a crucial entry point for assessing the accessibility conditions and availability of everyday life infrastructure in a given area. Specifically, the presence or absence of a school within a 20-minute travel radius is a key factor – along with access to healthcare services, digital infrastructure, and transportation – in determining the degree of peripherality of a territory. This factor plays a significant role in the National Strategy for Internal Areas (SNAI), which highlights the spatial distribution of essential services as a critical measure of regional development and accessibility (SNAI, MIUR 2014; SNAI 2021).

Intermediate Italy, by its nature, shares characteristics with both inner Italy and metropolitan areas, exhibiting similar conditions of accessibility across various municipal classifications. When examining the average distance to the nearest school, Intermediate Italy shows a broad range of intermediate values within the individual categories. For example, the average minimum distance from the nearest primary school (for children aged 6–10 years) in municipalities of Intermediate Italy is less than 2.5 km. In comparison, in metropolitan Italy, the distance is 1.2 km, while in Inner Italy, it increases to nearly 5 km. These distances must be analyzed in greater detail according to the municipal classification of Intermediate Italy (GRInS, spoke 7, DEL 3.1; Lanzani 2024). This reveals a variety of conditions (see Table 2).

Regarding the average distance to the nearest primary school, medium-sized cities generally offer the most favorable proximity conditions, with an average distance just over 1.2 km—slightly more than a 15-minute walk. This distance is shorter only in metropolitan capitals and urban poles. The most disadvantaged conditions are found in sparsely populated urban

continuums, where distances exceeding 4 km must be covered to reach a school beyond optimal proximity. In urban continuums with medium population density and metropolitan fringes, the distance averages around 2 km, aligning with the overall average for Intermediate Italy.

For the average distance to the nearest middle school, the most densely populated areas – such as metropolitan fringes, medium-sized cities, urban-rural continuums, and medium-density areas – can access the nearest school by bike within 15 minutes, a distance of less than 3.75 km. In medium-sized cities, this distance is about 2 km, reflecting the fact that school locations generally follow the population distribution, which tends to be concentrated in smaller, more compact settlements. In sparsely populated areas, the distance to the nearest middle school averages between 4 and 6 km, but in some cases, it can exceed 20 km.

For upper secondary education, the differences between sparsely populated and more densely populated areas are even more pronounced. In medium-sized cities, the high presence of high schools means that the distance to the nearest high school is just over 2.5 km. In contrast, the most disadvantaged conditions are found in sparsely populated rural-urban continuums, where the average distance exceeds 12 km, with some situations reaching over 30 km.

Classification	N° of primary schools 0-500 m	N° of primary schools 0-1.200	Average distance from the closest primary school	N° of secondary schools 0-1.000	N° of secondary schools 0-3.700	Average distance from the closest secondary school	N° of high schools 0-10 Km	N° of high schools 0-20 Km0	Average distance from the closest high school
1 INNER ITALY	0,16	0,49	4.950,81	0,23	0,68	6.565,96	2,84	4,90	12.611,71
2 INTERMEDIATE ITALY	0,25	1,20	2.470,92	0,44	2,15	3.330,27	10,58	14,62	5.988,34
2.1.1.1 - Sparsely populated mountain/inland hill urban-rural continuum	0,07	0,21	4.639,25	0,11	0,43	6.042,16	2,14	5,66	12.799,40
2.1.1.2 - Mountain/inland hill urban-rural continuum with medium population density	0,22	0,96	2.336,93	0,33	1,44	3.083,63	8,34	12,79	4.758,27
2.1.2.1 - Sparsely populated coastal and/or lowland urban-rural continuum	0,08	0,26	3.427,45	0,14	0,59	4.414,34	3,29	7,22	10.237,63
2.1.2.2 - Coastal and/or plain urban-rural continuum with medium population density	0,27	1,18	2.002,57	0,42	1,72	2.648,11	10,32	14,35	4.211,86
2.2 - Medium-sized city or non-FUA capital	0,43	2,28	1.361,76	0,83	4,52	2.083,99	18,11	20,54	2.511,78
2.3 - De facto or de jure metropolitan fringe	0,26	1,21	2.149,61	0,44	2,06	2.941,60	13,26	20,35	5.466,90
3 METROPOLITAN ITALY	0,46	2,58	1.158,51	0,94	7,50	1.608,06	57,21	77,17	2.587,66
National value	0,30	1,52	2.293,14	0,56	3,48	3.095,67	22,54	30,71	5.541,55

Tab. 2. Average distance from the closest school and the number of schools according to this distance. The values worse than the national average are shown in black; those worse than the national average but better than the macro class average are in dark gray; and values better than the national average but worse than the macro class average are in light gray.

2.2. Educational poverty and educational justice. Territorial gaps related to assets and equipment

School buildings across the country exhibit significant disparities, with marked differences between central and peripheral areas (see GRInS – Spoke 7, DEL3.2: Vulnerability Maps of educational landscapes). This variation is especially important when considering students' opportunities and the extent of educational poverty. If educational poverty is linked to both school and extracurricular activities (such as sports and cultural programs), it is crucial to note that, particularly in intermediate and rural areas, schools often serve as the primary community infrastructure. These schools provide essential services like sports facilities (gymnasiums), cultural halls (aula magna and auditoriums), and playgrounds (courtyards). Addressing these infrastructure gaps in different contexts is vital as it can help reduce territorial disparities and alleviate conditions of educational poverty in various communities. For example, updating data and information on the distribution of school sports facilities is essential to implement priority measures for the most vulnerable areas. Compared to the national average of 42%, Intermediate Italy is relatively well-equipped with educational infrastructures, including sports and cultural services. In fact, 43% of schools in Intermediate Italy have a gymnasium (with a smaller percentage having swimming pools). There are some variations: in fringe areas, medium-sized cities, and the medium-density urban continuum, gymnasiums are present in 44% to 47% of schools, while in the low-density urban continuum, the percentage is at or below 40% (see Tab. 3). This issue is closely tied to the condition of the school building stock (including construction and renovation periods – see Tab. 3), making it a key factor for guiding decisions on school infrastructure improvements at national, regional, and municipal levels.

Classification	Percentage of schools with incomplete sections	Subthreshold school percentage (less than 15 pupils each class)	Percentage of schools over 50 years old	Percentage of schools over 75 years old	Percentage of buildings without equipments	Percentage of school without any certifications	Percentage of primary school with full time	Percentage of secondary school with musical address	Number of schools	Number of secondary schools	Number of primary schools
1 INNER ITALY	8	22	58	28	41	31	30	14	5095	908	1536
2 INTERMEDIATE ITALY	4	9	57	28	35	26	26	14	34785	5207	11003
2.1.1.1 - Sparsely populated mountain/inland hill urban-rural continuum	9	24	57	28	32	26	22	11	6215	1217	2258
2.1.1.2 - Mountain/inland hill urban-rural continuum with medium population density	3	6	51	26	33	21	22	17	5596	758	1754
2.1.2.1 - Sparsely populated coastal and/or lowland urban-rural continuum	7	14	64	36	38	25	22	9	2789	588	1018
2.1.2.2 - Coastal and/or plain urban-rural continuum with medium population density	2	3	58	29	38	26	26	18	8197	1043	2371
2.2 - Medium-sized city or non-FUA capital	2	3	58	26	32	33	27	17	6047	709	1699
2.3 - De facto or de jure metropolitan fringe	4	7	56	28	38	26	36	12	5941	892	1903
3 METROPOLITAN ITALY	2	2	62	39	43	39	48	13	12415	1732	3782
National value	4	8	58	31	38	30	31	14	52295	7847	16321

Tab. 3. Assets, conditions and equipment of schools (ISCED 1, 2, 3) as significant variables for identifying territorial gaps in educational poverty. The values worse than the national average are shown in black, and the values better than the national average but worse than average macro class value are shown in dark grey.

At the same time, educational poverty is closely linked to the range of educational offerings available in a territory. The opportunity to access full-time schooling or specialized programs, such as music education in primary or middle schools, plays a significant role in shaping opportunities for students. Extending school hours, particularly in the afternoons, not only addresses educational gaps but also serves as a crucial support for female employment and work-family balance. In Intermediate Italy, however, there is a shortage of schools offering afternoon activities, which would allow students to remain engaged throughout the entire day. While nearly 50% of schools in metropolitan Italy offer full-time education, in Intermediate Italy, this figure is under 30% (with metropolitan fringes reaching 36%). In inner Italy, full-time schools make up about one-third of the total, which aligns with the national average of 31%. These disparities emphasize the need for policies that expand educational offerings, particularly in areas where family-based welfare structures tend to reinforce educational and territorial inequalities.

2.3. *Small schools: not only a rural concern*

Targeting the future of Italian schools requires addressing demographic trends and the country's declining birth rates. Socio-demographic data indicate a "de-youthing" process affecting many European countries, characterized by a sharp drop in birth rates and a shrinking young population, including among foreign residents.

Eurostat estimates that by 2030, 190,000 fewer children will be born than in 2020. Mediterranean countries, in particular, have entered a cycle of both quantitative and qualitative decline, one of the most severe in Europe, which limits regional development and well-being. Italy is among the least fertile countries in Europe, alongside Spain and Malta, with fewer than 1.3 children born per woman. In fact, it has the lowest birth rate in the EU27, recording just 6.8 births per thousand inhabitants in 2021, compared to the European average of 9.1. The number of births in 2022 was nearly one-third lower than in 2008 (-31.9%). According to ISTAT projections, 4 out of 5 municipalities are expected to lose population over the next decade, including nearly two-thirds of cities and towns with high population density. Additionally, the population of children aged 6 to 18 is projected to decrease by 13% over the next ten years (Eurostat 2019).

The Italian school infrastructure comprises over 53,000 schools. But will this network remain sustainable and necessary in the future? By 2030, 1.1 million pupils are projected to be absent, with higher losses in the southern regions and islands. This will result in a shortage of 43,000 classrooms and 66,500 teachers, and around 2 million square meters of educational space will become vacant (Fondazione Agnelli, 2019). Between 2015 and 2030, approximately 4,000 schools are expected to close, with two-thirds of these located in Southern Italy. This issue is not limited to peripheral and marginalized areas (Inner Italy); it also significantly affects Intermediate Italy, where many small schools are concentrated (Tab. 3). The challenge is twofold: How can we address and anticipate the decline in student numbers and the closure

of schools in Intermediate territories? What territorial criteria should guide public policies on school sizing and localization?

Two key indicators are essential for forecasting and guiding public decisions to address educational disparities: school size and the number of pupils per class. These indicators consider the number of classes and pupils based on the minimum national standards required to establish or maintain an elementary or middle school class. However, these standards are set at the national level with limited spatial considerations, primarily focusing on orographic and demographic factors. This index helps assess the role of small schools (Bartolini et al., 2023) in the country, making it a significant issue for public policies and decisions regarding school localization and sizing. Redefining the minimum national standards to reflect territorial needs, while accounting for the specific characteristics of Intermediate Italy, requires the development of support measures for the most vulnerable local communities.

2.4. Public transport to reduce educational gaps

In remote areas, educational gaps manifest as the absence of basic educational hubs for isolated communities. In a complex territorial context like Intermediate Italy, with few exceptions, population density ensures the presence of fundamental educational services. The key issue, however, is access to a diverse range of educational offerings, which are not evenly distributed but are instead concentrated in major centers. This necessitates the existence of a public transport network capable of supporting mobility across the region, typically at the provincial level. In contrast, regions with limited transport options force students to restrict their choices or compel families to arrange their own transport solutions.

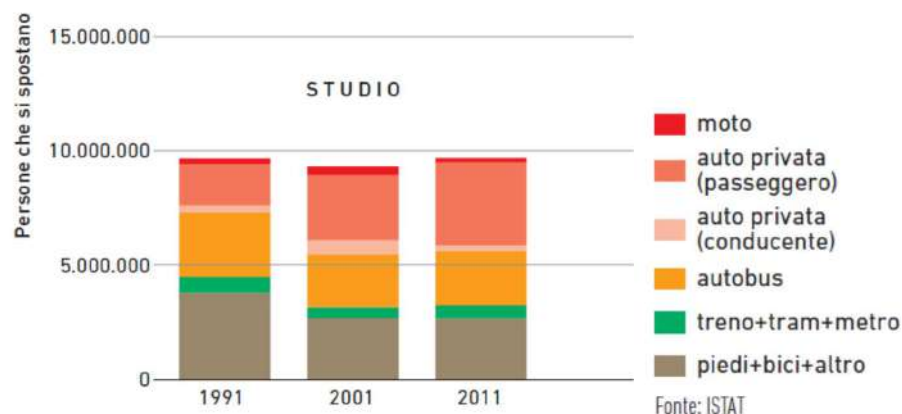


Figure 1. Systematic mobility for study (1991–2011). Source: Beria (2018).

Figure 1 dynamically illustrates the current fragility in school mobility. Between 1991 and 2011, the use of cars for school transport (accompanied) doubled, according to the last available ISTAT

OD matrix. This significant shift is driven by both a reduction in soft mobility and a decline in bus transport availability. As the school system has become increasingly centralized, this figure highlights the failure of public transport provision, especially for the student demographic, who are typically more reliant on buses and have limited access to private vehicles.

The primary cause of this issue is the reduction in public funding for transport subsidies, particularly as investments in improved rail and mass transit in metropolitan areas have siphoned resources from regional networks.¹⁶ More recently, a shortage of drivers has exacerbated the problem, leading to further cuts in essential bus services. These services, while often underused, are crucial for ensuring basic mobility for all.

One potential solution to this issue could be, where feasible, the redesign of existing networks to eliminate redundancies. These overlaps are not only instances of bus routes duplicating rail lines (which can be difficult to remove, as they serve intermediate locations), but also situations where rail services are performing tasks that buses could handle more efficiently. In fact, administrations often choose to maintain and extend rail services, even in low-density areas, leading to inefficient use of public funds, given that the cost per kilometer for rail is five to ten times higher than that of buses. A more effective integration of bus and rail systems – where buses continue to serve local communities and services like schools, while rail focuses on high-demand corridors – could result in significant savings. These savings could then be reinvested to improve bus frequencies and expand territorial coverage.

A well-integrated system requires not only functional coordination but also alignment in fare structures and timetable organization. When bus and rail services are connected, the interchange costs should be minimized to encourage seamless transitions between modes of transport.

Buses are not the only solution to ensure access to schools and the education system in Intermediate Italy, due to the structural challenges mentioned earlier. The use of bicycles, both for point-to-point travel and for first and last-mile connections, remains quite limited in Italy. However, rail network accessibility can be significantly improved with the integration of cycling. By using bicycles, up to 30-70% of the non-urban population in Intermediate Italy can effectively access rail stations within a 15-minute radius, and in urban poles, this share increases to 90% (Beria, Donadoni 2024).

Bike transport for educational accessibility can be categorized into three distinct forms:

- a. **Point-to-point connections** (from home to school): this requires the development of an extensive and continuous bike infrastructure that ensures the safety of students, protecting them from interactions with car traffic.

¹⁶ A significant example is Regione Umbria. The entire region spends about 35M€ (2007 contracts of service) for the entire regional bus network, including all urban networks, and 7,5M€ just for the Minimetrorò system serving part of Perugia municipality, a marginal fraction of total demand. A similar situation is found in many other regions, including Lombardia, where most of the subsidies go to Milan urban network and regional rail and just a fraction covers the rest of the region.

- b. **First-mile connections** (from home to station): this form is particularly concerned with providing secure facilities for bike storage at stations, as well as ensuring the availability of an alternative mode of transport, such as buses or walking, for the last leg of the journey.
- c. **First- and last-mile intermodal connections** (home-bike-train-bike-school): this requires a well-integrated system with adequate rolling stock that can accommodate a significant number of bicycles, not just occasional users. This ensures that students can seamlessly transition between biking and train travel while maintaining ease of use and accessibility.
- d. **Full intermodal options**, instead, require adequate rolling stock capable of hosting a significant number of bikes, not just a few occasional users.

The last element for better and more widespread access to educational facilities can be considered in the long term. It involves choosing locations for new schools and services that are more consistent with mass transit supply. In simple terms, it means agglomerating attractive functions, like schools (primarily high schools), around stations and highly accessible locations. This does not mitigate the first-mile problem but surely solves the more insidious last-mile one.

3. Gap Conditions: Local Focuses

This section provides a detailed description and quantification of territorial gaps in selected areas of Intermediate Italy. It highlights specific territorial situations and gap conditions, focusing on themes and indicators related to proximity and education. These gaps are examined through preliminary analysis, including selective, targeted core samples, to anticipate the main observations and findings that will emerge in the Case Study Reports (scheduled for Month 30). This section also refers to regional or local policies and initiatives that contribute positively or negatively to reducing or widening some identified gaps.

The following territorial gaps will be preliminarily considered in different contexts, organized under four themes:

- a) Service Gaps: small schools and lack of schools (3.1)
- b) Educational Gaps: full-time schooling and school facilities (3.2)
- c) Proximity Gaps: first cycle schools (6-13 years) and accessibility by foot and by bicycle (3.3)
- d) Accessibility Gaps: higher education (+14 years) and railway stations (3.4)

3.1. *Service gaps: small schools and lack of schools*

This gap refers to the presence or absence of schools and the size of educational institutions. This analysis allows us to examine the extent and concentration of primary educational offerings in Italy, providing a detailed understanding of the intricate nature of school

distribution. Many territories, particularly rural or peripheral areas, lack schools or only have small schools with limited resources and reduced educational offerings. This gap can be analyzed using maps and data from relevant sources, illustrating the distribution of schools and the density of educational services across the territory. Such shortcomings in the school network directly impact educational accessibility, increasing the need for travel for families living in disadvantaged areas.

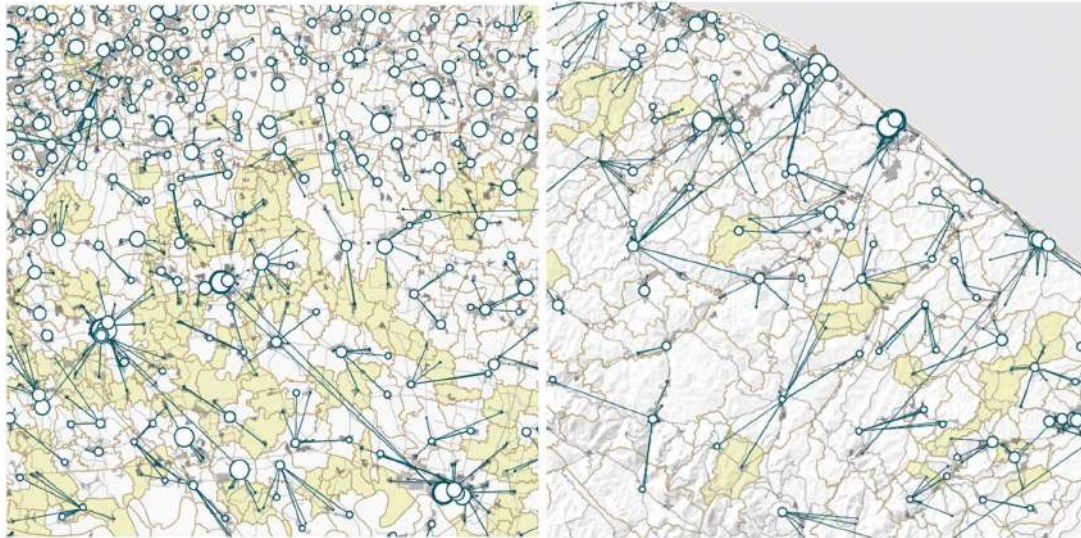


Figure 2. The local samples (60km x 60km), the Crema area (left) and Northern Marche (right), focus on Middle Schools (11-13 y.) and Institutional Networks: the size of the first-cycle secondary schools (number of classes per school) is represented by the circles. At the same time, the dots indicate the other schools (kindergartens and primary schools) affiliated with the same institution (autonomia scolastica). The lines converging on a school identify the campuses and the headquarters of the comprehensive institutions. Municipalities without middle schools (11-13 years) are highlighted in yellow. The maps depict two different territorial conditions, each measuring 60 km by 60 km, allowing for comparing the absence, presence, and size of the first-cycle secondary educational offerings.

By examining the presence (or absence) of educational services in first-cycle secondary schools (ages 11-13), this geography more effectively highlights specific territorial disparities in greater detail. At the national level, first-cycle secondary schools serve an intermediary territorial role between the widespread, immediate access to primary school infrastructure and the higher hierarchical order of second-cycle secondary schools. Their distribution and operation reveal micro-processes of territorial polarization, highlighting organizational structures and governance forms related to school autonomy.

The geography of municipalities lacking first-cycle secondary schools follows two trajectories. On one hand, it closely aligns with the geography of primary schools, reinforcing a lack of educational service points spanning multiple schooling levels and predominantly affecting specific areas of the country in an interrelated manner. On the other hand, it highlights the widespread presence of small schools, revealing a polarized distribution and marginality. Service gaps must be analyzed by extending school catchment areas, considering factors such as school size (number of classes, full-cycle sections activated, and student numbers)

to understand the territorial coverage of services and define inter-municipal catchment areas for educational offerings.

By analyzing the average number of sections in each first-cycle secondary school per municipality, we gain insights into school sizes and the relationships between neighboring municipalities, particularly those lacking educational services. In Intermediate Italy, small schools and municipalities without educational offerings are prevalent. Small and very small schools are particularly notable in contexts where they function as widespread facilities that establish certain centralities. For example, in the Marche Nord region, small schools play a significant role, though municipalities without middle schools are relatively few. The distribution of small middle schools is prominent along valley floors, accompanied by medium and large schools in coastal hubs. In the Crema area, a polarized distribution of schools is evident in a territory with a considerable number of municipalities lacking educational services for ages 11–13 (highlighted in yellow), especially in the southern section. The role of "catchment" schools, which are typically larger with more classes, is crucial as they act as reference points for wider territories.

3.2. *Educational gaps: full-time schooling and school facilities*

The educational gap is evident in disparities in full-time schooling and school facilities. In many areas, particularly those that are less central or more disadvantaged, schools lack adequate structures and sufficient resources to offer a comprehensive educational program. Limited availability of full-time schooling directly impacts the educational and social support provided to students. Adequate facilities are essential to ensure equal access to education, especially in regions without high-quality alternatives. Preliminary analyses highlight critical situations, identifying territories with significant shortages of facilities and educational resources, as well as variations in the organization of school infrastructure.

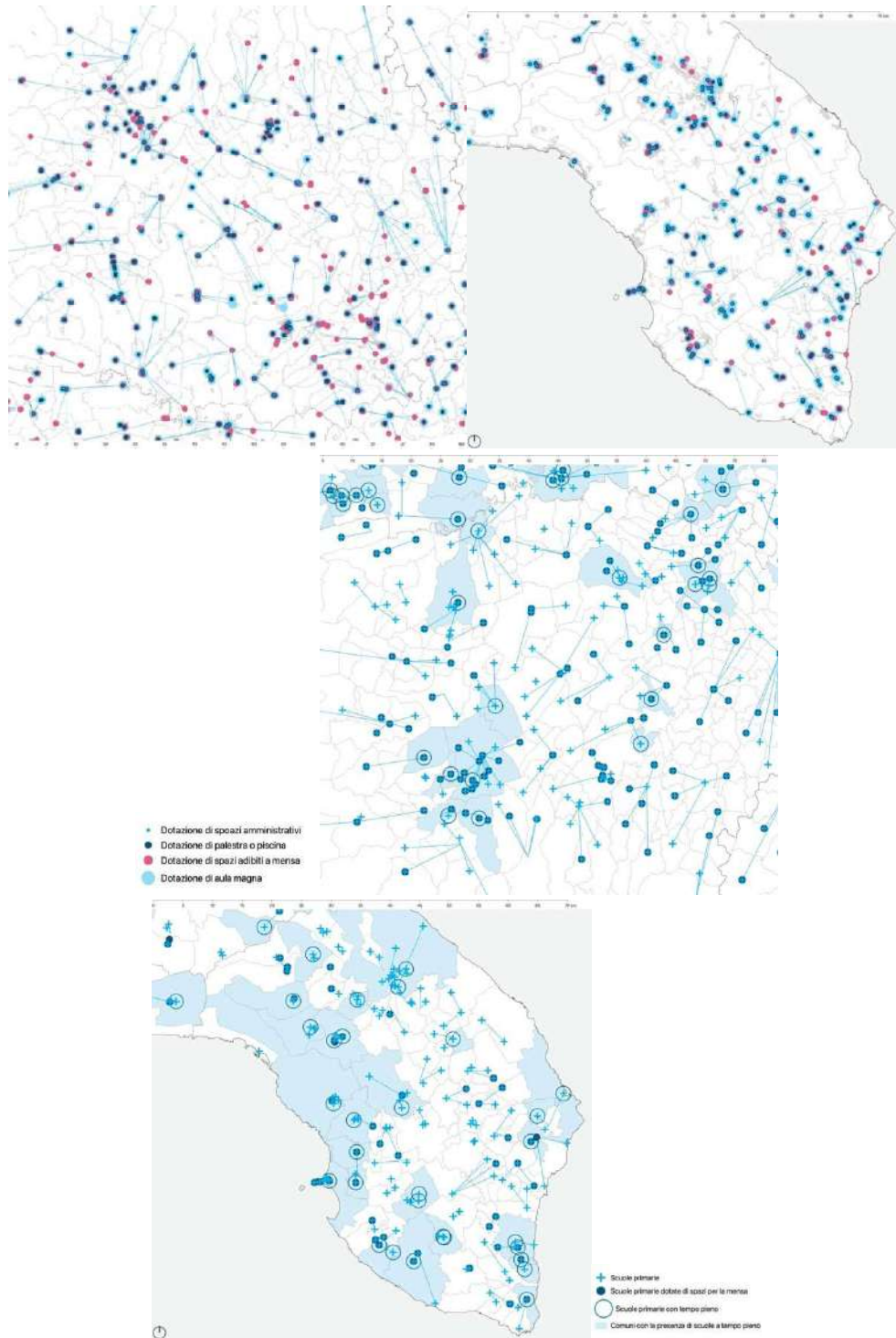


Fig. 3_ (above) School facilities (gym, auditorium, canteen) in South Piedmont (left) and south of Apulia (right); (below) Primary Schools with full time in South Piedmont (left) and south of Apulia (right)

The analysis highlights, for each school, the availability of internal facilities such as auditoriums (in light blue), gyms (in dark blue), and canteens (in pink), along with administrative spaces

typically associated with the central offices of comprehensive schools. These facilities enrich and diversify school spaces, offering critical support for various educational activities. When accessible to the community and local associations during extracurricular hours, they serve as valuable territorial resources, actively contributing to reducing educational poverty. In Southwestern Piedmont, these facilities are well-distributed geographically, extending beyond central institutions to include more marginal areas. Similarly, Southern Puglia demonstrates a good distribution of facilities, although the number of canteens is comparatively lower.

Reflecting on full-time educational offerings alongside the analysis of facilities enhances the understanding of territorial disparities, particularly regarding work-family balance conditions. The maps highlight municipalities with at least one full-time school (in blue), the individual schools providing this service, and those equipped with a canteen, which facilitates the organization of educational offerings. This underscores the strong correlation between material and immaterial actions. In Southwestern Piedmont, few municipalities provide full-time schooling, mostly concentrated in larger urban centers. Mountain areas lack this service, despite the presence of cafeteria spaces in schools. In Southern Puglia, full-time coverage is more prevalent in coastal municipalities, while inland areas of Salento show limited availability, potentially reflecting lower demand influenced by cultural specificities. Notably, schools with canteens are relatively scarce and do not always align with those offering full-time services.

The spatialization of these gaps is particularly significant concerning the PNRR-related calls for funding aimed at gyms, canteens, and the expansion of full-time schooling. While these areas are undeniably crucial, as previously emphasized, it is equally important to approach these actions with an integrated, cross-sectoral vision. This perspective must account not only for the facilities themselves but also for their role within the broader territorial context and the overall condition of school infrastructure, which is frequently outdated, poorly maintained, and inefficient.

3.3. Proximity Gaps: 1 cycle schools (6-14 y) and accessibility by foot and by bicycle

The proximity gap reflects the challenges in accessing first-cycle schools (ages 6-14) within a 15-minute walking or biking distance. This issue is especially pronounced in certain areas where the configuration of the territory and insufficient infrastructure create significant barriers for children. Studies reveal critical problems in these regions, such as the low density of primary and middle schools and the absence of safe routes for active mobility (walking or biking), underscoring the urgent need for targeted interventions to enhance accessibility.

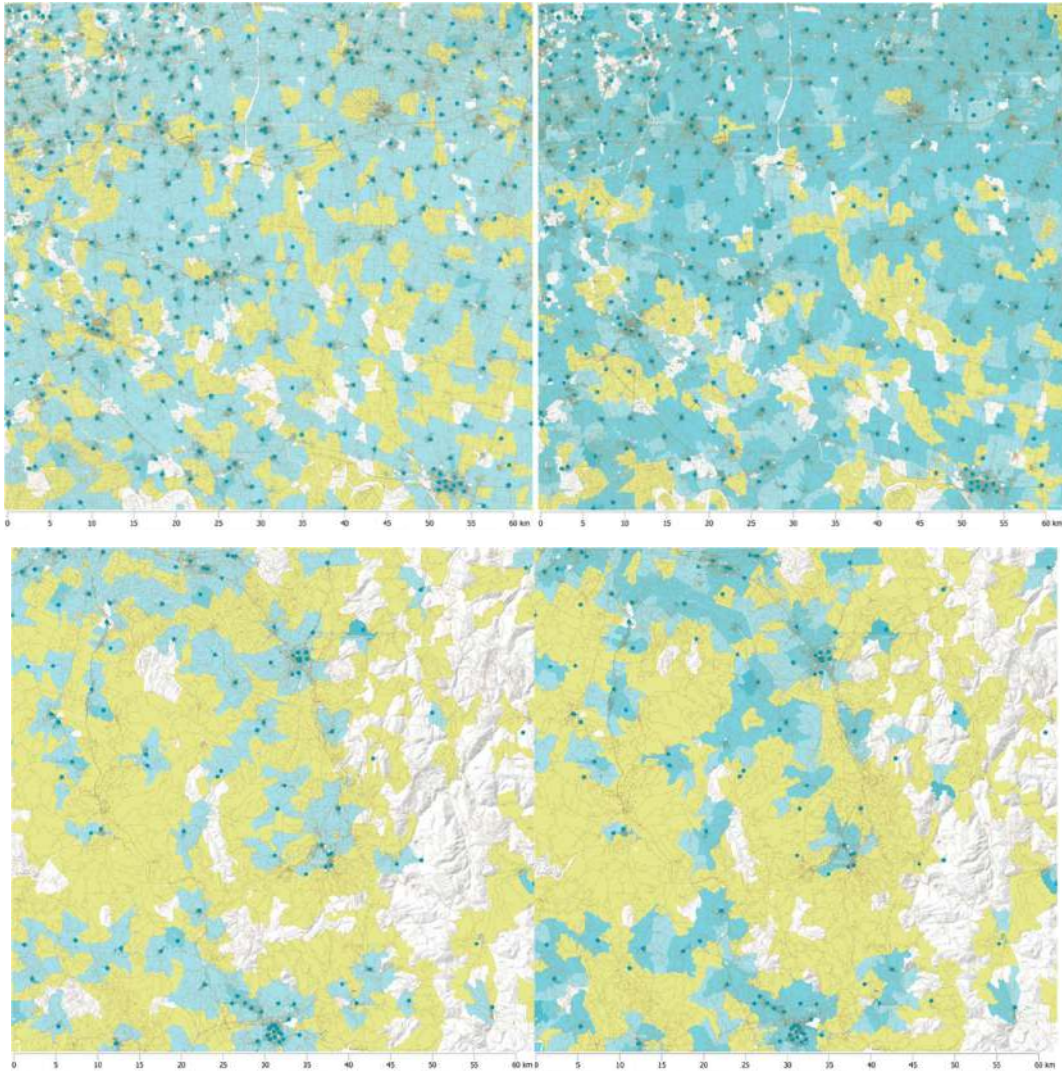


Fig. 4_ Crema area (above) and Terni/Foligno area (below). (left) Medium distance from the census zone to the nearest primary school (6-10y, dark blue 0-500m, medium blue 500-1200m, light blue 1200-3700m, yellow >3700m). (right) Medium distance from the census zone to the nearest middle school (11-13y, dark blue 0-1000m, medium blue 1000-3700m, light blue 3700-5000m, yellow > 5000m). In white, the census zones without population are highlighted. (speed: 5km/h by foot= 1200m/15min; 15km/h; by bicycle 3700m/15min; 20 km/h TPL 5000m/15min)

The Crema area distributes census sections "patchily" from the main school hubs, resulting in areas where the population is significantly distant from schools, making access to education less accessible for some residents. However, this condition is not predominant. This uneven distribution highlights disparities in the accessibility of educational services, leaving more isolated or peripheral areas without convenient access to school facilities.

At the same time, there is a relatively widespread distribution of school service delivery points, including both primary and secondary schools. However, these institutions are primarily concentrated in more populous urban centers, where population density justifies the presence

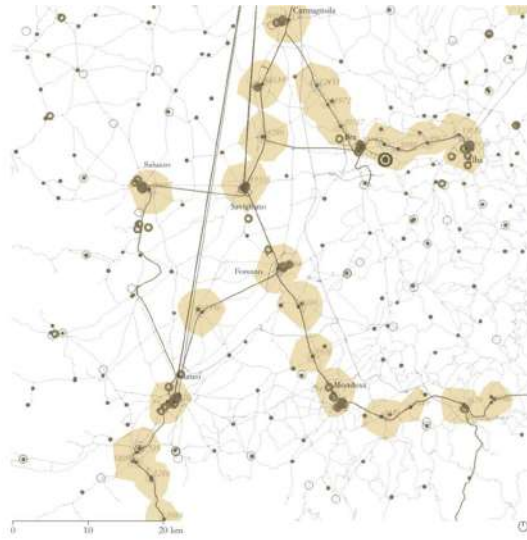
of more facilities. While this arrangement efficiently meets the needs of larger centers, it leaves decentralized areas uncovered or underserved.

In the territory of Terni and Foligno, accessibility to first-cycle schools presents a varied situation. On one hand, some residents live close to schools and can easily reach them through active mobility, such as walking or cycling. On the other hand, some communities are located at such distances from schools that these means of travel are impractical. The distribution of schools is mainly concentrated in flat areas, where population density is highest. However, this concentration is insufficient to serve all the territory's inhabitants. Many settlements are located far from schools, and although they may be near population centers with educational institutions, they remain out of reach for active mobility.

This situation generates disparities in access to education, with families in more remote areas facing greater difficulties in reaching schools. To improve school accessibility, it would be necessary to strengthen connections between remote settlements and schools through efficient public or school transportation services. Additionally, where possible, implementing active mobility infrastructure could encourage sustainable travel. An integrated approach would help reduce spatial inequalities, ensuring equitable access to education for all residents.

3.4. *Accessibility Gaps: high education and railway stations*

The accessibility gap concerns higher education, specifically access to secondary schools and university campuses in relation to nearby railway stations. This issue is particularly evident in regions like Piedmont, Salento, and Veneto, where higher education institutions are not always well-connected to public railway transport hubs. The lack of adequate connections makes access to schools and universities more challenging, especially for students from less urbanized areas. This increases dependence on private transportation and reduces opportunities for sustainable mobility.



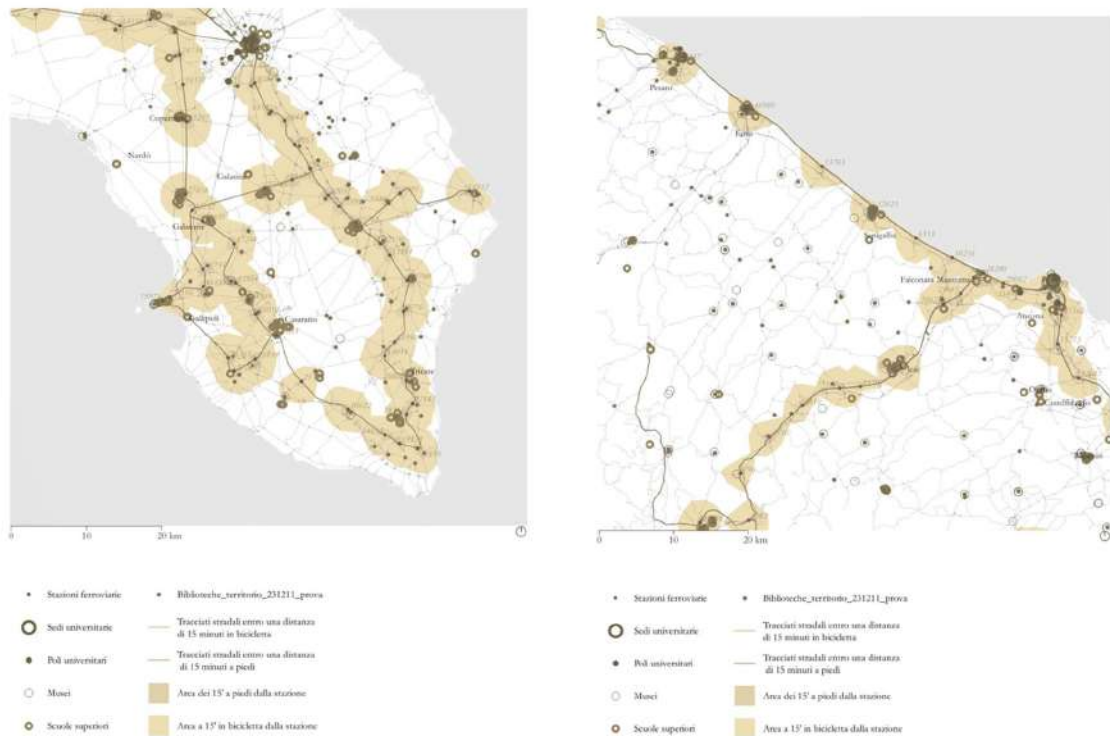


Fig. 5_ South-west Piedmont (left above), Central Veneto (right above), South Apulia (left below), Marche (Right below). The maps show the proximity areas of the railway stations related to the most essential points of the educational landscape: universities, museums, high schools, and libraries.

In the territory around the city of Cuneo (with more than 55,000 inhabitants) in the Piedmont region, many upper secondary schools and libraries can be reached within a 15-minute ride from the railway station. Some schools are very close to the train station (15 minutes on foot), particularly in the central, historic neighborhoods of major urban centers like Alba, Mondovì, and Saluzzo. Thanks to the EU-Next Generation funds, the province is investing in school infrastructure, with plans for five new secondary schools (in Cuneo, Mondovì, Bra, Verzuolo, and Fossano) and modern school gyms.

However, most cultural facilities, such as libraries and museums, are outside the catchment areas of train stations. Their distribution is diffuse but not homogeneous: in the eastern part of the territory, we can clearly recognize the systems of the Alpine valleys, while in the western part, facilities form a more extensive network. The area hosts two universities: one in Cuneo, a branch of the Turin campus offering various fields of study, and another in the village of Pollenzo, which is specialized in food sciences and linked to the Slow Food movement.

The Salento territory around the city of Lecce (with around 95,000 inhabitants) is a prime example of diffuse urbanization. However, the localization of educational services reveals a process of territorial hierarchization around key internal axes, such as railways. Most upper secondary schools, libraries, and museums fall within the 15-minute catchment area for bike proximity around train stations, and in some cases, schools can be reached on foot. While

secondary schools are relatively well distributed, many are concentrated in the province's capital city, Lecce. The University of Salento, located in Lecce, serves as a regional center and is famous for its student life, with over 20,000 students.

While there are few museums, libraries are also present in smaller rural villages. An interesting aspect is the coastline, which lacks educational and cultural services, with only a few exceptions, such as Otranto on the Adriatic Sea and Gallipoli on the Ionian Sea. These two areas are considered centralities and are well-served by the railway system. In recent years, the province has invested heavily in improving and modernizing the local railway network, including electrification and hydrogen technology, using EU-Next Generation funds. At the same time, supralocal bus transportation has been enhanced to better serve secondary students.

The Veneto rail public transport system demonstrates limited integration between railway stations and high schools, with poor pedestrian accessibility that hinders the use of rail transport by students and school staff. While bicycle access shows potential, pedestrian access to schools remains inconvenient, underscoring a weak connection between transport infrastructure and key school hubs.

Furthermore, the distribution of schools is highly dispersed, even within the largest urban centers. This approach prioritizes widespread territorial coverage where possible, rather than ensuring easy accessibility. As a result, it increases reliance on private cars, compelling families and students to use personal vehicles to reach schools and diminishing the effectiveness and efficiency of rail public transport. This situation highlights the need for integrated planning to enhance accessibility to school centers and decrease dependence on private transportation.

Along the Adriatic coast, high schools are significantly concentrated in major cities served by rail transportation. These schools are primarily located along the coastal strip and in valleys running perpendicular to the coast, where the rail network provides efficient connections. However, several notable cities hosting high schools are excluded from the rail network, forcing students and faculty to rely on alternative transportation methods. Additionally, while high schools are clustered in specific cities, many areas lack easily accessible institutions. This concentration restricts the distribution of school infrastructure and exacerbates logistical challenges for those living far from urban centers with high schools.

This situation necessitates an efficient and well-organized public bus system to provide frequent and punctual connections to the cities hosting educational institutions.

PART II – Housing Gap in Intermediate Italy. A Focus on Equity and Inclusion in the Residential Domain

1. General Issues and Targets Relating to Housing Conditions

When considering EU policies and their direct effects on housing and the housing stock, particularly in middle-sized cities and intermediate territories, several key trends and impacts emerge. These effects are shaped by EU-wide priorities such as energy efficiency, affordability, and sustainability, which trickle down to regional and local housing markets.

1.1. *Environmental Sustainability and Energy Efficiency*

A central focus is the drive toward a sustainable and energy-efficient built environment. The European Green Deal and the Energy Performance of Buildings Directive (EPBD) prioritize reducing carbon emissions and enhancing energy standards in housing, setting ambitious targets for modernizing residential buildings.

The Renovation Wave initiative, a key component of the Green Deal, promotes comprehensive renovation of existing buildings across the EU, with particular emphasis on transforming older, inefficient housing stock. Intermediate territories, which often have a high proportion of aging buildings, stand to benefit significantly as EU funding programs like the European Regional Development Fund (ERDF) and the Just Transition Fund (JTF) prioritize energy efficiency retrofits, especially in underfunded areas. The goal is not only to create more sustainable homes but also to alleviate energy poverty by reducing heating and cooling costs for residents. This transformation is anticipated to increase property values while advancing the EU's overarching objective of achieving climate neutrality by 2050.

Middle-sized cities and intermediate territories are thus poised to see gradual yet substantial improvements in the quality and energy efficiency of their housing stock. With the support of EU subsidies for retrofitting, these areas can bridge the gap between modern energy standards and the current state of their aging housing infrastructure.

1.2. *Urban Regeneration and Adaptive Reuse*

Urban regeneration, especially the adaptive reuse of existing structures, is another critical area addressed by EU policies. Many middle-sized cities and intermediate territories across Europe

face challenges related to urban sprawl and underutilized spaces due to past industrial activities or depopulation. EU programs like the Urban Innovative Actions (UIA)¹⁷ and JTF promotes the regeneration of these spaces, transforming vacant or abandoned buildings into new residential areas, public amenities, and green spaces.

A key component of this regeneration is the New European Bauhaus (NEB)¹⁸ initiative, which emphasizes sustainable urban design and community-oriented housing projects. Through the NEB, cities are encouraged to repurpose older buildings, reducing the environmental impact of new construction and creating vibrant, mixed-use neighborhoods that blend residential, commercial, and cultural spaces. This regeneration approach aligns with the circular economy principles advocated by the EU, encouraging the reuse of materials and promoting eco-friendly construction practices.

In practice, these policies empower these territories to not only address housing shortages but also to create more livable and inclusive urban areas. This strategy also preserves the cultural heritage and unique architectural characteristics of the areas while meeting the modern housing needs of residents.

1.3. Affordable Housing and Social Inclusivity

Ensuring access to affordable and inclusive housing is a fundamental EU objective, and it is particularly relevant in areas where affordable housing options are limited, often due to economic constraints or higher demand. Policies under the Cohesion Policy¹⁹, the Affordable Housing Initiative²⁰, and the Just Transition Fund provides financial and strategic support to improve both the quantity and quality of affordable housing in cities that may not otherwise receive substantial investment.

Housing initiatives across several EU countries, for example, serve as models for combining public-private partnerships to expand affordable housing. The goal is to balance the housing market, providing residents with reasonably priced rental and ownership options. Additionally, social housing retrofits—supported through funds like the ERDF—are a priority to ensure energy-efficient, safe, and affordable housing for low-income populations. This inclusivity goal aligns with the EU's objective of reducing social inequality and creating a fairer urban landscape, even in smaller and intermediate cities.

Over time, these programs aim to prevent gentrification and displacement of lower-income residents, ensuring that urban regeneration benefits all sections of society and that middle-sized cities remain accessible to a diverse demographic.

¹⁷ <https://www.uia-initiative.eu/en>.

¹⁸ https://new-european-bauhaus.europa.eu/index_en.

¹⁹ <https://www.europarl.europa.eu/factsheets/en/sheet/96/cohesion-fund>.

²⁰ https://single-market-economy.ec.europa.eu/sectors/proximity-and-social-economy/social-economy-eu/affordable-housing-initiative_en.

1.4. Resilience and Climate Adaptation in Housing

The EU's focus on resilience and climate adaptation increasingly shapes policies related to housing. This emphasis responds to the growing need for buildings and urban areas to withstand climate impacts such as extreme weather events, floods, and temperature fluctuations. Policies like the Green Deal²¹ and the Climate Adaptation Strategy²² support cities in developing climate-resilient housing solutions.

Middle-sized cities and intermediate territories, often situated in areas vulnerable to climate risks, benefit from funding for resilient infrastructure and climate-proof buildings. Strategies include the development of green roofs, rainwater harvesting systems, and the use of sustainable building materials that improve the resilience of residential structures. Integrating these measures not only protects the housing stock but also aligns with the EU's broader environmental and sustainability goals, creating urban environments that are better equipped to handle future climate challenges.

EU policies on housing, urban regeneration, and sustainability come together to address the unique needs of middle-sized cities and intermediate territories. By focusing on themes of environmental sustainability, affordability, digital innovation, and urban resilience, these policies collectively foster a built environment that is both future-proof and socially inclusive. For intermediate territories, which are often on the periphery of major funding flows, this integrated approach not only revitalizes the housing stock but also enhances livability, making these urban areas resilient, inclusive, and well-adapted to the EU's long-term vision for sustainable development.

2. Overcoming Housing Equity and Inclusion Gaps in the Italian Context

To carry out our gap analysis on Intermediate Italian territories, based on our research interests and competencies – but also due to the actual availability of data, at least at the municipal level – we chose to focus only on the two final key issues outlined in paragraph 1, with particular emphasis on "Affordable Housing and Social Inclusivity" (see paragraph 1.3).

2.1. Key analytical categories and related Indicators

Several simple and complex socio-economic indicators can help measure the gaps in housing equity and inclusion between different territories and evaluate the effectiveness of

²¹ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

²² https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en.

national and regional policies. According to the JRC Technical Report titled “Measuring Universality in Social Protection” (Aidukaitė and Ubarevičienė, 2022), which is based on the analytical framework developed by Muñoz de Bustillo Llorente et al. (2020), housing is a multidimensional phenomenon. Consequently, its policy treatment requires multiple indicators that can be grouped into two macro-categories: (a) housing coverage and (b) housing adequacy.

Housing Coverage refers to the extent and reach of housing policies, including how widely policies are implemented and whether they address various housing needs within the population. The reach and scope of Italian housing policies have expanded with the PNRR, which allocates funds for urban and housing renewal across Italy, including intermediate territories. Coverage varies widely by region, however, as wealthier areas tend to have better housing infrastructure. The government’s regional approaches and public-private partnerships are working to bridge these gaps, but significant regional disparities in housing support remain.

Housing Adequacy evaluates whether housing policies meet quality standards and inclusivity, ensuring that housing options available to the public are accessible and affordable but also adequate in terms of living standards and suitability for diverse needs. Italian housing policies aim to ensure that housing is not only available but also aligns with quality and inclusivity standards. Through programs like Piano Casa and the Just Transition Fund, policies focus on housing adequacy by promoting quality, energy efficiency, and mixed-income housing developments. While these efforts mark progress, the effectiveness of housing adequacy policies remains uneven, often more successful in urban than in rural or smaller city settings, where access to adequate housing may be limited.

According to this theoretical framework, affordability, availability, adequacy and accessibility indicators are essential to measuring the adequacy/quality gaps and designing effective housing actions. Before entering our gap analysis on the Italian intermediate territories, it is essential to clarify the definitions of those sub-categories of indicators and their role in Italian housing policies, considering that they can mix in very different ways within the various territorial situations (for example, housing could be available but unaffordable, or affordable but inadequate, or available and affordable but inaccessible).

Affordability refers to whether housing is financially accessible for low- and middle-income groups, typically measured by whether lower-income households (such as those in the bottom income quintile) can afford housing at market rates. Housing becomes unaffordable if these groups lack options within their means, like social housing. Italian housing policies tackle affordability primarily through incentives like the Piano Casa and the Superbonus 110%, which aim to reduce housing costs for lower and middle-income groups by subsidizing energy-efficient renovations. However, these policies often prioritize homeowners over renters, who are more vulnerable to market fluctuations. Public-private partnerships also work to increase affordable housing units, but affordability remains a challenge due to rising property prices, particularly in urban centers.

Availability indicates the sufficiency of housing supply, especially in terms of affordable housing. Inadequate availability often refers to a shortage of certain housing types or options affordable to lower-income groups. Availability is addressed through both the PNRR (National Recovery and Resilience Plan) and the Urban Agenda for Italy, which aim to expand affordable housing options, especially by converting underutilized or abandoned buildings. However, a limited supply of affordable rental housing persists, particularly in middle-sized cities where housing availability often fails to keep pace with demand from both lower-income residents and new economic opportunities.

Adequacy/quality represents the right to housing of acceptable quality, meeting basic standards of security, peace, and dignity. Adequate housing provides essential features like privacy, proper lighting, ventilation, temperature control, infrastructure, and access to necessary facilities, all at a manageable cost. Quality standards are central to Italian housing policies, with initiatives like the Superbonus focusing on energy efficiency, safety, and modernization. By promoting upgrades to insulation, heating, and structural safety, Italian policies aim to improve the adequacy of housing conditions. The Ecobonus and Superbonus not only enhance energy performance but also increase residents' comfort, ensuring that housing meets basic quality standards as set by Italian and EU guidelines.

Accessibility concerns how housing meets the needs of vulnerable groups, including the disabled, elderly, refugees, homeless individuals, and children. Accessible housing is designed to enable independent living for these populations, addressing both physical and social barriers. Accessibility remains a complex issue. Italian policies have measures for vulnerable groups, including incentives to adapt housing for the elderly and disabled, but broader accessibility concerns—like affordable housing for refugees and other marginalized groups—are less systematically addressed. Some regional programs help improve accessibility, yet a comprehensive national policy for accessible housing for all vulnerable populations is still under development.

In brief, Italian housing policies generally support affordability, quality, and housing coverage but face challenges in accessibility and consistent adequacy across regions. Middle-sized cities and intermediate territories, in particular, benefit from initiatives targeting energy efficiency and urban regeneration but often require further support to address availability and accessibility for vulnerable populations fully.

2.2. *Mind the (Housing) Gap: logical framework and vision*

To prepare the gap analysis, we use the housing vulnerability indicators developed in D7.3.2 (B.1 and B.2) and integrate them with additional state or flow indicators related to phenomena that may mitigate or exacerbate current levels of vulnerability in Italian intermediate territories. Specifically, the aim is to assess, based on the status quo mapped in the previous deliverable, how environmental, material, socio-economic conditions, and public investment policies may influence housing issues positively or negatively in the future.

Given the absence of precise quantitative targets, and relying instead on broad macro-objectives established at the European and national levels (see section 2.2), we structure the gap analysis using a logical framework that interprets the “gap” as the potential divergence between a future “tendential” scenario (approximately projected for 2030) and an “optimal” condition conventionally defined through an internal benchmarking approach, representing the conditions of the least vulnerable Italian territorial sub-typology (whether or not it belongs to the “Intermediate Italy” macro-class; see D7.3.1).

The underlying vision of this logical framework is that, by moving closer to the housing affordability standards found in certain peripheral and depopulated areas, Intermediate Italy could play a positive redistributive role by alleviating the pressures, precariousness, and housing exclusion that characterize large metropolitan centers.

3. Gap Analysis

3.1. Considered Indicators

To measure the housing gap, we sought to represent the key objectives identified in the policy analysis and literature on housing (see paragraph 2.2) through national-scale representations. As a foundation, we used the vulnerability maps from the previous report (Deliverable Grins D7.3.2). We supplemented them with a series of indicators available or computable at the municipal level for all Italian municipalities.

CODE	NAME	YEAR	SOURCE	CODE (GRINS D7.3.2)	UNIT
AC1	Index of Housing Exclusion or Precariousness	2021	GRINS D7.3.2	B.2	num. x 1000 ab
AC2	Ratio of residents with at least a diploma to the resident population aged 25 to 64 years	2022	Istat		%
AF1	Synthetic Index of Rental Unaffordability	2019/2021	GRINS D7.3.2	B.1	0-100
AF2	Percentage of employed population aged 20 to 64 years	2019	GRINS D7.3.2	G.5.3	%
AV1	Investments for Public Housing Recovery Interventions Pro Capite (total population considered)	2022	MIT/Istat		euro pro capite
AV2	Investments M5C2 - Regeneration and Housing (PNRR) Pro Capite (total population considered)	2023	Openpolis		euro pro capite
AV3	Vacant Housing or Housing Occupied Exclusively by Non-Habitual Residents as a Percentage of Total Housing	2021	Istat		%
AV4	Collective Housing Structures per 1,000 Occupied Dwellings	2021	Istat		num.
AD1	Investments for Interventions Against Natural Hazards (MASE) Pro Capite (exposed population considered)	1999-2023	Ispra		euro pro capite
AD2	Building Volume at Seismic Risk Level P3 - P4	2011	GRINS D7.3.2	D.3.2 + D.4.2	mc
AD3	Number of Buildings at Moderate Hydraulic Risk	2020	Ispra		num.
AD4	Number of Buildings at High or Very High Landslide Risk	2020	Ispra		num.
AD5	Other Types of Dwellings per 1,000 Occupied Dwellings	2021	Istat		num.

Table 1. Summary of considered indicators.

The first key objective considered in our analysis is accessibility (AC), which addresses the capacity of housing to meet the needs of vulnerable groups. In this analysis, due to available

data, accessibility is considered solely in its social sense, not physical. The indicators used include the Housing exclusion and precariousness index and the Ratio of residents with at least a high school diploma to the resident population aged 25–64. The first indicator, uncovered in Deliverable Grins D7.3.2 (Indicator B.2)—calculated based on indicators for houseless/roofless people (B.2.1) and population living in equipped camps, tolerated, and informal settlements (B.2.2)—expresses the number of inhabitants (per 1000 total residents) in housing exclusion conditions. The second indicator, based on municipal-level ISTAT data, attempts to represent the potential capacity to reduce the gap in exclusion from the rental market of areas with a higher concentration of people with at least a high school diploma. The hypothesis here is that individuals with higher education levels are more likely to find employment and thus generate income, potentially overcoming a situation of housing exclusion.

The second key objective is affordability (AF), which measures whether housing is financially accessible. To represent this objective, we used the Housing rental unaffordability index (B.1), also developed for the previous Deliverable Grins 3.2.2, which measures the risk of unaffordability in the rental market that could lead to housing exclusion. We paired this with an ISTAT-based indicator representing the percentage of the employed population aged 20–64, a proxy for the current capacity of areas to generate income and counteract housing exclusion. Tourist pressure indicators were not used in this section, as they are indirectly accounted for in the synthetic “unaffordability” index, given that the tourism and short-term rental market already affects average household income levels and property values, particularly rental rates.

The third key objective is availability (AV), which refers here both to housing adequacy and coverage. To measure availability—as both sheer quantity and variety of housing options—we used ISTAT data from 2021 on “vacant or seasonally occupied dwellings” as a percentage of total dwellings and “collective facilities per 1000 occupied dwellings.” These were supplemented by public funding data per capita for public housing restoration (MIT) and urban regeneration and social housing (PNRR Mission 2, Component 5, Investment 2), which finances urban regeneration projects aimed at reducing social marginalization, Integrated Urban Plans, and Innovative Programs for Housing Quality (PINQUA). Both public funding sources indicate a potential increase or improvement in housing supply within these territories.

The fourth and final key objective is adequacy (AD). Considering the high environmental risks that characterize the Italian peninsula, our specific approach refers both to the quality and safety of housing. For this reason, we selected indicators quantifying buildings exposed to various risks (hydraulic, landslide, and seismic) as potential factors reducing the availability of safe housing. The indicators used are: the number of buildings at medium hydraulic risk (Database Ispra 2020: available at [\[link\]](#)), which includes those at high risk; the number of buildings at high and very high landslide risk (Database Ispra 2020); and the sum of D.3.2 and D.4.2 indicators from Deliverable Grins 3.2.2, which report building volume at seismic risk levels P3 and P4 divided by the number of floors. Lastly, to capture potential improvements in housing adequacy, we included per capita investments in disaster risk reduction—of all types—calculated using georeferenced data from the ISPRA Rendis portal for the period 1999–2023.

Data were downloaded in February 2023, considering only projects “underway” or “in planning” from 1999 to 2019 and projects “underway,” “in planning,” or “completed” from 2020 to 2023.

Moreover, the only indicator considered for housing quality is the number of “other types” (non-conventional, inadequate, informal, etc.) of dwellings per 1000 occupied dwellings, based on ISTAT data from 2022. Notably, we chose not to use indicators related to housing overcrowding or access to basic services (e.g., indoor drinking water, indoor bathroom, bath or shower, heating, hot water) as these were only available for the 2011 National Census. Furthermore, it was not possible to consider the Italian government fiscal measure known as “Superbonus 110%” due to the unavailability of spatial data at the municipal level.

3.2. *Methodology*

The methodology developed to construct the Housing Gap index consists of six steps.

The first step involves cleaning the original database, which collects the indicators described in the previous section, intending to eliminate municipalities where necessary data are missing. Out of a total of 7,904 Italian municipalities, the presence of incomplete data reduces the usable sample to 7,713 municipalities. The choice to exclude municipalities with missing data stems from the need to ensure the data’s homogeneity, avoid distortions in the results, and represent only areas with complete data.

The second step involves the normalization of the selected variables. Normalization is necessary to compare variables that initially may have different scales and units of measurement, such as percentages, absolute values, or monetary values. Normalizing the data means transforming the variables in order to share the same scale, enabling coherent aggregation and comparison of all indicators contributing to the Housing Gap measurement. In practice, the standardized values are calculated as the ratio of two differences: the difference between the municipal value and the minimum value of the entire dataset and the difference between the maximum and minimum values of the same dataset. This step is essential to ensure that no variable overshadows others due to its original scale. For all municipalities with ratios with zero value in the denominator ($\#DIV/0!$), we opted to assign the average value of the remaining municipalities.

Next, we analyze correlations between variables to identify any overlapping information. Correlations are calculated between all pairs of variables to understand the relationship’s strength and direction. In our analysis, the correlation coefficients are generally low: the average absolute value of all correlation coefficients amounts to 0.063. The highest observed correlation value is 0.422, occurring between indicators AD2 and AD3. The lowest value, on the other hand, is 0, found in several correlations between indicators, as shown in Table 2. Since no correlation coefficient exceeds ± 0.5 , we can conclude that there are no linear relationships between the variables, allowing us to assign weights in the next step without concern that some variables will redundantly influence the results.

	AF2	AC2	AF1	AC1	AD1	AV1	AV2	AD2	AD3	AD4	AV3	AD5	AV4
AF2	1,00	0,36	-0,04	0,04	0,00	-0,06	-0,06	-0,04	0,05	-0,15	-0,25	-0,01	-0,11
AC2	0,36	1,00	0,14	0,00	0,01	-0,02	0,03	0,08	0,07	0,02	-0,01	0,05	-0,03
AF1	-0,04	0,14	1,00	0,06	0,00	0,05	0,09	0,14	0,17	0,11	-0,09	-0,02	0,07
AC1	0,04	0,00	0,06	1,00	0,00	0,01	0,03	0,08	0,07	-0,02	-0,11	-0,01	0,14
AD1	0,00	0,01	0,00	0,00	1,00	0,00	-0,01	-0,01	-0,01	-0,01	0,01	0,01	-0,01
AV1	-0,06	-0,02	0,05	0,01	0,00	1,00	0,02	0,03	0,04	0,03	-0,03	-0,01	0,01
AV2	-0,06	0,03	0,09	0,03	-0,01	0,02	1,00	0,02	0,07	0,06	-0,05	0,03	0,02
AD2	-0,04	0,08	0,14	0,08	-0,01	0,03	0,02	1,00	0,42	0,12	-0,13	0,00	0,02
AD3	0,05	0,07	0,17	0,07	-0,01	0,04	0,07	0,42	1,00	0,09	-0,13	0,00	0,01
AD4	-0,15	0,02	0,11	-0,02	-0,01	0,03	0,06	0,12	0,09	1,00	0,14	0,03	0,02
AV3	-0,25	-0,01	-0,09	-0,11	0,01	-0,03	-0,05	-0,13	-0,13	0,14	1,00	0,11	0,02
AD5	-0,01	0,05	-0,02	-0,01	0,01	-0,01	0,03	0,00	0,00	0,03	0,11	1,00	0,03
AV4	-0,11	-0,03	0,07	0,14	-0,01	0,01	0,02	0,02	0,01	0,02	0,02	0,03	1,00

Table 2. Correlations coefficients.

In this step, the weights and polarities of each variable are established. On the one hand, polarity indicates the direction of the relationship between the variable and the housing gap we want to measure (Table 3): if an increase in a variable implies a worsening of housing equity and inclusion, it will have a negative polarity; conversely, if a rise in the considered variable means an improvement of the housing condition, it will have positive polarity. On the other hand, weight is based on each indicator's hypothesized importance or directness in representing the overall housing gap phenomenon. Since the correlation analysis highlighted low correlation between the variables, the choice of weights was not influenced by correlation values. The assigned weights reflect the contribution of each variable to the Housing Gap Index ensuring a balanced representation of the four key-objectives described in paragraphs 2.2 and 3.1: the sum of weights assigned to the indicator of each category (affordability, availability, adequacy and accessibility) is equal to 1.

CODE	NAME	WEIGHT	POLARITY
AC1	Index of Housing Exclusion or Precariousness	0,800	-
AC2	Ratio of residents with at least a diploma to the resident population aged 25 to 64 years	0,200	+
AF1	Synthetic Index of Rental Unaffordability	0,800	-
AF2	Percentage of employed population aged 20 to 64 years	0,200	+
AV1	Investments for Public Housing Recovery Interventions Pro Capite (total population considered)	0,250	+
AV2	Investments MSC2 - Regeneration and Housing (PNRR) Pro Capite (total population considered)	0,250	+
AV3	Vacant Housing or Housing Occupied Exclusively by Non-Habitual Residents as a Percentage of Total Housing	0,250	-
AV4	Collective Housing Structures per 1,000 Occupied Dwellings	0,250	+
AD1	Investments for Interventions Against Natural Hazards (MASE) Pro Capite (exposed population considered)	0,300	+
AD2	Building Volume at Seismic Risk Level P3 - P4	0,175	-
AD3	Number of Buildings at Moderate Hydraulic Risk	0,175	-
AD4	Number of Buildings at High or Very High Landslide Risk	0,175	-
AD5	Other Types of Dwellings per 1,000 Occupied Dwellings	0,175	-

Table 3. Summary of weights and polarities assigned to each of the indicators.

At this point, the normalized and weighted values are aggregated for each municipality by calculating a weighted sum. This step provides an overall Housing Gap Index for each municipality, considering the relative importance of the different variables based on the assigned weights.

Finally, to designate the benchmark, as explained in section 2.3, we selected the highest value of the Housing Gap Index among the 13 territorial subtypes of municipalities. This benchmark value is then used to calculate the standard deviation of the observed statistical population, i.e. the municipalities belonging to Intermediate Italy (5,851 municipalities, about 76% of the municipalities considered so far). The number of standard deviations from the identified benchmark is finally used to classify the municipalities of Intermediate Italy.

3.3. Mapping and Measuring the Gap

The synthesis map in Figure 1 highlights areas with a high Housing Gap Index and those in better conditions than the benchmark. Municipalities located in Internal Italy and Metropolitan Italy are represented in white, while municipalities belonging to Intermediate Italy with missing or unavailable data are shown in grey with the label “no data.”

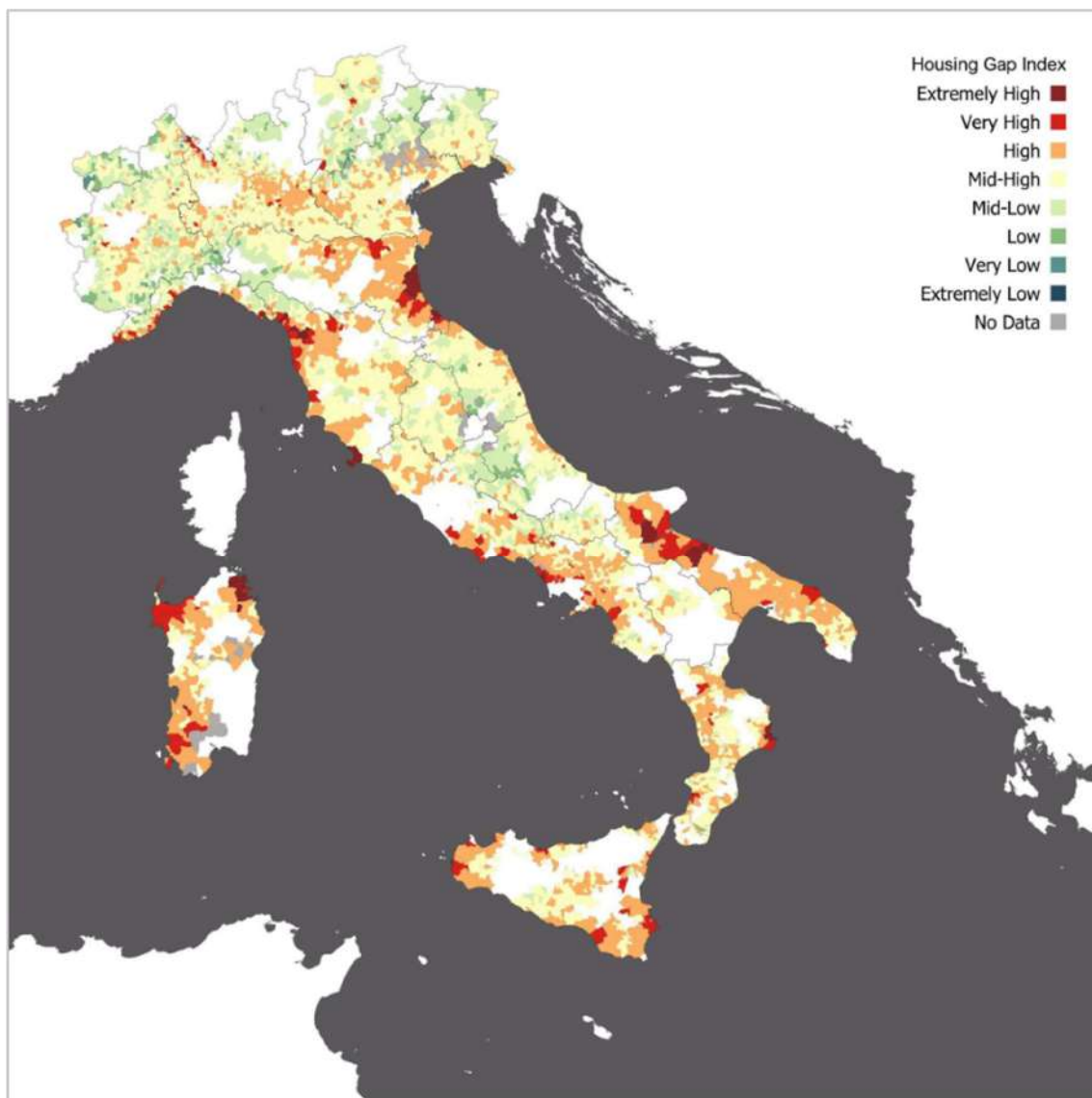


Figure 1. Housing Gap Index in Intermediate Italy: synthesis map.

Intermediate Italy has a Housing Gap Index (0.228) that falls between Metropolitan Italy (0.160) and Inner Italy (0.269), but with a clear skew towards the latter. The classes with the smallest gap are found in Inner Italy, which shows high values of the Availability index. In Metropolitan Italy, we see the most negative values across all four key objectives considered, except for Accessibility, which is lowest in Intermediate Italy. Among all those included in the Grins taxonomy, the classes that exhibit the most significant gap are, as expected, the more urban ones: namely, 3.2.2 Metropolitan Capital, 3.1 De facto metropolitan center, and 2.2 Medium-sized city or non-FUA capital. The class of Metropolitan Italy closest to the poles (3.2.1 De jure and de facto metropolitan area (not capital)) shows very similar behavior to class 2.1.2.2 Coastal and/or plain urban-rural continuum with medium population density, while class 2.3 De facto or de jure metropolitan fringe has distinctly more positive values despite having practically the same population density.

	Accessibility	Affordability	Availability	Adequacy	Housing gap
1 INNER ITALY	0,103	0,026	0,156	-0,015	0,269
1.1.1 - Inner, remote and sparsely populated area	0,103	0,034	0,160	-0,015	0,281
1.1.2 - Inner and remote area with medium population density	0,102	0,000	0,119	-0,014	0,206
1.2.1 - Sparsely populated inner area closest to a metropolitan area	0,100	0,018	0,172	-0,016	0,273
1.2.2 - Inner area with medium population density closest to a metropolitan area	0,096	-0,047	0,109	-0,023	0,135
2 INTERMEDIATE ITALY	0,104	0,040	0,098	-0,014	0,228
2.1.1.1 - Sparsely populated mountain/inland hill urban-rural continuum	0,108	0,050	0,128	-0,015	0,272
2.1.1.2 - Mountain/inland hill urban-rural continuum with medium population density	0,109	0,034	0,076	-0,013	0,205
2.1.2.1 - Sparsely populated coastal and/or lowland urban-rural continuum	0,093	0,056	0,079	-0,011	0,217
2.1.2.2 - Coastal and/or plain urban-rural continuum with medium population density	0,100	0,015	0,069	-0,013	0,172
2.2 - Medium-sized city or non-EUA capital	0,111	-0,020	0,077	-0,042	0,125
2.3 - De facto or de jure metropolitan fringe	0,102	0,033	0,088	-0,012	0,210
3 METROPOLITAN ITALY	0,110	-0,002	0,067	-0,015	0,160
3.1 - De facto metropolitan centre	0,117	-0,022	0,090	-0,054	0,091
3.2.1 - De jure and de facto metropolitan area (not capital)	0,111	0,001	0,068	-0,012	0,167
3.2.2 - Metropolitan capital	0,101	-0,095	0,062	-0,105	-0,037

Table 4. Sectoral and total Housing Gap Index for the Grins "Territorial Tipologies".

Among the classes within Intermediate Italy, the lowest values are found in medium-sized cities and class 2.1.2.2 Coastal and/or plain urban-rural continuum with medium population density. Conversely, the class with the most favorable values is 2.1.1.1 (Sparsely populated mountain/inland hill urban-rural continuum), which has values like those of Inner Italy's classes. The housing gap behaves similarly across different geographic divisions, with some nuanced differences across the various key objectives.

In the north-west, there is a greater gap in accessibility in the urban-rural continuum, with values comparable to metropolitan capitals, and a smaller gap in metropolitan poles and areas, where there is also good adequacy. The fringes show the best Housing Gap Index values among the more densely populated classes. In the Northeast, the most positive accessibility values are found in medium-sized cities and metropolitan capitals. In contrast, the best adequacy and affordability values, except in medium-sized cities, are found in Intermediate Italy. Here too, among the more densely populated classes, the fringes display the best Housing Gap values, while medium-sized cities have values similar to Metropolitan Italy. In the Center, Availability values in Intermediate Italy tend to be more harmful than other parts of Italy. Accessibility is high in medium-sized cities, and the metropolitan fringes have a notably smaller gap among the more populated classes. The South shows low accessibility in fringe areas, with values similar to Metropolitan Italy. However, the gap is smaller in medium-sized cities and the urban-rural continuum, where Adequacy is also higher. In general, in the Islands, Metropolitan Italy has the best Accessibility values, followed by fringes and medium-sized cities. In Intermediate Italy, the class with the smallest gap is the fringes, despite more negative Affordability values than other classes within this area, while the housing gap for medium-sized cities and the urban-rural continuum is affected by low Availability.

Focusing only on the municipalities within Intermediate Italy, the provinces with the highest Housing Gaps are Barletta-Andria-Trani – which remains one of the worst even when considering all Italian municipalities – and around the metropolitan systems of Prato and Naples. On the other hand, the provinces with a low Housing Gap are Belluno, Sondrio, and L'Aquila.

Looking at the geographies resulting from the Housing Gap, we can identify areas with a high Housing Gap, unified by similar socio-economic dynamics and configurations tied to how certain territories are structured.

Clusters of municipalities form the first typology with a high Housing Gap Index along infrastructural corridors, such as the Via Emilia, between Imola and Parma, and the Pedemontana along the border between Lombardy and Veneto; these gaps are primarily due to low Affordability, worsened by low Adequacy in Emilia.

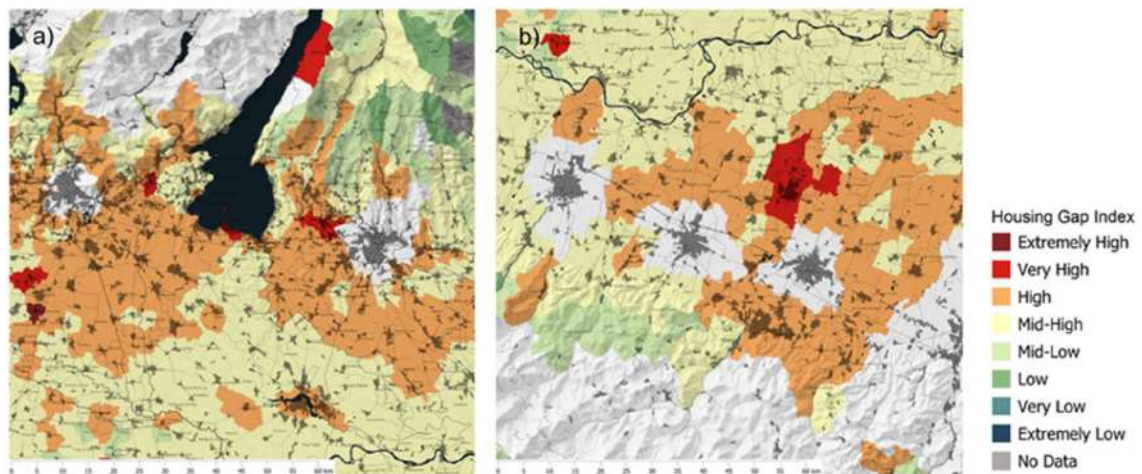


Figure 2. Housing Gap Index. zoom-in of two infrastructural corridors: a) Lombardy piedimont; b) Via Emilia.

The second typology includes medium-sized cities that, as previously highlighted, often stand out negatively due to high housing demand, linked to their role as centers for supra-local services. From North to South, examples of this can be found in the mapping of the Housing Gap in cities such as Bolzano, Asti, Arezzo, Terni, Brindisi, Crotone, and Marsala.

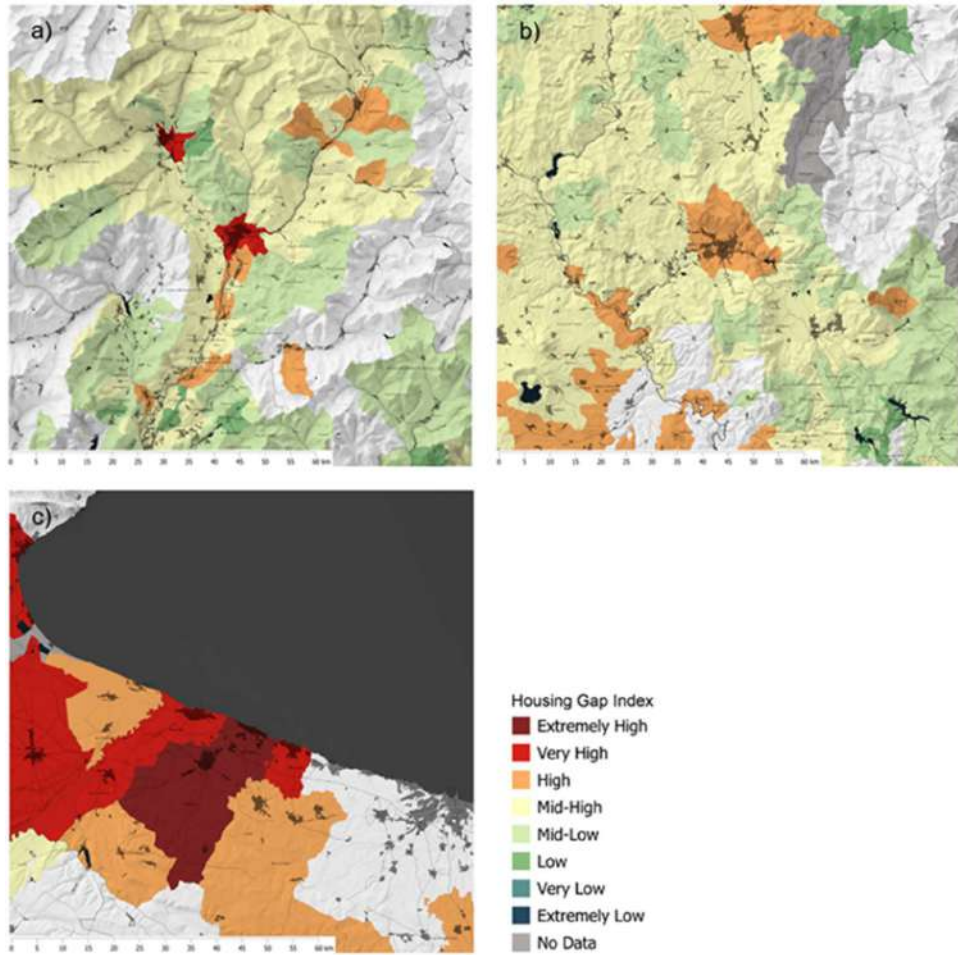


Figure 3. Housing Gap Index: zoom-in of different medium-sized cities: a) Bolzano; b) Asti-Alessandria; c) Terni; d) Barletta-Andria-Trani.

The third typology is the touristic coast, where we often find low affordability associated with high exposure to hydraulic risk; examples include Versilia in Tuscany, Romagna, and the Gallura coast.

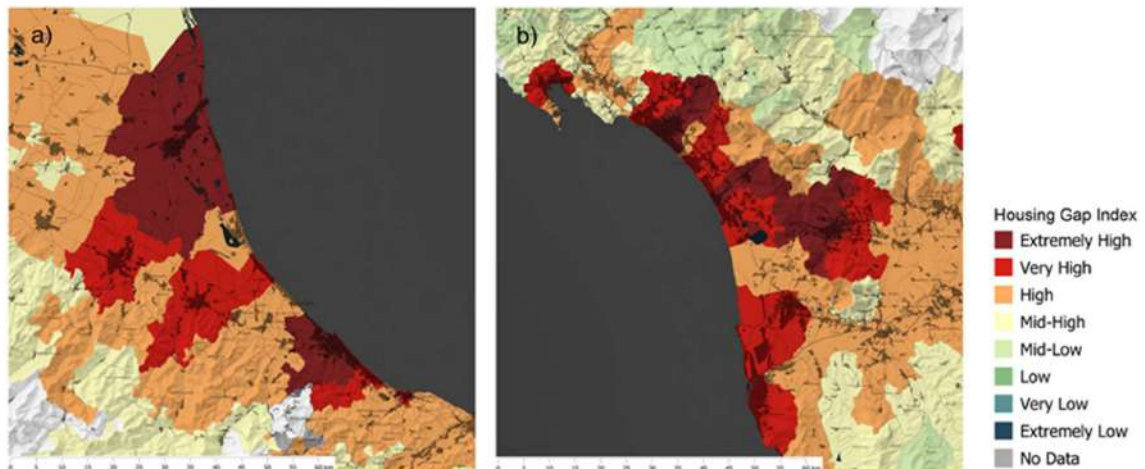


Figure 4. Housing Gap Index: zoom-in of two coastal areas with tourism vocation: a) Riviera Romagnola; b) Versilia.

The fourth typology is agricultural territories, characterized by very low accessibility; examples are the Foggia area, the Piana di Gioia Tauro, and the Ragusa area.

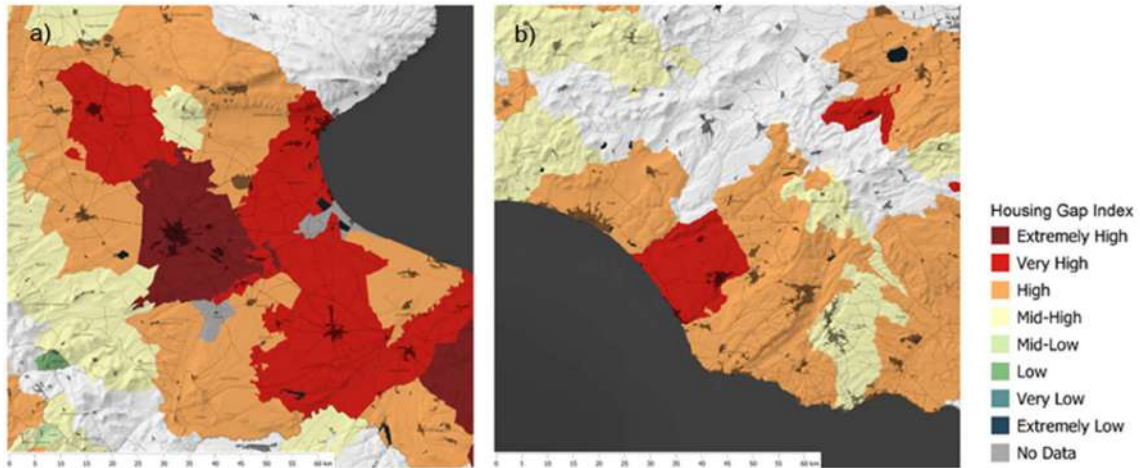


Figure 5. Housing Gap Index: zoom-in of two areas with agricultural vocation: a) Foggia Province; b) Ragusa Province.

The fifth typology is that of cross-border territories, such as around Lake Lugano between Lombardy and Switzerland, and the Ponente Riviera in Liguria.

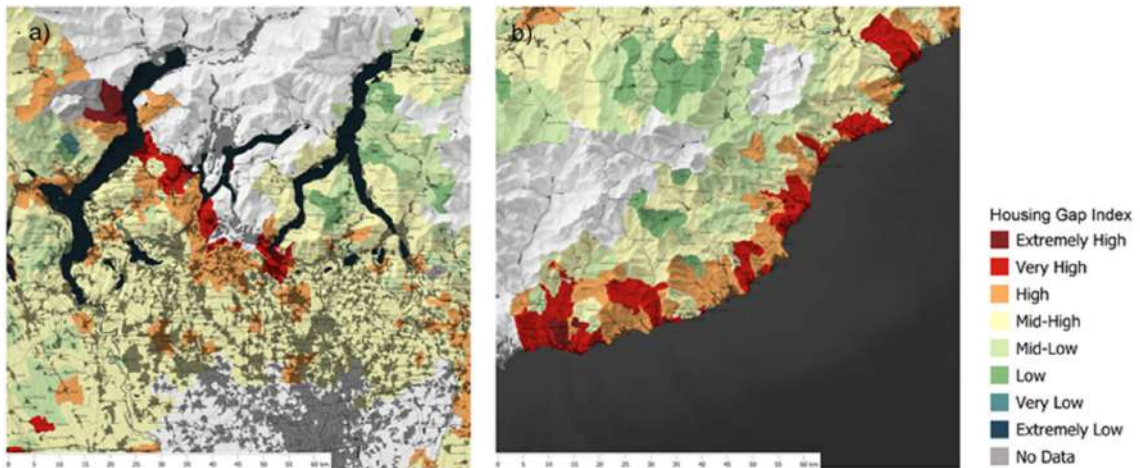


Figure 6. Housing Gap Index: zoom-in of two cross-border territories: a) the Italy-Switzerland border; b) the Italy-France border.

Finally, examining each key objective individually further clarifies the reasons behind certain geographical patterns, with some centers standing out for very negative values in one or two combined metrics: medium-sized cities with the lowest adequacy include Ravenna, Lucca, Ferrara, Massa, Forlì, Rimini, Andria, and Pistoia; those with low accessibility include Foggia, Crotona, Trani, Carbonia, Sassari, Cerignola, and Andria; the medium-sized cities with the

lowest affordability values are Bolzano, Barletta, Como, Brindisi, Rimini, Livorno, Bisceglie, and Massa; and those with lowest availability include Bolzano, Livorno, Arezzo, Carpi, Forlì, Ancona, and Terni.

PART III – Land Use Gaps in Intermediate Italy. A focus on Agricultural Landscapes in the light of Green and Energy Infrastructures

1. Relevant Issues and Benchmarks

1.1. *Agriculture, Biodiversity and Renewable Energy*

European agriculture is currently grappling with several challenges, one of the most notable being its declining prominence. For centuries, the term "rural" was virtually synonymous with "agriculture," with millions of farmers sustaining European society. Even today, in many rural areas, particularly in remote and peripheral regions, life remains intrinsically tied to agriculture. Over 40% of rural land is still dedicated to farming. However, the economic and employment contributions of agriculture, forestry, and fishing in rural regions have significantly diminished, now accounting for just 12% of all jobs and 4% of gross value added, even as the sector continues to play a vital role in maintaining food security within the EU (European Commission, Directorate-General for Agriculture and Rural Development, 2021).

The agriculture sector also faces significant challenges from and contributes substantially to the climate crisis. Agricultural economies, food systems, and their supporting ecosystems are particularly vulnerable to the impacts of climate change (Mal, 2024). Additionally, the energy consumption associated with food production is substantial: in 2013, approximately 26% of the EU's final energy consumption was attributed to cultivating, processing, packaging, and distributing food to European consumers (Monforti-Ferrario and Pinedo Pascua, 2015).

Another pressing concern is the loss of biodiversity in rural contexts, primarily due to agricultural intensification. This has direct implications for human health (European Environment Agency, 2019) and has weakened ecosystem services, making them more dependent on chemical inputs and creating negative feedback loops. The excessive use of chemical inputs, particularly pesticides, has severely affected wildlife, human health, and agricultural biodiversity. Biodiversity underpins agriculture by providing essential components for production—crops, livestock, and farmed fish—and the genetic diversity within these elements is crucial for adapting to current needs and ensuring future resilience (Commission des ressources génétiques pour l'alimentation et l'agriculture, 2010).

Various species and wild resources contribute to dietary diversity and nutrition (Guidance on Mainstreaming Biodiversity for Nutrition and Health, 1st ed, 2022). Biodiversity also supports essential ecosystem services such as pollination, pest management, nutrient cycling, soil erosion prevention, and water regulation. While agriculture benefits from these services, many species—an estimated 50% of all species in the EU—depend on agricultural habitats for

survival. This mutual dependence highlights the importance of sustainable agricultural practices that protect and enhance biodiversity.

In this context, the energy transition presents both opportunities and challenges for agricultural landscapes. Reducing greenhouse gas emissions is a critical goal for the future, and rural areas play an essential role in achieving it. The development of renewable energy in rural regions can generate jobs and deliver economic and environmental benefits to local communities (Perpiñá Castillo et al., 2024). However, the rapid expansion of renewable energy projects necessitates careful consideration of their impacts on natural environments (such as ecosystems and wildlife) and cultural landscapes (areas of historical or cultural significance) (Poggi et al., 2018). Renewable energy infrastructure can negatively affect landscape character, agricultural production, land-use patterns, local identity, and biodiversity (Van der Sluis et al., 2019; Guerin, 2019; Hernandez et al., 2014). Therefore, it is critical to reflect on the interplay between agriculture, nature, and renewable energy.

This study explores the gap between current land use for photovoltaic solar panels and landscape features in agricultural and rural contexts, comparing the present situation with the EU's targets for biodiversity restoration and renewable energy development. It identifies the shortcomings in meeting these regulatory goals by examining the extent to which rural and agricultural lands are used for photovoltaic solar panels and natural landscape elements. The "Land Use Gap" highlights the need for a balanced approach to land management that integrates renewable energy infrastructure with ecological preservation. Through a comprehensive analysis of the spatial and functional distribution of land, this study provides insights into optimizing land use to achieve sustainable development objectives. Ultimately, it aims to inform policy and decision-making processes to bridge this gap, ensuring a harmonious and sustainable future for energy production and biodiversity conservation.

1.2. Photovoltaics and Soil Consumption

During COP 21 in December 2015, 55 countries signed the Paris Agreement²³, committing to an action plan to limit global warming to below 2°C compared to pre-industrial levels. In December 2019, the European Commission launched the Green Deal²⁴, a set of political initiatives to achieve climate neutrality in Europe by 2050. Building on this, on July 14, 2021, the Commission presented the "Fit for 55" package²⁵, a collection of legislative proposals designed to support the Green Deal's goal of climate neutrality by 2050, while also setting an ambitious interim target to reduce greenhouse gas emissions by 55% by 2030 compared to 1990 levels.

The primary tool through which EU member states declare their climate and energy goals for 2030 is the National Energy and Climate Plan (NECP), introduced in 2019 as part of the "Clean

²³ <https://unfccc.int/process-and-meetings/the-paris-agreement>

²⁴ <https://www.consilium.europa.eu/it/policies/green-deal/>

²⁵ <https://www.consilium.europa.eu/en/policies/fit-for-55/>

Energy for All Europeans" package. The initial NECPs were submitted in 2019 and have now, in 2024, been updated. A key benchmark for understanding each country's approach is the 2030 planned renewable share of electricity generation in final energy demand. According to the latest NECPs, only Lithuania and Estonia have set a 100% target, followed closely by Denmark, Latvia, Austria, and Portugal. Italy, aligning with the European average, targets a 65% share (44.6% in 2023), with an overall national goal for renewables in gross final energy consumption set at 40% by 2030²⁶ (PNIEC 2023, p. 16).

Below the average, countries with the lowest renewables targets include France (35%), Slovakia, Cyprus, and Hungary. However, the outlook shifts considerably when clean energy is considered, encompassing renewables, nuclear power, and abated fossil fuels. In this broader context, France, Hungary, and Slovakia aim for targets exceeding 90%, largely due to nuclear energy, while Italy's target remains unchanged.

The two leading renewable electricity generation technologies in Europe, according to the NECPs, are solar and wind power, whose growth, expressed in installed electrical capacity (GW), is planned by each EU member state. As for hydropower, the overall European objective is not to increase capacity but to maintain the already installed capacity, mostly concentrated in France, Italy, Austria, Spain, and Sweden.²⁷ The EU's target for wind power capacity by 2030 is 425 GW. Germany, Spain, France, Sweden, Italy, and the Netherlands are currently the European countries with the highest installed wind power capacity and are also expected to install the most by 2030. Italy, specifically, has an onshore wind capacity target of 26 GW and an offshore capacity target of 2 GW by 2030. (WindEurope 2023, p. 41). The EU's target for solar power capacity by 2030 is 605 GW, of which 215 GW are expected to be installed in Germany, 95.5 GW in Spain, 79.2 GW in Italy, and 54 GW in France. These countries are already leaders in solar power capacity, together with Poland and the Netherlands.²⁸ However, in most cases, these capacity targets in GW are not specifically divided between rooftop installations and utility-scale projects, with exceptions for Spain, France, Croatia, Ireland, Portugal, and Romania.

At the European level, most solar energy production, amounting to 204 TWh (82%), is generated by ground-mounted systems, while only 46 TWh (18%) comes from rooftop PV systems. (Perpiñá Castillo et al., 2024, p. 20) In Italy, however, the situation is reversed: 34% of gross efficient installed capacity comes from ground-mounted systems, while 66% is installed on rooftops. Since 2011, when energy incentives led to equal installed capacities for ground-mounted and rooftop systems, the share of ground-mounted installations has gradually decreased. (GSE 2022, p. 11)

In Europe, ground-mounted PV potential per square kilometer is highest in Spain, Portugal, France, Romania, Bulgaria, Estonia, Lithuania, Hungary, Greece and Italy, setting Italy's untapped solar PV potential production to approximately 500 TWh/year. The key areas identified for closing this gap include the provinces of Ferrara, Viterbo, Foggia, and the major islands, regions already largely dedicated to this purpose. (Perpiñá Castillo et al., 2024, pp. 31-

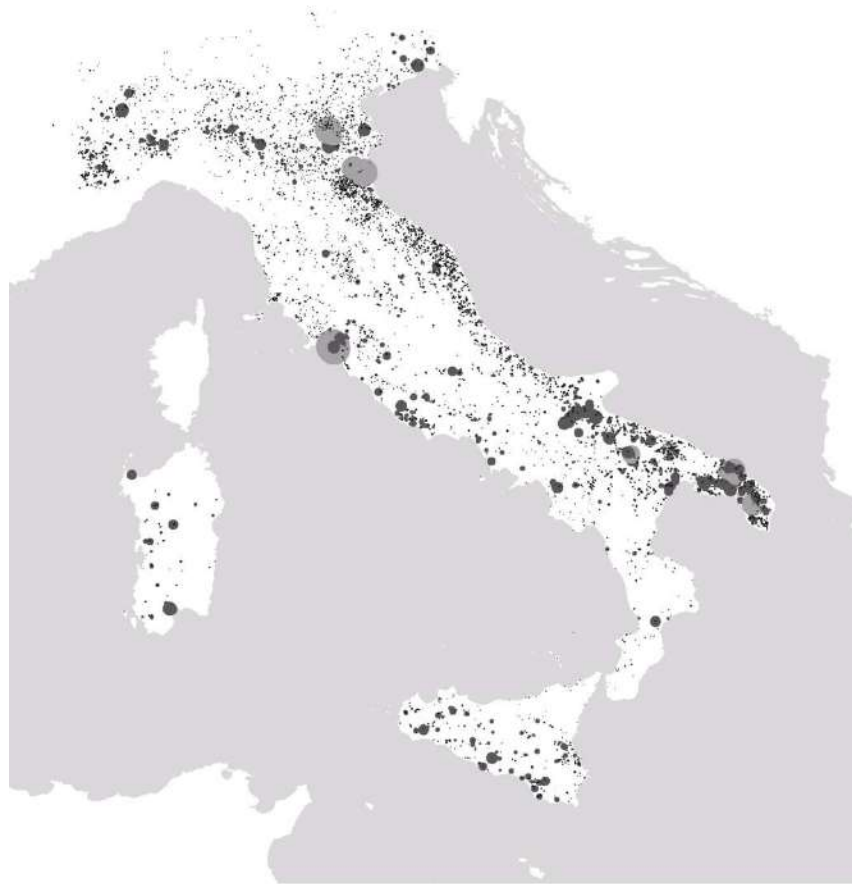
²⁶ <https://ember-energy.org/data/live-eu-necp-tracker/>

²⁷ Ibid.

²⁸ <https://www.solarpowereurope.org/advocacy/national-energy-and-climate-plans>

33) Currently, ground-mounted PV installations occupy around 15,700 hectares across Italy, with an average national land use of about 1.8 hectares per MW. (GSE 2022, p. 27) Unsurprisingly, the latest report on land use published by the National Environmental Protection System includes a dedicated section on photovoltaics (Munafò, M. (ed by), 2023, p. 228).

The map showing the sizes of ground-mounted photovoltaic installations (Fig. 1) reveals that these installations create different geographic patterns depending on their size. Small installations are scattered like fine dust across the country's plains, from the Po Valley to the Tavoliere in Apulia, covering the entire Adriatic coast in a continuous spread. The highest concentration of PV installations is found in Apulia, the leading region for land consumed by photovoltaic installations as of the end of 2022, with 4,312 hectares (GSE 2022, p. 11). In this region, clusters of medium-sized installations overlap with the finer spread in Foggia and Salento, culminating in a cluster of large installations around Brindisi. This area is one of four clusters of large PV installations in Italy, alongside Rovigo and Ferrara in the north and Viterbo in central Italy. Lazio ranks as the second region for land consumed by PV installations (1,572 hectares), followed by Sicily (1,560 hectares), where the entire southwestern coast is dotted with medium-sized installations. It is interesting to note how the negative space on this map corresponds to the Alpine-Apennine and metropolitan regions, highlighting the productive character of Italy's province. This pattern is equally evident on the map of energy production and consumption (Fig. 2), which considers all sources of electricity generation, including fossil fuels. Here large metropolitan cities like Milan, Turin, and Rome dominate in terms of energy consumption, while production remains concentrated in the provinces in Apulia and Lombardy.



- ≤ 1 Ha
- $1 \text{ Ha} \leq \text{value} \leq 30 \text{ Ha}$
- $\geq 30 \text{ Ha}$

Figure 1. Geographies of ground-mounted PV plants



Figure 2. Geographies of electric energy production and consumption

1.3. *Agriculture and Environmental Justice*

The 2030 Agenda Sustainable Development Goals (SDG) are the starting point for a better understanding of the EU policies on biodiversity protection and the future of agriculture. The most relevant in this context are Goal 2 – Zero Hunger; Goal 14 – Life Below Water; Goal 15 – Life on Land. Among the targets included in the three goals, the most notable are doubling the productivity and incomes of small-scale food producers (target 2.3), ensuring sustainable food production and resilient agricultural practices (target 2.4), reducing the marine pollution, especially the eutrophication caused by land-based activities (target 14.1); ending the

desertification and restoring degraded lands including those affected by desertification, drought, and floods (target 15.3); halting the biodiversity loss (target 15.5)²⁹.

Based on the objectives outlined in the 2030 Agenda, the European Union has developed a series of strategies to ensure a sustainable and resilient future. The EU Biodiversity Strategy for 2030³⁰ is a long-term plan focused on protecting and restoring nature. It aims to reverse biodiversity loss and ecosystem degradation, with particular attention to those capable of removing and storing carbon and preventing and reducing the impact of natural disasters. The EU Forest Strategy for 2030³¹ outlines concrete actions to improve the quantity and quality of EU forests, considering that well-maintained forest habitats also benefit an integrated mosaic of agroecosystems, grasslands, soils, and water. The EU Soil Strategy for 2030³² outlines a framework and concrete measures to protect and restore soils, limit wetland drainage, and restore drained peatlands, as well as measures to improve biodiversity in agricultural lands, which would help conserve and increase soil organic carbon. The Farm to Fork Strategy³³ aims to transition towards fair, healthy, and environmentally friendly food systems, ensuring food security, nutrition, and public health while having a neutral or positive environmental impact. The EU Green Infrastructure Strategy³⁴ aims to protect and enhance green spaces to prevent biodiversity loss and support ecosystem services. This network improves environmental quality, public health, and quality of life, while also promoting a green economy and job creation. The Natura 2000 network is central to this strategy. The Habitats

²⁹ UN General Assembly, «Risoluzione adottata dall'Assemblea Generale il 25 settembre 2015. Trasformare il nostro mondo: l'Agenda 2030 per lo Sviluppo Sostenibile» (New York: UN General Assembly, 21 ottobre 2015), <https://unric.org/it/wp-content/uploads/sites/3/2019/11/Agenda-2030-Onu-italia.pdf>.

³⁰ European Commission, Directorate-General for Environment. «Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions EU. Biodiversity Strategy for 2030. Bringing nature back into our lives». Brussels, 20 maggio 2020. <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52020DC0380>.

³¹ European Commission, Directorate-General for Agriculture and Rural Development. «Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. New EU Forest Strategy for 2030». Brussels, 16 luglio 2021. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0572>.

³² European Commission, Directorate-General for Environment. «Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. EU Soil Strategy for 2030. Reaping the benefits of healthy soils for people, food, nature and climate». Brussels, 17 novembre 2021. https://environment.ec.europa.eu/document/download/ae853f10-c9a2-4665-a9f2-c29d11c49374_en?filename=COM_2021_699_1_EN_ACT_part1_v4_0.pdf.

³³ European Commission, Directorate-General for Environment. «Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system». Brussels, 20 maggio 2020. <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52020DC0380>.

³⁴ European Commission. «Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Green Infrastructure (GI) — Enhancing Europe's Natural Capital», 6 maggio 2013. <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52013DC0249>.

Directive³⁵ aims to protect over a thousand species, including mammals, reptiles, amphibians, fish, invertebrates, plants, and 230 characteristic habitat types, to be maintained or restored to a favorable conservation status within the EU.

Many scientific studies have highlighted the importance of the agricultural landscape features (intended as small patches of natural or semi-natural vegetation that are not intended for agricultural production), emphasizing their crucial role in promoting biodiversity and environmental sustainability. These elements provide important ecosystem services, such as improving soil health, pollination, pest control, and increasing crop yields in nearby fields (MDC et al., 2022). Terraced soils, stone walls, and grassy margins help reduce soil erosion and retain sediments (Maetens, Poesen and Vanmaercke, 2012). Landscape complexity positively impacts biodiversity (Baaken, 2022), while its simplification reduces agricultural production (Dainese et al., 2019). Hedgerows and uncultivated field margins are important habitats for pollinator populations, contributing to pollination and reducing pesticide use (Holland et al., 2017; Martin et al., 2019). Proximity to flower-rich areas helps decrease pest numbers and increases overall production by 15% (Carvalho et al., 2011; Feltham et al., 2015; Albrecht et al., 2020). Additionally, practices such as no-tillage significantly restore soil quality, especially when combined with organic fertilization (Derpsch et al., 2014). Other studies indicate substantial potential for reducing or eliminating mineral fertilizers without decreasing yields. The yield gap between organic and conventional farming varies widely by crop (from 5% to 39%). Still, it decreases sharply over time when combined with diversification practices (Mijangos et al., 2011).

Experts have a growing consensus on the necessity of dedicating a portion of agricultural land to enhance biodiversity. Several authors suggest that birds and other wildlife could thrive again if at least 10%–14% of European agricultural land were allocated to non-productive areas (Busch et al., 2020; Traba et al., 2019; Walker et al., 2018; Pe'er et al., 2014), as well as the positive increase of the biodiversity thanks to well-managed fallow land (Bush et al., 2020; Traba et al., 2019). The need to enhance landscape features in agricultural contexts is emphasized by the Biodiversity Strategy to 2030, which specifically highlights the necessity of allocating at least 10% of agricultural land to high-diversity landscape features. This target is adopted in the 'Recommendations to Member States on their Common Agricultural Policy Strategic Plans' document³⁶.

³⁵ The Council of the European Union. Council Directive 2013/17/EU of 13 May 2013 adapting certain directives in the field of environment, by reason of the accession of the Republic of Croatia, Pub. L. No. L 158/193 (2013). <http://data.europa.eu/eli/dir/2013/17/oj>.

³⁶ European Commission, Directorate-General for Agriculture and Rural Development (2020) Commission Staff Working Document Commission Recommendations for Italy's CAP Strategic Plan, accompanying the document 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions'. Recommendations to the Member States as regards their Strategic Plan for the Common Agricultural Policy. SWD/2020/396. Brussels. Available at: <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52020SC0396>.

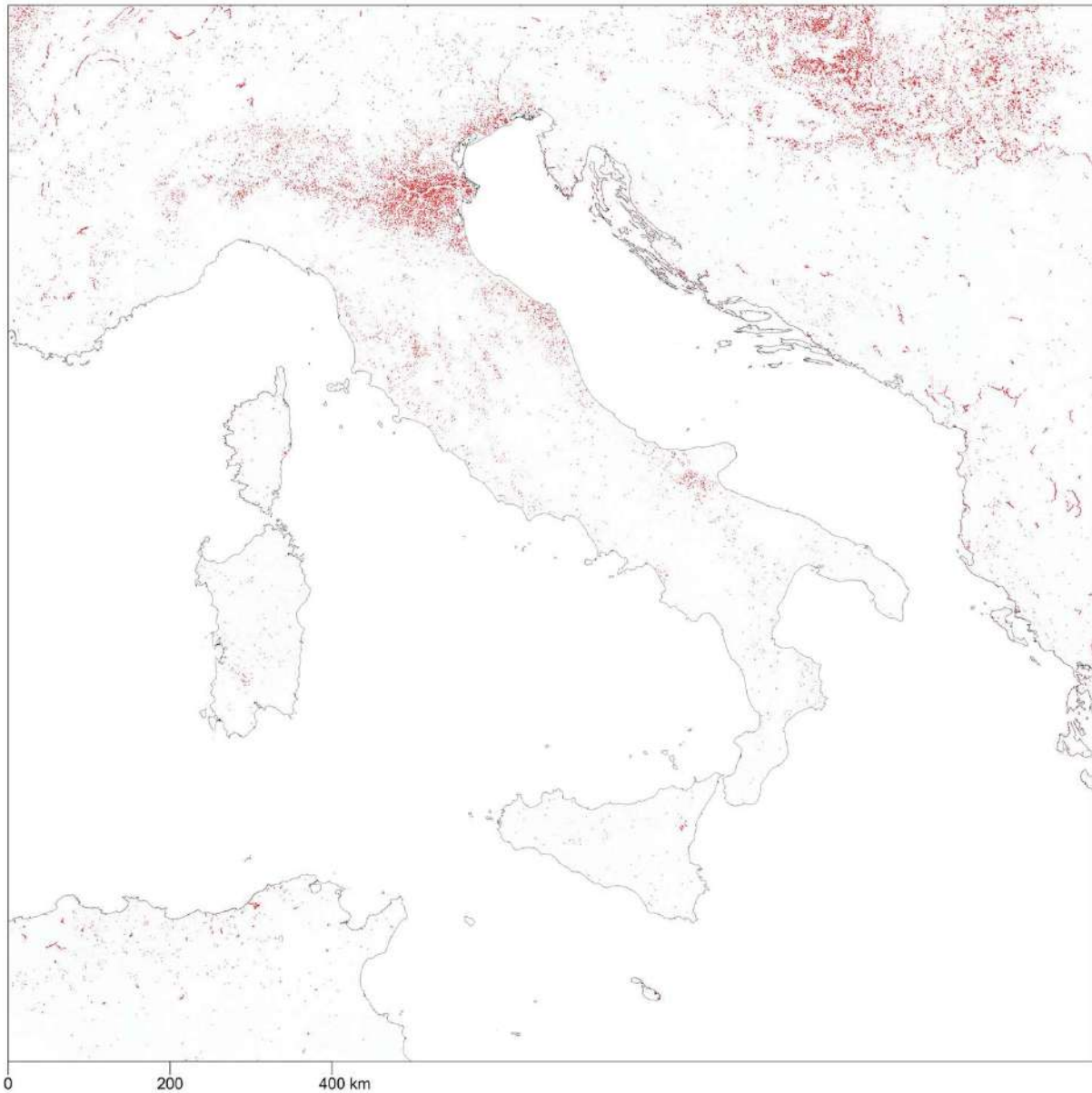


Figure 3. Unlike 2023, 2022 was a particularly dry year. By comparing the vegetation index (NDVI) calculated in July of the two years, one can see which soils were most negatively impacted by the climate change.

To ensure that agricultural practices do not harm the environment and contribute to sustainability, in the frame of the Common Agricultural Policy (CAP), the Good Agricultural and Environmental Conditions (GAEC) represent a set of requirements to protect soil, water, and biodiversity, that farmers must meet to receive direct payments and other types of support. Landscape features, nonproductive surfaces, and areas devoted to improving biodiversity are the topic of the GAEC 8 – the minimum percentage of Agricultural Land Allocated to Non-Productive Areas. Italy sets this standard at a minimum of 4% of arable land on each farm, including fallow land. However, serious critiques have been provided against this measure, considered inadequate to reach the 10% biodiversity target (BirdLife Europe and European

Environmental Bureau policy briefing, 2022) and unable to provide a real change since the actual percentage for Italy is 3,7%³⁷.

The inadequacy of agriculture in addressing climate change can be observed by comparing two years: 2022, a particularly dry year, and 2023, a significantly wetter year. By calculating the NDVI (Normalized Difference Vegetation Index) for July 2022 and July 2023 and then determining the difference between these two indicators, a third indicator is obtained: the difference between the two NDVIs. Despite the inevitable climatological differences across various parts of Italy, it is evident that some soils, particularly in the Alpine and Apennine regions and the islands, have not undergone significant changes. In contrast, the flat soils of the Po Valley and the internal Apennine basins show signs of criticality. Among these, the areas of Emilia Romagna, Veneto, and Lombardy, near the final stretch of the Po River, exhibit the greatest criticality. These are the contexts of arable land, flat plots where agricultural fields are flat slabs devoid of vegetative borders that could promote biodiversity or prevent excessive heating of the agricultural surface, making agricultural soils more vulnerable to climatic variations over time. For this reason, it is useful to quantify landscape features on a closer scale.

2. Overcoming Territorial Gaps

2.1. *Measure the Gaps Within a Variety of Territories*

In this paragraph, we will measure the continuity gaps in three sample areas, each measuring 10 km by 10 km. This is not intended to provide a comprehensive national overview but to highlight Italy's challenges through three representative cases. The selected areas are the province of Ferrara, between Argenta and the Bonifica della Valle del Mezzano; the province of Viterbo near Montalto di Castro; and the area east of Foggia. One case pertains to northern Italy, another to central Italy, and the third to southern Italy, thus encompassing diverse geographical contexts. These areas are emblematic because they are dominated by intensive agriculture, primarily arable farming, and in all cases, there is a noteworthy phenomenon of photovoltaic installations. They are also characterized by being subjected to agrarian reform and hydraulic reclamation in the last century.

Regarding landscape features, we will use the 10% threshold suggested by the EU Biodiversity Strategy 2030 as the benchmark for measuring the gap. Currently, this threshold includes fallow land. However, since fallow land is often part of farm dynamics, such as crop rotation, for this gap analysis, we will exclude fallow land from calculating landscape features. Instead, we will focus on the permanent elements of the ecological infrastructure. Measurements will be conducted using data from the CLC/Backbone 2021 project, the most up-to-date and detailed national-scale map describing land cover and use. This approach will allow us to

³⁷ See Recommendations to the Member States as regards their Strategic Plan – Annex 1, pag.3.

obtain a more precise and relevant assessment of agricultural areas dedicated to high-diversity landscape features. In this way, we can better direct conservation and land management policies, effectively contributing to the sustainability and biodiversity goals set by the EU.

Regarding renewable energy, we will measure the amount of land currently occupied by photovoltaic panels. Photovoltaics are not the only available renewable energy source, but among them, it involves the widest range of actors, from large energy companies and managers to energy communities and a multitude of small actors and individuals. Additionally, in the last decade, the cost of solar panels has dropped dramatically, making solar one of the cheapest forms of electricity to date. Solar technologies can deliver energy in different forms, such as heat, cooling, and electricity, and power various other energy-related applications such as hydrogen generation and water desalination. The gap in this case will be measured against the 2.2% threshold, considering that ground-mounted PV systems are the technology contributing the most to the EU's total potential (93%) (Perpiñá Castillo et al., 2024, p. 30).³⁸

2.2. Intensive Agriculture in the Po Valley and Distributed Energy Production (Ferrara/Ravenna)

In Ferrara and Ravenna, large-scale photovoltaic fields dominate, with the two largest installations covering around 60 hectares each, positioned to the south of the part of the territory in the exam. Smaller photovoltaic arrays are interspersed within the inhabited agricultural landscape. The surrounding fields are primarily used for rotational crops, making up 85% of the surveyed soil, and feature a regular, grid-like pattern of canals typical of reclaimed agrarian landscapes (referencing the traditional reed-cutting patterns of the area). Close to the Mezzano Valley, a region originally swampy but transformed into productive agricultural land through drainage, levelling, and the addition of soil amendments, the landscape has undergone significant human alteration.

Today, this area presents a flat landscape, where photovoltaic fields are screened by tall hedgerows or discreetly located behind houses on plots that vary in size, some small, others narrow and elongated. While the landscape retains significant natural areas (like the Comacchio Valleys and the Apennines, as well as historic sugar refineries or hemp-retting pools), at a local level, the remaining natural features (LFs) are limited mainly to the edges of irrigation canals, a few rows of trees, and slender strips of uncultivated soil that support perennial grasses and shrubs.

³⁸ "After applying all exclusions and constraint factors [...] the maximum suitable land for a sustainable deployment of solar PV ground-mounted systems amounts to 92 800 km², which is equal to 2.2 % of the EU's total land area" Renewable energy production and potential in EU rural areas, pag. 30.













	Sealed	3.12 %	
	Photovoltaic pannels	1.24 %	
	Periodically herbaceous	85.54 %	} productive features
	Low growing woody	1.84 %	
	Permanent herbaceous	9.04 %	
	Woody needle leaved trees	} 2.02 %	} landscape features
	Woody Broadleaved deciduous trees		
	Woody Broadleaved evergreen trees		
	Rivers and canals	} 1.30 %	
	Water surfaces		



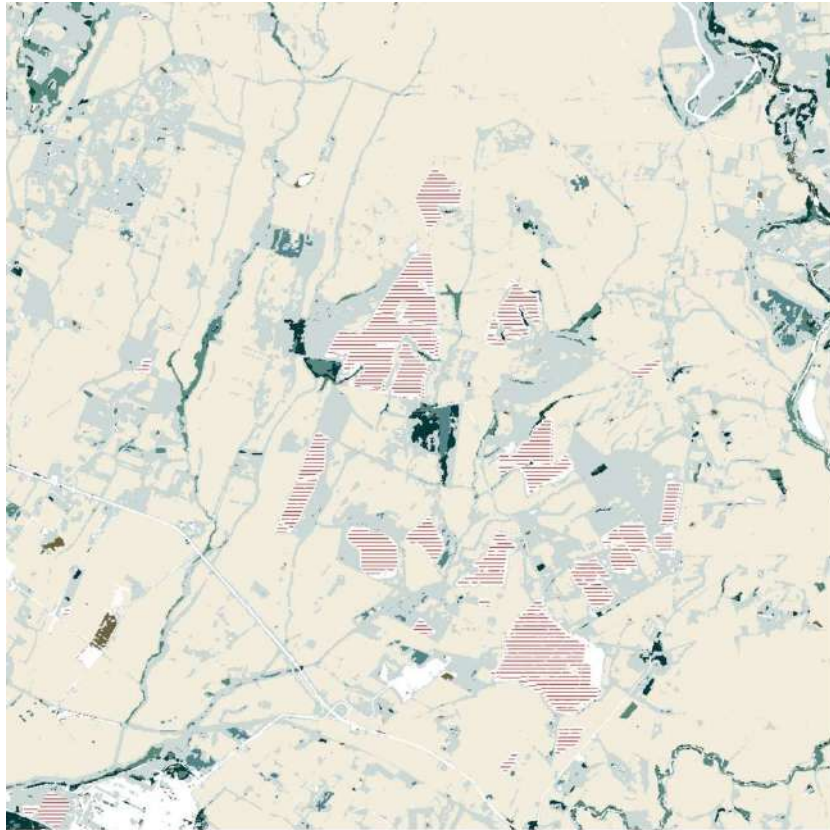
Figure 4. Zoom-in (10 km x 10 km) and Google Street View photo of the area of Alfonsine (Ravenna)

2.3. Agriculture of the Tyrrhenian Hinterland and Focal Points of the Energy Production (Viterbo)

Large-scale photovoltaic fields ranging from 10 to 100 hectares in Viterbo form an extensive, aggregated energy landscape. This emerging energy infrastructure network is built upon the pre-existing grid previously used by the now-decommissioned "Alessandro Volta" thermoelectric power plant in Montalto di Castro. Although the satellite survey used for the study has yet to be fully captured, signs of future installations indicate that the area of photovoltaic coverage will likely double in the coming years.

The terrain is gently hilly, and the layout of fields follows the natural contours. The folds and slight elevation changes in the land make it challenging to organize fields for agricultural or energy use, creating "unused trenches" of land that support natural vegetation growth. Unlike the regular grid observed in Ravenna, the landscape here features a more irregular pattern. However, the rational layout of photovoltaic installations creates a technical overlay that conforms to the topography while following organized orientations and distribution.

To the east, the landscape includes extensive agricultural zones, olive groves, and significant areas of permanent pastures for grazing. The hilly undulations, coastal urbanization, and visible power lines distinguish this landscape from the Maremma region. On a regional scale, landscape features are shaped by waterways that run perpendicular to the coastline. At a closer level, key landscape elements include uncultivated roadside edges and soil folds, which resist dense energy infrastructure but provide fertile ground for meadow, riparian, and shrub vegetation.



Sealed	5.16 %	
Photovoltaic pannels	4.47 %	} productive features
Periodically herbaceous	71.84 %	
Low growing woody	0.75 %	
Permanent herbaceous	23.82 %	
Woody needle leaved trees	} 2.64 %	} landscape features
Woody Broadleaved deciduous trees		
Woody Broadleaved evergreen trees		
Rivers and canals	} 0.47 %	
Water surfaces		



Figure 5. Zoom-in (10 km x 10 km) and Google Street View photo of the area of Montalto di Castro (Viterbo)

2.4. Arable Land, Vineyards, Olive Groves, and Orchards in Southern Italy and Medium-sized Photovoltaic Systems (Foggia)

In Foggia, medium and small photovoltaic installations create clustered and dispersed patterns. The flat terrain shapes a level landscape, interrupted mainly by an increasing presence of wind turbines and occasional sparse tree rows that fade into isolated stands. Rational agricultural forms here have produced a diverse mosaic, with fields oriented in various directions. Despite this varied layout, the soil composition indicates a lack of crop diversity, with statistics showing a strong dominance of periodic herbaceous crops. The uniform ground cover is interrupted only by vineyards, which constitute about 9% of the area.

The water infrastructure does little to form buffer zones that could support riparian vegetation. Generally, land use extends up to road edges, preventing the formation of hedgerows and uncultivated strips that could contribute to landscape features. This intensive use leaves almost no room for resting or fallow land.

In this area, some landscape features include olive groves occupying specific parcel shapes from historic land reform patterns. Overall, the territory resembles a mosaic of parcels dominated by periodic crops, interspersed with varied uses such as vineyards, olive groves, herbaceous crops, and photovoltaic installations. To enhance landscape features, the layout suggests focusing on individual parcels rather than restoring broader ecological continuities.

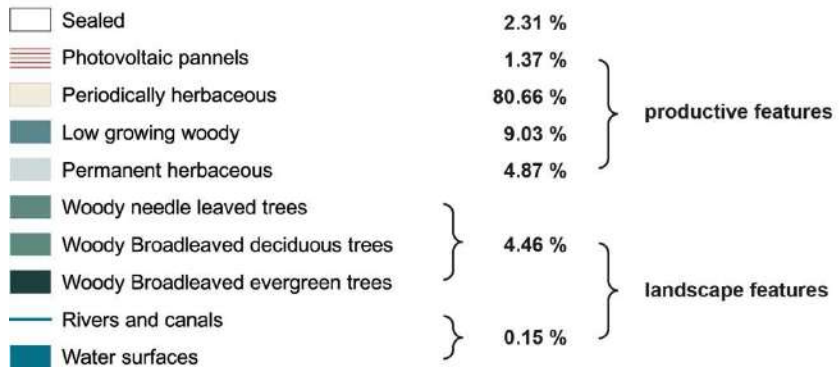
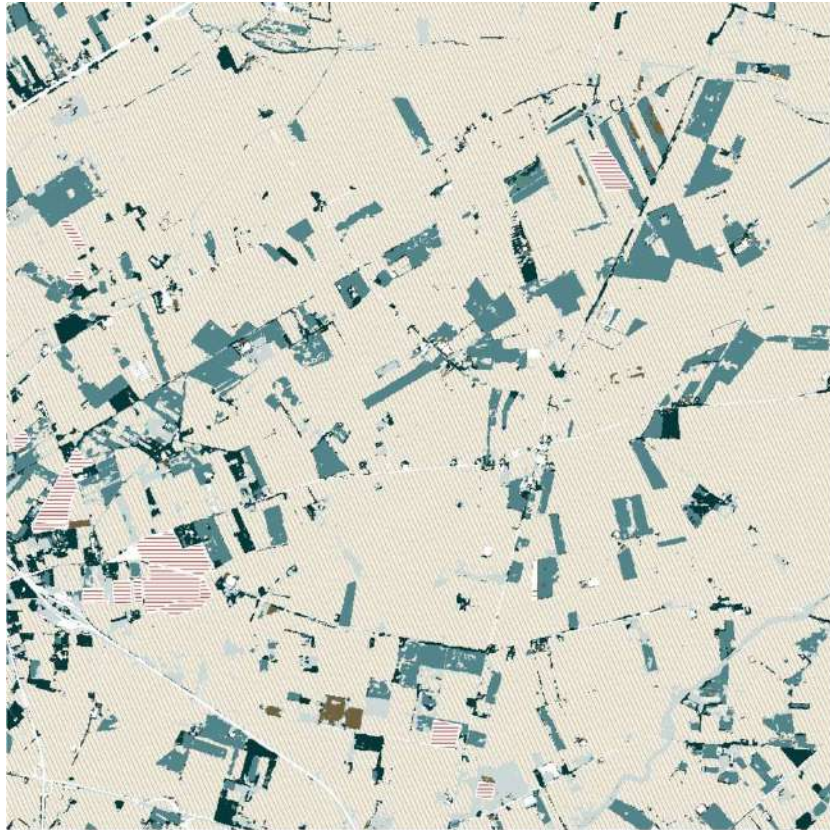


Figure 6. Zoom-in (10 km x 10 km) and Google Street View photo of the area of Foggia

3. Gap Conditions: Local Focuses

3.1. *Measuring The Gaps to Characterize the Territories Better*

The measurement conducted in the three case studies shows that we are significantly below the target for landscape features in all three cases. The same applies to the land used for photovoltaic panels, except in the case of Viterbo, which is the only one to exceed the European target. However, the graph highlights three emblematic situations. In Ferrara, where we have small-scale photovoltaic installations and large plots of land, the context is particularly critical today due to the few landscape features and the need for more photovoltaic fields. Nevertheless, there is potential for improvement and a high potential for integration between agriculture, energy, and landscape features.

Conversely, Viterbo exemplifies a situation where the proportion of photovoltaic installations exceeds the threshold limit while the proportion of landscape features falls significantly below the target threshold. On one hand, this can be seen as positive because it allows other areas to avoid using land for energy production. On the other hand, it raises serious concerns because, in this case, photovoltaics is not integrated with agriculture but represents a change in land use from agricultural to industrial. Additionally, when the technology becomes obsolete, it is likely that we will need to question the future of this land, as there are no margins for integrating agriculture, nature, and clean energy.

Finally, Foggia is an example of a context with medium-sized photovoltaic fields and arable land with a higher presence of landscape features. In this case, there is potential for improvement, although not as much as in Ferrara, since the PV fields are starting to reach a size that hinders full integration between agriculture, energy, and landscape features. Nonetheless, the initial situation is positive, and the proportion of landscape features exceeds the national average, making it easier to achieve the landscape feature target set by the EU Biodiversity Strategy.

Type	CLC+ Backbone 2021 Soil Classification	Case 1 Ferrara	Case 2 Viterbo	Case 3 Foggia
	Sealed	3.121.979,00	5.159.113,00	2.304.868,00
Landscape Features	Woody (Needle leaved trees)	14.700,00	98.012,00	14.900,00
	Woody (Broadleaved deciduos trees)	1.925.491,00	1.401.451,00	116.258,00
	Woody (Broadleaved evergreen trees)	39.600,00	1.114.507,00	4.281.834,00
	Water	1.258.727,00	449.873,00	149.400,00
	Non and sparsely vegetated	176.400,00	297.638,00	539.815,00
Agricultural land	Low-growing woody	1.840.754,00	752.746,00	9.031.506,00
	Permanent herbaceous	8.749.712,00	22.588.733,00	4.758.086,00
	Periodically herbaceous	82.829.381,00	68.115.059,00	78.767.707,00
	Solar panels	1.196.100,00	4.240.800,00	1.339.000,00

Table 1: Land Cover Measurement (m2)

		Case 1 Ferrara	Case 2 Viterbo	Case 3 Foggia
a.	Actual Agricultural Land Coverage (m ²)	93.419.847,00	91.456.538,00	92.557.299,00
b.	Total Landscape Features Coverage (m ²)	3.414.918,00	3.361.481,00	5.102.207,00
c.	Percentage incidence of Landscape Features on Agricultural soils (%) [b/a]	3,66%	3,68%	5,51%
d.	Percentage incidence EU Biodiversity Target (%)	10,00%	10,00%	10,00%
e.	Amount of Landscape Features attended EU Biodiversity Target (m ²) [d*a]	9.341.984,70	9.145.653,80	9.255.729,90
f.	Gap between actual situation and EU Biodiversity Target (%) [d-c]	6,34%	6,32%	4,49%
g.	Gap between actual situation and EU Biodiversity Target (m ²) [e-b]	5.927.066,70	5.784.172,80	4.153.522,90

Table 2: GAP Measurement (Landscape Features)

		Case 1 Ferrara	Case 2 Viterbo	Case 3 Foggia
h.	Actual Solar Panels Coverage (m ²)	1.196.100,00	4.240.800,00	1.339.000,00
i.	Actual Percentage Incidence of Solar Panels [h/100.000.000]	1,20%	4,24%	1,34%
j.	Target Percentage Incidence of Solar Panels	2,20%	2,20%	2,20%
k.	Target Solar Panels Coverage (m ²) [h*j]	2.200.000,00	2.200.000,00	2.200.000,00
l.	Gap (%) [j- i]	1,00%	-2,04%	0,86%
m.	Gap (m ²) [k-h]	1.003.900,00	-2.040.800,00	861.000,00

Table 3: GAP Measurement (Solar Panels)

The case studies examined do not cover all the issues present at the national level, even when considering those relevant to agricultural land and the production of renewable energy. However, they serve to clarify certain issues. The gaps described here identify serious challenges that Italy and Europe will have to face soon. On one hand, driven by the energy transition, we are witnessing a massive commitment of agricultural land to energy production, to the extent that it constitutes a change in land use and poor integration with the territory. On the other hand, we observe that large portions of agricultural land are still far from achieving the integration between agricultural practices and biodiversity as envisioned by European strategies, although some virtuous examples are emerging.

At the same time, behind these gaps, we observe a specific morphology of the phenomena: in Ferrara, the photovoltaic fields are so small and scattered that they appear like dust on an agricultural mosaic set on an extremely regular grid; in Viterbo, the solar panels are aggregated into large plates embedded in the territory and interspersed with the main

ecological corridors; in Foggia, the medium-sized photovoltaic plates are contributing to a simplification of the agricultural mosaic through the amalgamation of multiple plots. Thus, a distinctiveness in these territories, evident in their form, geography, and history, renders them exemplary in certain aspects and unique in others. This dual nature of being both specific and representative is a critical factor that should not be overlooked.

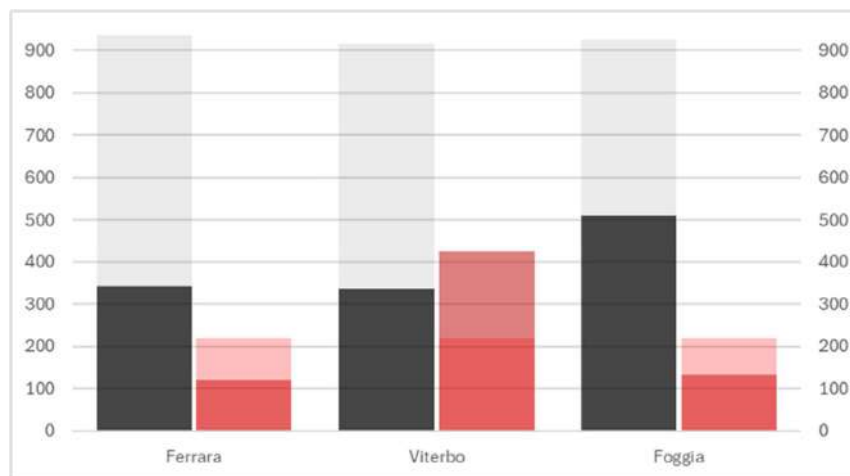


Figure 7: Gap Measurement: the left column refers to the existing Landscape Features (black) and target (grey); the right column describes the existing extension of solar panels (red) and the target to reach (pink). In the central column, the actual situation is above the target.

3.2. Cross-cutting Issues and Challenges for the Near Future

On August 18, 2024, the Nature Restoration Law came into effect. The final approved text excluded the proposal to allocate 10% of agricultural land to landscape features and biodiversity interventions. In response to farmers' protests, the CAP requirement to allocate 4% of land to non-productive features was also relaxed, making it voluntary. Similarly, the restoration of wetlands for farmers and private landowners became voluntary. The obligations now fall on the States rather than individual farmers, focusing on the overall enhancement of biodiversity. This is measured by indicators such as the presence of grasslands, butterflies, and the stock of organic carbon in cultivated soils. By 2030, States must implement restoration measures in at least 20% of the EU's terrestrial and marine areas³⁹.

Precisely because the 10% threshold was removed, this gap analysis should not be viewed solely from a quantitative perspective. The objective here has been to understand, on a smaller geographical scale, the obstacles and critical issues that a strategy for new ecological connectivity should address, as also advocated by European strategies⁴⁰. Nevertheless, there

³⁹ See <https://www.infodata.ilsole24ore.com/2024/08/24/biodiversita-la-nature-restoration-law-e-in-vigore-e-adesso/>.

⁴⁰ See "Member States will need to translate the 10% EU target to a lower geographical scale to ensure connectivity among habitats, especially through the CAP instruments and CAP Strategic Plans, in line with the Farm to Fork Strategy, and through the implementation of the Habitats Directive." (European Commission, Directorate-General for Environment, 2020).

remain some critical issues in the study we have conducted. Firstly, the quantification of land designated for renewable energy production and land with landscape characteristics was carried out within quadrants without considering the surrounding territories. Conversely, future projects and policies will need to address the issue of Italian territories by working at different scales, capturing relationships, interdependencies, and idiosyncrasies between different areas. Secondly, in strategic planning, it is important to remember that the issues presented here are the result of a complex web of decisions and powers where continental, national, and European strategies interact, not always in a linear and coherent manner.

The purpose of this gap analysis is to lay the groundwork for a multiscale project action. This analysis aims to frame the problem, recognizing the necessity of outlining the issues within a new landscape design. Achieving strategic objectives requires more than just indicators; it necessitates a comprehensive landscape design. Only through this approach can we, for example, achieve true integration between the scattered photovoltaic panels in the province of Ferrara and a new ecological network. Similarly, this method allows us to envision a robust ecological counterbalance to the large photovoltaic fields in Viterbo, which currently result in land consumption. It also helps prevent the simplification of the agricultural mosaic caused by medium-sized photovoltaic fields in the Foggia area.

Beyond political challenges, the most significant obstacle to achieving European objectives lies in the essential effort to deeply understand territorial geographies and to conceptualize a new design that incorporates them. Rural contexts are arenas of conflict among three primary considerations: agricultural and food production, the strengthening of ecological infrastructures and natural capital, and the transition to renewable energy production. While the desired scenario is coherent, we are witnessing the intensification of certain dichotomies. Therefore, the objective for the near future is to understand the ongoing dynamics and to envision new frameworks of coherence.

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Report C – INNER ITALY

1. Gap Analysis of the Inner Italy⁴¹

1.1. Introduction

Italian inner areas, like many marginal regions across Europe, are territories characterized by significant complexity but also immense potential. Historically, these areas have faced structural inequalities compared to urban centers, driven by limited access to essential services, inadequate capacity to address environmental challenges, and economic vulnerability compounded by insufficient infrastructure security. This deliverable seeks to identify the primary barriers hindering the development of these areas and to propose a strategic vision supported by measurable targets.

The methodology combines quantitative and qualitative analyses, employing specific indicators across three core dimensions: social gap, environmental gap, and economic gap. The ultimate objective is to design policies and interventions that can be scaled and adapted to other European contexts, thereby helping to reduce territorial inequalities and foster an inclusive, sustainable development model.

1. Targets

1.1. National and International Policies: Opportunities for Inner Areas

The National Strategy for Inner Areas (SNAI) is a pivotal Italian policy aimed at fostering territorial development and cohesion in marginal, mountainous, and inland regions. Its primary objective is to combat depopulation and abandonment in these areas, which are often characterized by significant distances from essential service centers such as healthcare, education, and transportation. Despite their peripheral and fragile nature, these areas are endowed with rich natural and cultural resources that hold immense potential for sustainable and inclusive development.

In the short term, SNAI seeks to improve access to and the quality of essential services while promoting projects that enhance local heritage and support regional production chains. In the long term, the strategy aims to reverse negative demographic trends through targeted interventions that generate new income and employment opportunities. The European Cohesion Policy, through its Partnership Agreements, has established criteria for identifying these areas, prioritizing territories facing significant socio-economic and environmental challenges.

During the 2014–2020 programming cycle, SNAI designated 72 inner areas, encompassing over 1,000 municipalities and approximately two million residents. For the 2021–2027 cycle, an additional 56 areas were identified, continuing the mission to strengthen services and

⁴¹ This Paragraph was written by UNINA_DiARCH and UNIBO research group.

promote local development. By 2022, the selection process for these new areas was finalized, reaffirming many previously designated areas and incorporating new priority territories. The National Recovery and Resilience Plan (PNRR) provides a significant boost to SNAI under Mission 5, Component 3, allocating €825 million to enhance education, healthcare, and social services. This funding is divided into two main focus areas: strengthening social infrastructure and community services, and improving local healthcare. An additional €300 million from the complementary plan is earmarked for improving road accessibility in inner areas.

SNAI is structured as a place-based policy initiative that promotes multi-level governance to address demographic and territorial challenges through an integrated approach. The overarching goal is to create favorable conditions for residency and economic development, counteracting demographic decline while preserving and enhancing cultural and natural heritage. This strategic intervention not only aims to reduce territorial inequalities but also serves as a foundation for attracting new economic activities and ensuring high-quality services—critical for revitalizing Italy's inner areas.

This research uses the context of national and international policies as a starting point to identify thematic priorities and interpret the territorial gaps in inner areas, setting specific strategic objectives for these regions. The definition of measurable targets is the first step toward addressing the challenges of inner areas in a structured and coherent manner. These objectives, grounded in analyses of European and national strategies and informed by best practices from scientific literature, provide a clear framework for guiding interventions and tracking progress toward greater territorial equity.

Target 1: Access to Essential Services

The first target focuses on improving access to essential services such as education, healthcare, and digital connectivity. In Italy's inner areas, the average distance to schools and hospitals is significantly greater than in urban zones, adversely affecting residents' quality of life and encouraging younger populations to migrate to cities. By 2025, the strategy aims to ensure that all inner areas have access to high-speed broadband exceeding 100 Mbps, aligning with the European strategy "Europe's Digital Decade." By 2030, the goal is to reduce average distances to schools and hospitals by 30%, thereby fostering greater social inclusion.

Target 2: Ecological Transition and Environmental Sustainability

The second target emphasizes ecological transition and environmental sustainability. Inner areas, often rich in natural resources, face challenges such as inefficient resource management and limited capacity to adapt to climate change. By 2030, the strategy aims to enhance resilience through increased investments in sustainable agricultural practices and water infrastructure. Additional efforts include reducing water losses in local networks, addressing a critical issue for many rural communities.

Target 3: Safety and Economic Management of Hazard-Prone Areas

The third target addresses the safety and economic management of areas at risk from seismic and landslide hazards. Italy's inner areas, frequently exposed to such risks, contain vulnerable building stock that often fails to meet modern safety standards. By 2030, the plan aims to reduce the vulnerability of buildings to landslides and earthquakes through targeted structural consolidation measures, while promoting the regeneration of abandoned building stock.

1.1.2. Accessibility to essential services

Rural areas in Europe face challenges about transport infrastructures, internet speed, access to essential services, that may play a role in attracting economic growth, but also household income, population decline and aging (Castillo et al., 2024). This situation also characterizes the Italian context. Following these challenges, as it is presented in Figure 1, the framework identifies four key dimensions i.e., Stronger, Connected, Prosperous, and Resilient, focused on tackling these challenges by promoting several aspects including access to services and digital connectivity. The EU Rural Vision (EU, Rural Vision) and associated studies highlight those rural areas, especially in Italy, suffer from poor transport connections, digital infrastructure gaps, and limited access to essential services such as healthcare and education. These issues hinder economic growth, exacerbate population decline, and restrict the quality of life for residents.

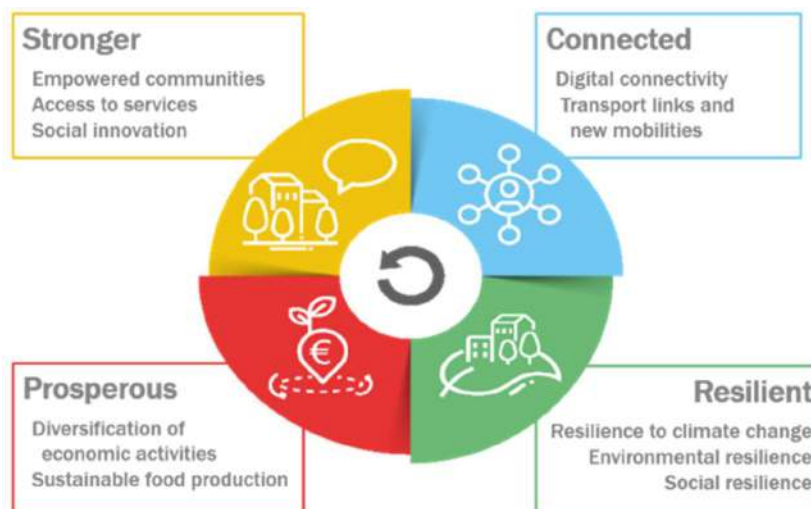


Figure 1: Ten shared goals of a long-term vision for rural areas by 2040 (EU, Rural Vision)

On the other hand, the COVID-19 pandemic has shifted perceptions of rural areas. According to the Flash Eurobarometer survey results⁴², while 30% of EU citizens are now more likely to visit rural areas for leisure purposes, 45% in Italy express reluctance to relocate to rural regions (Eurobarometer, 2021). This post-pandemic shift highlights the need to make inner areas more attractive through improved infrastructure, which can enhance accessibility and encourage population movement back into these regions.

The need for better access to healthcare and education is another major concern. In both the EU and Italy, 27% of respondents highlighted healthcare as a key need (Eurobarometer, 2021). In Italy's inner areas, the average distance to healthcare facilities and schools often exceeds national and EU averages, making it harder for residents to access basic services. According to Castillo et al. (2024), the population living in remote rural areas needs to travel more than five times to reach these public services compared with people living in cities and almost 40%

⁴² The Flash Eurobarometer survey was commissioned by the EC's Directorate-General for Agriculture and Rural Development to gather inputs from EU citizens to complement the results of the open public consultation of the long term Vision for Rural Areas (the Vision), thus contributing to assessing which priorities the Vision should focus on.

of the remote rural areas present distances to services much longer than the EU average. Addressing these gaps by improving physical infrastructure and service delivery will be crucial to reversing the trend of depopulation and improving the well-being of residents.

As with other territorial issues, the National Recovery and Resilience Plan (NRRP) includes investment lines addressing education, focusing both on accessibility and quality. Mission 4—Education and Research—targets these aspects, structured into two components: C1—Enhancement of Education Services from Early Childhood to Universities, and C2—From Research to Business. Under the Minister of Education's decree No. 66, issued on April 12, 2023, a portion of available funds, totaling €450 million, is allocated within Mission 4, Component 2, to Investment Line 2.1, "Integrated Digital Learning and Digital Transition Training for School Staff." This investment aims to promote the "creation of a multidimensional system for the continuous training of teachers and school staff in digital transition," involving approximately 650,000 educators and school staff across more than 8,000 educational institutions. These initiatives are essential for improving learning quality and accelerating innovation within the education system. They include the development of a national center for digital education to train teachers and school staff, the establishment of an integrated network of regional training centers, and the creation of a catalog offering around 20,000 training courses covering all school curriculum subjects. Additionally, a platform will be developed to provide digital education content and innovative teaching methodologies for teachers, students, and families. The plan also involves establishing inclusive and sustainable "Digital Education and Future Skills Agreements."

Transport is the most frequently mentioned need in rural areas, with 44% of respondents across the EU identifying it as critical. In Italy, this percentage rises to 46%, underscoring the importance of developing better road and public transport links to connect isolated regions to urban centers (Eurobarometer, 2021). Indeed, more than 70% of remote rural areas in Europe have lower transport performance than the EU average (Castillo et al., 2024). Many Italian inner areas struggle with access to services like supermarkets, healthcare, and educational facilities, with a significant portion of the population unable to reach these essential services by public transport. This situation demands a strategic focus on improving transport links, which will reduce isolation and foster regional economic development.

Digital connectivity is becoming increasingly vital for rural areas, with 26% of EU respondents mentioning digital infrastructure as a pressing need (Eurobarometer, 2021). Italy mirrors this trend, where digital infrastructure remains underdeveloped in many inner areas. Improving broadband and mobile network access is essential to support remote work, e-commerce, education, and telemedicine. The targets of digital strategies in the EU can serve as a benchmark for Italy, aiming to achieve 100 Mbps broadband coverage in rural areas by 2025 (Europe's Digital Decade), which will be critical in ensuring that inner areas are not left behind in the digital transition.

Studying infrastructure and accessibility in Italy's inner areas is crucial for addressing the pressing challenges that rural communities face. Improvements in transport, digital connectivity, healthcare, and education will not only align with the broader EU Rural Vision but also ensure that Italy's inner regions become more connected, resilient, and economically viable.

1.1.3. *The Ecological Transition for Agricultural Productivity in Marginal Areas*

The latest European policy related to the ecological transition of agricultural assets is embodied in the Common Agricultural Policy (CAP) for the period 2023–2027⁴³. The CAP aims to strengthen the vitality and economic sustainability of rural areas through funding and actions aimed at fostering their development.

The CAP also supports the sustainable development of rural areas through three long-term objectives: promoting the competitiveness of agriculture and forestry, ensuring sustainable management of natural resources and climate action, and achieving balanced development of rural economies and communities. It is funded by two European funds: the European Agricultural Guarantee Fund (EAGF) and the European Agricultural Fund for Rural Development (EAFRD).

The CAP came into effect on January 1, 2023, to support farmers and rural stakeholders across the 27 EU Member States, while also reinforcing pre-existing policies such as the European Green Deal⁴⁴, the Farm to Fork Strategy⁴⁵, and the Biodiversity Strategy for 2030⁴⁶.

At the national level, the key component is Component 1, “Sustainable Agriculture and Circular Economy,” under Mission 2, “Green Revolution and Ecological Transition,” of the National Recovery and Resilience Plan (PNRR), which targets two essential sectors: agriculture and waste management. This initiative has launched numerous calls to foster innovation within the agricultural sector.

The aforementioned policies have spurred a series of research projects, many of which have already been completed, including:

GRASSMARGINS⁴⁷: Funded by the EU, this project identified perennial grasses most suitable for cultivation on marginal, non-arable lands, promoting biomass production and contributing to the sustainability of marginal agricultural areas.

Agroecology⁴⁸: The adoption of agroecological practices is encouraged at both the European and national levels to enhance sustainability and resilience in internal and marginal agricultural areas. These practices encompass crop diversification, efficient resource use, and biodiversity conservation. Within this Results Pack, funded projects such as DIVERSify, Diverfarming, and DiverIMPACTS highlight the various ways in which agroecology can support sustainable agriculture and environmental protection.

The Water Framework Directive (2000/60/EC) is the main regulatory pillar for the protection and management of water resources in Europe. This directive establishes a comprehensive legal framework for the protection of inland, coastal, and groundwater, aiming to achieve “good ecological status” for all EU waters by 2027⁴⁹. The key principles of the directive include the river basin approach, participatory management, and the “polluter pays” principle. The European Commission has deemed the directive largely fit for purpose but has noted

⁴³https://agriculture.ec.europa.eu/common-agricultural-policy_i

⁴⁴https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

⁴⁵https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

⁴⁶https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

⁴⁷<https://cordis.europa.eu/article/id/92681-growing-grasses-on-the-margins-the-route-to-cost-effective-biomass-crops/it>

⁴⁸<https://cordis.europa.eu/article/id/430692-agroecology-transitioning-toward-sustainable-climate-and-ecosystem-friendly-farming-and-food/it>

⁴⁹eur-lex.europa.eu

significant delays in achieving its objectives. In this regard, the Common Agricultural Policy (CAP)⁵⁰ could incentivise sustainable farming practices in the EU by making payments conditional on compliance with environmental standards. Regarding water use, sustainable agriculture is among the current strategic objectives of the CAP and the proposals for the post-2020 CAP.

The Water Framework Directive is complemented by the Groundwater Directive (2006/118/EC)⁵¹, which sets strict limits for pollutants and establishes monitoring requirements, and the Drinking Water Directive (2020/2184)⁵², which updates previous standards by including new quality criteria and promoting practices to reduce excessive water consumption.

The Circular Economy plays an essential role in the sustainable management of water resources in agriculture. The EU Regulation on Water Reuse for Agricultural Use (2020/741)⁵³ provides a harmonised framework for the reuse of treated wastewater, aiming to reduce dependency on freshwater resources. The regulation sets minimum criteria for wastewater treatment to ensure suitability for agricultural irrigation and encourages Member States to promote reuse practices in areas affected by water stress.

Aligned with the objectives of the European Green Deal, the Farm to Fork Strategy promotes agricultural practices that minimise the use of pesticides and fertilisers, thereby reducing their impact on water quality. This strategy is part of a broader plan to enhance the sustainability of the European agri-food system, targeting pollution reduction and the protection of aquatic ecosystems. The EU Strategy on Adaptation to Climate Change⁵⁴ further reinforces the EU's commitment to building climate resilience by promoting efficient irrigation technologies and integrated water resource management to address climate change challenges.

The EU has established several specific research and development programmes to support innovation in water management, particularly in agriculture and marginal areas:

PRIMA Programme (Partnership for Research and Innovation in the Mediterranean Area)⁵⁵: Supports research and innovation projects that develop solutions for the sustainable management of water resources in agriculture in Mediterranean regions.

Water4All⁵⁶: A European partnership supporting research projects on topics such as climate resilience and sustainable water use, with an active 2023 call for transnational projects aimed at improving the adaptation of water resources to climate change.

In Italy, the transposition of European directives is implemented through a complex regulatory and governance framework that includes national laws, regional plans, and local agreements. A key instrument is the River Contracts (Contratti di Fiume, CdF), introduced to address the challenges of integrated water resource management. The European Agricultural Fund for Rural Development (EAFRD)⁵⁷ provides significant financial support for projects aimed at improving water resource use in agriculture. Through the EAFRD, Italy has developed numerous programmes to encourage water efficiency and adopt innovative solutions for water

⁵⁰https://agriculture.ec.europa.eu/common-agricultural-policy_i

⁵¹<https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX%3A32006L0118>

⁵²<https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32020L2184>

⁵³<https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32020R0741>

⁵⁴https://ec.europa.eu/commission/presscorner/detail/it/ip_21_663

⁵⁵obiettivoeuropa.com

⁵⁶mimit.gov.it

⁵⁷politicheagricole.it

management in agricultural areas, especially those most vulnerable to the effects of climate change.

The National Recovery and Resilience Plan (NRRP), in collaboration with the Ministry of Agriculture, Food, and Forestry Policies, not only funds various projects to improve water infrastructure but also includes specific measures to enhance irrigation efficiency and reduce losses in the national water network⁵⁸.

1.1.4. Built Heritage and Natural Risks in Marginal Territory

The European Union has adopted a comprehensive approach to managing natural risks, particularly in marginalized and earthquake-prone areas, recognizing the need for coordinated, multidimensional strategies. Central to this framework is the integration of socio-economic resilience with innovative technological solutions. Programs such as NEXTAPPENNINO, funded through the Complementary Fund to the National Recovery and Resilience Plan (PNRR), illustrate the EU's commitment to revitalizing regions affected by seismic events, notably in Central Italy. This initiative focuses on strengthening social and economic infrastructure, fostering local excellence, and promoting sustainable employment growth.

Projects like REAKT, supported by the EU between 2011 and 2014, emphasize the development of high-sensitivity seismographs and early warning systems, addressing vulnerabilities across Southern Europe and the Black Sea regions. These efforts highlight the EU's emphasis on data-driven strategies and advanced monitoring to mitigate seismic risks. Similarly, initiatives under the PNRR, such as "Recovery Art," prioritize seismic safety in cultural heritage sites, aiming to protect and restore structures vital to community identity while fostering socio-economic revitalization through skilled employment and youth engagement.

The LINKS project further exemplifies the EU's holistic approach by focusing on strengthening the connections between technology and society. By promoting advanced learning on the use of social media and crowdsourcing in disaster management, LINKS aims to enhance community resilience through integrative research involving risk perception, disaster governance, and community technologies. This framework ensures that policymakers, researchers, and practitioners are equipped with practical tools and scientific methods to navigate complex disaster scenarios.

Overall, European policies underscore the importance of cross-disciplinary integration, where research outcomes are closely linked with real-world applications, ensuring that stakeholders—from policymakers to local communities—actively contribute to and benefit from these advanced risk management strategies. This comprehensive approach not only addresses immediate vulnerabilities but also builds long-term resilience in marginalized territories.

⁵⁸<https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/14869#main>

2. Vision

Contrary to the traditional perception of inner areas as marginal territories needing to be "bridged," the strategy outlined in this deliverable adopts a different perspective: inner areas are spaces rich in potential, capable of becoming laboratories for sustainable innovation and social inclusion. Realizing this transformation requires an integrated approach centered on three core themes: social inclusion, environmental sustainability, and infrastructural resilience.

Inner areas must ensure equal opportunities for all citizens by guaranteeing access to essential services and reducing isolation. Digitalization, for example, can be a strategic tool for overcoming geographical barriers, connecting even the most remote territories to basic services such as healthcare and education. However, social inclusion extends beyond accessibility—it entails fostering cohesive communities where individuals have access not only to services but also to opportunities for participation, growth, and personal development.

The second pillar focuses on environmental sustainability, emphasizing the responsible management of natural resources and the adoption of innovative production practices. With their abundant environmental assets, inner areas have the potential to play a crucial role in combating climate change. Investing in sustainable agriculture, efficient water resource management, and the prevention of hydrogeological risks not only protects these territories but also generates new economic opportunities.

The third pillar addresses infrastructural resilience, encompassing the safety of built heritage and urban regeneration. Enhancing the safety of buildings and infrastructure is not merely a technical concern but a vital prerequisite for attracting investment and improving quality of life. Moreover, urban regeneration presents an opportunity to repurpose abandoned buildings into valuable community assets, creating modern, sustainable residential and productive spaces.

This vision seeks to break the cycle of marginalization that has historically defined inner areas, transforming them into attractive and thriving territories at the heart of sustainable development.

3. Gap Analysis

To understand and quantify the disparities present in Italian municipalities, a methodological approach that integrates various indicators and territorial data in a precise and rigorous manner is necessary. The analysis of gaps begins with the selection and normalization of six key indicators that allow for the assessment of social, environmental, and economic aspects.

The normalization of data is a crucial step to ensure that the values of the indicators are comparable with one another. The MIN-MAX rule was used to scale the data to a common range from 0 to 1. This range was chosen to precisely identify extreme vulnerabilities (values close to 0) and high sustainability conditions (values close to 1). Such normalization makes it possible to evaluate and identify significant gaps in Italian municipalities, with particular attention to inland areas.

The gap analysis was conducted using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) evaluation method. This method is part of the branch of multi-criteria analysis (Huang et al. , 2011). This method takes the basic concept that the preferable option should have (in Euclidean space) the “shortest distance” from the “ideal solution” and the “greater distance” from the “non-ideal solution”. Note that the concept of “distance” could be interpreted in various ways, but the TOPSIS uses geometric interpretation, i.e., referring to the Euclidean distance. The criterion of the Euclidean distance was then used to evaluate the relative proximity of the offers to the final solution, and the final order of options preference is obtained by comparing these relative distances (Çelikkilek & Tüysüz, 2020).

The software used for the entire project was QGIS, which allows data from different sources to be merged into a single territory analysis. Data, split into layers, can be analyzed and the ensuing image map is created with the thematism that can be customized by the user and eventually complies with typical GIS analyses, such as color gradation, color gradient and unique value.

In particular, the VectorMCDA plugin contains seven algorithms that refer to many multi-criteria evaluation methods (Rocchi et al. 2015) and, in this case, taking into account the quantitative nature of the available data, the TOPSIS method was used (Technique for Order of Preference by Similarity to Ideal Solution), explained by the “geo-TOPSIS” algorithm. The tool belongs to the vectorMCDA category, which is a QGIS plugin that utilizes various MCDA (multi-criteria decision analysis) algorithms to perform multi-criteria analysis within a GIS framework and was developed by the Environmental Laboratory of the University of Perugia (Massei, 2015).

Once the data was normalized, the indicators were combined into a single composite index to provide an overview of the environmental, social, and economic conditions. This aggregation process was carried out using a geometric technique that prevents total compensation between variables. In this way, municipalities with high values in one indicator but low in another are not mistakenly classified as sustainable; rather, the real disparities between adaptive capacity and vulnerability become evident.

This quantification of territorial gaps was supported by a geographical analysis that allowed for the visualization of the most critical areas.

The indicators used for the Gap Analysis were developed in Deliverable 3.2 'Interactive Maps on Local Vulnerability'. The descriptions of the indicators are briefly reported in each section.

These represent key indicators for describing gaps through vulnerabilities and are as follows:

For detailed descriptions and bibliographical references, please refer to the Deliverable 3.2.

<i>Gap Analysis dimensions</i>	<i>Typology</i>
Social Gap Analysis	
<i>Map A.1 – Vulnerability of accessibility to school offer</i>	<i>cost</i>
<i>Map B.3 - Index of real estate abandonment due to lack of digital coverage</i>	<i>gain</i>
Environmental Gap Analysis	
<i>Map C.1 - Index of ecological transition of agricultural asset</i>	<i>gain</i>
<i>Map C.2 - Sustainable agricultural index for water resources</i>	<i>gain</i>
Economic Gap Analysis	
<i>Map D.1 – Indicator of exposed buildings to landslide hazard at municipal scale</i>	<i>gain</i>
<i>Map D.6 - Indicator of exposed buildings to seismic hazard at municipal scale</i>	<i>gain</i>

Table 3/a: Gap analysis indicators

The indicators were paired based on the prevalence of their vulnerability: social, environmental, and economic. For each of these dimensions, a partial assessment was generated using the TOPSIS evaluation method. The three partial assessments were then integrated into a final evaluation, also using TOPSIS. To highlight disparities more clearly, an aggregation was carried out based on the geographical proximity of municipalities, and an average of the final evaluation was calculated. This approach allows the generation of zones that display disparities according to territorial conditions.

These indicators are essential for assessing vulnerability and conducting gap analysis within inner areas, as they provide a detailed view of the specific deficiencies and risks that impact the welfare and sustainability of these regions. By emphasizing the socio-spatial gaps, each indicator sheds light on different aspects that, without targeted intervention, could deepen the marginalization of these territories.

Vulnerability of accessibility to school offer is a critical factor for inclusive development, as education represents a fundamental tool for reducing social and economic vulnerability, improving growth prospects, and fostering local stability. Limited access to education equates to fewer opportunities, thus intensifying the peripheralization of residents in these areas.

The indicator of **real estate abandonment due to lack of digital coverage** highlights a significant obstacle to resilience in inner areas. The absence of digital infrastructure not only stifles economic innovation and the development of new activities but also restricts access to essential services, which increasingly rely on digital technologies. This digital isolation

exacerbates the gap with more connected and developed areas, furthering these territories' peripheralization.

The **index of ecological transition of agricultural assets** holds strategic importance, as agriculture in inner areas, though often neglected and subject to abandonment, represents a resource that could be revitalized with proper investment. Transitioning toward more sustainable and environmentally respectful agricultural practices is crucial for preserving local natural capital and sparking economic revival, transforming agricultural abandonment into opportunity.

The **sustainable agricultural index for water resources** draws attention to the importance of monitoring agricultural areas in light of hydrogeological risks. Inner areas are often prone to landslides and floods, events that—if not countered by targeted investments and preventive measures—heighten the risk of peripheralization. Managing these risks sustainably is essential to protect not only agriculture but also local communities, enhancing both safety and resilience.

Finally, the indicators of **exposed buildings to landslide hazard** and **exposed buildings to seismic hazard** highlight the inherent vulnerability of many inner municipalities, often located in areas prone to seismic and hydrogeological events. These risks threaten the security and integrity of urban and rural infrastructure, underscoring the urgency of implementing interventions that protect communities and reduce isolation risks. Without targeted investments, these hazards contribute to the marginalization of inner areas, widening their gap from the rest of the country.

3.1. Social Gap Analysis

The Italian territory, marked by a complex interplay between often marginalized inner areas and expansive metropolitan zones driving regional urbanization towards central Italy, is confronted with significant social challenges. Many of these are linked to the accessibility of essential services and the availability of digital infrastructure. Two key indicators provide insight into these dynamics: the vulnerability of accessibility to school provision and the index of real estate abandonment due to inadequate digital coverage.

The **vulnerability of accessibility to school offer (MAP A.1)** assesses the average minimum distance between residences and primary, lower secondary, and upper secondary schools, using benchmarks established by the 1975 ministerial decree. This indicator reveals that, especially in inner and peripheral regions of the country, distances to schools increase with the educational level, highlighting conditions of vulnerability that impede access to education and restrict student mobility. By extending the analysis beyond municipal borders, a more comprehensive view of school catchment areas is achieved, underscoring the need for targeted policies to shorten these distances, improve accessibility, and foster educational inclusion.

The **index of real estate abandonment due to lack of digital coverage (MAP B.3)** emphasizes the connection between poor technological infrastructure and property abandonment, particularly in rural areas. Broadband access is a critical driver of regional development: its

uneven distribution deepens economic disparities, limits service accessibility, and encourages depopulation.. The index, derived from municipal data on average download speeds and the percentage of unoccupied housing, highlights how insufficient digital infrastructure depresses property values, discourages investments, and prompts migration to better-connected areas. This indicator forms the basis for policy interventions designed to close the digital divide between urban and rural zones, revitalizing the most vulnerable areas and promoting balanced regional development.

The purpose of this gap analysis is to identify territorial disparities that hinder access to school services and digital connectivity, aiming to develop strategies to address these vulnerabilities. Both indicators point to a complex scenario where the economic dimension is tightly interwoven with the infrastructural development of the territory. Enhancing access to educational services and ensuring widespread digital connectivity represent not only crucial challenges for the economic resilience of the country but also significant opportunities to bolster social cohesion and counteract the trends of abandonment and depopulation affecting many parts of Italy.

3.1.1. Description and quantification of the gap

The specific assessment of gaps for each of the two selected indicators (see figure 3.1_1) is crucial for understanding the dynamics that influence territorial cohesion and socio-economic development in inner areas. The A.1 and B.3 indicators, analyzed using the TOPSIS evaluation tool, offer complementary perspectives: the first highlights the vulnerability of municipalities in terms of accessibility to school services, while the second assesses the impact of inadequate digital infrastructure on real estate abandonment. Both indicators allow for the identification of discontinuities that hinder the inclusion and competitiveness of territories, providing essential data for policies aimed at bridging the urban-rural divide and promoting sustainable, integrated development.

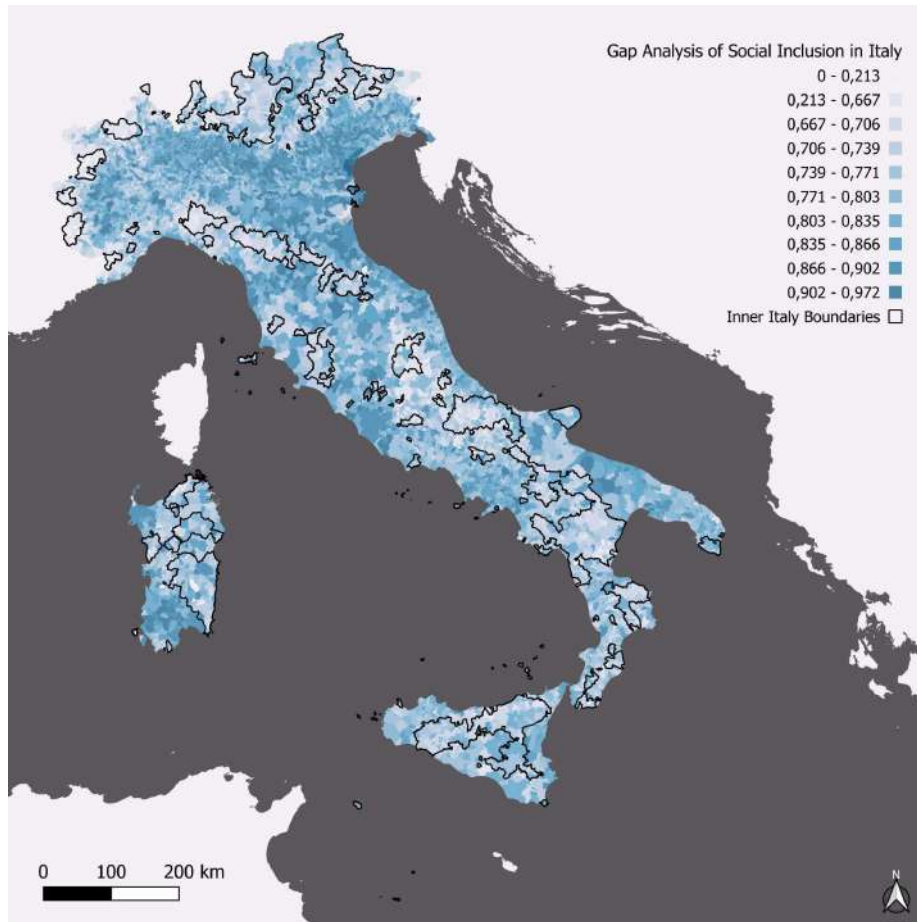


Figure 3.1_1: Gap Analysis of Social in Italy

The indicator developed to integrate the two indices (A.1 and B.3) provides an overview based on representative indicators of social vulnerability and housing resilience, expressed in digital terms, for municipalities in Italy's inner areas. The thematic map uses a scale ranging from 0 to 0.972 and employs a gradient of blue colors to represent different value ranges:

- **0 - 0.667:** Municipalities within this range, depicted in very light shades of blue, represent areas with the highest levels of vulnerability. These municipalities display significant gaps in access to both school and digital services, highlighting infrastructural deficiencies that could hinder connectivity and educational inclusion, with economic repercussions stemming from depopulation.
- **0.667 - 0.866:** This range indicates an intermediate level of performance and encompasses all three territorial typologies. Municipalities within this category are largely part of Intermediate Italy. Many municipalities, including several provincial capitals within Metropolitan Italy, fall into this range. The municipalities of Inner Italy represented in this interval are those on the outer edges, geographically more connected to Intermediate Italy. Specifically, those in the lower end of this range (0.667-0.706) include some sparsely populated inner areas which, likely due to tourism, exhibit a sufficient level of efficiency in the analyzed infrastructures.

- **0.866 – 0.972:** Municipalities within this range, shown in dark blue, demonstrate the best performance in terms of school and digital accessibility. These values are primarily concentrated in Metropolitan Italy, especially within the urban fringe or suburban belt, as well as in Intermediate Italy.

3.1.2. *Description and quantification of the gap in Inner Italy*

The indicator developed to integrate the two indexes (A.1 and B.3) offers a perspective based on indicators representing social vulnerability and housing resilience, particularly in digital terms, for municipalities within the inner areas of Italy. The thematic map (see figure 3.1_2) uses a scale from 0 to 0.972, employing a gradient of blue shades to denote different value ranges:

1. **High Gap Areas (from 0 to 0.667):** This range captures the lowest values. The subcategories of Inner Italy included in this range are “Inner remote and sparsely populated area” and “Sparsely populated inner area closest to a metropolitan area.” Mountainous regions are more prominently affected by such vulnerabilities. Even though some central areas of Inner Italy are closer to well-connected regions, they still exhibit infrastructural gaps, as seen in the case of L’Aquila. This phenomenon is not limited to the most remote areas but also affects those closer to urban centers that likely depend on them for essential services. Low population density is both a discriminating factor and a consequence of this condition. Such low values, indicating significant gaps, are present across almost all Inner Italy, with the exception of Puglia and with lower intensity in Tuscany. They are particularly visible in the Inner Italy of Valle d’Aosta, Piedmont, Lombardy, Liguria, and Abruzzo–Molise, manifesting prominently in the Northwest and Central Italy. In other parts of the country, the phenomenon appears less entrenched.
2. **Medium Gap Areas (0.667 to 0.835):** This range encompasses all four territorial types within Inner Italy, making it the most widespread interval of values. The lower values (0.667–0.706, 0.739–0.771 and 0.771–0.803) mainly pertain to the “Inner remote and sparsely populated area” category, which is nonetheless present across all intervals. The territorial types of Inner Italy closest to more infrastructured and medium-density areas (“Sparsely populated inner area closest to a metropolitan area” and “Inner area with medium population density closest to a metropolitan area”) are mostly concentrated in the higher end of the medium vulnerability range. No clear physiographic disparity is evident; the vulnerabilities represented by these gaps are present equally across mountainous, hilly, and coastal regions. This range of values emerges as a widespread social gap. In the inner areas of Trentino Alto Adige, Friuli–Venezia Giulia, Emilia–Romagna, Campania, Basilicata, Calabria, Sicily, and Sardinia, the lowest values are recorded. In the inner areas of Campania (Alta Irpinia and Cilento), the gap forms a significant socio-economic vulnerability alongside Basilicata.
3. **Low Gap Areas (0.835 to approximately 1):** This range includes municipalities belonging to all territorial types of Inner Italy. However, such low vulnerability, indicating a minimal social gap, is absent in the Northwest, as well as in Tuscany, Marche, Umbria, and the inner areas of Southern Campania (Cilento and Alta Irpinia). Some pockets of low vulnerability are present in Sardinia.

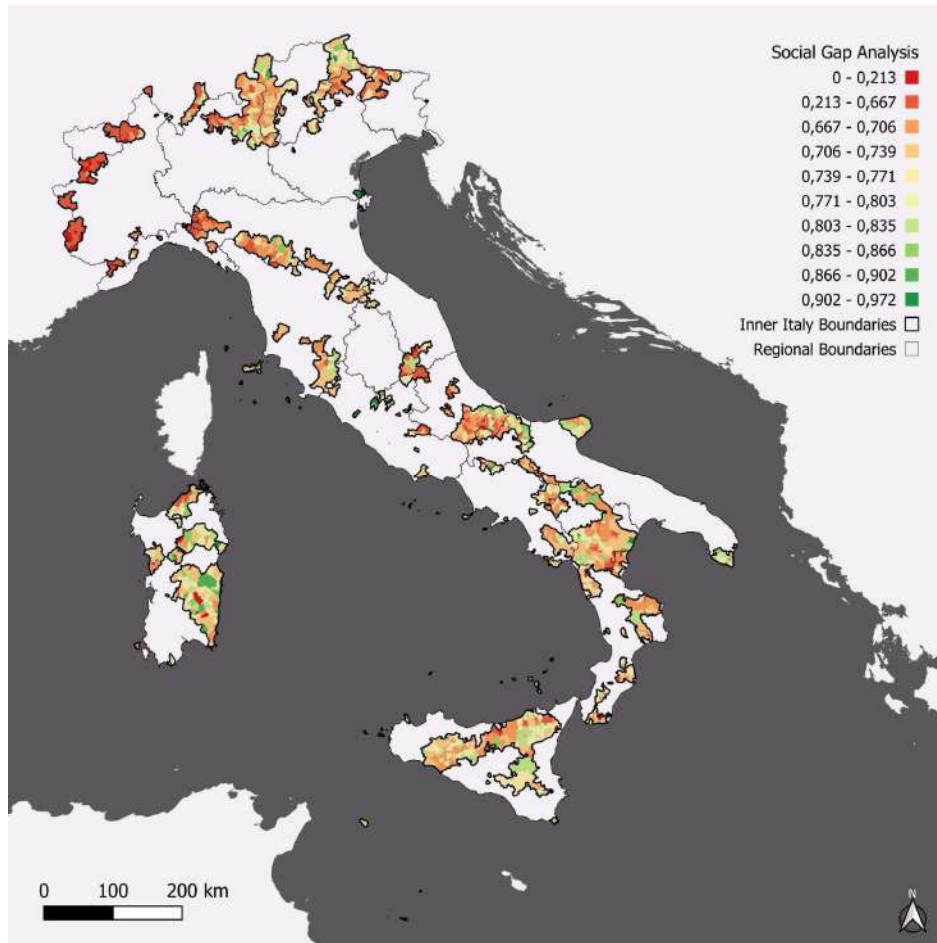


Figure 3.1_1: Gap Analysis of Sustainable Environment in Inner Italy

Inner Italy includes municipalities classified as "Inner remote and sparsely populated area," "Inner and remote area with medium population density," "Sparsely populated inner area closest to a metropolitan area," and "Inner area with medium population density closest to a metropolitan area." Within these municipalities, values are highly variable, and the social gap is reflected through levels of vulnerability (high, medium, low). High vulnerability is especially visible in mountainous areas of the Northwest, Liguria, the Tuscan-Emilian Apennines, and inner regions shared by Umbria, Marche, and Abruzzo, as well as in those spanning Abruzzo and Molise. Medium values of vulnerability are concentrated in the inner areas of Northeast Italy, lower Tuscany, Campania, Puglia, Sicily, and Calabria. Low vulnerability is sporadically present, particularly in areas closer to regional centers and with medium population density.

This gap is exacerbated by geographical isolation and a lack of efficient connectivity, which makes it harder for local communities to access educational and digital opportunities, thus increasing vulnerability to depopulation and social and economic marginalization. In many of these municipalities, the combination of insufficient digital infrastructure and difficulties in accessing local schools creates significant barriers to social and economic growth. The gap underscores a shortage of investment in digital infrastructure and a lack of local policies that encourage new strategies in education and, more broadly, on civic standards that allow for social growth and the possibility of experiencing a different dimension from the urbanity of

metropolitan or intermediate areas. The significant divide between inner and better-connected urban zones creates spatial and social inequalities that prioritize "concentration," in this case of population, as the primary target for territorial investments.

3.1.2.1 Description and quantification of the gap, an example in Inner Abruzzo

Digging into specific case studies which are relevant according to the gap analysis results, specific considerations on the role of accessibility to basic services affecting the social gaps can be posed. By considering Abruzzo as representative of a highly vulnerable territory, it stands as a strong case for further study in terms of social gaps, given its extreme accessibility to some services.

Starting from considering the accessibility to education services, the average distance to primary schools (see Figure 3.1_2) in Abruzzo inner areas is 15.26 km, whereas the national inner and national overall average is 12.78 km and 8.71 km respectively. The map shows a non-well distribution of this service, with a concentration of areas well above the average in inner areas of Chieti province.

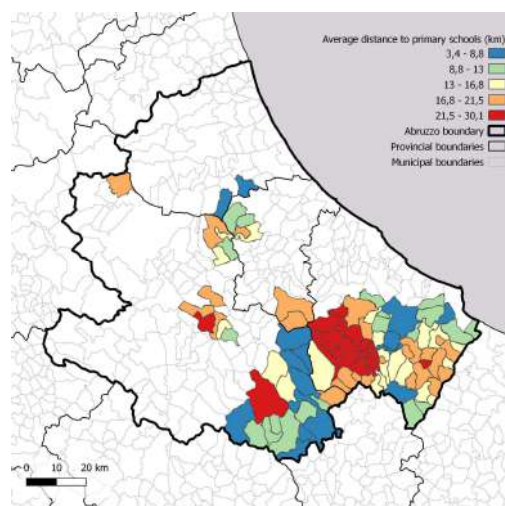


Figure 3.1_2: Average distance to primary schools in inner Abruzzo (data source: Rural observatory)

The situation is worse when it comes to the accessibility to secondary schools (see Figure 3.1_3) Abruzzo's inner areas experience an average distance of 28.77 km to these education services, well above the national inner-area average of 22.74 km. This suggests that secondary educational infrastructure is a significant challenge in Abruzzo, with residents facing longer commutes to access schooling compared to other regions, thus limiting opportunities in terms of access to education. Moreover, while some municipalities benefit from close proximity to primary schools, others, particularly in mountainous areas of Chieti and L'Aquila provinces, face significant accessibility challenges, with travel distances more than 33 km.

Given its above-average distance, Abruzzo stands as a key case for examining how educational facilities can be improved and made more accessible, especially in regions where geographic barriers like mountains and rural landscapes exacerbate these challenges.

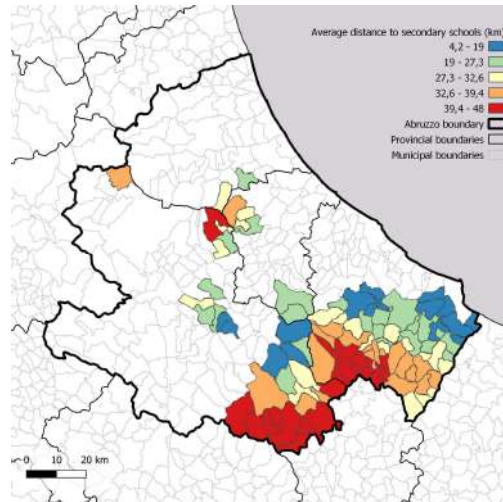


Figure 3.1_3: Average distance to secondary schools in inner Abruzzo (data source: Rural observatory)

For sure access to education may limit the possibility of the younger generation to stay in or be attracted by rural life, however education is not the only service that affects the quality of life and possibility to live in inner areas from the actual and future residents. Access to healthcare facilities (see Figure 3.1_4) is a key indicator (Castillo et al., 2024), representing another important challenge. In Abruzzo's inner areas, the average distance to healthcare facilities is 22.47 km, closely mirroring the national inner-area average of 22.64 km. This places Abruzzo in a representative position for studying healthcare accessibility challenges. The proximity to healthcare services in Abruzzo reflects the broader issues seen across Italy, where residents in inner areas face significant barriers in accessing essential health services. By analyzing the map it is possible to see that in this case the situation is more jeopardized underlying a different localization rule concerning healthcare services if compared to education.

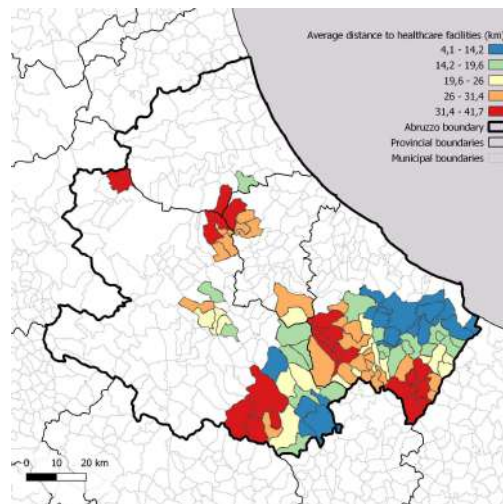


Figure 3.1_4: Average distance to healthcare facilities in inner Abruzzo (data source: Rural observatory)

Transport accessibility is another important aspect worsening social gaps in rural areas, since it has a strong impact on most vulnerable residents who do not have access to private cars, such as youngsters, older people, and people with disabilities. (Velaga et al., 2012). Distance to train stations (see Figure 3.1_5) is a relevant indicator measuring the lack of accessibility in terms of public transport. If we consider the situation in Abruzzo inner areas, with an average distance of 28.58 km to train stations, they align closely with the national inner-area average of 29.40 km. The worst cases are distributed in the mountainous areas of Chieti and L’Aquila provinces.

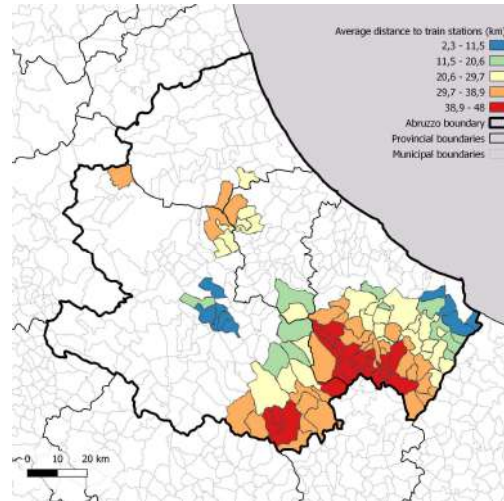


Figure 3.1_5: Average distance to train stations in inner Abruzzo (data source: Rural observatory)

Together with transport accessibility, telecommunications is another fundamental driver for social cohesion and rural development, easing rural-urban connections and virtual proximity (Camarero and Oliva, 2019). Unlike what happens with accessibility, which is affected by geographical as well as infrastructural conditions, the digitalisation of rural territory follows very varied geographies, for which it becomes difficult to find a rule. In the case of Abruzzo, it stands out for its fixed broadband network speed (see Figure 3.1_6), with an impressive average of 7270.73 Mbps in inner areas, far surpassing the national inner-area average of 5332.52 Mbps, while the mobile broadband network speed (see Figure 3.1_7) in the Region (3788.18 Mbps) is in line with the national average (4581.11 Mbps). The broadband speed (both fixed and mobile) does not have a homogeneous distribution varying a lot between bordering municipalities. This disparity in digital infrastructure can impact economic growth, education, and access to services, making it crucial to focus on improving digital connectivity in underserved areas.

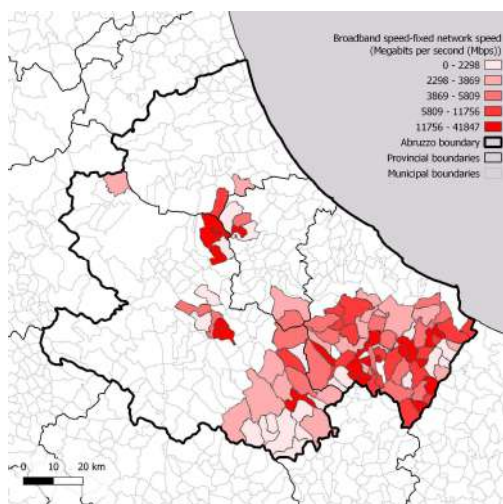


Figure 3.1_6: Broadband speed (fixed network speed) in Inner Abruzzo (Mbps) (data source: Rural observatory)

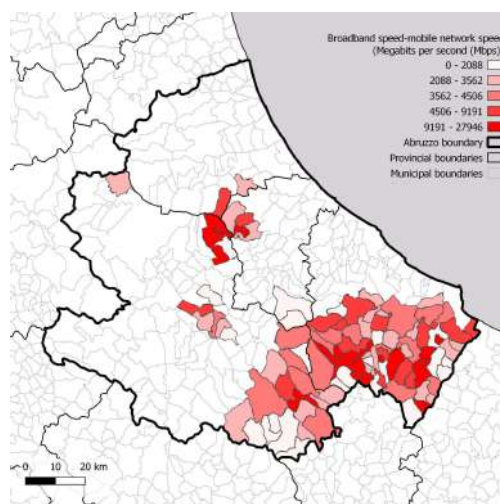


Figure 3.1_7: Broadband speed (mobile network speed) in Inner Abruzzo (Mbps) (data source: Rural observatory)

3.2. Environmental Gap Analysis

The territory of Italy, characterized by a vast agricultural area and a territorial diversity ranging from mountainous to coastal regions, faces crucial challenges, particularly in the environmental domain. In this context, the ecological transition and sustainable management of water resources represent significant challenges, especially within the framework of an agriculture sector that spans large areas and constitutes a substantial part of the national economy. The Italian agricultural sector, marked by a high diversity of crops and production techniques, is increasingly under pressure due to climate change, the need to innovate agricultural practices, and the imperative to safeguard natural resources. In a rapidly evolving climate scenario, with extreme weather events becoming more frequent, it has become essential for Italian municipalities to adopt a resilient and sustainable approach.

The National Recovery and Resilience Plan (PNRR), through its Mission 2 "Green Revolution and Ecological Transition," aims to address these challenges by providing financial resources to support the agricultural sector in its path towards greater sustainability. However, despite efforts to align agriculture with European ecological directives and the Sustainable Development Goals (SDGs) of the 2030 Agenda, significant territorial disparities emerge, making it difficult to achieve a uniform transition across the country. Some areas, especially rural and inland regions, suffer from a lack of targeted investments, remaining vulnerable both economically and environmentally.

The objective of the gap analysis is to identify and quantify the existing disparities between Italian municipalities, particularly those in internal areas, by specifically analyzing two key indicators: the *Index of Ecological Transition of Agricultural Assets* (Map C.1) and the *Sustainable Agricultural Index for Water Resources* (Map C.2). These indicators allow for a better understanding of the municipalities' vulnerability levels in relation to their ability to adapt and innovate in the agricultural context and in the sustainable management of water resources. In

this report, we use these tools to highlight territorial gaps, providing a detailed analysis of critical issues and opportunities for improvement.

In particular, the *Ecological Transition of Agricultural Assets* (Map C.1) evaluates the vulnerability of Italian municipalities in adopting sustainable and circular agricultural practices, in relation to the investments received under the National Recovery and Resilience Plan (PNRR). The objective is to identify which municipalities are less vulnerable due to the available and received investments aimed at accelerating the ecological transition and which, despite having agricultural land used for productive purposes, do not receive funding to transition towards more sustainable agriculture.

On the other hand, the *Sustainable Agro-Forestry Index for Water Resources* (Map C.2) assesses the vulnerability of municipalities in facing hydraulic threats (such as floods and overflows), the harmful effects, and the damage generated by hydrological risks on agro-forestry assets, in relation to specific investments they receive. These investments include, for example, interventions related to hydrogeological risk mitigation, rewilding of areas, the design of primary water infrastructure for water security, and investments aimed at reducing losses in water distribution networks, including the digitization and monitoring of these networks.

The objective of the gap analysis is to identify and quantify the existing disparities between Italian municipalities by integrating the two indicators to understand the degree of vulnerability of municipalities in relation to their capacity to adapt and innovate within the agricultural context and in the sustainable management of water resources. In this report, we use these tools to highlight territorial gaps, providing a detailed analysis of critical issues and opportunities for improvement.

3.2.1. Description and quantification of the gap

The specific assessment of the gaps (See *Figure 3.2_1*) for each of the two selected indicators is essential for understanding the dynamics that influence the ecological transition and water resource management. Indicators C.1 and C.2 provide a complementary perspective: while C1 focuses on the vulnerability of municipalities in transitioning towards sustainable agriculture by accessing funds from the National Recovery and Resilience Plan (NRRP), C.2 evaluates the vulnerability of municipalities in facing environmental threats, considering whether or not they receive funding.

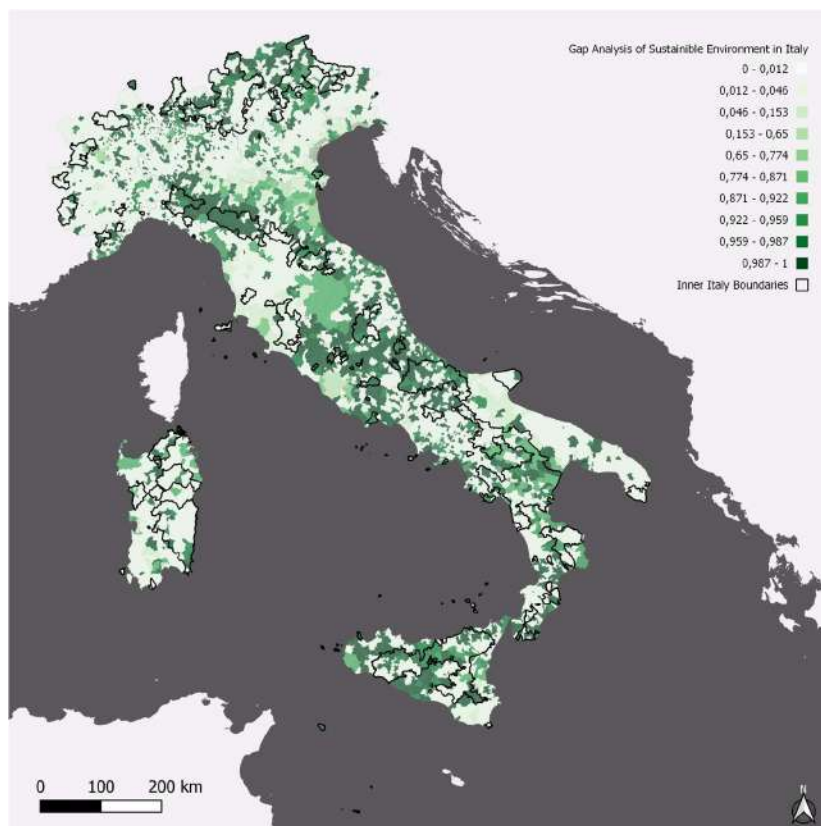


Figure 3.2_1: Gap Analysis of Sustainable Environment in Italy

Territorial typology	C.1	C.2	C1_C2
1 INNER ITALY	17,09%	21,00%	18,43%
1.1.1 - Inner remote and sparsely populated area	12,87%	15,39%	13,73%
1.1.2 - Inner and remote area with medium population density	1,61%	1,47%	1,57%
1.2.1 - Sparsely populated inner area closest to a metropolitan area	2,21%	3,57%	2,67%
1.2.2 - Inner area with medium population density closest to a metropolitan area	0,39%	0,57%	0,46%
2 INTERMEDIATE ITALY	75,70%	71,24%	74,17%
3 METROPOLITAN ITALY	7,21%	7,76%	7,40%

Table 3.2/a: Value of environmental indicators for each territorial typology

The indicator developed to integrate the two indexes (C1 and C2) provides an overall view of the environmental vulnerability and agricultural sustainability of municipalities in inland Italy. The thematic map ranges on a scale from 0 to approximately 0.92. The map uses a gradient of green colors to represent different value ranges:

- **Values 0 - 0.0007:** Municipalities in this range, depicted with very light shades of green, indicate areas with the highest vulnerability. These municipalities show a significant

investment gap despite having extensive agricultural areas or being exposed to hydraulic risks. In these regions, the support policies and received funds have not been sufficient to effectively promote a transition towards sustainable agricultural practices or to adequately manage water resources.

- **0.0007 - 0.371 and 0.371 - 0.4161:** These intervals represent municipalities that, while not in the lowest range, still display high vulnerability. Even though some local or regional initiatives have been implemented, the results indicate a limited capacity to improve sustainability and hydraulic resilience.
- **0.4161 - 0.8844:** The darker green shades in this range indicate municipalities with intermediate performance. These municipalities have either benefited from partial investments or have reduced vulnerability due to favorable local conditions. However, there is still room for improvement, especially in terms of resource efficiency and the integration of innovative agricultural technologies.
- **0.8844 - 0.9191:** Municipalities in this range, shaded in dark green, are those with the highest performance in terms of sustainability and resilience. These areas have received significant investments, successfully integrating modern agricultural practices and hydraulic management infrastructure that effectively mitigate climate change-related risks.

3.2.2. Description and quantification of the gap in Inner Italy

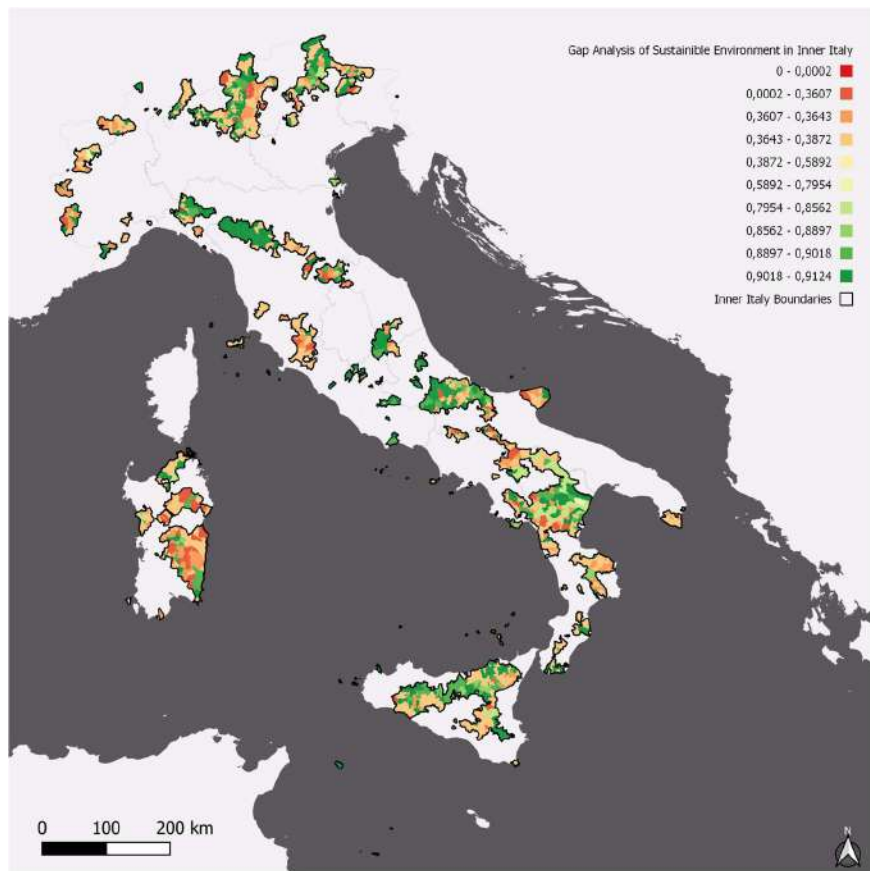


Figure 3.2_2: Gap Analysis of Sustainable Environment in Inner Italy

The thematic analysis identifies three patterns (see figure 3.2_2) of vulnerability that are useful for pinpointing territorial gaps:

1. **High Gap Areas (from 0 to approximately 0.5):** This category identifies municipalities with low values predominantly located in northern regions, parts of southern Italy, with a significant presence in Sardinia, Sicily, and parts of Calabria. In these regions, despite the substantial agricultural land area, support policies and funds have not been sufficiently directed towards agricultural modernization and sustainable water resource management. These areas, often characterized by traditional agriculture and inadequate infrastructure, suffer from a lack of targeted investments needed to tackle environmental and climate challenges. The result is a high level of economic and environmental vulnerability, evidenced by large agricultural surfaces that cannot adequately benefit from the opportunities offered by the ecological transition.
2. **Medium Gap Areas (0.5 to 0.8):** This category represents a larger percentage in Southern Italy and Sicily. These municipalities have received a certain level of support, but infrastructure and investments in innovative technologies remain insufficient to ensure a complete transition towards sustainable agriculture. Some municipalities in these regions, despite having a higher agricultural and infrastructural density than other southern areas, still display gaps in terms of hydraulic resilience, especially in mountainous or hilly areas prone to flood risks.
3. **Low Gap Areas (0.8 to approximately 1):** The areas with the best performance are mainly found in Northern Italy, in regions such as Lombardy, Veneto, Emilia-Romagna, and parts of Trentino-Alto Adige and Friuli-Venezia Giulia. In these municipalities, the combination of significant investments and an already-developed agricultural structure has enabled implementing innovative technologies and water resource management infrastructures. These municipalities represent a successful model in adapting to ecological transition policies, thanks to the presence of advanced agricultural cooperatives and easier access to European and national funds. The high sustainability of these areas demonstrates the effectiveness of an integrated approach that combines infrastructural investments and the promotion of circular agricultural practices. Noteworthy examples also include some municipalities in the Abruzzo and Sicily regions.

Italy is one of the European countries most heavily and frequently affected by landslides, mainly caused by heavy rainfall and influenced by its unique geological, landscape, and tectonic features (Trigila et al, 2010).

Inner Italy, which includes municipalities classified as "Inner remote and sparsely populated area" or "Inner and remote area with medium population density," represent one of the most evident critical points. Despite constituting a significant part of Italy's agricultural fabric, these territories show high levels of vulnerability. The inland areas of Central and Southern Italy, such as parts of Tuscany, Marche, Abruzzo, and Calabria, have not received adequate funding to innovate agricultural infrastructure or effectively protect agricultural surfaces from hydraulic risks. This gap is exacerbated by their geographical isolation, making it more challenging to attract investments and develop effective support policies.

In many of these municipalities, the presence of agricultural land with high hydraulic vulnerability, combined with the lack of investments in water resource management,

significantly increases the risk of economic and environmental damage in the event of extreme climate events. The absence of targeted policies and local initiatives capable of addressing the specificities of these territories amplifies the divide between inland and more developed areas.

Territorial typology	C.1	C.2	C1_C2
1 INNER ITALY	17,09%	21,00%	18,43%
1.1.1 - Inner. remote and sparsely populated area	12,87%	15,39%	13,73%
1.1.2 - Inner and remote area with medium population density	1,61%	1,47%	1,57%
1.2.1 - Sparsely populated inner area closest to a metropolitan area	2,21%	3,57%	2,67%
1.2.2 - Inner area with medium population density closest to a metropolitan area	0,39%	0,57%	0,46%
2 INTERMEDIATE ITALY	75,70%	71,24%	74,17%
3 METROPOLITAN ITALY	7,21%	7,76%	7,40%

Table 3.2_1: Value of social indicators for each territorial typology

3.2.2.1 Description and quantification of the gap, an example in Inner Abruzzo

The gap analysis results are confirmed by the actual situation of the natural risks that are affecting the territory of Italy and its inner areas. By analyzing the situation in Abruzzo, which is recognized as an area with high exposure to landslide hazards and risks by National and regional inventories (Herrera et al, 2018), it shows significant exposure to multiple landslide types, underscoring the environmental vulnerability of these zones. Geohazard impact areas are categorized to show widespread collapses/overturning, superficial landslides, and subsidence, alongside specific landslide types.

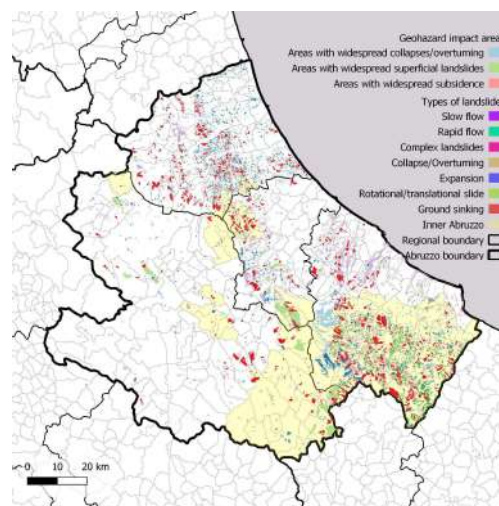


Figure 3.2_3: Gap Analysis of Sustainable Environment in Inner Italy (data source: ISPRA)

Slow and rapid flow landslides are dispersed throughout the region, with clusters in the inner areas, as the inner areas as shown in Figure 3.2_3. These areas are highlighted with a yellow background and display geohazards categorized by the type of landslides. These clusters indicate varying movement speeds and risk levels, with some areas more susceptible to rapid changes in land stability. Complex landslides, and collapse/overturning events, are concentrated in regions with intricate geological settings, particularly within the inner Abruzzo. Additionally, rotational/translational slides and ground sinking are widespread, especially in the inner areas, highlighting concerns with ground stability. The high density of these landslide types within the inner areas reflects the influence of Abruzzo's unique geological, morphological, and tectonic characteristics on its susceptibility to geohazards. These phenomena negatively affect the possibility for economic activities, such as agriculture, to persist in the rural areas and be competitive.

3.3. Economic Gap Analysis

Italy's territory is characterised by a complex geological and geomorphological structure, making it particularly vulnerable to various natural hazards, including landslides and earthquakes. The country's morphology, featuring extensive mountain ranges such as the Apennines and the Alps, combined with its location along the Eurasian tectonic plate, exposes it to high levels of seismic and hydrogeological activity. These factors, together with the uneven distribution of infrastructure and population centres, create differentiated vulnerability conditions at the territorial level.

In the context of natural hazard mitigation policies and adaptation to environmental dynamics, it becomes crucial to conduct a precise and integrated assessment of the vulnerability of the country's various areas. The aim of such assessments is to provide a clear and scientifically grounded picture of territorial disparities (so-called *gaps*) in order to direct resources towards the most exposed municipalities and areas, as well as to promote and support strategic planning and appropriate territorial risk management policies.

This study aims to analyse the existing gaps in the economic and building fabric of Italian municipalities through the integration of two key indicators selected to evaluate the exposure of Italian municipalities to landslide and seismic risks. The selected indicators—the Indicator of Exposed Buildings to Landslide Hazard (Map D.1) and the Indicator of Exposed Buildings to Seismic Hazard (Map D.6)—allow for an assessment of buildings' exposure to landslide phenomena and seismic events, respectively. Indicator D.1 measures the degree of exposure of buildings located in municipal areas susceptible to landslides by overlaying geomorphological hazard data provided by ISPRA (Italian Institute for Environmental Protection and Research) with information on buildings, based on ISTAT data and satellite surface surveys. Conversely, Indicator D.6 evaluates buildings' exposure to seismic risk by correlating data on mean spectral acceleration (HSM) with the structural vulnerability of buildings, determined by their height and volume, on a 90m x 90m spatial resolution grid.

The integration of these indicators, as outlined in Deliverable D3.2, has enabled an accurate mapping of vulnerabilities at the municipal level, facilitating risk quantification and the identification of infrastructural gaps. The methodology employed is based on a multi-scale

and multi-criteria approach, integrating environmental and socio-economic variables to provide a comprehensive and detailed picture of risk conditions.

These indicators have been developed and mapped using the GeoTopis geospatial multicriteria system, which allows the overlaying of seismic hazard and landslide susceptibility data with information on the characteristics of buildings and infrastructure at the municipal level. The objective is to identify, describe, and quantify the existing territorial disparities among Italian municipalities in terms of vulnerability to the aforementioned natural hazards.

The combination of these two indicators has enabled a detailed representation of economic and infrastructural gaps, highlighting the areas with the highest levels of exposure to destructive natural events. Such gaps result from a combination of factors, including local geological conditions, the distribution of public investments in anti-seismic and anti-landslide infrastructures, and the socio-economic characteristics of the territories.

3.3.1. Description and quantification of the gap

The final map(see figure 3.3_1) , produced by integrating indicators D.1 and D.6, displays Italy divided by economic risk levels associated with landslides and earthquakes. The colours represent different vulnerability ranges, with the darkest purple indicating municipalities with the lowest vulnerability, while lighter shades represent higher levels of risk.

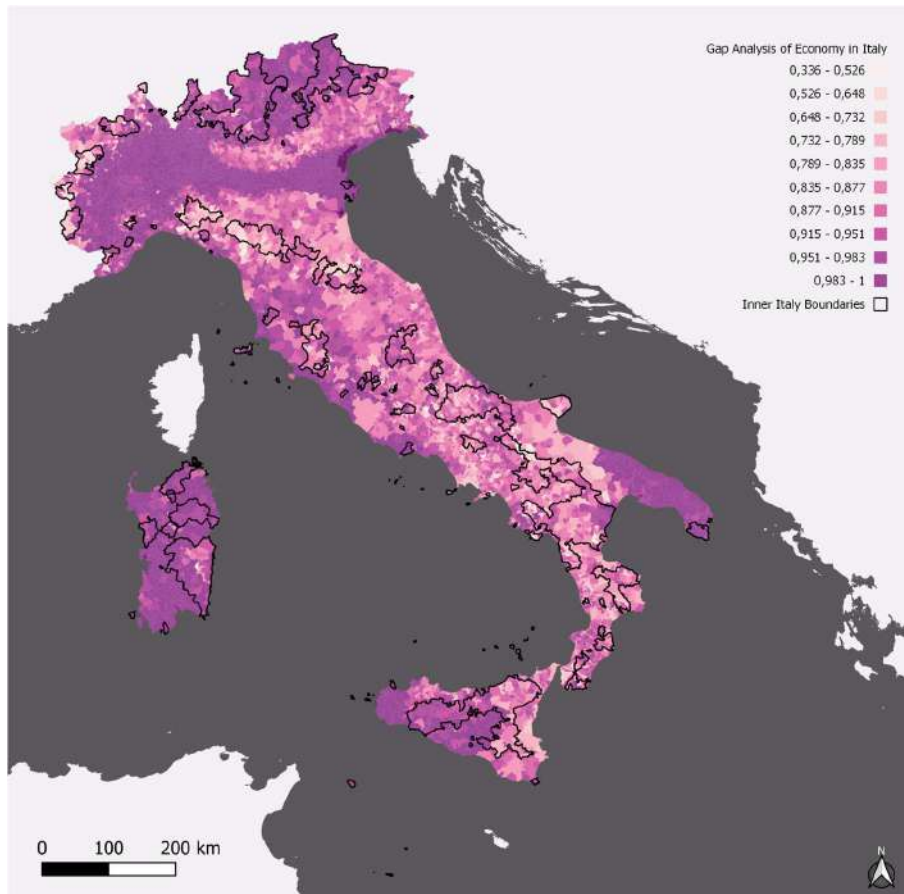


Figure 3.3_1: Gap Analysis of Economy in Italy

Territorial typology	D.1	D.6	D1_D6
1 INNER ITALY	34,74%	16,85%	16,69%
1.1.1 - Inner. remote and sparsely populated area	26,73%	11,51%	12,56%
1.1.2 - Inner and remote area with medium population density	1,20%	1,76%	1,61%
1.2.1 - Sparsely populated inner area closest to a metropolitan area	6,36%	2,81%	2,09%
1.2.2 - Inner area with medium population density closest to a metropolitan area	0,45%	0,77%	0,37%
2 INTERMEDIATE ITALY	61,47%	74,20%	76,11%
3 METROPOLITAN ITALY	3,79%	8,96%	7,21%

Table 3.3/a. Value of economic indicator for each territorial typology

The map shows vulnerability values as follows:

- **0.336 - 0.648:** This range indicates municipalities with the highest level of economic vulnerability. These municipalities are most exposed to landslide and earthquake risks and have fewer economic and infrastructural resources to cope with these hazards.
- **0.648 - 0.789:** These municipalities exhibit moderate vulnerability, with infrastructures that provide partial protection but still remain significantly exposed to risks.
- **0.789 - 0.877:** Municipalities with medium-low risk vulnerability fall within this range. These municipalities have developed infrastructures and policies that help reduce risk.
- **0.877 - 1:** The areas in this category display very low vulnerability, demonstrating a strong capacity to respond to natural events.

In particular, the North of Italy, economically more developed and characterised by an advanced infrastructure network, generally shows low vulnerability. However, differences emerge between the plains and metropolitan areas, which exhibit a high response capacity, and the Alpine mountainous areas. Despite having more economic resources, these mountainous regions show moderate vulnerability due to their complex terrain and exposure to landslides. The contrast between these areas highlights that, despite effective risk management in cities and industrialised areas, rural and mountainous zones still require targeted investment policies to bridge the gap. The Central Apennines, which run through central Italy and connect regions such as Umbria, Marche, and Abruzzo, reveal a significant territorial divide compared to the plains and coastal areas. The Apennine areas, impacted by both seismic risk and frequent landslides, are among the most vulnerable. The light pink shades indicate low economic resilience, due to the historic nature of the building stock and the lack of sufficient investment in modern and secure infrastructures. On the other hand, metropolitan and coastal areas, such as those in Tuscany, demonstrate a greater capacity for risk management, significantly reducing the gap compared to the internal areas. This disparity underlines the importance of targeted interventions in mountainous regions to ensure an equitable distribution of resources and to enhance the resilience of central Italian municipalities.

Southern Italy and the islands (Sicily and Sardinia) are characterised by high economic vulnerability, as shown by the light and medium pink shades on the unified map. Despite the low population density in Southern Italy, these areas face high risks from landslides and earthquakes and have limited resources for mitigation and prevention. Regions such as Calabria and Basilicata clearly display a combination of high natural exposure and weak economic capacity, resulting in a marked territorial gap compared to northern regions. The analysis of the islands, particularly Sicily, reveals that both coastal and internal areas require strategic investment plans to reduce risk and enhance infrastructural resilience. This gap underscores an urgent need for integrated development policies to improve the economic and territorial resilience of the South.

3.3.2. Description and quantification of the gap in Inner Italy

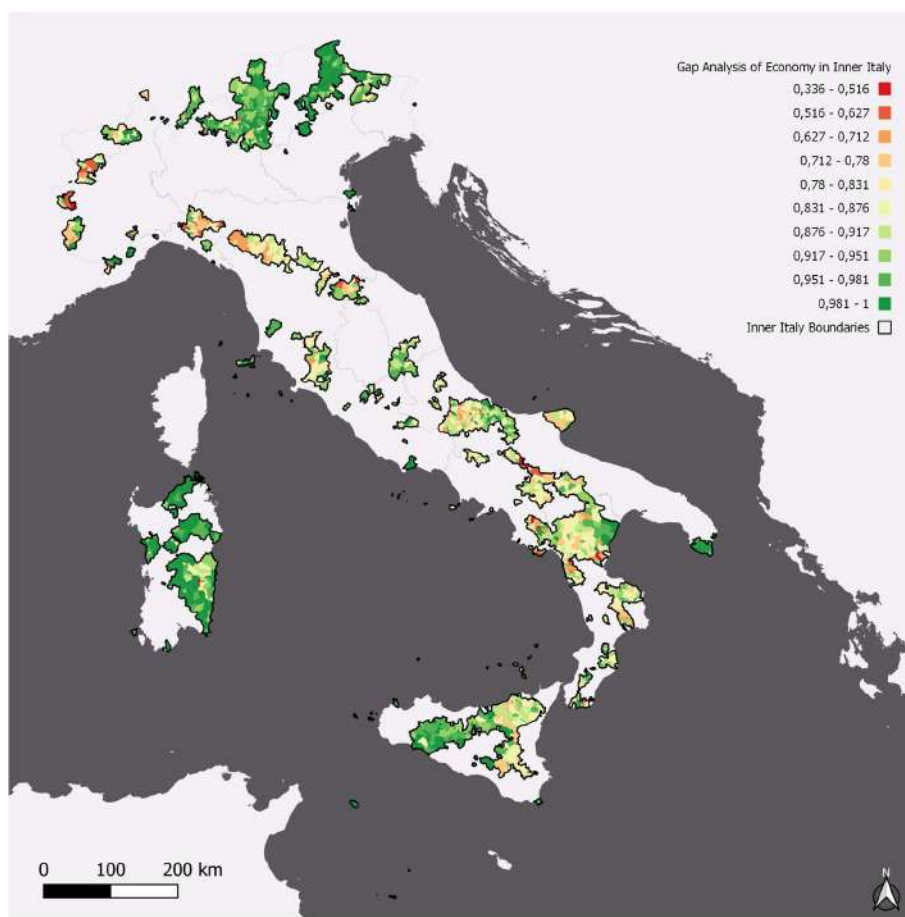


Figure 3.3_2: Gap Analysis of Sustainable Environment in Inner Italy

The thematic analysis identifies three patterns of vulnerability (see figure 3.3_2) that are useful for pinpointing territorial gaps:

1. **High Gap Areas (from 0 to approximately 0.71):** High vulnerability areas are predominantly concentrated in Italy's southern and insular regions, with the exception of

certain municipalities in Piemonte and Valle D'Aosta. In Calabria, numerous internal and mountainous areas fall within the highest exposure category, marked in red and orange. Here, the combination of complex morphology and high exposure makes municipalities highly vulnerable to both seismic and landslide risks. The lack of effective prevention policies and the scarcity of funds for structural interventions further exacerbate the situation. A similar scenario is observed in Basilicata, where internal rural areas share a high level of vulnerability due to both seismic activity and unstable terrain. In Sicily, internal areas distant from major urban and coastal centres are also classified as highly vulnerable. Sicilian municipalities in mountainous zones demonstrate that the exposure to risk is still strongly correlated with economic resource constraints and insufficient modernisation efforts. Shifting to Central Italy, regions such as Abruzzo and Molise present similar conditions. The mountainous zones of the central Apennines, characterised by isolated and vulnerable municipalities, clearly show a high economic fragility due to frequent landslides and significant seismic activity. The insufficient availability of funds for the safeguarding of buildings and infrastructure makes these areas among the most exposed in the country.

2. **Medium Gap Areas (0.712 to 0.91)**: Medium vulnerability areas, represented by shades of yellow and yellow-green, are distributed across central and southern Italy, but also include parts of the islands. In Campania, for instance, internal municipalities frequently fall within this vulnerability range. Here, the combination of seismic and hydrogeological risks is mitigated to some extent by local policies and infrastructure that, while not entirely modern, provide a certain level of risk reduction. In Sardinia, a similar situation is observed in the central mountainous areas, where natural hazards are present but prevention and adaptation projects have partially improved the response capacity. In these zones, the lower population density and some local initiatives have contributed to reducing overall vulnerability, albeit not completely. In Marche and Umbria, regions of the central Apennines, there are also municipalities classified under medium vulnerability. The hilly and mountainous areas, although significantly exposed to natural hazards, show improvements thanks to risk management policies that have moderated the exposure levels. Nevertheless, the vulnerability remains notable, and further investments are required to strengthen the infrastructure.
3. **Low Gap Areas (0.917 to 1)**: Low vulnerability areas, represented in light and dark green shades, are primarily concentrated in northern Italy and certain central hilly areas. In Tuscany, several municipalities located in the hilly and mountainous regions of the central Apennines demonstrate relatively low vulnerability compared to other internal regions. This outcome is likely due to the presence of modern infrastructure and the consistent implementation of effective local risk management policies, which have contributed to keeping risk levels manageable. In Piemonte, there are also municipalities in mountainous areas that fall within this low vulnerability category. The careful urban planning and effective resource management in these regions have enabled them to better manage natural hazards, thereby reducing the economic impact of potential disasters. A similar pattern is observed in some areas of Emilia-Romagna, where the attention to territorial policies and risk prevention has led to a significant decrease in vulnerability. Finally, Sardinia exhibits some internal and hilly areas with low vulnerability, thanks to a combination of low population density and targeted infrastructure interventions. This

confirms how long-term policies and well-planned development projects can significantly mitigate the impact of natural risks, even in traditionally vulnerable areas.

The map highlights the uneven territorial distribution of economic vulnerability in Italy's inner areas, with the southern regions and parts of the central Apennines exhibiting high vulnerability due to a combination of natural exposure and weak infrastructure. Medium vulnerability areas demonstrate partial progress but underscore the need for further interventions and investments to ensure greater security and resilience. Finally, low vulnerability areas, primarily located in the north and certain central hilly regions, showcase the effectiveness of well-structured mitigation policies and advanced infrastructural management. This analysis suggests that, to bridge the territorial gaps, it is essential to focus efforts on targeted interventions in the most critical areas, ensuring an equitable distribution of resources and promoting sustainable and resilient development throughout the national territory.

3.3.2.1 Description and quantification of the gap, an example in Inner Abruzzo

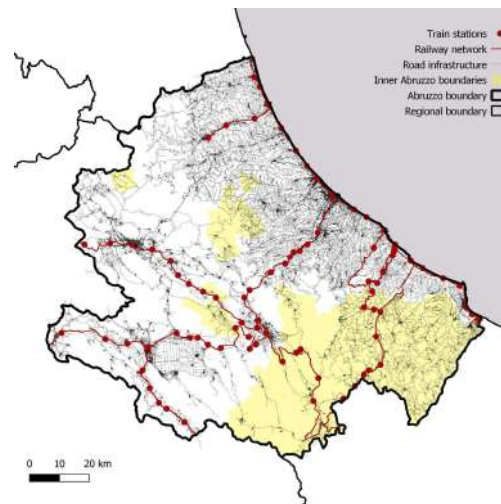


Figure 3.3_3: Road and railway network in the region of Abruzzo (data source: IGM)

Again accessibility is a key aspect also in relation to environmental risks, making territories more resilient in case of adverse events. Having a redundant network of roads makes it possible to have more options in case of emergency during and after a disaster (see Figure 3.3_3).

By considering the Abruzzo region, in comparison to the well-connected coastal and northern regions, the inner areas face significant infrastructure gaps. As it is clear in Figure 3.3_3, this gap is particularly related to rail and road infrastructures' connectivity. The road network in these regions is sparser, relying largely on secondary roads that may limit efficient access to economic centers and essential services. Similarly, the railway infrastructure in these inner areas is minimal, with few railway lines traversing the region and a limited number of train stations. This dual limitation in both road and rail infrastructure underscores the relative isolation of these inner areas, making transportation to and from these communities more challenging.

3.4. Final Gap Analysis

The final assessment integrates (see figure 3.4_1) all three dimensions: social, environmental, and economic. It is developed through the evaluation method 'Technique for Order of Preference by Similarity to Ideal Solution' (TOPSIS), which is a Multiple-Criteria Decision Analysis (MCDA) method. The fundamental concept underlying this method is that the preferred option should have the shortest distance in Euclidean space from the 'ideal solution' and the longest distance from the 'non-ideal solution.' The Euclidean distance criterion is then employed to assess the relative proximity of different alternative proposals to the final solution, and the final order of preferences among the options is derived by comparing these relative distances.

This evaluation is carried out using the VectorMCDA plugin in QGIS through the "geo-TOPSIS" algorithm. The resulting maps highlight areas where gaps, analyzed through vulnerabilities, are more pronounced, potentially representing spatial injustices in the more marginalized regions of Inner Italy. Additionally, they reveal territories where territorial policies have already addressed these gaps, specifically municipalities where the assessment shows results close to the 'ideal solution,' which for the algorithm corresponds to a value of 1. Therefore, it has been possible to identify the gaps that need to be addressed to activate integrated policies across various dimensions and position urbanization processes within the paradigms of sustainability, resilience, and inclusion.

In the Final Gap Analysis, all three partial indicators are intersected (developed in sections 3.1, 3.2, and 3.3): the social gap analysis index, the economic gap analysis, and the environmental gap analysis.

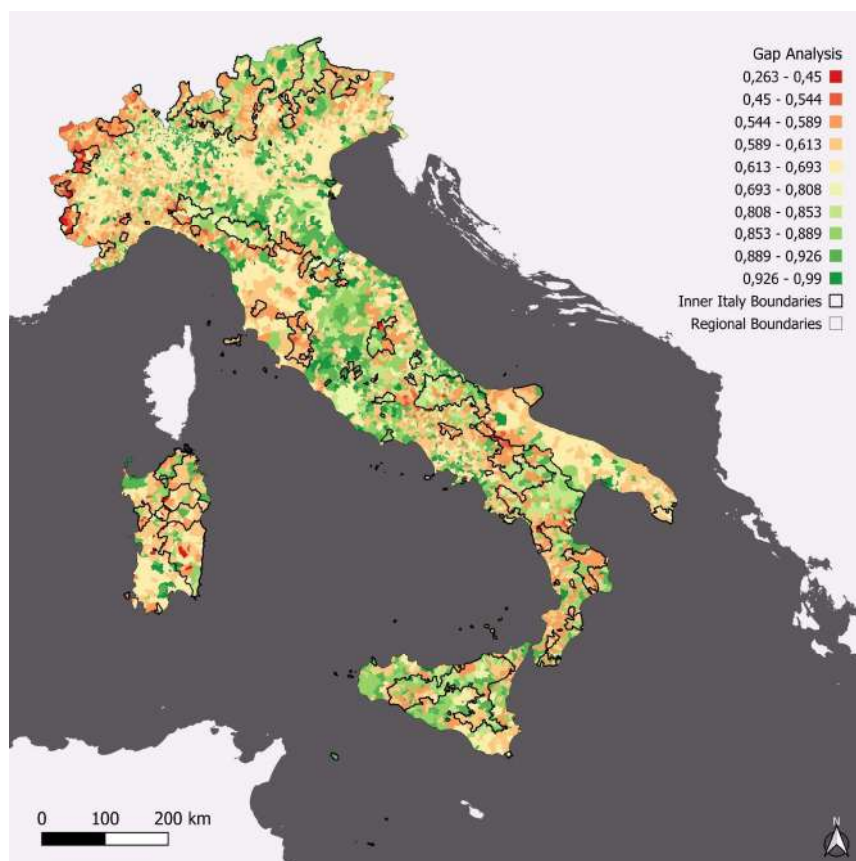


Figure 3.4_1: Final Gap Analysis of the three dimensions

Territorial typology	C1_ C2	A1_B 3	D1_D 6	Final GAP
1 INNER ITALY	18,43%	15,49%	16,69%	16,95%
1.1.1 - Inner, remote and sparsely populated area	13,73%	11,49%	12,56%	12,63%
1.1.2 - Inner and remote area with medium population density	1,57%	1,64%	1,61%	1,61%
1.2.1 - Sparsely populated inner area closest to a metropolitan area	2,67%	1,97%	2,09%	2,28%
1.2.2 - Inner area with medium population density closest to a metropolitan area	0,46%	0,40%	0,37%	0,42%
2 INTERMEDIATE ITALY	74,17%	76,71%	76,11%	75,51%
3 METROPOLITAN ITALY	7,40%	7,79%	7,21%	7,54%

Table 3.4_1/a: Final gap analysis values for each territorial typology

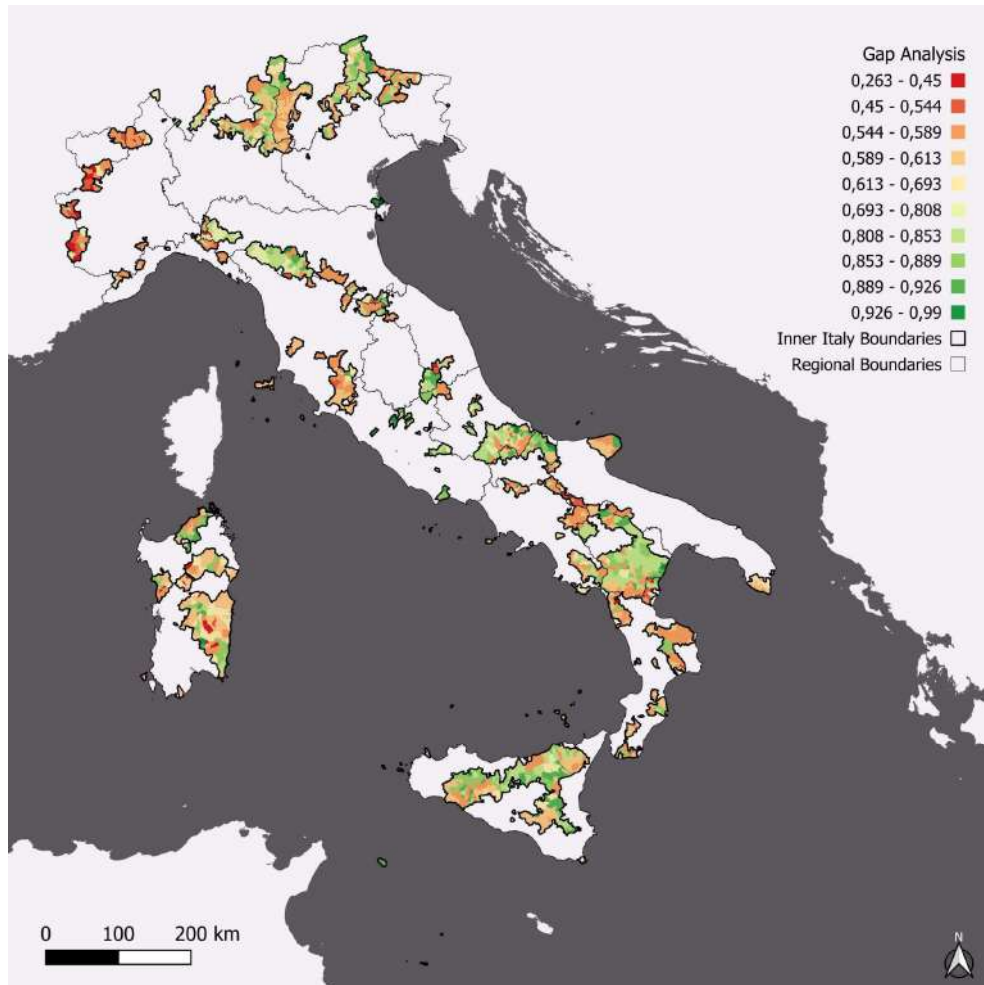


Figure 3.4_2: Final Gap Analysis of the three dimensions in Inner Italy

Final assessment reveals (see figure 3.4_2) significant disparities within Inner Italy:

1. **High Gap Areas (from 0.263 to approximately 0.589):** This range encompasses the lowest values. Mountainous and hilly regions of Italy are particularly exposed within this interval. Notably visible are areas in the North-West, as well as more inland and sparsely populated zones of Trentino Alto Adige, Friuli Venezia Giulia, Alta Irpinia and Cilento in Campania, lower Lucania in Basilicata, and Calabria.
2. **Medium Gap Areas (0.589 to 0.853):** In this range, the more populated territorial types are 'Inner remote and sparsely populated area' and 'Inner and remote area with medium population density.' The average values are observed in Inner Italy within Piedmont, along the Tuscan-Emilian Apennines, in Abruzzo, Calabria, Basilicata, and the islands.
3. **Low Gap Areas (0.853 to approximately 1):** Municipalities within this range belong to all territorial types of Inner Italy. Such low vulnerability is found in a discontinuous manner across Inner Italy. Coastal municipalities and those geographically close to provincial capitals fall within this interval.

A further assessment can be conducted on the municipal averages from the previous evaluation by aggregating municipalities based on geographic proximity (Fig. 3.4_3). This aggregated evaluation makes the gaps spatially explicit. High vulnerability is observed in the Inner Italy regions of the Northwest (Valle d'Aosta and Liguria), as well as in Tuscany, Puglia, Sardinia, and Calabria. Low vulnerability is present only in Lazio and Abruzzo. The remaining geography of the inner areas exhibits medium vulnerability.

The gap analysis is particularly influenced by vulnerabilities within the economic sector, where indicators such as the 'indicator of exposed buildings to landslide hazard at municipal scale' and the 'indicator of exposed buildings to seismic hazard at municipal scale' reveal significant challenges for inner areas. These regions, especially in the Northwest, experience lower economic performance in part due to the high exposure to natural hazards, which threaten infrastructure stability and community safety. Such vulnerabilities not only impede economic resilience but also discourage new investments, intensifying the marginalization of these territories.

Moreover, these economic gaps are further compounded by limited environmental transition policies, especially within the agricultural sector. The 'index of ecological transition of agricultural assets' and the 'sustainable agricultural index for water resources' provide a clear perspective on how, in the absence of adequate support, the agricultural sector struggles to adopt sustainable practices. In inner areas, where agriculture is often a neglected yet potential asset, the inability to shift towards ecological sustainability deepens socio-economic divides. These gaps in environmental adaptation and sustainable water resource management, combined with the risk of hydrogeological and seismic hazards, place inner areas in a state of heightened vulnerability, making the prospect of achieving resilient, inclusive, and sustainable development increasingly challenging.

The 'vulnerability of accessibility to school offer' and 'real estate abandonment due to lack of digital coverage' are key indicators that highlight not only infrastructural but also social issues in inner areas, in terms of vulnerability, inclusivity, resilience, and sustainability. Limited accessibility to school offerings represents a profound social barrier to the development of inclusive and cohesive communities, as education is an essential resource for reducing social inequalities and promoting economic mobility. In many inner areas, the distance and lack of nearby schools can discourage families from settling or remaining, triggering a process of depopulation that affects young people and low-income families in particular, with negative repercussions on the overall social fabric.

Similarly, 'real estate abandonment due to lack of digital coverage' highlights how digital infrastructures are now essential for active participation in social life and access to services. Without reliable connectivity, these areas remain isolated from informational, educational, and social support networks, limiting access to opportunities for remote work, distance learning, and digital services that are crucial for daily well-being and social cohesion. Inadequate digital coverage makes these areas less attractive to young people, professionals, and families who might be interested in a lifestyle more in tune with nature but still require effective connectivity to the wider world.

These indicators emphasize the urgent need to rethink infrastructure policies in inner areas with a perspective that considers not only economic, but also social factors. Strengthening school accessibility and improving digital coverage could help revitalize the social fabric by offering opportunities that support diverse lifestyles and encouraging new residency in these zones. Investments in educational and digital infrastructures not only create more resilient

communities but also foster an environment that values local specificities and builds social cohesion capable of addressing future challenges. In this view, inner areas could not only retain but also attract new residents, creating a sustainable model of active, participatory, and inclusive communities.

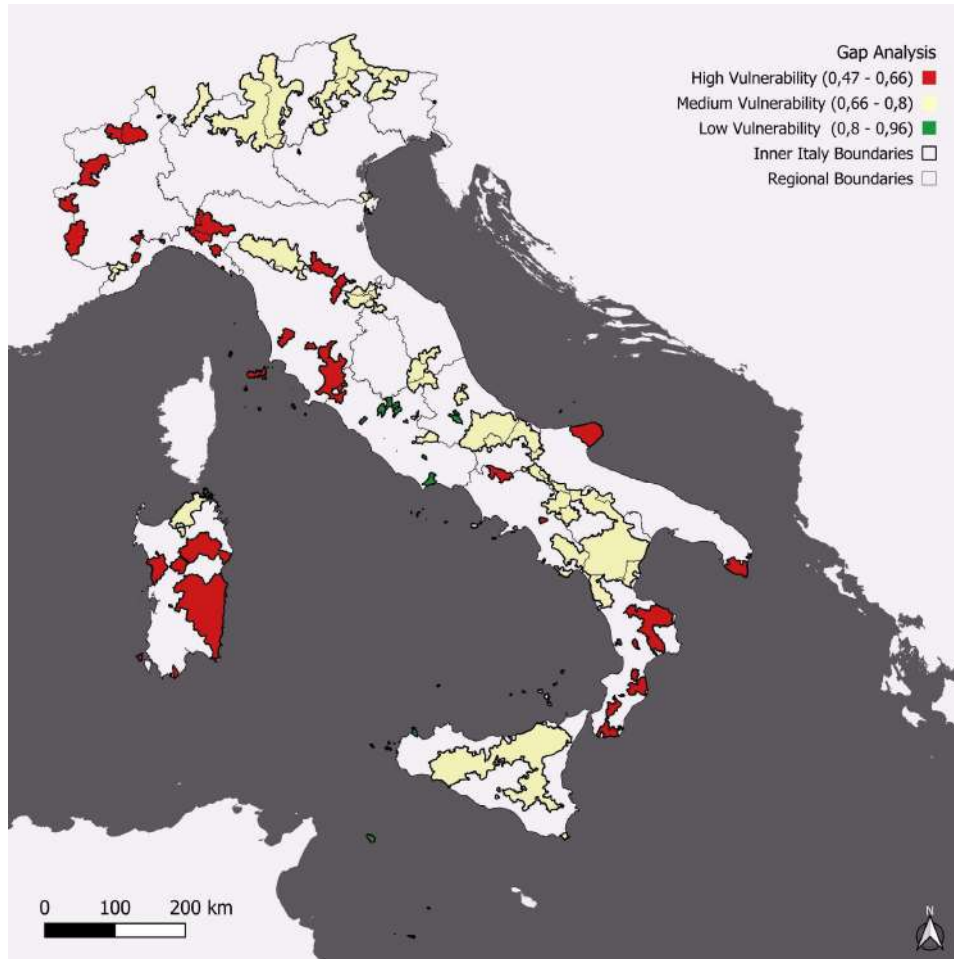


Figure 3.4_3: Aggregated Final Gap Analysis in Inner Italy

4. Action to fill the gap

The final outcome of the Gap Analysis methodology will be the preparation and publication of four policy documents, each tailored to a specific territorial typology, by the end of the project (M36). These reports will serve as the primary tools for translating the results of the multidimensional analysis into actionable guidelines and strategic interventions, customized to the unique characteristics of each territorial context.

Each policy document will be developed based on a data-driven and measurable objectives approach, addressing the identified vulnerabilities and gaps in Italy's inner areas. The focus for each territorial typology is as follows:

- **Typology "Inner remote and sparsely populated area"**: Policies will aim to reduce geographical isolation through targeted improvements in digital and physical connectivity while enhancing local resources to foster new economic, social, and cultural opportunities.
- **Typology "Inner and remote area with medium population density"**: Proposed actions will emphasize strengthening economic and environmental resilience, adopting sustainable agricultural and forestry practices, and enhancing educational and healthcare infrastructure to ensure living standards comparable to those of more developed areas.
- **Typology "Sparsely populated inner area closest to a metropolitan area"**: Policies will focus on strengthening connections with neighboring urban centers by improving access, transport networks, and economic and social market integration, while preserving local identities and cultural heritage.
- **Typology "Inner area with medium population density closest to a metropolitan area"**: Policies will consolidate the role of these areas as connectors between urban and rural systems, fostering innovation, entrepreneurship, and sustainability. Particular attention will be given to improving infrastructure and mitigating seismic and hydrogeological risks.

Each document will be developed through a participatory approach, engaging key stakeholders at local, regional, and national levels. This ensures that the policies are not only aligned with the specific needs of each territory but also supported by institutional and social consensus. The documents will be structured into distinct sections, providing a detailed analysis of the critical issues identified and proposing targeted intervention strategies to address the gaps, based on data from previous analyses and integrating both quantitative and qualitative indicators of social, environmental, and economic gaps:

1. **Contextualized Introduction**: A summary of the Gap Analysis results for each territorial typology, highlighting key vulnerabilities and drivers of marginalization, supported by thematic maps produced using GIS tools.
2. **Priority Actions to Address Gaps**: A set of operational proposals categorized by the three main dimensions:
 - Social: Enhancing access to education and healthcare, strengthening digital connectivity, and fostering initiatives to build social capital in local communities.

- Environmental: Promoting sustainable agricultural practices, reducing hydrogeological risks, and improving water resource management through innovative and technologically advanced measures.
 - Economic: Anti-seismic structural reinforcement and landslide prevention, regeneration of building and infrastructure assets, and improvement of transport networks to boost economic resilience and territorial attractiveness.
3. **Multilevel Governance Models:** Recommendations for effective coordination across different levels of government (local, regional, national, and European), integrating European Cohesion Policy funds, the PNRR, and other financial instruments. A participatory approach will be emphasized, ensuring active involvement of local stakeholders to enhance policy sustainability and feasibility.
 4. **Indicators for Monitoring and Evaluation:** Identification of indicators to measure progress in overcoming the detected gaps, ensuring continuous assessment of policy effectiveness and enabling necessary adjustments.

The resulting policy documents will be the product of a rigorous scientific process, combining spatial data analysis with advanced evaluation methodologies and enriched by multidisciplinary expertise. These documents aim to provide practical tools for addressing territorial inequalities and fostering inclusive, resilient, and sustainable development. Moreover, they are designed to be replicable in other European contexts with similar vulnerabilities.

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REPORT D – ISLANDS

1. Gap Analysis for the Insularity

1.1. Introduction

Insularity encompasses several critical dimensions. Within the European Union (EU), islands⁵⁹ are recognized as distinct territories requiring specific attention. At the national level, the importance attributed to islands in programs and legislation often varies based on their size. Insular regions face structural economic disadvantages rooted in geographic isolation, limited market access and connectivity, unsustainable transport systems, restricted access to essential services, reliance on narrow economic activities (often dominated by tourism or fisheries), vulnerability to environmental and climate-related risks, and dependence on imported energy and water. These challenges hinder their ability to compete equally with mainland territories, as acknowledged by Articles 174 and 349 of the Treaty on the Functioning of the European Union (TFEU) and highlighted in economic geography literature.

Studies drawing on New Economic Geography (NEG) theories emphasize the disadvantages of remoteness, including increased transportation costs and limited economies of scale, which reduce competitiveness and hinder investment attraction (Krugman, 1991). These constraints are further exacerbated for Outermost Regions, which experience “double insularity” due to geographic and economic remoteness. Improved connectivity and market integration can mitigate these disparities, as highlighted by Venables (2005). EU strategies under Cohesion Policy, the European Green Deal, and instruments like the European Structural and Investment Funds (ESIF) aim to address these gaps through sustainable investments in connectivity, energy efficiency, and innovation, fostering long-term resilience.

Programs like Horizon 2020 and INTERREG⁶⁰ have supported islands through research, innovation, and funding for green and digital transitions. Initiatives such as the “Clean Energy for EU Islands” and “Smart Islands Initiative” promote sustainability and energy independence. Achieving equitable development, however, requires granular planning, enhanced data collection, transnational cooperation, and tailored solutions.

Italy’s largest islands, Sicily and Sardinia, represent significant components of the Mediterranean and European island population, hosting approximately 5 million and 1.6 million inhabitants respectively—around one-third of Europe’s total island population. Despite their size, these regions face many challenges associated with insularity.

⁵⁹ EU insular regions encompass both traditional islands and Outermost Regions (ORs).

⁶⁰ The European Territorial Cooperation (ETC) programs, part of the Cohesion Policy, aim to address cross-border challenges and collaboratively unlock the potential of diverse territories, fostering balanced development and stronger regional integration

1. Economic Activity and Competitiveness

Sicily and Sardinia perform below Italian and European averages in key indicators, including GDP per capita, labor market efficiency, and youth employment. Investments, particularly in transport infrastructure, are crucial to improving the islands' trade balance and boosting competitiveness in international markets.

2. Connectivity and Accessibility

High transportation costs and limited accessibility to mainland and intra-island services (e.g., education and healthcare) remain significant barriers. Poor road and rail infrastructure further amplify these challenges, particularly in remote areas.

3. Structural Gaps and Vulnerabilities

According to Torrisi et al., Sicily and Sardinia experience a "double burden" of geographic and infrastructural disadvantages. Sicily's GDP per capita is significantly lower than both the Italian mainland and EU averages, while Sardinia faces even more pronounced accessibility issues in its eastern municipalities.

Torrisi et al. highlight that export performance in Sicily and Sardinia is hindered more by economic marginality than distance. For instance, agricultural exports face severe limitations due to inefficiencies in innovation and infrastructure. Trade losses compared to northern Italian regions reach 90% for Sicily and 83% for Sardinia. Port infrastructure positively influences trade, but inadequate road and rail networks often diminish these gains.

Sicily and Sardinia also suffer disproportionately high transportation costs, driven by factors like fuel, maintenance, and time, which collectively constitute up to 60% of transport expenses. Zammarchi's efficiency index reveals that insular regions consistently face transport costs well above the European average, exacerbating economic isolation.

Licio and Pinna's analysis of municipal accessibility underscores significant regional disparities. In Sicily, 40.3% of municipalities are classified as "Peripheral," while in Sardinia, 13.5% are "Ultra-Peripheral," both exceeding national averages. Travel times to essential services and infrastructure are markedly higher in Sardinia⁶¹, particularly in its eastern regions, where some municipalities require over 90 minutes to reach urban centers⁶² or transport hubs.

Access to transportation infrastructure also varies. In Sicily, 31% of municipalities take over an hour to reach a railway station, while in Sardinia, central and southeastern regions face prolonged travel times to ports and airports. These disparities highlight the urgent need for targeted investments to improve connectivity.

The compounded challenges of insularity demand targeted policies focused on:

- Enhancing infrastructure, particularly maritime transport and digital connectivity, to reduce trade and accessibility costs.
- Improving human capital through investments in education and training, addressing below-average tertiary education rates.
- Fostering innovation to overcome economic marginality and enhance competitiveness.

⁶¹ Sardinia has no motorways

⁶² The municipality that provides all three types of essential services: healthcare, education, and mobility.

- Addressing environmental vulnerabilities through sustainable resource management and climate-resilient strategies.

The European Commission's renewed strategy for outermost regions emphasizes eliminating poverty, enhancing public services, and boosting green and blue economies. By aligning with these goals, tailored policies for Sicily and Sardinia can address their unique challenges while promoting sustainable development.

Sicily and Sardinia exemplify the multifaceted challenges of insularity, including economic marginality, limited accessibility, and environmental vulnerability. However, with targeted investments in infrastructure, human capital, and innovation, these islands can leverage their unique assets to overcome structural disadvantages and contribute to a more inclusive and resilient European Union.

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Gap Analysis for the Insularity⁶³

1. Target

1.1. *The numbers on the gaps of the major Italian islands in the European and national context*

Insular regions have permanent characteristics and peculiarities that distinguish them from continental regions, whether they are more or less peripheral. This derives from the incontrovertible fact that insularity, understood as territorial discontinuity, implies specific economic, transport, environmental, social and demographic characteristics that determine an objective disadvantage compared to continental territories. In the EU, insularity also represents a significant topic of political, economic and social debate, also due to the number and size of this type of territory.

Europe is characterized by a high number of islands (362), 17.7 million inhabitants and 3.7 million of which in the ultraperipheral regions. Sicily with its approximately 5 million residents (28% of the "island" population) represents the largest European island in terms of size and economic importance. But despite this primacy, it is among the last in terms of GDP per capita. It differs not only from the European average but also from the average levels of other EU islands where there is strong variability compared to the levels of wealth of some European islands (Meloni, Sanjust di Teulada, 2017).

Official statistics show that the further north you go, the higher the levels of development of the 362 EU islands. The GDP per capita of the Northern European islands is higher than the EU average. On the other hand, the Southern European islands have a GDP per capita that is much lower than both the EU average and the average of the 362 islands. These data provide a description of the importance of economic marginality compared to geographical peripherality. There are many islands that are peripheral to the EU, but if they are large, there are few on the margins of economic competitiveness.

In the EU context, Sicily and Sardinia are below the Italian and European average in most social and economic indicators (European Commission Nuts2). Furthermore, there are clear employment imbalances in Sicily and Sardinia with a growth forecast for 2028 far behind the rest of Italy. The strong variability of wealth levels represents one of the many elements of development heterogeneity. Figure 1, which reports the GDP per capita of some European Islands classified territorially as Nuts2 and Nuts3. From the figure it is clear that the GDP per capita of the Northern European islands examined is higher than the EU average level and also the average GDP per capita of the 362 European Islands. On the other hand, the Southern European Islands have a GDP per capita much lower than both the EU average and the average of the 362 Islands.

⁶³ This paragraph was written by the UNICT research group, with the contribution of: Lucio Siviero, Marina Cavalieri, Salvatore Corrente, Giampiero Torrissi and Salvatore Scuderi (post-doc researcher).

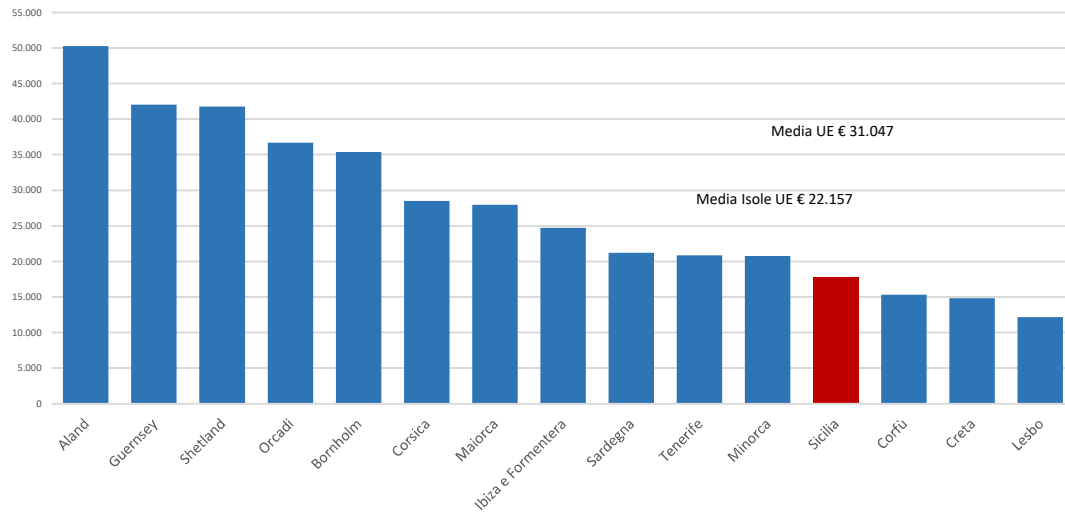


Figure 1: Per capita GDP of some European islands – Year 2018. Source: Eurostat data processing

In general, in the EU context, Sicily is placed below the Italian and European average in most of the social and economic indicators that the European Commission adopts to make appropriate spatial and temporal comparisons between the Nuts2 regions. In particular, the measure of competitiveness summary deserves specific attention using a complex indicator called Regional Competitiveness Index (RCI), elaborated annually and with respect to which Sicily shows negative positions on some important dimensions, such as: infrastructure, human capital, innovation and, in general, also the quality of administrative action (figure 2).



Figure 2: Competitiveness Index – Year 2019 - Source: European Commission

The following tables (1-2-3-4) provide a clear representation of the positioning of Sicily and Sardinia in the EU context, in terms of GDP and unemployment.

		PIL pro capite corretto per il potere d'acquisto											
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union		25.700	25.800	26.000	26.600	27.500	28.200	29.300	30.300	31.300	30.100	32.700	35.500
Italy		27.000	26.600	26.200	26.100	26.700	28.000	28.800	29.400	30.200	28.200	31.500	34.400
Sicilia		17.100	17.200	16.800	16.300	16.700	17.200	17.800	17.900	18.400	17.500	19.400	21.000

Table 1: GDP per capita adjusted for purchasing power, Sicily 2011-2022. Eurostat data. Source: Eurostat data processing

		PIL pro capite corretto per il potere d'acquisto											
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union		25.700	25.800	26.000	26.600	27.500	28.200	29.300	30.300	31.300	30.100	32.700	35.500
Italy		27.000	26.600	26.200	26.100	26.700	28.000	28.800	29.400	30.200	28.200	31.500	34.400
Sardegna		19.800	19.900	19.200	19.100	20.000	20.200	20.800	21.200	22.000	20.600	22.900	25.000

Table 2: GDP per capita adjusted for purchasing power, Sardinia 2011-2022. Eurostat data. Source: Eurostat data processing

		Tasso di disoccupazione											
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
15-74 anni	European Union	9,9	10,9	11,4	10,9	10,1	9,1	8,2	7,3	6,7	7,1	7,1	6,2
	Italy	8,4	10,7	12,2	12,7	11,9	11,7	11,2	10,6	9,9	9,2	9,5	8,1
	Sicilia	14,3	18,4	21,0	22,2	21,4	22,1	21,5	21,3	19,9	18,1	18,7	16,6
15-29 anni	European Union	22,0	23,8	24,6	23,5	21,8	20,1	18,0	16,1	15,1	16,8	16,7	14,5
	Italy	29,2	35,3	40,0	42,7	40,3	37,8	34,7	32,2	29,1	29,7	29,7	23,7
	Sicilia	42,5	51,2	54,3	57,0	55,9	57,2	52,9	53,6	51,1	48,4	48,8	43,2

Table 3: Total and Youth Unemployment Rate, Sicily 2011-2022. Eurostat Data. Source: Eurostat data processing

		Tasso di disoccupazione											
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
15-74 anni	European Union	9,9	10,9	11,4	10,9	10,1	9,1	8,2	7,3	6,7	7,1	7,1	6,2
	Italy	8,4	10,7	12,2	12,7	11,9	11,7	11,2	10,6	9,9	9,2	9,5	8,1
	Sardegna	13,6	15,5	17,5	18,7	17,4	17,3	17,0	15,4	14,8	13,0	13,5	11,5
15-29 anni	European Union	22,0	23,8	24,6	23,5	21,8	20,1	18,0	16,1	15,1	16,8	16,7	14,5
	Italy	29,2	35,3	40,0	42,7	40,3	37,8	34,7	32,2	29,1	29,7	29,7	23,7
	Sardegna	42,2	47,5	53,7	50,0	56,4	56,3	46,8	36,0	45,2	40,1	38,7	27,4

Table 4: Total and Youth Unemployment Rate, Sardinia 2011-2022. Eurostat Data. Source: Eurostat data processing

Over the last thirty years, the gaps between Sicily and Sardinia have increased especially compared to the regions of Northern Italy, and part of this is attributable to infrastructural gaps, the competitive nature of the production system, the efficiency of the labor market, and factors such as geographical distance from the centroids of economic development (geographic peripherality), chronic economic marginality and insularity (in Armano G., Torrissi and Others (2021) Estimation of the costs of insularity in Documents of the Sicilian Region)

In the description of the context, gross fixed investments emerge; figure 3 highlights the island's lower propensity to invest; figure 4 shows the liveliness of trade but also the vulnerability to changes in the reference markets.

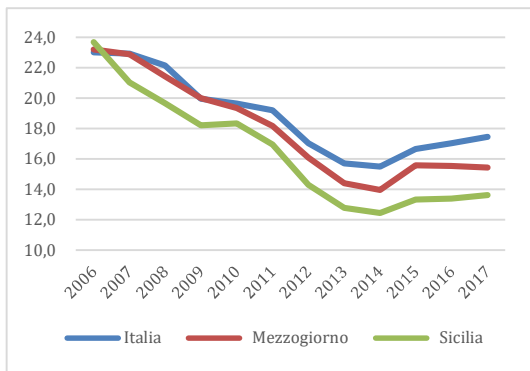


Figure 3: Gross fixed investments – Years 2008-2017 (% incidence on GDP, chained values 2015). Source: Istat data processing

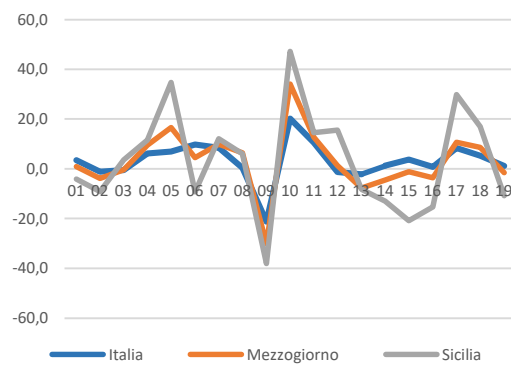


Figure 4: Imports and exports with foreign countries – Years 2001-2019 (% changes). Source: Istat data processing

The investment in human capital recorded in the Italian islands is low (see Figure 5).

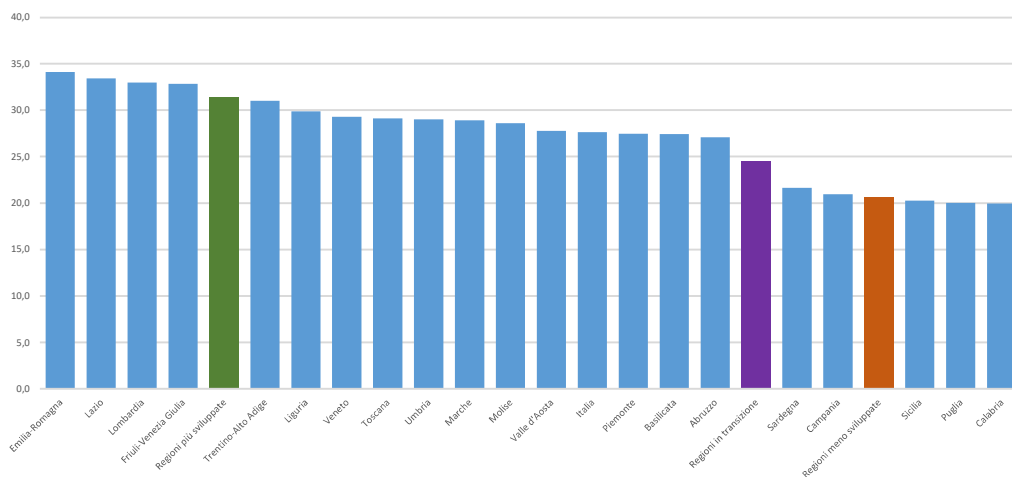


Figure 5: Tertiary education rate in the 30-34 age group by region – Year 2019 (%). Source: Istat data processing

Figure 6 below represents the average Generalized Transport Costs (GTC) of all recipients for each region as an inverse measure of accessibility. As shown, geographically central regions have the lowest transport costs due to their central location within the road network, while peripheral regions generally suffer from higher transportation costs

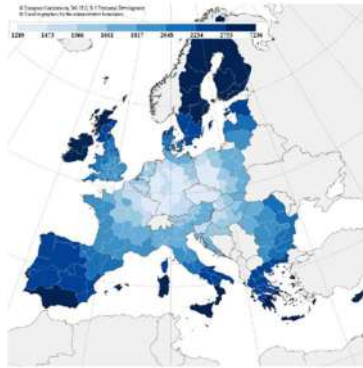


Figure 6: Average GTC for each NUTS 2 region

When analyzing the breakdown of the cost of transport, 60% can be attributed to time and fuel. The cost of time is composed of the value of wages and the value of rest time. While distance costs are determined by fuel prices and fuel consumption. Other relevant cost components are related to maintenance, insurance, financing, depreciation, and indirect costs, which count for around 40% (Eurostat, 2016). From Figure 7 and figure 8 below, it emerges that even the breakdown into the two main components of 'distance' and 'time' shows a marked heterogeneity between regions.

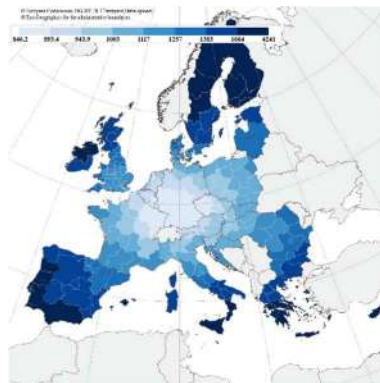


Figure 7: Distance and time related costs of GTC for each NUTS 2 region Distance-related costs

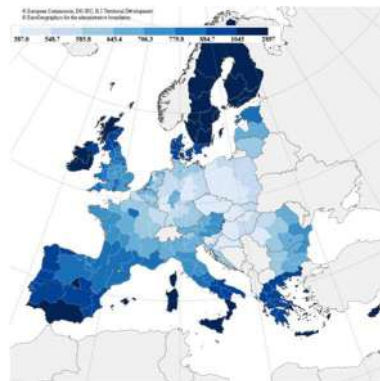


Figure 8: Distance and time related costs of GTC for each NUTS 2 region b) Time-related costs

An alternative cost estimation strategy to the one considered so far is to weight the cost measures between regions i and j by the bilateral trade flow between regions i and j using the data provided by Thissen et al. (2019). In reports those weighted transportation costs. It makes the marginality of some regions more apparent.

Even from a more general perspective than focusing on transport costs, it emerges that the competitive capacity of regions shows similar patterns. This is evident from the Regional Competitiveness Index (RCI).

Hence, we can affirm that the two islands on which this work focuses (Sicily and Sardinia), from a descriptive point of view, are characterised by a marginal position not only from a merely geographic point of view, but also from the point of view of transport costs and, more generally, of territorial competitiveness. A more detailed analysis will be offered below to verify the effects of this marginality on their economic performance.

The data on the context of the islands clearly express the competitive disadvantage of Sicily and Sardinia. This translates into costs for companies and citizens.

From this context arises the need to study and measure the determinants of the recorded regional gaps. The objective will be to formulate empirical contributions that study and quantify the determinants of the gaps by estimating the costs of insularity, economic marginality and geographical peripherality.

Below we will describe the empirical approaches used to estimate the weight that some determinants have on the level of wealth (GDP), commercial performance, attractiveness and resilience, of a territory (GDP) that presents conditions of insularity, economic marginality and peripherality. From our research questions (Spoke 7 CT) we obtained the results described in the points that will follow, enriching the scientific debate with empirical contributions on which to orient policies.

After the Bruno Leoni Institute that estimated the impact on the GDP of the insularity effect of Sicily and Sardinia, our contributions respond to the research objectives by identifying:

- the infrastructures that significantly impact the trade balance of Sicily and Sardinia (contribution of Siviero L, Torrìs B, (2023) *"Insularity and international trade: the case of Sicily"* in Rivista Italiana di Economia Demografia e Statistica Volume LXXVII n.1 Gennaio-Marzo 2023);
- whether the loss of wealth estimated by the Bruno Leoni Institute was entirely attributable to the island effect or to structural effects linked to economic marginality (from the contribution Cavalieri M, Di Pasquale D, Torrìs B, Torrìs G. (2023) *An empirical take on the economic effects of insularity: the Italian regional case* in Rivista Italiana di Economia Demografia e Statistica Volume LXXVII n.1 Gennaio-Marzo 2023).
- how much are the trade losses for both the manufacturing and agricultural and agro-industrial sectors in international relations between the islands (Sicily and Sardinia) with the rest of the world and with the EU regions, for the three dimensions analysed: island effect, economic marginality effect and geographical peripherality effect (in the contributions of Siviero L, Torrìs B, Scuderi S. (2024 full draft completed and almost ready to be submitted) *"Trade gravity models and regional infrastructural connectivity: the*

effects on international trade in island conditions “ and in Torrasi B., Siviero L., Rizzo M., Scuderi S. (2024 full draft completed and almost ready to be submitted) International trade and regional transport infrastructure in island and marginal conditions for the Agri-food products in Italy

- the effects of the condition of insularity, economic marginality and peripherality (geographical distance) on the attractiveness of the regions in the EU (in the contribution of Corrente S., Torrasi B., Torrasi G.. (2024 full draft completed and almost ready to be submitted) *European Regions Attractivity and Economic Peripherality: an empirical approach*

The development of a territory depends on various factors such as competitive capacity, the degree of schooling, centrality with respect to developed contexts, and territorial positioning. What happens when all these factors interact in an 'island' context?

1.2. Literature and our research proposals

This issue is still under debate and the extant literature reports mixed evidence with pros and cons of insularity. Fellmann (2020) highlights how insularity is potentially an advantageous factor in terms of competitiveness and socio-economic development. Such aspects should be taken into account when comparing the islands she mentions such as Gotland or Bornholm, in Denmark, with, for example, the two largest Italian islands: Sicily and Sardinia. Indeed, it has already been pointed out in the literature how insularity can be considered a phenomenon of permanent economic and social peripherality that structurally hinders the development and the achievement of specific objectives that are more easily attainable by benefiting from territorial continuity. Deidda (2014) highlights how insularity, as a condition of distance from the nodes or pivots of the development of commercial interactions, determines an increase in costs—including, but not limited to, those related to distance—with a consequent decrease in economic competitiveness with negative effects also on overall productivity. Cocco et al.(2018) point out the importance for those who run a business to be located in a networked territorial environment on the mainland by taking advantage of the proximity of their customers or distribution centers; in addition, their analysis shows how in some instances insularity is a condition of peripherality and remoteness that restrains the development of the production system and negatively affects the welfare of consumers. The debate arising from the comparison of the various contributions, therefore, highlights the strengths and weaknesses of the effect of insularity on economic performance. Building upon this debate, the contribution *Cavaliere M, Di Pasquale D., Torrasi B., Torrasi G.* aims to analyze the spatial uneven effects of trade Italian regions controlling for their competitiveness and (the costs of) their distance.

The European study, 'The Development of islands—European Islands and Cohesion Policy' (ESPON & University of the Aegean, 2011), provides some indications on the environmental and economic parameters that can negatively and/or positively influence the attractiveness of the islands. In this case, insularity is considered a factor highly correlated with accessibility and

with, therefore, the aspects linked to geographical discontinuity and the difficulties of accessing transport infrastructures.

Behrens et al. (2006) studied the impact of changes in inter- and intra-national transport costs on the internal geography of countries while considering asymmetric transport costs. They argue that disadvantaged regions do not necessarily always coincide with island areas; there are regions that, owing to the lack of direct access by sea, must use the road or railway network to access the maritime network, which involves additional costs (Behrens et al., 2006). They then conclude that islands and economically marginal regions have a competitive disadvantage externally but a competitive advantage in the local market, whereby natural protection conditions are created.

The Bruno Leoni Institute (IBL) conducted an insularity and economic development survey in 2020 (in Amenta et al., 2020), making an interesting contribution.

The regional multi-sector model applied to Sardinia was subsequently applied to Sicily. This Sardinia model analyses the transport costs due to insularity and the effects that arise from it on the sectors of activity and on economic operators and in 'the condition of insularity as an economic disadvantage, the case of Sardinia' edited by Meloni and Sanjust di Teulada (2017). The studies on transport infrastructure, Alamá-Sabater et al. (2011, 2013) proved the role of transportation networks in Spanish inter-regional trade. Márquez-Ramos (2016) found that regional port facilities positively affect trade enhancement, although this effect is largely due to spatial spillovers arising from neighbouring regions.

Recent studies have aimed at assessing the impact that reduction in time to trade, due to trade facilitation reforms or infrastructure improvements, has on trade flows (Djankov et al., 2010; Hummels and Schaur, 2013; Baniya, 2017). Second, several studies have analysed the trade effects of infrastructure projects (Donaldson, 2018; Duranton et al., 2014). Finally, a subset of the literature relies on georeferenced data and geographic information system (GIS) analysis to examine the trade and spatial effects of transport infrastructure (Roberts et al., 2010; Baniya et al., 2020).

The discussion on the role of ports in the case of the impact of the quality of port infrastructure on trade is similar to that in Bacchetta et al. (2012), who discuss the issue of controlling for MR when the interest of the research relies on country (or region) specific variables.

It highlights the disadvantages generated by insularity due to the discontinuity of the territory, preventing connections between regions and reducing the flow of passengers using the network (Carlucci et al., 2018).

Finally, this study draws upon the 'Trade Gravity Model', which considers the effect of distance and territorial size on trade, and the 'New Economic Geography' or New Trade Theory, which evaluates the key role of economies of scale and network effects on trade.

An new attempt is made to measure the losses in international trade relations in the manufacturing sector (*in Torrisci B., Siviero L., Scuderi S.*) and in the agricultural-agro-industrial sector (*in Torrisci B., Siviero L., Rizzo M., Scuderi S.*) taking into account the geographical distance (peripherality), the distance from the centroid territories of economic development (economic marginality) even in island conditions.

The presence of advantages and disadvantages resulting from insularity can be factors that influence the **attractiveness of a territory**, i.e. its ability to attract investments. The

measurement of the attractiveness of a territory is of recent construction with respect to “competitiveness”. It assumes a fundamental importance in terms of localized policies, on which policy makers debate in the choice of indicators to modify in order to change the scenarios. While competitiveness aims to maximize the performance of an economy that compares itself with others (Cresta A., Greco I. , 2019, p. 158), attractiveness is intended to highlight the strengths of a territory that are able to attract investment and ensure its success. The concept of attractiveness is configured (Musolino D. , 2016, p. 46) in the form of real, revealed and perceived attractiveness.

Gompers and Lerner (1998) point out that there are more attractive opportunities for entrepreneurs if the economy is growing rapidly. Wilken (1979) argues that economic development facilitates entrepreneurship as it provides greater accumulation of capital for investment. Romain and van Pottelsberghe de la Potterie (2004) find that investment activities are regulated by a cyclical trend and are significantly correlated to GDP growth. Artige L. and Nicolini R. (2005, p. 18) come to the conclusion that investments with a positive correlation between GDP. Gompers and Lerner (1998, p. 20) also demonstrate the strong link between attractiveness and GDP with spending on research and development being a source of excellent entrepreneurial opportunities as it has the capacity to activate the activity of risk capital” (Romain and van Pottelsberghe de la Potterie, 2004, p.14). Geographical distance (peripherality) and economic distance (economic marginality) in Husmann C., 2016, p. 421. In this context are important *the Capital Market* (Nero and Gilson (1998), and Gompers and Lerner (2000), Schertler (2003), Greene (1998), Hellman et al. (2004); *the Taxes* (Gompers and Lerner (1998), Bruce and Gurley (2005), Djankov et al. (2008)); *The social and human environment* (Djankov et al. (2002) Baughn and Neupert (2003), Lee and Peterson (2000); *The Importance of Environmental Opportunities* (Megginson (2004), Schertler (2003); *Administrative Burdens and Regulatory Limitations* (Worzala (1994) and Adair et al. (1999), McGreal, Parsa, Keivani (2001); *Accessibility - Infrastructures* (Musolino D., 2014, pp. 1-7; Basile R. et al, 2009, p. 16; Airoidi A. et al, 2009, pp. 43-45); *School and training* (Basile et al, 2005, p.18; Airoidi A. et al, 2009, pp. 35-42).

In the light of the theoretical elements accompanying the empirical analysis, it is clear that the measurement of the attractiveness of a territory is represented by a clear multidimensionality of factors, which interact with each other and determine its characteristics of economic and social development. But when we move from the macro-economic analysis (national or multinational contexts) to the micro-economic definition in island contexts, the literature seems quite lacking both in terms of theory and empirical terms.

Therefore, the contribution *Corrente S., Torrisi B., Torrisi G.*, represents a first attempt to focus attention on the measurement of attractiveness in regional territories in EU and in particular in regions islands through the construction of scores that take into account the geographical distance (peripherality), the distance from the centroid territories of economic development (economic marginality) even in conditions of islandhood. Furthermore, the study presents analyses and reflections on the macro variables on which to intervene to address regional economic gaps.

1.3. *Different approaches to empirical analysis*

The econometric model used by the Bruno Leoni Institute, using a panel of territorial data at regional level and in historical series (2000-2018) on which a fixed effects regressive procedure was built.

From the IBL model it emerges that it is possible to quantify the loss of annual GDP per capita for Sardinia and Sicily.

The analysis of *Cavaliere M, Di Pasquale D, Torrisi B, Torrisi G. (2023)* reveals spatial heterogeneity in the effects of foreign trade between Italian regions and the determinants of the effect can be attributed to **innovation** and **efficiency**. A two-step analysis was performed. An RCM was used in the first step and, then, the spatial differences in the estimated RCs were explored in the second step. This procedure fails to detect a generalized island effect for the Italian case. However, a negative and statistically significant effect is found for Sicily. This confirms that such an effect is place-specific.

From the decomposition of the competitiveness index, further elements of analysis emerge both in the generic vision and in the island condition. In the latter case, innovation and efficiency are also negatively influencing Sicily's exports.

Undoubtedly, this interesting results calls for further research on its main drivers and, more generally, on the extent and sectors to which it eventually applies.

In *Siviero L, Torrisi B, (2023)* approach confirm the importance that port infrastructures predominantly assume on exports vs. foreign countries with respect to the negative effect (determined by the differential of the two parameters estimated at 0 or 1 for Sicily) generated by the road, railway and of its geographical marginality.

The initial results show an interesting scenario thanks to application of gravitational models, without which the aspects linked to particular territorial characteristics, would not have emerged.

If the variable effects under examination are analysed based on international exports in a general territorial context where territorial continuity exists, all the variables are significant and each one clearly indicates their effect on trade relations and commercial dealings; the other major relevancy emerges when the same variables are applied to an island location with territorial discontinuity.

The impact generated by road or rail networks is insignificant due to the isolated location and lack of territorial continuity, isolating them from the national transport network and crucial hubs.

It is possible to surmise a policy scenario from these conclusions that foresees a strong relationship in terms of investment into internal infrastructures and into infrastructures that guarantee territorial continuity, thus raising regional competitiveness capability indicators for international trade.

The effects of infrastructure on the trade balance in the manufacturing sector and in the agricultural and agro industrial sector of regions close to the economic development benchmarks of geographically peripheral regions, as well as the effects of economic

marginality and insularity, are detected in *Siviero L., Torrisci B., Scuderi S. (2024)* and in *Torrisci B., Siviero L., Rizzo M. Scuderi S. (2024)*. The analysis was conducted using a panel dataset with distances, infrastructure, and trade balance (imports and exports) of Italian regions from 2007 to 2020 from/to all countries considered (full sample) and only the 27 European Union countries (EU27 sample).

The results show that ports and highways influence the trade balance of regions, depending on their proximity to the benchmarks, whether they are economically marginal areas or they are islands.

We verify that in island scenarios, infrastructure has different effects on the manufacturing and agricultural sector. These results cannot be generalised to the 362 EU islands, especially if they are large, and the effects of infrastructure on trade relations between Sicily and Sardinia are different. This is even more true if regions and/or islands are located in the southern EU.

These data provide a description of the importance that structural variables of "economic marginality" and the distance from "geographical peripherality" assume in the relationship on the trade balance. Many islands are "peripheral to the EU", but among the large ones, few are on the "margins of economic competitiveness".

In *Corrente S., Torrisci B., Torrisci G. (2024)* contribution to demonstrate how the coexistence of conditions of discontinuous and marginal isolation can produce competitive positioning and attractiveness rankings that cannot escape the main statistical indicators.

These aspects represent the core of the contribution with the aim of demonstrating through the application of multi-criteria analysis the ranking estimate and the changes of the scenarios on the attractiveness characteristics of an island territory, trying to demonstrate whether being an island produces advantages or disadvantages in terms of attractiveness of new investments, or if all this depends on the condition of economic marginality and therefore on the lack of development strategies.

We obtained a triad of indicators that were statistically robust and representative of reality, as we were able to satisfy the construction of a global complex score, weighted with respect to GDP (which also answered the real representation) and weighted with respect to distance. In addition, the comparison with respect to the reference benchmarks (global and partial centre of economic development for each macro variable) led to results of particular interest. They show the extent to which proximity to the areas of highest global or partial development per macro variable can influence the region's position in relation to attractiveness. Added to these results are those referring to EU island regions and here too we were able to show that being an island is a negative factor if it is also economically marginal, whereas where islands are proximal to areas of greater economic development (benchmarks) the island effect is not perceived. Finally, from these analyses it is possible to decipher for which macro variables the overall effect of the attractiveness scores are conditioned and on which macro variables to act as a priority. For regions that are economically marginal, peripheral but also islands, the global scores will not change unless priority action is taken not only on infrastructure but also on training and the labour market. These areas will remain marginal and will see their social poverty and economic attractiveness grow.

2. Vision

A BRIEF DESCRIPTION OF THE MODELS USED TO ACHIEVE THE GOALS IN THE ABOVE DESCRIBED APPROACHES

Below we will describe the empirical approaches used to estimate the weight that some determinants have in regional territories on the level of wealth (GDP), on commercial performance, on attractiveness, in conditions of insularity, economic marginality and peripherality.

We began our analysis by studying the model used by the Bruno Leoni Institute applied to estimate the costs of insularity for Sicily and Sardinia. With the following model they calculated how much insularity affects the regional GDP losses. The Institute applied a multiple regression model with 12 explanatory variables.

We have applied the RANDOM COEFFICIENTS MODEL (RCM) to estimate the effects of distance on the GDP of the Islands (Sicily and Sardinia) but also of the structural effects (innovation and efficiency) (*Cavaliere M, Di Pasquale D, Torrisi B, Torrisi G. (2023)*). Using the distance cost data, the impact of exports on the GDP of Italian regions was estimated using a Random Coefficients Model (RCM). (export-based) model, based on well-established literature dating back to the 1950s (see, among others, the important contributions of North (1955) and Tiebout (1956)) was augmented control for the specific effect of distance (i.e., its cost).

With GRAVITY MODEL we estimate the effect of infrastructure on international trade of Sicilia e Sardegna (Siviero L, Torrisi B, (2023)).

The basic model uses an augmented gravity structure to control for the countries' unilateral and bilateral (dyadic) characteristics. In the basic model we consider the gross domestic product of the region of origin and of the country of destination.

In Siviero L, Torrisi B, Scuderi S. (2024) study, we estimate a gravity model of exports and imports for the 20 Italian NUTS2 regions of the European classification, considering attraction/generation variables such as the GDP per capita of the region and the importing country, the distance (impedance) variable, and various infrastructural variables to assess the economic impact of regional infrastructure on the territory's export/import capacity. The flow data for both exports and imports related to global and European partner countries pertain to the manufacturing sector and its industrial subgroups.

The baseline empirical model, fitted for our aggregate sectors using the full and EU27 samples. To derive the trade flows for a regional profile to be compared with others that could serve as benchmarks, we defined two regional profiles, one of which serves as the benchmark. This was performed based on the observed levels of the covariates of interest for a regional benchmark profile, BP, and the one against which it should be compared, CP.

The modification of the basic equation allowed to estimate the percentages of loss recorded in the trade balance of the regions of origin in relation to the impact of infrastructures, of the economic distance from the national reference benchmarks (economic marginality), of the geographical distance (peripherality). and from its insularity.

In line with the purpose of the analysis, in Torrìsi B., Siviero L., Rizzo M., Scuderi S. (2024) we have derived an econometric specification from the gravity theoretical framework for modelling international trade flows and its determinants. In particular, we have estimated a specific augmented gravity model for the exports and imports of the agri-food industrial sectors of the 20 Italian regions (European NUTS2 classification) towards 120 countries in the 2007–2020 period. The model considers the per capita GDPs of the region and partner country as well as the geographical distance (geographical impedance and peripherality) as structural variables of this regional gravity model. The basic specification has been augmented with infrastructural variables related to multi-modal transportation infrastructures endowment in regional territories.

Moreover, another advantage of PPML estimator is that they are consistent and reasonably efficient for data with high heteroscedasticity. The increasing availability of large panel datasets, coupled with advances in estimation techniques for high-dimensional fixed effects (HDFE) has enabled researchers to control for multiple sources of heterogeneity. In this study, we apply the PPMLHDFE estimator implemented in Stata, which carefully ensures the existence of a maximum likelihood solution, adapting innovations and approaches described in Correia et al. (2020).

Our baseline empirical model is fitted with the aim of evaluating regional trade flows elasticities with reference to the aforementioned dimensions. Another objective of this study is to evaluate flows' deltas of some regions if they are compared to benchmark regional aggregates. To achieve this goal, we have estimated trade flows for a regional profile to be compared with others that could serve as benchmark.

The last approach we used focuses on regional classification ability in relation to attractiveness. Performing a ranking of EU regions evaluated on a set of indicators is a typical Multiple Criteria Decision Analysis (MCDA; Belton and Stewart 2002; Greco et al. 2016; Keeney and Raiffa 1976) problem. In our paper, we are interested in ranking problems where the alternatives have to be ordered from the best to the worst with the possibility of some ex-aequo. To aggregate the alternatives' evaluation three different families of methods are known in the literature: (i) value functions (Keeney and Raiffa, 1976), (ii) outranking methods (Roy, 1996); (iii) decision rules (Greco et al., 2001). In this paper, we opted for an outranking method and, in particular, PROMETHEE II (Behzadian et al., 2010; Brans and Vincke, 1985). The two main reasons for which this method has been selected are the following: (i) PROMETHEE II (as well as outranking methods in general) avoids compensation between criteria, (ii) weights attached to the criteria are interpreted as importance coefficients and not as tradeoffs. PROMETHEE methods (as, in general, outranking methods) mitigate such compensatory effects. In our context, we believe that compensation between criteria should be avoided because their inherently different nature makes direct comparison impossible.

3. The results on the Gaps estimated

3.1. *Gap results on the estimated wealth loss in relation to the island effect or to structural effects linked to economic marginality*⁶⁴

From a more general perspective than focusing on transport costs, it emerges that the competitive capacity of regions shows similar patterns. This is evident from the Regional Competitiveness Index (RCI).

Hence, we can affirm that the two islands on which this work focuses (Sicily and Sardinia), from a descriptive point of view, are characterised by a marginal position not only from a merely geographic point of view, but also from the point of view of transport costs and, more generally, of territorial competitiveness.

The preliminary estimates confirm a statistically positive impact of exports on economic performance. More precisely, the coefficient reported (0.256) shows that a unit increase in export w.r.t. the mean value has a 25.6 unit effect on GDP. Put another way, a one-million deviation of exports from the mean has an estimated effect on GDP of 2.56 million. Although this is a preliminary estimate, this result – which, as mentioned, controls for the distance between the regions involved in the trade in question – confirms the crucial role that exports play in the economic performance of the Italian regions. Likewise, the interaction term between exports and distance shows a positive and statistically significant coefficient. Although of a negligible magnitude. Distance per se, however, is not statistically significant.

With respect to the overall positive effect of the exports on GDP, each region suffers from a kind of penalty due to local conditions which seem to be generally higher for northern regions than for the southern ones. We conjecture that this penalty is, at least partially, linked to the extent to which the region is engaged in external trade which is generally higher in the North.

The analysis is augmented with a dummy variable for Sicily and Sardinia (D_island) aiming to capture the potential presence of an “island effect”.

Our empirical analysis fails to detect such a generic island effect. However, by considering two separate dummies for Sicily (D_Sic) and Sardinia (D_Sar), the former is negative and statistically significant at 10%.

Therefore, although the hypothesis of a generalized negative effect of insularity must be rejected based on the current analysis, a negative effect of isolation is detected for Sicilian Island. Undoubtedly, this result calls for further analysis exploring the causes as well as the main drivers of such evidence. Nonetheless, it is worth stressing how it confirms that it is not the condition of ‘isolation’ per se that generates negative effects on economic performance, rather, it seems to depend on place-specific characteristics.

The regional competitiveness – as measured by the RCI – is not statistically significant to explain the uneven effects of export at the regional level. Nonetheless, a more granular analysis individually considering the 3 pillars of RCI (i.e., ‘basic’, ‘efficiency’, and ‘innovation’, see Dijkstra

⁶⁴ This paragraph was taken from: Cavalieri M, Di Pasquale D., Torrisi B., Torrisi G. (2023)

et al. (2011)) offers nuanced results and further stimulus for additional research. The empirical results are reported in table 4.

Indeed, as shown in table 4, the efficiency pillar is statistically significant and positive both in the case of a single dummy for the island and in the case of 2 separate dummies for the main islands. Hence, the efficiency dimension of competitiveness confirms its crucial role in allowing the regional economies to exploit the potential benefits of export. Quite interestingly, the pillar related to innovation shows a statistically significant negative sign. The dummy for Sicily confirms the usual sign and statistical significance. Thus, the main result for the case at hand (i.e. the penalizing effect of Sicilian insularity) proves to be robust to a variety of econometric specifications.

In conclusion, the analysis revealed the spatial heterogeneity in the effects of foreign trade between the Italian regions.

The determinants of such a heterogeneous effect seem to be based on innovation and efficiency, and on these it is necessary to act promptly to fill the economic and social gaps. Furthermore, the robust evidence that the "island" effect plays as a limiting factor in the Sicilian case calls for specific policies. Put differently, our empirical analysis offers a twofold result and, in turn, an additional stimulus for research at different spatial levels. First, at the system level, in order to foster the positive effect of external trade both policymakers and practitioners should place a clear focus on measures aiming to improve the level of efficiency. Second, the datum related to the negative effect of insularity in the Sicilian case only, on the one hand, somehow signals the existence of case-specific structural limiting factors and, on the other hand, challenges the public policy discourse to design and implement place-based policies to address the issue by targeting the main drivers for such negative effect.

3.2. Gap results of the effect can infrastructures or logistics hubs produce with regard to competitiveness in international trade⁶⁵

The results are interesting with regard to the size of the effect generated in both general territorial contexts and in island contexts. Infrastructural indicators for railways and ports indicators are positive and very significant and have a positive impact on international trade relations, while the indicator for roadways is significant and negative.

In order to capture the effects on international trade relations that infrastructures can generate and to highlight the weaknesses of continuous and central nodal network connections, we have formulated the model with island fixed effects specific to Sicily.

These preliminary results show how the infrastructure indicator that determines positive effects on Sicilian trade is that of the ports, while roadways and electrified railways indicators are significant and negative. These result are also confirmed considering the time-related costs as spatial "impedance factor" (X_3) which include travel time over the road segment, salaries in the transport sector, national speed limits, and the European transport regulations on resting times for a shipment by a representative 40 tons articulated truck (Perysin et al., 2020).

⁶⁵ This paragraph was taken from: Siviero L., Torrisi B., (2023).

These results are naturally in line with Sicily's 'insularity conditions' where a large part of the exported goods is transported by sea. Investment in the maritime infrastructure could greatly increase the value of Sicilian exports.

In conclusion in according to this logic, the policy indications emerging from the results are clear: where investment continues to be made for infrastructure development, such as intermodal links within an area of territorial continuity, the effects greatly benefit commercial activity, while they are less effective for island territories where infrastructure development is mainly necessary to ports and shipping. The impact generated by road or rail networks is significant but with negative signs due to the insular location and lack of territorial continuity, isolating them from the national transport network and crucial logistics hubs.

It is possible to surmise a policy scenario from these conclusions that foresees a strong relationship in terms of investment in infrastructures that guarantee territorial continuity, thus raising regional competitiveness capability indicators for international trade.

3.3. Gap results on the regional agricultural and agri-industry trade balance in relation to the rest of the world and with EU countries⁶⁶

For the regional export of Food Products (exp CA10), the regional GDP and those of the partner countries have a positive sign and are significant. Distance is a factor that has a negative effect on world exports.

The degree of railway infrastructure is not significant, while road and maritime infrastructure are significant with elasticities of 1.486% and 0.303% respectively.

The positive effect on the exports of a well-developed regional road network clearly emerges. For the export of the AA01 sector, the elasticity coefficient relating to the regional GDP is not significant, therefore the effect of the regional economic mass on the regional agricultural sector is absent while that relating to the GDP of the partner countries is significant, with a typical positive sign.

The non-significance of distance emerges. As regards infrastructure, a high and significant elasticity value is recorded for the road modality, equal to 1.389%, while railway and sea are no longer significant. For the export of Made in Italy products (exp 4A-ITA), GDP and distance are significant with expected sign and values in the norm. The road infrastructure variable is significant, and so is the port infrastructure variable. Rail is not significant.

To summarize, the effect of regional economic wealth on regional world export is generally positive except for agricultural primary sector; the effect of economic masses of partner countries is always positive but with lower elasticity's value, whereas distance, as proxy of all impedance factors on regional trade, has a high negative effect for food processed products,

⁶⁶ This paragraph was taken from: Torrisi B., Siviero L., Rizzo M., Scuderi S. (2024).

no effect for agricultural sector and a lower negative effect for Made in Italy. Railway network density has no effect on regional trade for these aggregates. Only road infrastructure has a significant impact on trade (lower for exp 4A-ITA) while ports facilities have a lower positive one with respect to road.

Moving on to imports from countries around the world (Table 4), for food products we can see that per capita GDP of importing region has a lower elasticity's value when compared to that related to exports and the same can be said for GDP of exporting partner countries whereas distance has a high detrimental effect on regional trade with an elasticity of -1.862% . Road infrastructure provision is significant with an elasticity value of 0.646% , whereas railways and maritime provisions are not. For regional agricultural imports, the regional GDP is significant whereas that of partner countries is not; distance is strongly significant and with a high elasticity of -1.288% lower when compared to that of CA10 sector. None of the infrastructure variables is significant for the import of this sector. For Made in Italy aggregate sector imports, GDPs and distance have the expected sign, although the distance coefficient is higher in magnitude compared to exports, at -1.213% . Road infrastructure provision is significant with an elasticity value of 0.426% , whereas railways and maritime infrastructural provisions are not. After assessing results for regional world import, it can be highlighted that: regional per capita GDP have a positive impact on global imports for these aggregates but generally with less intensity with respect to export; exporting partner economic wealth, as measured by their per capita GDP, has a lower impact on regional trade from the import side; impedance factor, distance, has more negative impact when compared to export values. Among infrastructural proxies, only highways' endowment emerges as a trade boosting factor although with less intensity if compared to export trade.

The regional export of food products is positively affected by economic mass of regions with a high and significant coefficient of elasticity, but it has no effect in relation to the agricultural sector. However, its effect increases if we consider Made in Italy aggregate. Importer's GDP has a positive effect for all the sectors under examination, but its magnitude is generally lower when compared to the world sample.

Distance has negative sign with higher values for the agro-industrial sectors. The railways are not significant for the EU27 sample as well, whereas the magnitude of roads and ports is in line with the findings for the global sample. Moving on to imports from EU27 countries, it emerges that importers' per capita GDP has a similar effect to the world sample on regional import for CA10 and 4A-ITA aggregates but a lower impact on the agricultural sector. Exporter partner countries' GDP shows no statistical significance for food product. The negative effect of distance is generally more pronounced for all these sectors if compared to the world sample. The elasticity coefficients of road infrastructure are higher in magnitude than the ones showed by the world sample, and they are statistically significant for all sectors, while railways and ports seem to have no effect on regional imports from EU28 countries.

The paper estimates for North-west macro-region in Italy. It emerges that the railway mode has an augmented impact on export of CA10 sector products as well as the maritime mode although with less intensity. The same boosted impact can be observed for ports if we consider

Made in Italy aggregate (4A-ITA). The great endowment of maritime infrastructure in Liguria contributes to the effect on export of the macro-region.

Considering the North-east macro-region effect, it emerges the same boosted impact of railways for sector CA10. The same holds for Exp 4A-ITA where the effect of maritime infrastructure is magnified (column 3).

The most productive industrial macro-regions clearly show the use of all modes of transport for exports of goods produced.

A different pattern can be observed if we consider agricultural primary goods (Exp AA01) where Sicily seems to perform well, in fact, with respect to an average Italian Region the delta is positive at 66% for the world sample and higher for EU27 one standing at 77%, while with respect to an average region in Northern Italy figures are less positive standing at 13.59% and 23.77% for world and EU28 sample respectively. Deltas for imports are always negative but with lower magnitude (see columns 1 e 2 for Sicily). In relation to the other regions considered, Sardinia and Calabria show that percentage deltas are always negative with respect to the two benchmarking regional profiles, clearly indicating that these Italian regions have a minor integration into continental and global trade of Agro-Industrial and Made in Italy products

In our work, the position taken by the experts of the primary sector products with respect to the peripherality of Sicily and Sardinia appears interesting. The results clearly show that the greater elasticity is determined more by effects of economic marginality than by distance compared to the benchmarks. On Made in Italy aggregate sector products the effect changes.

There are studies that highlight these effects in a general and non-sectoral logic. The sectoral analysis leads to more specific results with respect to the generality of the phenomena on the trade balance.

These results lead us to note that recognizing the disadvantageous conditions of the "ultra peripheral" areas is not enough. Rather, peripherality does not always coincide with economic marginality. Therefore, the development of a primary sector associated with the secondary sector passes through the development of a regional context that addresses structural issues rather than peripherality. This means that if policies aim to increase employment and reduce gaps, dealing with economic marginality rather than peripherality becomes necessary.

As far as economic and environmental sustainability is concerned, port infrastructures in particular can be considered as "special areas" for the environmental transition of transport. Indeed, they facilitate the systemic choice of the intermodal transport, which is increasingly considered as the real possible green choice that can be made for the freight international transport in Italy in the short to medium term.

3.4. Gap results on the regional manufacturing trade balance in relation to the rest of the world and with EU countries⁶⁷

The empirical models estimation results based on the full sample and related to sectoral exports and imports are reported in tables of paper, respectively, while those based on the EU27 countries. In table shows the elasticities of exports from the overall manufacturing sector and some of its aggregates. Evidently, the elasticity of Italian regional exports (exp M) relative to the rest of the world depends significantly more on the regional GDP per capita (GDPcap_r) than on that of the importing country (GDPcap_d). This trend is also confirmed for the other economic aggregates (pure manufacturing, manufacturing characterising the 'Made in Italy', and high knowledge intensity sectors).

Distance shows an elasticity consistent with the results of the scientific community, with a negative and significant coefficient only for Italian regional exports (exp M = -0.630%) and for the 'Made in Italy' (exp M = -0.566%). Road and port infrastructure exhibit significant elasticity; they influence regional trade relations with the rest of the world with varying results. Railways do not show statistically significant elasticity. In table shows that Italian regions import more from areas with lower GDP and that the elasticity is generally lower than the GDP per capita of the importing partners. This study also highlights the effects of a region's economic wealth on global imports. Infrastructure does not show any significant elasticity except for the 'Made in Italy' with roads (0.426%) and for ports in relation to global imports (exp M = 0.151%).

Interesting results emerge regarding the trade relationships between Italian regions and the EU27 countries. The elasticity trends have the same sign, but with higher values, as the results for trade relationships with the rest of the world.

The effect of regional GDP per capita on exports is greater in trade relationships with the EU27 countries (exp M = 1.85%; exp PureM = 2.227%; exp Mml = 2.142%; exp Hkl = 2.619%). This is similar to the GDP per capita of the trade partners. Distance shows a different variation in elasticity between the two trade samples examined (the full sample and the EU27 sample). The effect of distance is smaller in the EU27 sample compared to the rest of the world (consistent results). For infrastructure, roads and ports also show significant elasticity, but with higher values in trade relationships with the EU27 sample (except for exp PureM and exp Mml). For imports, the strongest trends are also evident in relation to the EU27. A comparison between Tables 4 and 6 reveals the recorded elasticity trends. Distance in the EU27 sample shows an elasticity effect greater than that in the full sample. Roads and ports exhibit significant elasticity for imports (imp Mml = 0.523% for roads; imp M = 0.184% for ports; imp PureM = 0.046% for ports).

Port facilities represent an important factor in developing international trade. Ports have positive and significant coefficient values for all sectoral aggregates for exports to all countries considered in the full sample and to the EU27 countries except for the total M sectors. In addition, the macro region in the South and Islands, characterized by greater land distance, denotes non-significant land-based infrastructure to total exports due to the low endowment available.

⁶⁷ This paragraph was taken from: Siviero L., Torrisi B., Scuderi S. (2024).

These results confirm the correct estimations of the applied models, considering the specific geographic and logistics characteristics of different Italian and macro regions.

Focusing on evaluating the performance of Sicily, which is both economically and geographically marginal, as well as an island, we observe that the loss of export amounts to, on average, -82.87% compared with the Italian region and -90.94% compared with the Northern Italian region when considering the overall trade aggregates. Globally, this loss is smaller at -81.03%, but larger when considering the EU27 countries. With respect to the Northern Italian region, percentage deltas are amplified, at -90.94% for all aggregates considered, -89.91% for the world sample, and -91.98% for the EU27 countries.

For imports, compared with the average Italian region, there is an overall average loss of -78.29%, which becomes -77.82% for the full sample and -78.75% for the EU27. Magnified values are recorded if we use the median Northern Italian region as a benchmark for Sicily.

These results provide an evaluation of the loss of commercial relations opportunities in the Italian regional manufacturing sector. Some regions have become attractive for productive and commercial investments owing to infrastructure, whereas others experience not only peripherality but also economic marginality compared to development benchmarks. These factors have become decisive in the development of some regions in the manufacturing sector.

In conclusion, the results show that ports and highways influence the trade balance of regions, depending on their proximity to the benchmarks, whether they are economically marginal areas or they are islands.

We verify that in island scenarios, infrastructure has different effects on the manufacturing sector. These results cannot be generalised to the 362 EU islands, especially if they are large, and the effects of infrastructure on trade relations between Sicily and Sardinia are different. This is even more true if regions and/or islands are located in the southern EU.

These data describe the importance of 'economic marginality' compared to 'geographical peripherality'. Many islands are peripheral to the EU, but only a few of the large ones are on the margin of economic competitiveness.

The European study (ESPON & University of the Aegean, 2011) confirms our hypotheses that the accessibility, geographical discontinuity, and functionality of the transport infrastructure influence the competitiveness of the islands.

In the status quo, the port indicator (also confirmed for Sardinia) is the infrastructure indicator that positively determines the commercial effects in the Sicilian region, whereas the motorway endowment and railway quality indicators assume negative impact values for Sicily but are insignificant for Sardinia. These results are compatible with Sicily's insularity; most exports can be achieved only through maritime transport.

Investment in this infrastructural sector can significantly increase the value of exports of island and marginal regions. The quality of logistics infrastructure, distribution of intermodal structures within countries, number of logistics operators, and their specialisations are considered increasingly important factors in strengthening international competitiveness. This is true given territorial and infrastructural continuity (Carlucci et al., 2017, 2018).

The 'border effect' from other regions (including foreign ones) or from national territorial benchmarks contributes to creating geographical areas that are not homogeneous from the perspective of socioeconomic characteristics.

This lack of effect is evidently very weak, if not absent, in island regions, particularly peripheral regions, and can be compensated for in the case of international commercial traffic by efficient transport infrastructure and services, particularly maritime and co-modal road-sea transport.

Furthermore, the effects increase for trade relations between marginal and island areas and EU countries compared with the rest of the world. The effect on commercial competitiveness differ from that of the two analysed samples.

To increase EU competitiveness, providing a high level of service infrastructure to marginal areas is necessary to reduce the effects of the gaps between regions and benchmarks. This would produce positive effects in relation to ports, reducing the gaps in the marginality of islands compared with the rest of the world. This infrastructure is crucial for the development of trade in the manufactured products analysed in this study.

The EU Commission has recognised the disadvantageous conditions of ultra-peripheral areas and has realised that geographical peripherality does not always coincide with economic marginality. We employ a quantitative analysis to answer this research question by demonstrating the effects derived from geographical peripherality, economic marginality, and insularity, both in the trade relationship with the rest of the world and in the EU. Investments in infrastructure and tax relief for the attractiveness of new productive investments are policies that can bridge the wide gaps. Our results demonstrate the competitive gap of marginal, as well as peripheral and island, regions.

With this analysis, we clarify both the contribution of regional infrastructure and the effects generated in the trade balance of the Italian manufacturing sector in trade relations with the EU27 and with the rest of the world.

3.5. Gap results in relation of attractivity region in economic marginality and in island conditions⁶⁸

From the analysis of the 238 EU regions for which we gathered a fully balanced dataset, we have obtained the following results which should be read both vertically (positioning in the attractiveness ranking) and horizontally, i.e. taking into account the role of the variation in the relative score of the distance (GDP, distance). For example, let us consider the Austrian case and focus on the Burgenland region. This region ranks 32nd in the EU ranking exercise considering the set of 33 indicator and it ranks in a similar position with respect to GDP only (30th). Moreover, once explicitly considered its distance from the national pole (EU ranking in relation to its country's benchmark), it improves its position ranking 25th.

Put differently, as aforementioned, the latter result shows that based on (the socio-economic indicators and) the distance from the main economic pole, Burgenland could achieve a better ranking (25th) than the one actually observed on the basis of socio-economic indicators

⁶⁸ This paragraph was taken from: Corrente S., Torrisi B., Torrisi G. (2024).

(30th), only. That is, based on our ranking exercise, there is a potential premium for the centrality of 5 positions in the ranking that the region is not exploiting. The main policy implication, hence, is that the region should implement policies focusing more on its location in order to better exploit the potential benefit arising from it.

If we analyse the regions with the best attractiveness performance, then the evaluation scores become even more informative. The results based on socio-economic indicators substantially overlap the ones considering the simple GDP indicator. Furthermore, our empirical evidence seems to signal a potential role of centrality. The case of the NL regions, Sveden, and Hamburg are rather indicative. For them it is apparent that proximity to the highest scoring regions has an influence. The closer the centre of development (less peripheral), the higher the attractiveness scores.

If we analyse the case of the Italian regions (EU-wide ranking), Lombardy, Piedmont, Veneto, and Emilia Romagna are confirmed as the regions with the highest attractiveness scores. Once more, this seem to confirm the importance and consistency of the indicator with respect to proximity or centrality in the EU context.

Furthermore, focusing the analysis on the positioning of the islands the ranking exercise continues to support the hypothesis that the highest scores are recorded if these islands are proximal to the centres of development. Put differently, from our ranking exercise it clearly emerges that, in addition to the main effect of socio-economic marginality (as measured by structural indicators), the distance does play a residual role. Moreover, focusing on island we find evidence that the economically less marginal islands are those closer to the regions of EU countries with higher economic attractiveness scores; e.g., Sjælland, La Rioja, Åland register scores higher than the Italian main islands Sardinia and Sicily. Even more, Sicily and Sardinia rank at the bottom of the EU ranking (Sicily ranks 204th in EU, 211th in EU with respect to GDP and 212th with the distance effect; Sardinia 225th in EU, 226th with respect to GDP and 227th with the distance effect). Hence, in addition to supporting the tenet that the distance affects the socio-economic performance of regions, our methodological approach provides a quantitative tool to measure it.

For example in our analysis result that the ranking of Sicily with respect to the three evaluation scores (Without distance, distance compute from the GVA pole, and distance from the ER pole) for each domain. Preliminary, it is worth noting how the worst position is recorded with reference to 'education' followed by 'labour market efficiency', 'tech readiness', 'taxes', and 'economic development'. Therefore, the relative positioning in each sector signals a potential agenda to set policy's priorities in order to improve attractiveness. To the case at hand, for example, the relatively poorer performance under the labour market and education domains, for example, signals them a potential priority for policy makers.

Furthermore, it is worth noting that in all the considered domains the performance without the inclusion of the distance (red dots) is better than the performance explicitly considering the distance (both in terms of GVA and ER). According to our framework of analysis, this evidence signals the ability to at least partially overcome the potential gap arising from its peripheral condition. From a different angle, our exercise contribute towards the argument that in the Sicilian case the main driver of economic regional economic performance is not the

geographical peripherality per se, rather, more attention is deserved by socio-economic structural factors translating into socio-economic marginality (Cavalieri et al., 2023).

This aspect is further analysed reporting Sicily rankings across the 11 domains in relation to the national context. Also in this case, the relative underdeveloped condition of the island is confirmed. Indeed, Sicily never rank first or, at least, in the first 5 positions. The best ranking position is 8th out of 20 regions for the 'health' domain (without distance). For all the remaining domains (except for 'infrastructure', 9th) it always ranks in the 2nd half of the distribution. The above negligible role of distance is further confirmed. In all cases, indeed, the score without distance

These results clearly contribute towards the research questions concerning (a) robust indicators able to estimate the economic attractiveness of a territory; (b) how do territories position themselves with respect to both the globalised European contexts and with respect to their national context. Furthermore, in our opinion, a significant novel contribution of our analysis concerns the research question on (c) how does the positioning on the measure of attractiveness relates to geographical distance from poles of national development; thus, addressing the issue of the effects of economic marginality and/or geographical peripherality in a rather comprehensive way. (d) what happens to the activity when in addition to configuring the condition of economic marginality and geographical peripherality (distance) one is also an island.

The paper managed to answer the multidimensionality of the research questions in a complex manner. We obtained a triad of indicators that were statistically robust and representative of reality, as we were able to satisfy the construction of a global complex score, weighted with respect to GDP (which also answered the real representation) and weighted with respect to distance. In addition, the comparison with respect to the reference benchmarks (global and partial centre of economic development for each macro variable) led to results of particular interest. They show the extent to which proximity to the areas of highest global or partial development per macro variable can influence the region's position in relation to attractiveness. Added to these results are those referring to EU island regions and here too we were able to show that being an island is a negative factor if it is also economically marginal, whereas where islands are proximal to areas of greater economic development (benchmarks) the island effect is not perceived. Finally, from these analyses it is possible to decipher for which macro variables the overall effect of the attractiveness scores are conditioned and on which macro variables to act as a priority. For regions that are economically marginal, peripheral but also islands, the global scores will not change unless priority action is taken not only on infrastructure but also on training and the labour market. These areas will remain marginal and will see their social poverty and economic attractiveness grow. This would represent the failure of the 'economic, social and territorial cohesion' policies mentioned in Article 174 of the TFEU that push towards convergence and the reduction of gaps between European regions.

4. In future prospects

The analyses above provide an in-depth picture of the gaps and at the same time provide measures on how much still needs to be done to fill the gaps due to both insularity, economic marginality and geographical peripherality. The results highlight a clear failure of cohesion policies, in light of the persistence of conditions of economic marginality prevailing in geographical peripherality and insularity.

We will continue to improve our analyses to formulate potential policies to mitigate this excessive divergence between the insular areas of southern Europe and those of central and northern Europe.

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Gap Analysis for the Insularity⁶⁹

1. Introduction

1.1. *Definition of Insularity*

The term “insularity” refers to the unique combination of geographical, social, and economic factors that characterize areas separated from mainland territories by the sea. This concept extends beyond mere geographical isolation to encompass elements that significantly influence the infrastructure, socio-economic development, and accessibility of these areas. Due to their isolation, insular regions—regardless of size—often face numerous challenges, including limited market access, reliance on external sources for products and services, and higher transportation costs (Agius et al., 2021). However, isolation can also confer advantages, such as increased tourism appeal and enhanced capacity for preserving cultural heritage.

From a geographical perspective, insularity typically implies physical separation from larger landmasses, which directly impacts the ease and cost of transporting people and goods. The effects of this isolation are particularly pronounced in small insular states or regions with limited infrastructure, where natural barriers like seas and oceans exacerbate the expense and difficulty of communication and transportation (Encontre, 1999).

Socially, geographic isolation often fosters a strong sense of local identity and cultural uniqueness. This isolation can preserve languages, customs, and traditions that might otherwise be diluted by interaction with larger mainland civilizations (Padilla-Iglesias, 2020). However, these cultural benefits are often offset by significant drawbacks, including limited healthcare, restricted educational opportunities, a lack of economies of scale, high production costs, and vulnerabilities to climate change. On smaller, more remote islands, the scarcity of essential services can exacerbate inequalities, hinder human capital development, and limit social mobility (de la Croix, 2014).

Environmental threats also disproportionately affect insular regions, as climate change intensifies risks such as hurricanes, rising sea levels, and other natural disasters. These threats can have devastating consequences for local economies and communities. To address these unique challenges, many insular areas operate with greater autonomy than the mainland territories of their respective nations (Hepburn, 2010).

In this report, we define an insular territory as a geographically isolated NUTS-2 region that is entirely or predominantly surrounded by water, such as the Balearic Islands (Spain) or Sardinia (Italy). As detailed in the sections below, these regions face distinct challenges compared to continental NUTS-2 areas, particularly regarding accessibility and transportation costs.

⁶⁹ This paragraph was written by UNICA research group.

1.2. *Relevance of studying insularity in economic and social contexts*

The condition of insularity is a very influential factor in the socio-economic development of a region. For NUTS-2 regions, studying insularity is particularly relevant because it can highlight the economic and social disparities that exist between island and continental regions. The insularity regions can be described as areas far from the mainland, with access to a limited amount of own resources, and with a particular socio-economic environment (e.g., labor market structure). They usually are more vulnerable to socio-economic or climate changes, therefore governments should develop targeted strategies to promote resilience and diversification. For example, the COVID-19 pandemic had a severe impact on insular economies that depend on tourism, as travel restrictions have prevented large numbers of people from reaching them, damaging one or more tourism seasons and increasing existing inequalities (UNCTAD, 2020). Insularity has also an impact on human capital development, labor markets and access to essential services such as healthcare and education. Remote island communities often show lower levels of education, brain drain and shortage of qualified workers, resulting in socio-economic problems such as lower wages or higher unemployment levels (de la Croix, 2014). Environmental vulnerability is another important issue, as insular regions are particularly exposed to the repercussions of climate change. Geographic isolation also leads to higher transportation costs, which limits the competitiveness of local industries and companies (Haase et al., 2021). NUTS-2 insular regions such as the Canary Islands, often pay higher costs for goods and services, have fewer job opportunities and less infrastructure investment. These aspects can have a relevant impact on their long-term economic dynamics compared to other EU regions. By studying insularity, researchers and policy makers can develop effective strategies to promote sustainable development, resilience and social inclusion in these regions.

2. *Insularity concept and impact*

2.1. *Economic and social characteristics of Island regions*

Despite their different physical characteristics (e.g. size, distance from the mainland), insular regions have similar characteristics and face several similar challenges, such as difficulties in producing goods and services (in quantities that can benefit from economies of scale) or in providing social services (e.g. education, healthcare). NUTS-2 insular regions, except bigger territories such as Sicily or Sardinia, often show a narrow range of types of economic activities, often related to tourism or agriculture. In fact, the distance from bigger markets and the lack of access to continental transport networks, combined with the need to import most of the necessary goods by ship or air, increase the cost of goods and reduce the profitability of exported products (Borgatti, 2008). This situation leads to higher costs for consumers and companies and a reduction in external competitiveness. In comparison to continental NUTS-2 areas, these regions may potentially provide fewer options for essential services like health and education, which would degrade quality of life and limit economic growth. Smaller insular regions often rely on a limited number of economic sectors (e.g. tourism, fishing, agriculture)

for their survival and are therefore more exposed to external shocks. The reduced job supply market also leads to greater difficulty in terms of employment, creating higher unemployment and difficulty in finding highly skilled workers (Spilanis et al., 2012). For these reasons, there is an increasing amount of the so called “brain drain”, i.e. young graduates who cannot find the job they studied for in their own territory and go in search of better opportunities on the mainland or abroad. All this contributes, among other things, to the aging of the population and the shrinking of the workforce, factors that are a hindrance to economic growth.

2.2. *Insular versus continental regions*

When comparing insular regions with continental regions, several structural differences emerge. Continental regions, unless they are particularly isolated, generally benefit from more convenient access, both in terms of timing and choice, to transport networks (road, rail and air links), which facilitate the movement of goods and people. Proximity to major urban and economic centers provides continental regions with a wider range of opportunities, such as access to larger labor markets (Spilanis et al., 2012). Continental regions often enjoy greater public investment in infrastructure due to their economic and logistical importance, with positive effects spilling over into healthcare, education and public utilities. In contrast, insular regions must rely on maritime or air transport, which are typically more expensive, slower and less frequent than road or rail options. The absence or reduced natural defenses make these regions more vulnerable to environmental risks due to climate change (e.g. sea level rise) and to lower investments in infrastructure, resulting in lower levels of infrastructure development in insular regions (Bacciu et al., 2021). To quantify these differences, the efficiency indices developed in this report assess the regional performance of all European NUTS-2 regions by comparing costs, distances and times, thus obtaining a measure of the economic efficiency of insular regions compared to continental regions, identifying areas where targeted policy interventions could help to bridge the gap between them.

3. Social consequences of insularity

3.1. *Education levels and access to opportunities*

Education influences not just people’s financial and economic possibilities, but also the growth of countries or regions. Individuals with higher levels of education typically have better access to well-paying jobs, more career mobility, and easier entry into the workforce. In NUTS-2 insular regions, labor market segmentation is often very high, with many workers employed in seasonal sectors such as tourism or agriculture, while in NUTS-2 mainland regions, the labor market is more diversified and employment is spread across many different sectors, with more stable economic conditions and better long-term possibilities for workers. Regions with higher levels of education are more likely to attract investment and focus on innovation, contributing to the overall competitiveness and economic well-being of those areas (Roth and Gros, 2008).

For individuals, higher levels of education are related to better health and longer life expectancy (Zajacova and Lawrence, 2018), creating a virtuous circle in which education leads to better economic outcomes, which in turn allow for further investment in education. However, access to education and opportunities is not evenly distributed across regions, with remote, rural or island areas being the most disadvantaged. This may result in lower quality and lower educational levels, which affects students' knowledge and skills that, upon finishing their studies, will have to compete against those who have received better training (this is especially true in sectors or types of activities where emigration is more common) (CNA Sardegna, 2024). The isolation of insular regions also makes it more difficult to attract and retain qualified teachers, leading to a potential shortage (Garcia-Rodriguez et al., 2018). Addressing educational inequalities in these regions requires interventions that aim, among other things, at improving transportation infrastructure. Investments in infrastructure are essential to carry out a series of construction works aimed at building secondary schools and universities. In addition, providing scholarships, incentivizing the retention of qualified educators and the training of professional figures specific to the local job market can represent a way to better exploit educational resources and opportunities (Garcia-Rodriguez et al., 2018).

3.2. *Employment challenges and labor market segmentation*

Employment challenges and labor market segmentation are critical issues in pursuing economic development and social equity, especially in insular regions. Labor market segmentation refers to the division in subgroups (segments) that have different access to employment opportunities, wages, working conditions (ILO, 2024). Education is a very important factor for labor market inequalities, but geographic location can also be important. Among the major inequalities associated with labor market segmentation there is an unequal access to job opportunities, resulting in a division between a primary labor market (where jobs are stable, secure, and well-paid), and a secondary labor market (characterized by unstable, low-wage jobs) (Wilkinson, 2013; Doeringer and Piore, 1971). NUTS-2 insular regions often experience more evident labor market segmentation due to geographic isolation, lack of infrastructure, and low diversification of economic activities. In insular NUTS-2 regions, such as the Canary Islands or Crete, seasonal employment is the most common type of work, which results in erratic employment availability and unstable income. In these regions, the economy is often dominated by the agriculture and tourism sectors, which request almost exclusively seasonal or low-paid jobs with little opportunity for career advancement (Armstrong et al., 2014). This contrasts with more diversified labor markets in continental NUTS-2 regions, where employment is spread across various sectors, leading to more stable economic conditions and better long-term prospects for workers. In many insular regions, besides the problem of employers in specialized sectors struggling to find workers with high technical skills, it may also happen that workers are overqualified for available jobs, leading to underemployment and a waste of human capital (Wilkinson, 2013). Last but not least, gender inequalities also play a role in labor market segmentation. Women are often more present in the secondary labor market, occupying part-time, temporary, or jobs with lower wages and fewer benefits (Tijdens, 2002).

4. Dataset and methodology

4.1. *Overview of NUTS-2 regions and data sources*

The NUTS (Nomenclature of Territorial Units for Statistics) classification system is the standard for referring to the subdivisions of countries for statistical purposes. The main source of NUTS-2 data is the Eurostat (the statistical office of the European Union), which provides statistics on economic, social and many other indicators. The availability of official and consistently published data over time is important to allow researchers to conduct in-depth studies on many topics. Despite this, and especially when the analyses involve the use of data over a rather long-time horizon, it may still be necessary to standardize the data as the nomenclature has been modified several times over time. In the last 10 years, for example, an update to the index has been proposed roughly once every 3 years in 2013, 2016, 2021 and 2024. We decided to adapt the nomenclature to that of 2021 which was the most recent at the time the analyses began. In general, the NUTS nomenclature was developed to divide the entire territory of the European Union into regions according to the different levels of numbering used and the NUTS-2 level, in particular, is the level used for regional analysis (Eurostat, 2024). NUTS-2 regions generally represent territories with a number of inhabitants ranging from 800,000 to 3 million. The main function of the NUTS-2 classification is to provide a stable reference over time for the regional statistics of European states, allowing comparisons between regions, which is essential for making assessments at a more granular level. NUTS-2 regions can vary from entire regions (e.g. Scotland or Bavaria) to much smaller areas, such as individual provinces. This division into regions is also important in the evaluation of the European Union's cohesion policies, which aim to reduce economic and social disparities across Europe (a concept particularly applicable to island areas). In fact, one of the main goals of EU policies is to use resources for job creation and to promote economic progress in less developed regions. For example, labor market data, such as employment and unemployment rates, can be used to assess the effectiveness of policies to reduce unemployment and to represent disparities in job opportunities between regions. Other important datasets at NUTS-2 level available in the Eurostat portal that will be used in future analyses are the gross domestic product (GDP) per capita, the investments, the unemployment rates, and the education levels (Eurostat, 2024).

4.2. *Costs and distance metrics: geodesic distance, road distance, time*

In carrying out an analysis that aims to compare the approximately 300 European NUTS-2 regions in relation to the costs incurred for the transport of goods, the concept of distance is of fundamental importance. It is easy to imagine that a greater distance from the center of the European continent entails an increase in costs in absolute terms. In addition to providing an initial overview of the situation from this point of view, however, in our work we also focus on transport efficiency, therefore comparing costs with distances travelled. When referring to island regions (even more if they are geographically located in the peripheral areas of Europe), measuring distance from various points of view is essential to assess the repercussions of isolation. Distance can be assessed through various metrics, and in our work we will refer to the

geodesic distance (or distance “as the crow flies”), road distance and travel time. Although strongly linked to each other, each of these metrics allows for targeted assessments relating to transport costs.

Geodesic distance, also known as great-circle distance, measures the shortest path between two points on the Earth’s surface. It is one of the simplest metrics to use and is an approximation of the distance between locations that does not take into account physical obstacles such as mountain ranges or seas. For example, an island region may be close to another (island or not) in terms of geodesic distance, but the actual route a vehicle must travel may involve hours of ferry stops or loading and unloading cargo from an airplane. For this reason, geodesic distance often underestimates true transportation costs, especially for island regions (Persyn et al., 2016). However, in the case of island regions, geodesic distance can provide a good basic assessment of the physical isolation of these areas from the mainland (or, as in our case, from other European regions) (Persyn et al., 2016).

Road distance provides a more realistic measure of transportation costs, especially in regions where road networks are well developed, because road distance takes into account the actual routes that vehicles must travel based on the current road network in a region. This may be one of the main issues of this distance, because while the road network in a developed country does not change dramatically over time, traffic problems, diversions, closures or the opening of new roads can significantly change the road distance between two places. This makes an analysis based on this distance good for the short-to-medium term, but not in the long term. Geodesic distance, on the other hand, is immutable.

Travel times are an important metric for evaluating costs and accessibility between regions. Travel time incorporates by default the physical distance between two locations, but also takes into account the efficiency of transport infrastructure and, where applicable, potential delays due to areas with heavy traffic, road closures or other elements that may affect the route of a given road section. However, this strength can also become an element that is difficult to disambiguate when considering other aspects for which it would be necessary to separate the pure distance part from the efficiency in covering it. In the case of insular regions, travel time is strongly influenced by the efficiency of maritime and air transport and by the times required to handle incoming and outgoing goods.

In the context of NUTS-2 regions, the computation of geodesic and road distances between regions, especially island regions such as the Aegean islands (Spilanis et al., 2012), highlights the additional costs due to geographical isolation. This has enabled to understand the economic disadvantages faced by insular regions compared to continental regions, such as increased travel times for goods and people.

5. Economic costs of insularity

5.1. *Efficiency index: costs to distance ratios to identify gaps in economic performance*

Building an efficiency index that is able to assess the differences at the NUTS-2 level with regard to the ratio between costs and distances is important to understand which (and where) interventions can be carried out to improve the economic and social situation of a region. Insularity is known to lead to an increase in transport costs as the means to reach these places are limited compared to the choices available on the mainland and the costs incorporate a part due to the poor scale economies. If transport costs prove to be much greater than what would be reasonable to assume given the distance, then we are faced with inefficiencies, the causes of which must be investigated. For insular NUTS-2 regions, an efficiency index based on cost-distance ratios can help to quantify how geographical location can be an obstacle to economic activity. For example, the high costs of importing goods and services to islands can be directly related to the availability of transport infrastructure (i.e., ports, airports). An efficiency index can highlight which islands have excessively high costs compared to their distance from the mainland, thus providing an indication of the usefulness of targeted investments in transport infrastructure, such as improving ports or increasing the frequency of ferry services to reduce travel times and costs (Groizard, 2014).

In essence, our efficiency index compares transport costs with the distances of the NUTS-2 regions that must be reached. The work of Persyn et al. (2016) that we took as a reference considers transport costs also those related to fuel costs, toll payments, taxes, maintenance costs and the salary of the truck driver. All these costs were added together to obtain a total “distance” cost variable. The authors base their estimate on a simulation of possible routes among a dataset of over 4 million road-segments for the movement of goods that involve the creation of centroids along which a representative 40t heavy duty vehicle (HDV) moves. Since road transport represents 76.4% of total freight transport in the EU (Eurostat, 2016) a simulation of these costs can be of great help in providing reliable estimates. About the methods to calculate the distances, please refer to paragraph 4.2. Based on the dataset made available by Persyn et al., we updated the total distance variable using the HICP rates. HICP is the acronym for Harmonised Index of Consumer Prices, which is a measure of inflation that allows comparisons across countries and over time. This dataset is available on Eurostat and has 2015 as its reference year. This means that the reported values indicate how much prices have changed compared to the 2015 values. A value of 102 in 2016, for instance, means that prices increased by 2% in one year. By using this information we updated the costs computed for 2016 for all the years where HICP were available (2017 – 2023). In order to do so, we set 2016 as the reference year and calculated relative changes based on how prices evolved after 2016. These values were multiplied by the 2016 total distance cost to obtain the update for this cost category. The update of these values will be homogeneous for all those regions within the same country, since inflation rates are available only at national level and not regional. Subsequently, we obtained the population data for the NUTS-2 areas for the years 2017 – 2023 from the Eurostat archive. Following the approach proposed by Bucci et al. (2021), the

accessibility measure was computed as the ratio between A_i^T and A_i , where A_i^T is computed as:

$$A_i^T = \sum_{j=1}^N m_j C_{ij}$$

while A_i is computed as:

$$A_i = \sum_{j=1}^N m_j D_{ij}$$

where m is the mass that indicates the importance attributed to the arrival location (such as, for example in this report, the resident population), C is the cost incurred to move from location i to location j , and N is the number of locations. These values were obtained for each of the 231 NUTS-2 regions in our dataset and were compared to their respective means to be able to obtain a relative value that indicates whether in that region the A_i^T and A_i values were above or below the average. Let us define these values as N and V , then they are simply defined as the mean-scaled version of the weighted costs and distances, respectively. For each of the i locations, we computed the ratios $N_i = \frac{A_i^T}{A^T}$ and $V_i = \frac{A_i}{A}$, respectively. Lastly, in order to be able to obtain I_i^T we computed the ratio between N and V of each NUTS-2 region, such as:

$$I_i^T = \frac{N_i}{V_i}$$

Table 1 shows an excerpt of the dataset aggregated at NUTS-2 level which is attached to this report. These values were used to obtain maps that offer a clear and useful visualization of the indices. Each map represented in Figures 1 to 3 provides an easily interpretable representation of the A_i^T index, the A_i index and the I_i^T ratio, respectively. It is straightforward to observe regional variations by looking at the color gradients which range from darker colors (lower values) to lighter colors (higher values) that help to distinguish different intensities across the mapped areas. Figure 1 shows the updated total distance costs between each NUTS-2 region and all other EU regions. As expected, peripheral regions (such as northern Europe) show higher costs than the European average region. Similarly, Figure 2 shows the geodetic distances between each NUTS-2 region and all other EU regions, while Figure 3 represents the ratio between the two indices. In practice, if a region is far from the European center, it will have an A_i value greater than one but if, hypothetically, its costs are lower compared to the European average, then the ratio I_i^T will be lower than one. The last map (Figure 3) shows that many peripheral regions are in a condition that can be interpreted as good efficiency or as the fact that costs do not increase linearly with distance.

Similar maps can be produced for any other year from 2018 to 2023 to be able to appreciate the evolution of these indicators over time.

In the Appendix, two alternative versions of Figures 1 to 3 are shown. The maps in Figure 4 were created using A_i values computed with road distance instead of geodetic distance, while the maps in Figure 5 were created using A_i values computed with time instead of geodetic distance.

Table 1. Computed values for the indices N_i , V_i and I_i^T for years from 2017 to 2023

NUTS ID	A^T	A^T	A^T	A^T	A^T	A^T	A^T	A_i	A_i	A_i	A_i	A_i	A_i	A_i	I^T	I^T	I^T	I^T	I^T	I^T	I^T
	2017	2018	2019	2020	2021	2022	2023	2017	2018	2019	2020	2021	2022	2023	2017	2018	2017	2017	2017	2017	2017
AT11	0.82	0.82	0.82	0.83	0.84	0.83	0.84	0.75	0.75	0.75	0.75	0.75	0.75	0.76	1.09	1.1	1.1	1.11	1.11	1.1	1.11
AT12	0.8	0.8	0.8	0.81	0.81	0.8	0.81	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.06	1.07	1.07	1.08	1.08	1.07	1.08
AT13	0.8	0.81	0.81	0.81	0.82	0.81	0.82	0.75	0.75	0.75	0.75	0.75	0.75	0.76	1.07	1.08	1.08	1.09	1.09	1.08	1.09
...
SK02	0.78	0.79	0.8	0.81	0.82	0.84	0.87	0.84	0.84	0.84	0.85	0.85	0.85	0.85	0.93	0.93	0.95	0.96	0.96	0.98	1.03
SK03	0.82	0.83	0.84	0.85	0.86	0.88	0.92	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.92	0.92	0.94	0.95	0.95	0.97	1.02
SK04	0.89	0.9	0.91	0.92	0.93	0.95	0.99	1.01	1.02	1.02	1.02	1.02	1.02	1.02	0.88	0.88	0.9	0.91	0.91	0.93	0.97

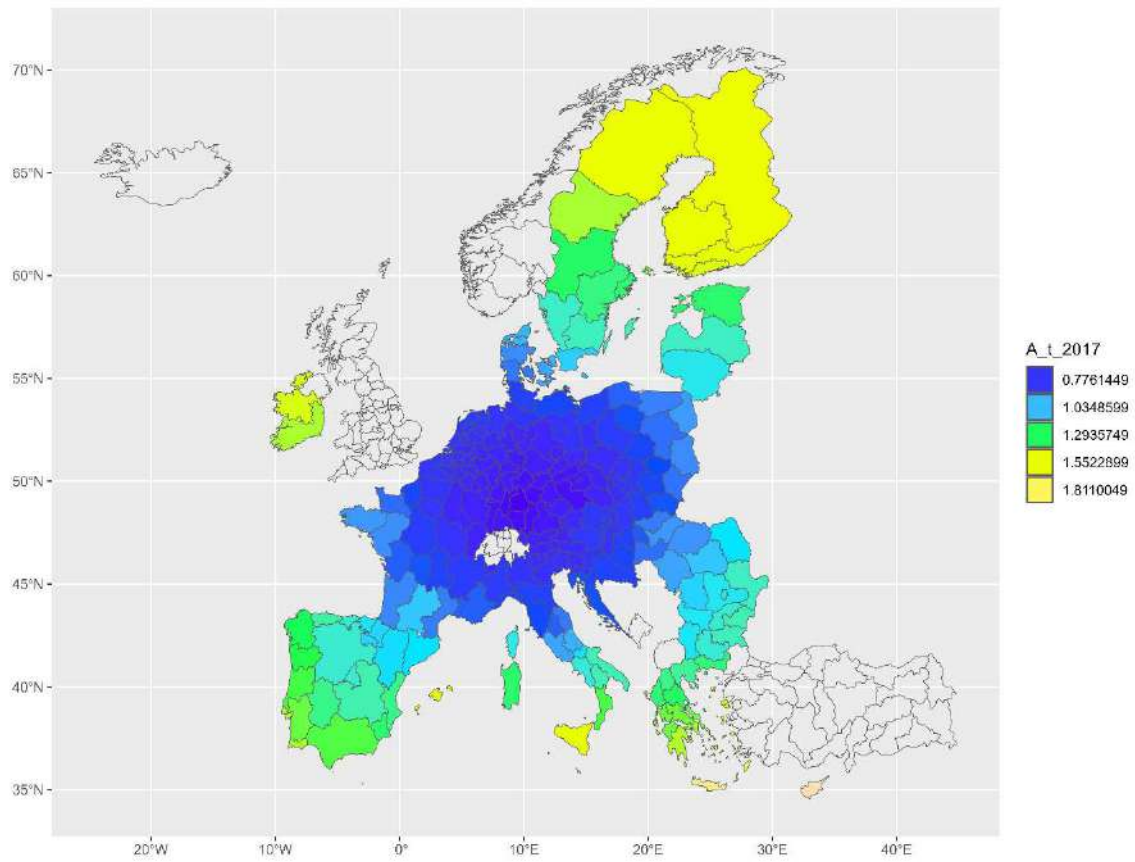


Figure 1. Values of the N_i index ($\frac{A_i^T}{A_i^*}$) for 2017

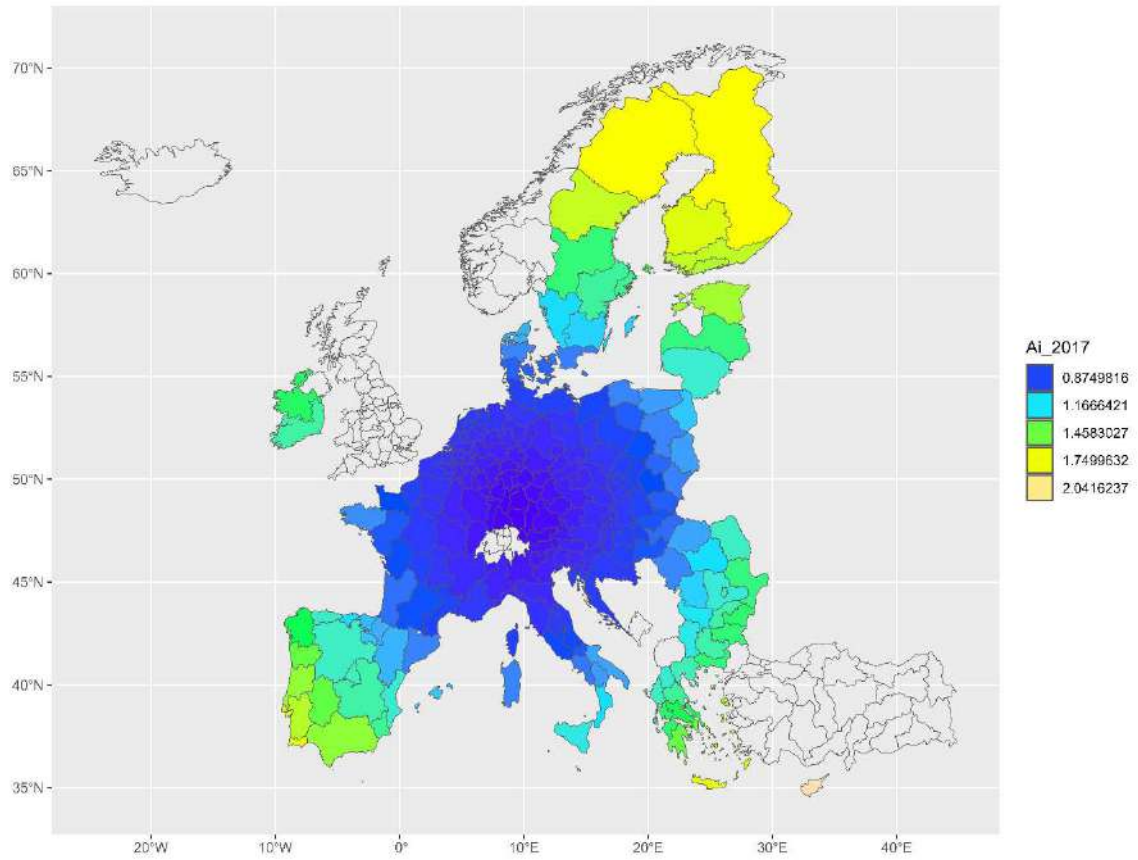


Figure 2. Values of the V_i index ($\frac{A_i}{A}$) for 2017

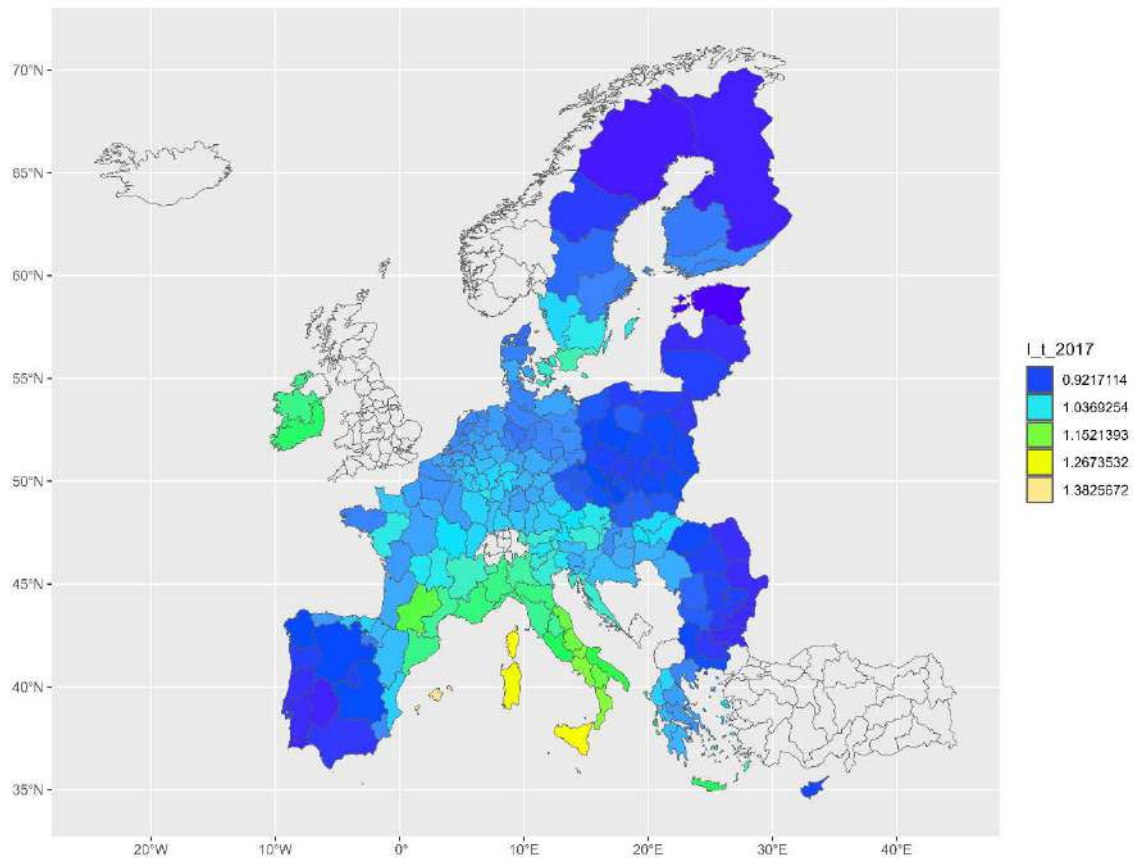


Figure 3. Values of the I_i^T index ($\frac{N_i}{V_i}$) for 2017

5.2. Socio-economic indicators: GDP, education levels, investments

Socio-economic indicators are important tools useful to understand economic systems, in particular in the context of NUTS-2 regions, because in the case of insular areas, these indicators can reveal the challenges islands face due to their geographical isolation and limited resources. Indicators such as the Gross Domestic Product (GDP), education levels and investment levels convey information into the economic development and social well-being of different regions. Gross Domestic Product (GDP) reflects the monetary value of all goods and services produced in a specific period in a country or region and allows for monitoring and comparisons over time. For insular economies, GDP often results to be stable without relevant fluctuations, while others, particularly those with tourism as their main activity, may show significant uncertainty (Spilanis et al., 2012). Education is also an important socio-economic indicator, as it has direct implications for the labor market and economic growth. Higher levels of education usually lead to increased human capital, which has positive repercussions on the economy (e.g., greater innovation), but insular regions may have lower levels of education than mainland regions because they face significant difficulties in retaining skilled workers given limited job opportunities and the “temptations” of larger urban centers with more attractive labor markets (Spilanis et al., 2012). For

this reason, it is very important to understand where and how to make the necessary investments to improve educational facilities. Finally, investment is an indicator of the willingness of local and non-local governments to allocate resources to growth and development. A good level of investment generates confidence in the economic prospects of the region, which leads to the creation of new jobs and improved infrastructure. The problem is that insular regions often struggle to attract investment due to geographical isolation, limited market size and higher transport costs which reduces the accessibility of these regions (ESPON, 2006). Investments in areas such as transport networks, telecommunications systems, renewable energy, and tourism, can stimulate sustainable economic activity and help mitigate the effects of isolation and attract investment by improving business competitiveness (Spilanis et al, 2012).

Appendix

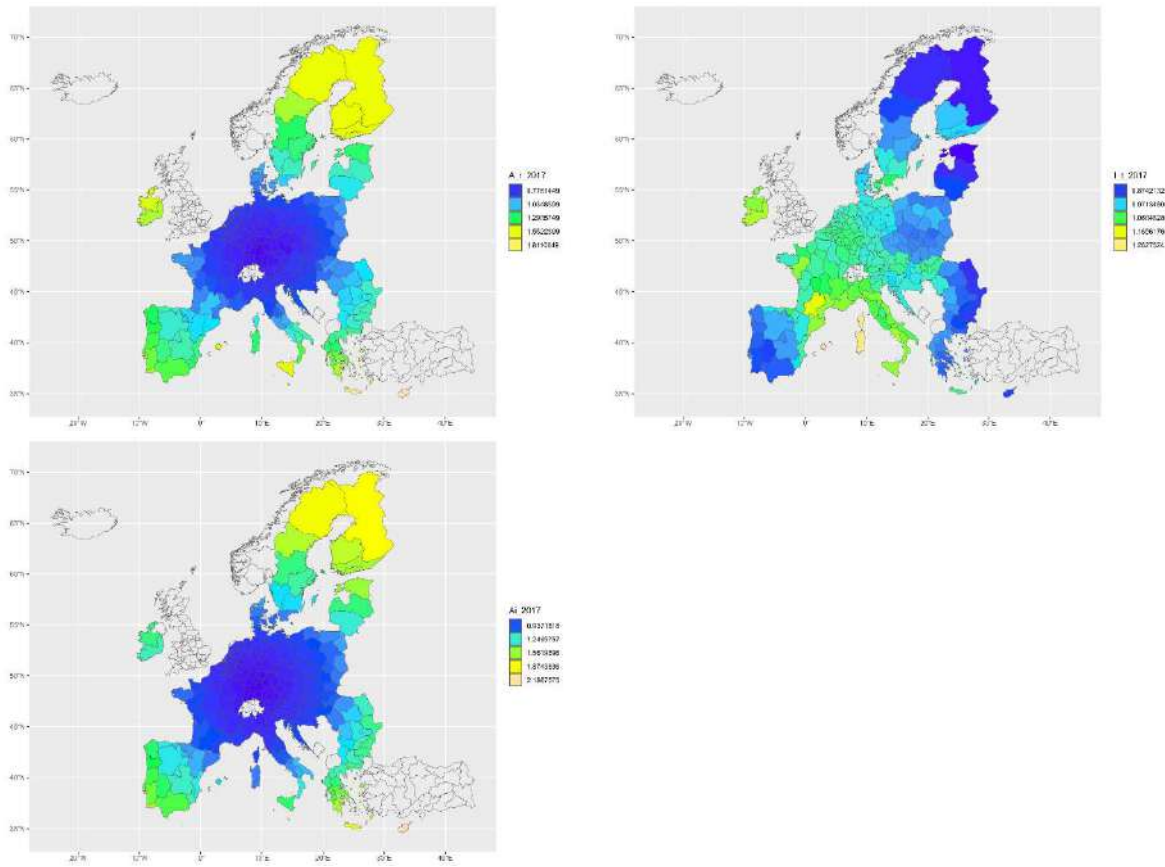


Figure 4. Alternative version of the N_i , V_i and I_i^T ratios for 2017 using road distance instead of geodetic distance

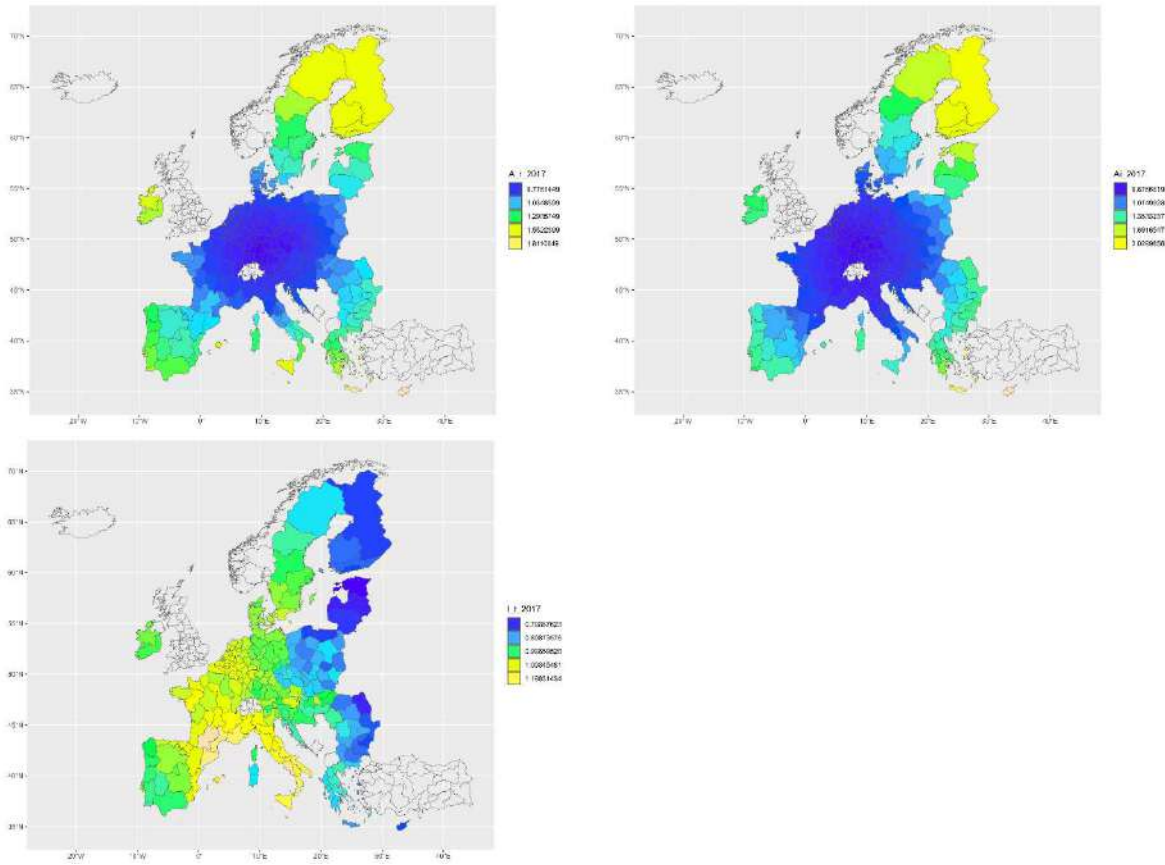


Figure 5. Alternative version of the N_i , V_i and I_i^T ratios for 2017 using time instead of geodetic distance

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Measuring accessibility within island⁷⁰

1. Introduction and literature background

The condition of insularity encompasses significant variability. As Licio and Pinna (2021) argue, there is a notable distinction between *being an island* and *having islands*, with differences occurring across islands themselves. Simply being an island does not inherently entail substantial costs; instead, the costs associated with insularity are amplified by specific characteristics, such as remoteness, size, and territorial dispersion.

The literature identifies several factors that exacerbate the challenges of insularity. Armstrong and Read (1995) emphasize the disadvantage posed by small size combined with geographic isolation. Gillis (2004) and Borgatti (2008) highlight the role of remoteness and its interaction with distance. Furthermore, territorial dispersion—common in archipelagos—leads to higher production costs, larger public sectors, and shortages of skilled labor. Licio and Pinna (2021) developed a composite insularity index, measuring insularity globally and identifying the greatest costs for islands that are remote, small, and dispersed.

Vulnerability is another critical dimension of insularity. As Briguglio (1995) and Atkins et al. (2000) note, islands are particularly exposed to exogenous shocks, including environmental and climatic events, which severely impact their economies. Governance structures further compound these challenges. Licio and Pinna (2021) distinguish between islands that are autonomous states and those dependent on larger countries, finding that non-sovereign islands face the greatest disadvantages of insularity.

Small-island nations and sub-national island jurisdictions (SNIJs) have been the focus of international programs and policies, underscoring the inadequacy of addressing insularity solely at the national level. This was first acknowledged in global frameworks like the UN's Agenda 21 and the 1992 Earth Summit. The EU has also recognized the unique challenges faced by island regions, particularly in the Maastricht Treaty revision, emphasizing the need for tailored solutions.

Research on island economies gained momentum in the 1990s, focusing on Small Island Developing States (SIDS), economic growth, vulnerabilities, sustainable tourism, and the costs of insularity. More recently, the COVID-19 pandemic brought renewed attention to island remoteness, highlighting both the benefits of isolation and its economic drawbacks, particularly in tourism-dependent economies.

However, while substantial research has been conducted on insularity, the assumption that these challenges uniformly affect an entire island is overly simplistic. In larger islands, internal disparities can result in some areas experiencing greater isolation, remoteness, and costs than others.

⁷⁰ This paragraph was written by Vania Licio and Anna Maria Pinna (UNICA).

Internal remoteness and marginality have been explored in broader geographical contexts, particularly in rural and peripheral areas. In Italy, the National Strategy for Inner Areas (SNAI) addresses these issues by promoting policies to tackle depopulation and improve accessibility in areas with limited opportunities. Recent studies have expanded on this framework, offering alternative classifications of marginal areas based on mobility, demographics, and socioeconomic indicators (Gallo & Pagliacci, 2019; Compagnucci & Morettini, 2024; Vendemmia et al., 2021).

This study focuses on the condition of insularity in Italy's two largest islands, Sicily and Sardinia, examining accessibility to services and transport infrastructure. Specifically, we analyze travel times from municipalities (Local Administrative Units - LAU) to cities and urban centers that provide essential services such as healthcare, education, and transportation, as well as to key infrastructure enabling intra-island and mainland connections.

Key Findings:

1. Peripheral and Ultra-Peripheral Municipalities:

In Sicily, 40.3% of municipalities are classified as "Peripheral," while in Sardinia, 13.5% are "Ultra-Peripheral," exceeding national averages.

2. Travel Times:

- Approximately 35% of towns on both islands require over 40 minutes to reach their reference municipality.
- Sardinia has 26 municipalities with travel times exceeding 90 minutes, compared to only 6 in Sicily.
- Eastern Sardinia faces the longest travel times, with 32 municipalities requiring over 90 minutes to access a large city. In contrast, most Sicilian municipalities have travel times of 30 to 45 minutes.

3. Transportation Infrastructure:

- Sardinia lacks motorways, and travel times to railway stations and airports are significantly longer, particularly in its central and eastern regions.
- Port access is more favorable in Sicily, while Sardinia's central and southeastern regions experience extended travel times to ports, often exceeding 90 minutes.

While both islands face challenges in accessibility, Sardinia's struggles, particularly in its eastern municipalities, are more pronounced. Addressing these disparities requires targeted interventions to improve connectivity, enhance transport infrastructure, and ensure equitable access to essential services. These measures are crucial for reducing isolation and fostering socio-economic development across insular regions.

2. Data and methodology

We aim to present a comprehensive analysis of accessibility within island, using detailed data on accessibility and travel times⁷¹ provided by Istat at the municipal level (LAU). Our analysis draws from three main data sources from Istat.

To estimate travel times to cities, we use a detailed dataset of origin–destination matrices, which measure distances in kilometers and travel times in minutes between all Italian municipalities⁷². This dataset, processed using Geographic Information Systems (GIS) tools and a commercial road graph, maps out 7,903 municipalities as of January 1, 2021. The matrices integrate updated geographic and traffic data from the 2020 TomTom road graph, which reflects real-world traffic conditions, road characteristics, and factors like congestion, traffic signals, and other potential delays. Travel times were recorded on October 2, 2020, at 8:30 AM, a peak urban commuting hour, and were calculated using the Dijkstra algorithm, which minimizes total travel distances. The data includes variable speed profiles that reflect different traffic speeds throughout the day, providing a realistic view of travel conditions. We combine this dataset with 2021 Census data, focusing on cities with at least 50,000 inhabitants.

Our second data source is the Composite Fragility Index (IFC),⁷³ a summary measure that identifies municipalities most exposed to certain risk factors, facilitating analysis of territorial fragility over time. The index is built from twelve indicators representing key territorial, environmental, and socio-economic dimensions of fragility. We use the index of accessibility to essential services, which measures how remote a territory is from centers offering three crucial services (education, health, and mobility) as defined by the National Strategy for Inner Areas (SNAI).⁷⁴ The indicator reflects the average road travel time using a private vehicle between the center of a municipality (identified by the centroid of the census section where the town hall is located) and the corresponding center of the nearest Core or inter-municipal Core. The Core or inter-municipal Core municipalities are identified based on the availability of all three essential services: a hospital with an emergency department; a complete cycle of upper secondary schools (at least one classical or scientific high school and at least one technical or vocational institute); and a railway station with active passenger service, at least of “Silver” category (i.e. a medium-small train station). Travel times to these service providers refer to 2019.

The third data source focuses on municipal accessibility to key transportation infrastructure.⁷⁵ Through an agreement between ISTAT and the Management Authority of the PON “Governance and Institutional Capacity 2014–2020,” ISTAT has developed new statistical indicators at the municipal level regarding accessibility to infrastructure nodes for road, rail, sea, and air transport networks. Accessibility is generally measured by the ease of reaching a given destination, which is calculated based on the distance or travel time

⁷¹ Travel times represent the flip side of accessibility. They act as a proxy for transportation costs and are a key factor in determining market potential.

⁷² <https://www.istat.it/non-categorizzato/matrici-di-contiguita-distanza-e-pendolarismo/>.

⁷³ https://esploradati.istat.it/databrowser/#/it/dw/categories/IT1,Z0930TER,1.0/CFI_MUN.

⁷⁴ According to the Inner Areas Map (*Mappa delle Aree Interne*, in Italian), Italian municipalities are categorized based on their proximity to essential services. This map identifies municipalities that jointly offer three types of services—health, education, and mobility—referred to as Cores or Inter-municipal Cores. Other municipalities are represented according to their distance from these Cores in terms of actual travel times, classifying them into four categories of increasing relative distance: Belt, Intermediate, Peripheral, and Ultra-peripheral. This classification highlights the potential disadvantages in accessing services for those farther away.

⁷⁵ <https://www.istat.it/comunicato-stampa/laccessibilita-dei-comuni-alle-principali-infrastrutture-di-trasporto/>.

between the origin and destination. This dataset covers the administrative geography as of January 1, 2021, and includes 7,903 municipalities. It tracks access to 258 railway stations (with active passenger services, including long-distance trains), 2,842 highway access points, 35 commercial airports, and 54 ports with passenger traffic. Distances are measured in travel times using the TomTom road graph, and we rely on the "Cost to Closest" index, which calculates the minimum time needed to reach one of these key infrastructure points from any given origin in 2022.

Given the large volume of data, we employ maps to visually represent our findings, helping to highlight spatial patterns in accessibility. These maps will serve as the foundation for discussing the results in the following section.

3. Results and discussion

Accessibility and travel times are strictly related to geography and transport infrastructure endowment. Accessibility refers to the ease with which individuals can reach desired services or locations. It is influenced by the distance to these locations, the availability of transportation options, and the quality of the infrastructure. Travel times are the other side of the coin, encompassing the duration it takes to travel from one place to another. It is affected by factors such as the mode of transportation, traffic conditions, and the physical distance between locations.

From a purely geographical perspective, Sicily and Sardinia are the two largest islands in the Mediterranean Sea. Administratively, they are two NUTS 2 Italian regions. Examining accessibility and travel times within both islands helps to identify differences across territories within each region, as well as to compare the two islands, highlighting both similarities and distinctions.

Sicily covers an area of 25,711 km², with much of its landscape dominated by mountainous terrain. Major mountain ranges include the Madonie, Nebrodi, and Peloritani, while Mount Etna, Europe's tallest and most active volcano, is prominent feature in eastern Sicily. Etna not only shapes the island's landscape and contributes to soil fertility but also affects the operation of Catania's airport when volcanic ash is released into the atmosphere. Standing at 3,369 meters, Etna is the highest peak in Sicily, where the average elevation is 413 meters. In terms of transport infrastructure, the island has more than 700 km of motorways, extending to over 1,700 km when major roads similar to motorways are considered. Sicily is also equipped with 6 airports,⁷⁶ 8 municipalities with ports⁷⁷ – 6 of which have passenger ports – and 40 train stations that are classified as at least "Silver" category.

Sardinia spans an area of 24,090 km², with much of its landscape characterized by rugged mountains and rolling hills. The island's highest peak is Punta La Marmora, located in the Gennargentu mountain range, standing at 1,834 meters. Other prominent ranges include the Monte Limbara in the North and the Sulcis mountains in the South. The average elevation of the island is 334 meters. In terms of transport infrastructure, Sardinia has no motorways, but the State Road 131 Carlo Felice (SS 131) serves as the main transportation artery of the island, compensating for the absence of motorways in the region. It also holds

⁷⁶ Catania, Comiso, Lampedusa, Palermo, Pantelleria, and Trapani.

⁷⁷ Augusta, Catania, Messina and Tremestieri, Milazzo, Palermo, Porto Empedocle, Termini Imerese, Trapani.

some importance beyond the island, as it is part of the multimodal corridor connecting Sardinia to the mainland, the Trans-European Transport Networks, and the European route E25 (of which it constitutes the final and southernmost section). The island has 3 main airports,⁷⁸ 8 ports,⁷⁹ 5 passenger ports,⁸⁰ and fewer than 15 railway stations that are classified as at least “Silver” category. Differently from Sicily, Sardinia has no long-distance trains. As of January 1, 2021, Sicily included 390 municipalities, while Sardinia had 377.⁸¹ According to the Map of Inner Areas, ISTAT classifies Italian municipalities based on their accessibility to three types of essential services: healthcare, education, and mobility. These services are provided by municipalities known as Cores or Inter-municipal Cores, which represent the so-called primary destination municipality (comune di destinazione prevalente, in Italian). As the distance (measured in road travel times) from these centers increases, municipalities are classified as Belt, Intermediate, Peripheral, or Ultra-peripheral. Sicily has 14 Cores,⁸² while Sardinia has 8.⁸³ These centers provide essential services to the remaining municipalities. Table 1 provides the distribution of municipalities according to the 2021–2027 Inner Areas classification.

Area	Core	Belt	Intermediate	Peripheral	Ultra-peripheral
North-West	2.5	63.7	20.2	11.3	2.2
North-East	4.0	54.7	19.5	17.1	4.8
Center	4.5	40.6	33.0	19.7	2.2
South	2.5	33.4	28.6	27.4	8.1
Islands	2.9	22.2	28.9	34.9	11.1
Sardinia	2.1	27.6	27.3	29.4	13.5
Sicily	3.6	16.9	30.5	40.3	8.7
Italy	3.0	48.4	24.4	19.3	4.8

Table 2 Distribution of municipalities according to the classification of Inner Areas 2021–2027, percentage values. Source: Own elaborations on Istat (data)

ISTAT notes that over 48% of Italian municipalities are classified as “Belt” municipalities, meaning that their travel distance to a reference hub is less than the median travel time of 27.7 minutes. Another 24.4% are classified as “Intermediate,” referring to municipalities with a travel distance from the hub between 27.7 and 40.9 minutes (third quartile). “Peripheral” municipalities represent 19.3% and have a distance of 40.9 to 66.9 minutes from the nearest hub (95th percentile). Finally, 4.8% are considered “Ultra-Peripheral” municipalities, where travel to the nearest hub (representing 3% of Italian municipalities) takes more than 66.9 minutes. These percentages vary significantly by macro-region. The Center and North-East of Italy have a larger number of Cores and inter-municipal Cores relative to their total municipalities. In contrast, the North-West has the highest percentage of Belt municipalities. The Islands, however, stand out with the highest proportion of Peripheral and Ultra-

⁷⁸ Alghero, Cagliari, and Olbia.

⁷⁹ Cagliari, Golfo Aranci, Olbia, Oristano, Porto Torres, Portoscuso, Santa Teresa di Gallura, Sarroch.

⁸⁰ Arbatax (Tortoli), Cagliari, Golfo Aranci, Olbia, Porto Torres.

⁸¹ As of January 1, 2024, there are 391 municipalities in Sicily.

⁸² Agrigento, Caltanissetta, Catania, Cefalù, Erice, Marsala, Mazara del Vallo, Messina, Milazzo, Palermo, Ragusa, Siracusa, Termini Imerese, Trapani.

⁸³ Cagliari, Carbonia, Iglesias, Olbia, Oristano, Sassari, San Gavino Monreale, Villacidro.

Peripheral municipalities. In both Sicily and Sardinia, travel from nearly 35% of municipalities to their reference center takes over 40 minutes, and in 11% of cases, travel times exceed one hour. In Sardinia, Ultra-Peripheral municipalities account for 13.5% of the total. The island has the highest number of Ultra-Peripheral municipalities: 51. Sicily, instead, has, on the one hand, the second highest number and proportion of Peripheral municipalities:⁸⁴ they are 157, representing 40.3% of the total. On the other hand, the fraction of Belt municipalities is very low: 16.9%.

This distribution is illustrated in Figure 1, which shows travel times by car from each Sicilian and Sardinian municipality to its primary destination municipality in 2019. A distinct spatial distribution emerges for Sardinia, with notably lower accessibility in the eastern part of the island, where travel times to the nearest hub exceed 100 minutes. For most of these, Cagliari serves as the primary service provider. The mountainous geography and, in particular, the distance from Sardinia's main highway (S.S. 131) divide the island clearly into East and West. As many as 26 Sardinian municipalities require more than an hour and a half to reach their reference hub, and 18.8% of Sardinian municipalities have travel times exceeding 60 minutes. In Sicily, the situation is somewhat more favorable, with a greater number of areas where travel times range between 30 and 45 minutes. Only 6 municipalities have travel times higher than 90 minutes, and 4 of these are in the islands of Lampedusa and Linosa, Pantelleria, Salina, and Ustica. However, in 63 municipalities (16%), travel times exceed one hour.

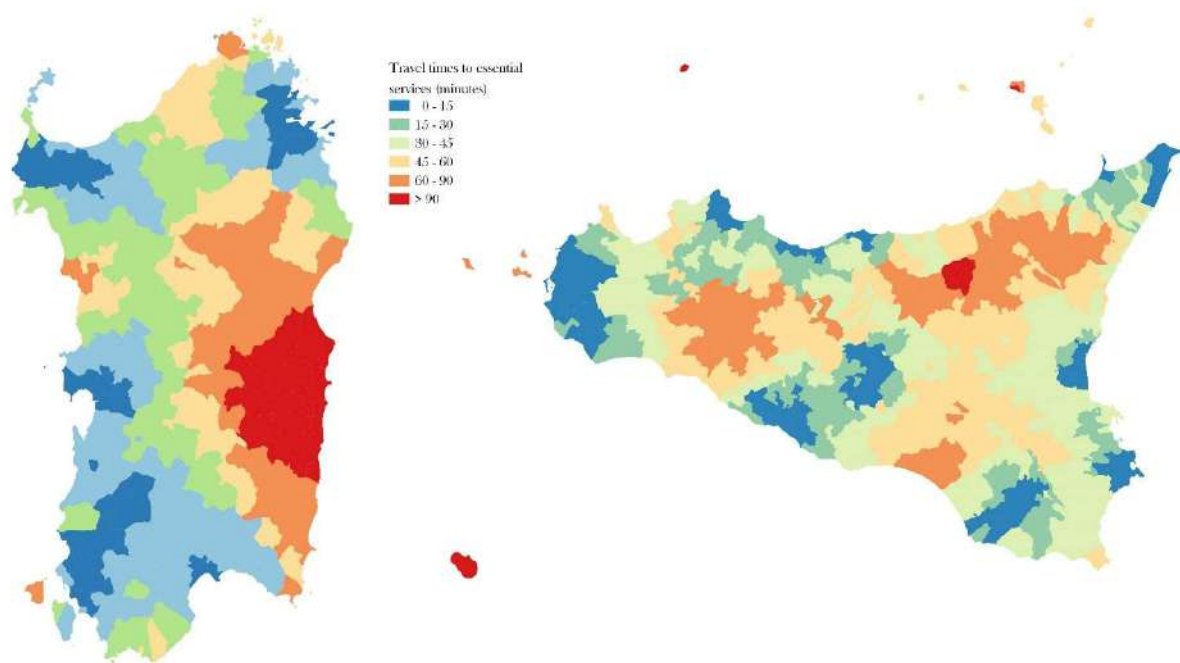


Figure 1 Travel times (minutes) to access essential services (health, education, transportation). Source: Own elaboration on Istat data

⁸⁴ The Italian NUTS 2 region that ranks first for the highest proportion of Peripheral municipalities is Molise (47.8%). Basilicata, instead, ranks first for the highest proportion of Ultra-Peripheral municipalities (33.6%).

Travel times to cities serve as an alternative measure of accessibility to essential services. Large cities function as hubs for healthcare, education, retail, and specialized services, so assessing travel times to these areas helps evaluate access to these critical resources. Following the approach of Weiss et al. (2018), we include all Italian municipalities with populations exceeding 50,000 inhabitants in 2021.⁸⁵ Results are shown in Figure 2. In Sardinia, the eastern region has the longest travel times to cities, with 32 municipalities requiring over an hour and a half to reach a large city. In the central part of the island, travel times range between 60 and 90 minutes, affecting 122 municipalities (32%). In contrast, Sicily has a more favorable situation: aside from six municipalities on smaller islands (Lampedusa and Linosa, Pantelleria, Salina, and Ustica), only two municipalities on the main island have travel times exceeding 90 minutes. Most areas in Sicily have travel times between 30 and 45 minutes, covering 134 municipalities (34% of all Sicilian municipalities).

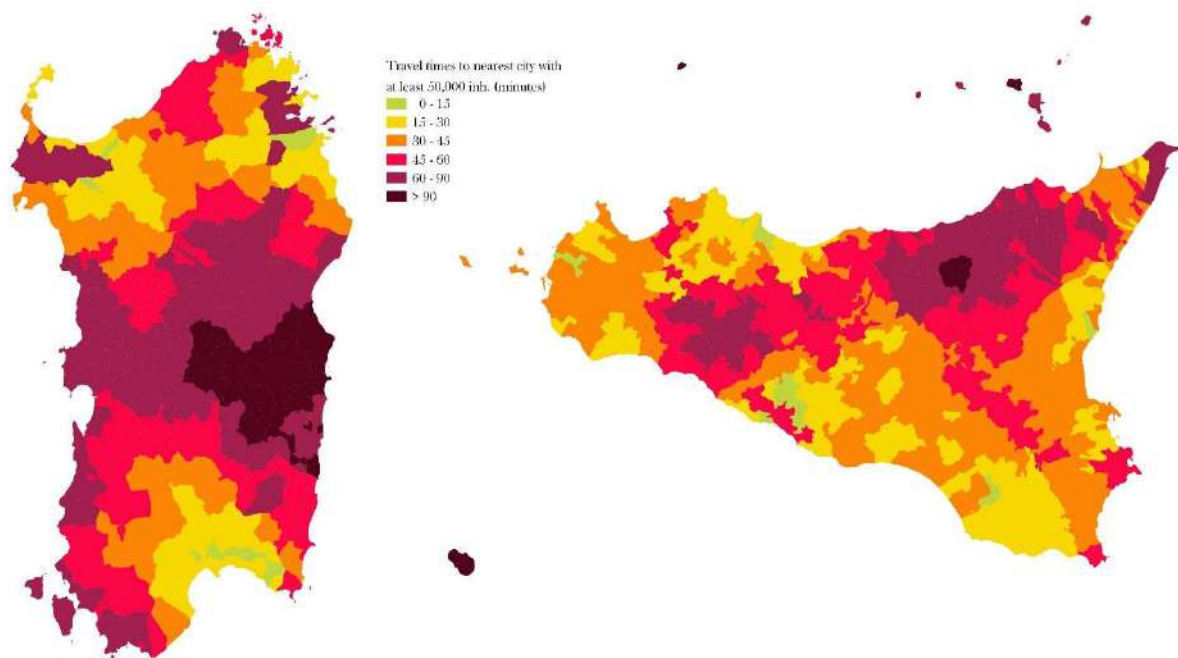


Figure 2 Travel times (minutes) to the nearest city with at least 50,000 inhabitants. Source: Own elaboration on Istat data

Travel times to motorway access points offer an initial measure of accessibility to transport infrastructure. Since Sardinia lacks motorways, roads with a travel speed of at least 90 km/h, classified as major extra-urban roads, are used by Istat for this calculation. The results in Figure 3 highlight a contrast between southeastern and western Sardinia, as well as between central-southern and coastal regions of Sicily. In Sardinia, much of the interior and southern areas experience longer travel times. In 23 municipalities more than one hour is required to reach a major road, and 12.5% of municipalities need more than 45 minutes. Similarly, in Sicily, central areas face significantly longer travel times: 29 municipalities,

⁸⁵ According to 2021 Census data, Sicily has 15 municipalities with populations of at least 50,000 inhabitants: Acireale, Agrigento, Bagheria, Caltanissetta, Catania, Gela, Marsala, Mazara del Vallo, Messina, Modica, Palermo, Ragusa, Siracusa, Trapani, and Vittoria. In Sardinia, there are 4 such municipalities: Cagliari, Olbia, Quartu Sant'Elena, and Sassari.

indicated in dark brown, have travel times to motorways longer than 60 minutes, and 19% of municipalities need more than 45 minutes. Coastal regions, especially in the North-East and North-West, have more frequent motorway access, resulting in lighter spots.

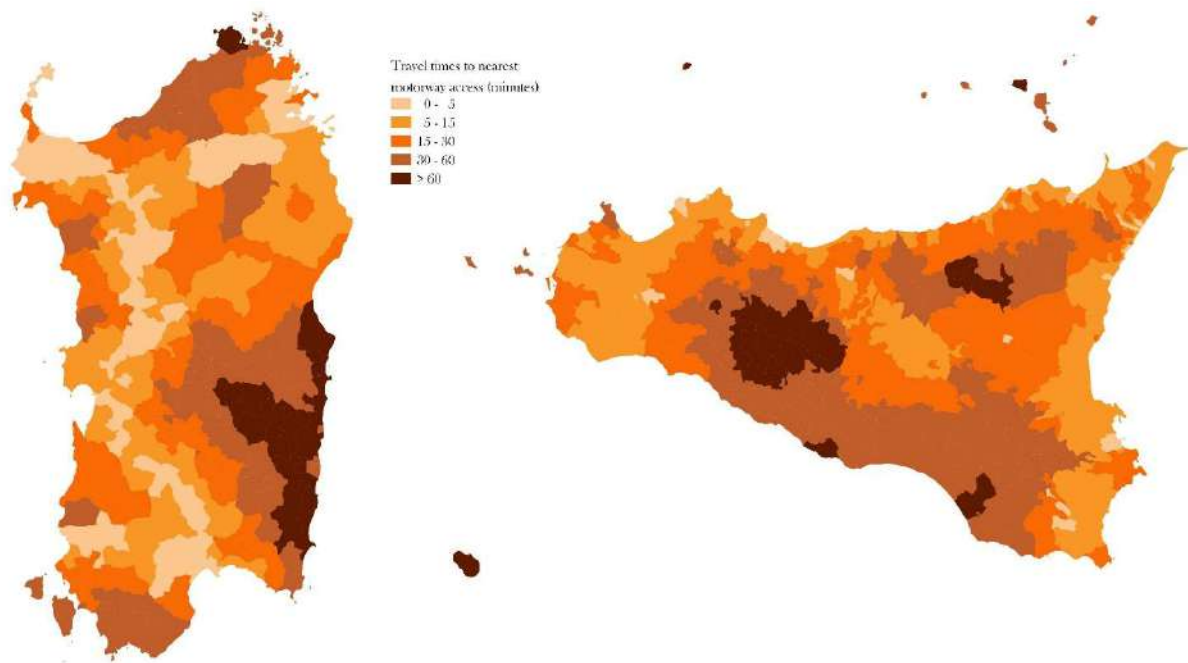


Figure 2 Travel times (minutes) to nearest motorway (Sicily) or major extra-urban road (Sardinia) access.
Source: Own elaboration on Istat data

The contrast between eastern and western Sardinia is apparent in Figure 4, which illustrates travel times to the nearest railway station with active passenger service and long-distance train stops. Since Sardinia lacks long-distance trains, Istat uses regional railway stations for this calculation. In this case, there is a clear division between the East and West: 13 municipalities require over an hour and a half to reach the nearest station, while 37 municipalities take more than one hour (10% of all Sardinian municipalities). For Sicily, the disparity is noticeable between the southwestern part of the island and the rest of the region. There is a dark spot in the central region, the same area with high travel times to essential services and cities. In total, 41 municipalities (10.5% of all Sicilian municipalities) take more than 90 minutes to reach a train station, with 120 municipalities (31%) needing more than one hour.

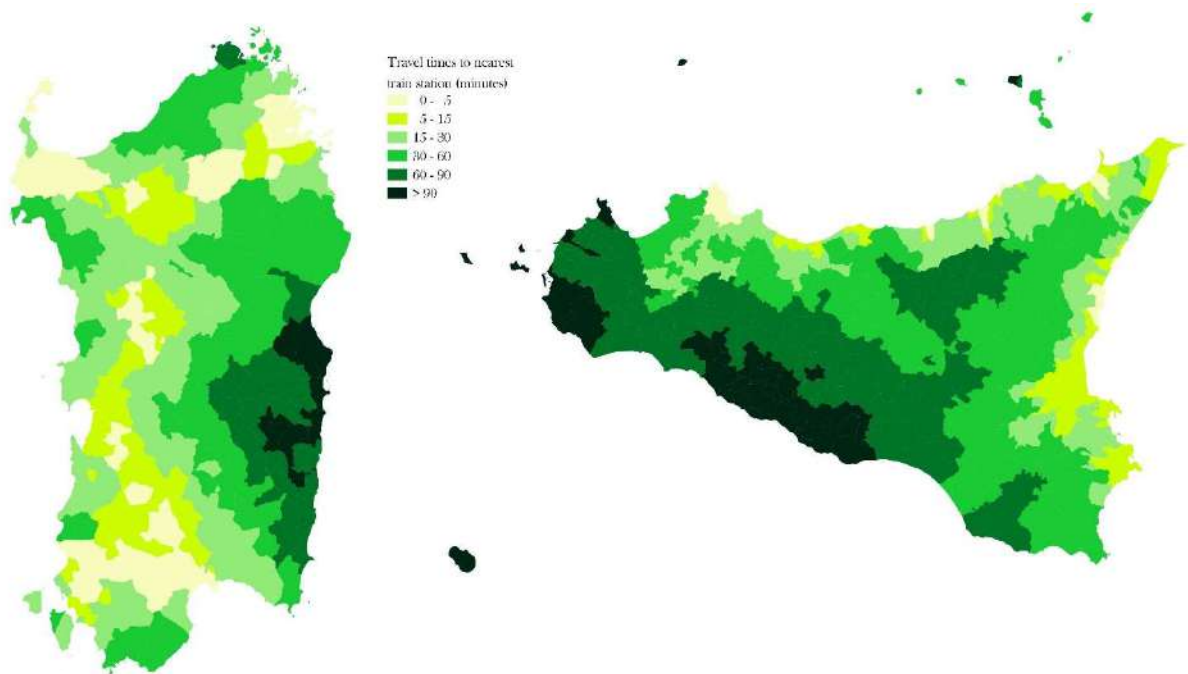


Figure 4 Travel times (minutes) to the nearest railway station with active passenger service and long-distance train stops. Source: Own elaboration on Istat data

Figure 5 depicts travel times to passenger ports. As previously mentioned, Sardinia has five passenger ports, whereas Sicily has six. The accessibility of sea transport infrastructure is notably better in eastern Sardinia: Arbatax, a passenger port located in the municipality of Tortolì, allows residents in this region to reach a port in under an hour. In contrast, a large area in central Sardinia, extending into the southeastern part of the island, experiences longer travel times to ports, with durations exceeding 90 minutes (14 municipalities) or ranging between 60 and 90 minutes (122 municipalities, almost one third of all Sardinian municipalities). Similarly, in Sicily, certain regions also face travel times that exceed 60 (89 municipalities, 23% of Sicilian municipalities) or even 90 minutes to reach ports. Particularly, the North-central region of the island is the most underserved, along with two areas in the South-West and Central-South of Sicily.

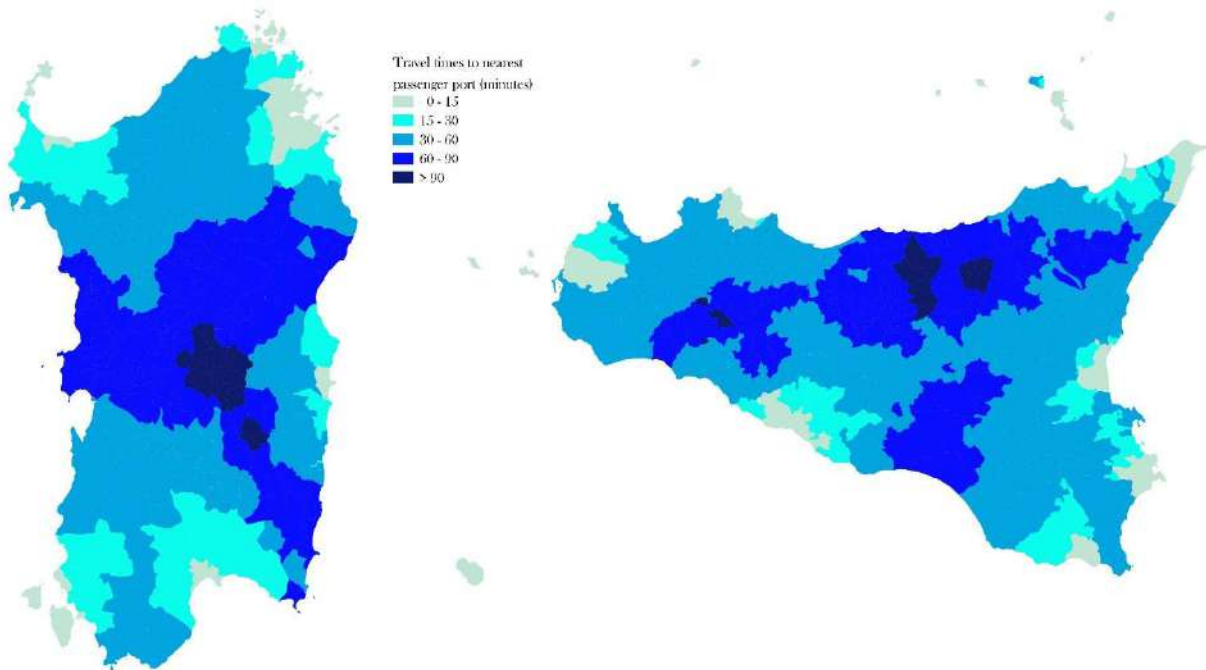


Figure 5 Travel times (minutes) to the nearest passenger port. Source: Own elaboration on Istat data

Our final measure of accessibility is depicted in Figure 6. The accessibility to airports reveals a distinct dichotomy for both islands. In Sardinia, the contrast exists between the Central-East and the northern and southern regions of the island. Once again, the most disadvantaged areas are in the East, where travel times to reach an airport exceed 90 minutes, as well as in the center of the island, where travel times range from 60 to 90 minutes. In 44% of Sardinian municipalities, more than one hour is need to reach an airport. In Sicily, the divide lies between the central region and the island's eastern and western areas, with a large, darker-shaded area indicating that central Sicily faces travel times to airports exceeding one hour—and in some cases, even one and a half hours. A total of 94 municipalities (24% of all Sicilian municipalities) require over 90 minutes to reach an airport, while 225 municipalities (58%) need more than 60 minutes.

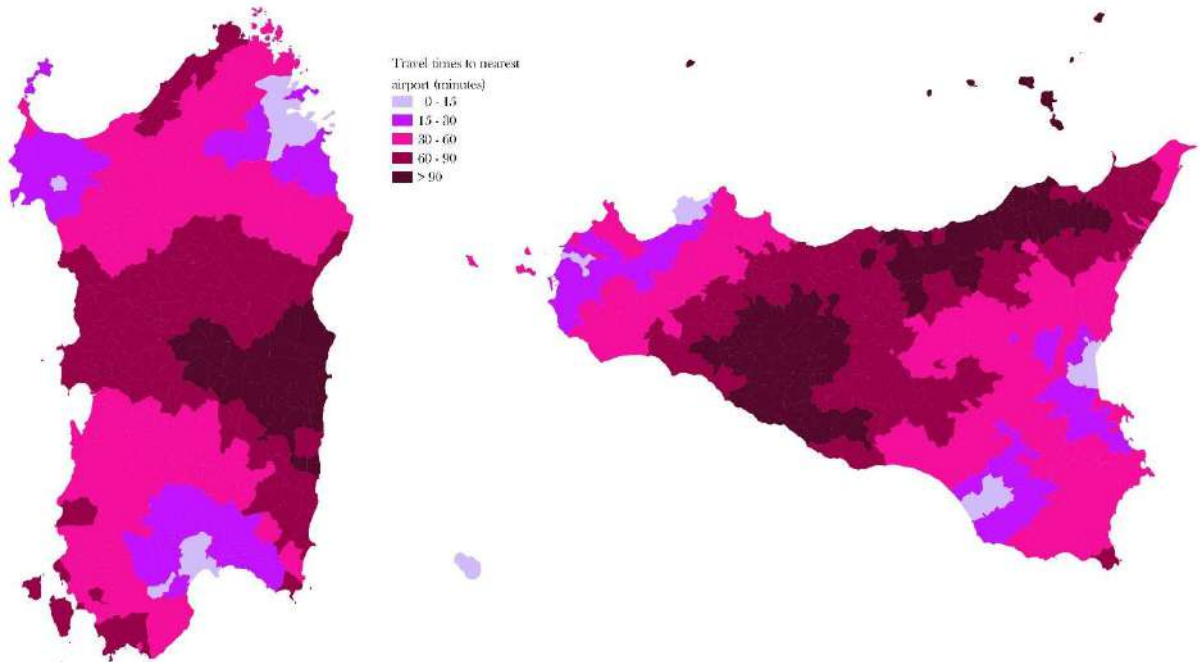


Figure 6 Travel times (minutes) to the nearest airport. Source: Own elaboration on Istat data

4. Policy implications

The analysis of municipal accessibility in Sicily and Sardinia highlights critical policy priorities for improving connectivity and access to essential services. With a significant proportion of municipalities classified as Peripheral or Ultra-Peripheral, particularly in Sardinia, targeted investments in infrastructure and transportation are urgently needed. Policymakers should prioritize upgrading road networks and public transport systems to reduce travel times to core urban centers, healthcare facilities, and educational institutions—especially in eastern Sardinia, where accessibility challenges are most acute. Expanding the availability of essential services in smaller, non-inter-municipal hubs on both islands could help distribute resources more evenly and reduce the burdens faced by remote and marginalized communities. Moreover, integrating regional development strategies that focus on improving access to rail and air transport will be critical for promoting economic growth and fostering social equity.

By addressing these accessibility gaps, policymakers can advance inclusivity, enhance the quality of life for residents, and support more balanced regional development in Italy. This approach not only benefits the residents of Sicily and Sardinia but also contributes to broader national objectives for equitable growth and sustainable development.

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