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RESEARCH

Healthcare Network Inequality and Resilience Gaps: Evidence from Italy

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Abstract

This paper investigates spatial disparities in healthcare network infrastructure across Italian provinces from 2010 to 2021 and examines how these imbalances affect the resilience of the healthcare system to shocks such as the COVID-19 pandemic. Using data on hospital beds by type of care (acute, rehabilitation, and long-term) and applying inequality measures from the Generalized Entropy class, we assess both the level and evolution of territorial disparities. The decomposability of these indices allows us to distinguish inequality arising *between provinces* from inequality *within provinces*, providing insights about how hospital capacity is spatially configured across the national territory. As the Italian hospital network is organised along a regulated hub-and-spoke logic, the predominance of the within-province component of this spatial configuration should be read jointly with the regulatory framework. Our findings reveal persistent and substantial inequality, with the within-province component accounting for more than half of total inequality in most years, and disparities intensifying after 2016 and during the pandemic. By capturing the concentration of hospital capacity and its evolution over time, entropy-based measures offer a useful monitoring tool to identify structural vulnerabilities in the healthcare network infrastructure that weaken system-wide adaptability and responsiveness. The results show that resilience in Italy is undermined not only by the well-known North–South divide but also by uneven capacity within provinces, highlighting the need for policies that strengthen hospital networks at multiple territorial levels.

Keywords Healthcare network infrastructure · Spatial inequality · Health system resilience · Vulnerability · Generalized Entropy indices · COVID-19

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1 Introduction

The Italian healthcare system combines public and private provision within a regionally decentralized framework and is predominantly financed by public resources. While this model guarantees universal coverage, it has also generated significant territorial disparities in the distribution of healthcare infrastructure and services (Betti et al. 2023). Northern regions display higher healthcare capacity - measured in terms of hospital beds, advanced diagnostic technologies, and medical personnel – than the South, contributing to unequal access and health outcomes.

The unequal spatial distribution of hospitals constrains the capacity of some territories to meet routine and emergency healthcare needs. Infrastructural scarcity in underserved areas often results in longer waiting times, limited inpatient availability, and greater travel distances for patients. Gaps in access to essential medical technologies (e.g., MRI machines, CT scanners, robotic surgery systems) and shortages of healthcare professionals further delay diagnosis and treatment, particularly in peripheral or rural territories.

These disparities represent not only an equity issue but also a resilience challenge. A healthcare system characterized by uneven spatial distribution of infrastructure is less capable of responding to shocks such as pandemics, environmental crises, or demographic transitions. At the European level, the COVID-19 pandemic revealed how territorial heterogeneity in health resources hampers collective preparedness and recovery capacity, prompting the European Commission 2020) to identify resilience building as a priority for the European Health Union.

Resilience in healthcare systems is typically defined as the ability to absorb shocks, adapt to changing conditions, and maintain core functions during crises (Alam and Mahal 2014; OECD 2023). In the case of hospital infrastructure, resilience depends not only on the aggregate stock of resources but also on their spatial configuration. Uneven territorial endowments constrain the reallocation of resources and the coordination of emergency responses. Conversely, vulnerability arises when local systems lack redundancy or flexibility, leaving certain areas more exposed to disruptions such as pandemics or population aging (Briguglio et al. 2009).

From a network perspective, healthcare provision can be conceptualized as a system of interconnected facilities, where weakly connected or under-resourced nodes undermine system-wide adaptability. Regions with low healthcare connectivity - characterized by limited bed capacity, insufficient technological resources, and underfunded facilities - constitute vulnerable nodes in the national healthcare network. Their limited integration into broader healthcare systems reduces overall adaptability and responsiveness. This interpretation aligns with insights from the network resilience literature, which emphasizes that systemic fragility often originates from weaknesses in infrastructure connectivity (Reggiani et al. 2015).

In this paper, we use the term *structural vulnerability* to describe persistent weaknesses embedded in the spatial organization of healthcare networks. Unlike temporary shortages, these vulnerabilities stem from entrenched disparities in the distribution of resources, limited redundancy across territories, and weak interconnections among facilities. These features constrain the system's capacity to absorb shocks and adapt to evolving health needs, thereby undermining resilience and perpetuating inequalities in access to care (Modica et al. 2019; Reich 2019).

From this conceptual perspective, assessing resilience in healthcare systems requires measuring the structural dimensions of vulnerability, which are reflected in the territorial distribution of infrastructure and resources. Spatial inequality in hospital capacity provides a proxy for such systemic weaknesses: when resources are concentrated in a few locations, the network's ability to redistribute demand or coordinate crisis responses diminishes. Conversely, balanced territorial configurations enhance redundancy and flexibility, key components of resilience.

Building on this conceptual link between spatial inequality and network resilience, this paper analyzes the territorial distribution of hospital infrastructure in Italy over the last decade, including the period affected by the COVID-19 pandemic. Italy represents a particularly relevant case, as it was the first and one of the hardest-hit European countries, with over 190,000 COVID-related deaths (World Health Organization, 2024). Moreover, the combination of a decentralized governance system and long-standing regional disparities provides an ideal setting to investigate how structural vulnerabilities embedded in healthcare networks translate into unequal resilience capacities.

To quantify these disparities, we employ inequality measures from the Generalized Entropy (GE) class, which are decomposable into within-group and between-group components (Shorrocks 1980). This allows us to distinguish inequality across provinces from disparities within them. The analysis is conducted at the provincial (NUTS-3) level, using the number of hospital beds per 10,000 inhabitants, distinguishing among acute, rehabilitation, and long-term care.

Although hospital organization in Italy is planned primarily at the regional level, the provincial perspective is essential because, for most citizens, the province represents the most immediate reference for accessing healthcare. Significant differences can also exist between provinces within the same region in terms of hospital distribution, demographic composition, and service demand. Geographic accessibility, the concentration of specialized facilities, and intra-regional patient mobility further amplify these differences. Understanding inequality at the provincial level therefore provides a more realistic picture of how citizens experience healthcare availability.

This paper offers three main contributions to the related literature. First, by applying GE indices at the NUTS-3 level, we capture intra-regional heterogeneity that regional-level necessarily leave aside, as it is at this territorial scale that citizens experience access to care. Second, the additive decomposability of GE indices allows us to locate inequality at the provincial relative to the sub-provincial scale, thereby reporting the spatial configuration of hospital capacity. Because of the spatial configuration of healthcare structures, this configuration must be read jointly with the regulatory framework: since DM 70/2015 organises hospital provision along a hub-and-spoke logic, some degree of within-province concentration is expected by design. This implies that its resilience implications are established jointly with the regulatory framework and with the empirical evidence that this study reported. Third, unlike previous studies that examine either hospital efficiency (Barra et al. 2022) or access patterns (Pecoraro et al. 2024), we focus on structural capacity that determines the potential of the system to absorb shocks before efficiency or accessibility mechanisms occur. Consistent with this focus, we provide direct empirical grounding for the resilience gap argument by showing that provinces with greater within-province dispersion in bed endowment experienced higher pandemic mortality (see Sect. 4). The COVID-19 pandemic provides an ideal setting to assess how unequal endowments of health facilities may either help absorb or, conversely, exacerbate health shocks (see Thomas et al. 2020). While realized access depends on a combination of supply conditions, health needs, patient behavior, and mobility across territories, potential access reflects the underlying distribution of healthcare infrastructure. For this reason, it provides a more appropriate lens for examining territorial disparities in healthcare system preparedness. We acknowledge that patterns of realized utilization may differ from those observed in potential access due to demand-side factors and institutional arrangements; therefore, our results should be interpreted primarily as evidence on spatial differences in healthcare system capacity, with implications for infrastructure planning and territorial resilience.

The remainder of the paper is structured as follows. Section 2 reviews the related literature on accessibility and healthcare resilience. Section 3 describes the data and the methodology. Section 4 discusses the results, and Sect. 5 concludes.

2 Related Literature

This study builds upon a multidisciplinary body of literature on accessibility to healthcare services, and related measurement methods, with specific emphasis on how spatial connectivity influences systematic resilience and vulnerability. A foundational concept in the field is accessibility, commonly defined as the ease with which people can reach essential services. Originating from transport geography (Handy and Niemeier 1997; Geurs and van Wee 2004), accessibility metrics have since been adapted to health geography, where they mediate the relationship between built environments and health outcomes (Perchoux et al. 2013; Neutens 2015).

In the context of healthcare, geographical accessibility refers to the physical capacity of individuals to reach medical services, shaped by distance, travel time, and infrastructure availability. Spatial inequality in healthcare is thus conceptualized as variation in access across social and territorial groups, often driven by differences in the spatial distribution of healthcare resources and population needs (Langford and Higgs 2006; Mao and Nekorchuk 2013). Joseph and Phillips (1984) importantly distinguish between potential access – the spatial availability of services, which is the focus of this paper - and realized access, the actual utilization of those services. This distinction underscores that spatial proximity alone does not guarantee effective service delivery, as numerous barriers – spatial and aspatial – can hinder the transition from availability to use (Penchansky and Thomas, 1981). Building on this perspective, the literature identifies five key dimensions of access: availability and accessibility (explicitly spatial), affordability, accommodation, and acceptability (primarily non-spatial, linked to socioeconomic and cultural factors). Availability refers to the presence of services within a catchment area, while accessibility captures the effort required (distance, time, cost) to reach them.

A wide range of methods has been developed to quantify disparities in healthcare access. Among them, population-to-provider ratios (PPRs), such as the number of hospital beds per 10,000 inhabitants used in this paper, are especially valuable for capturing availability, one of the two spatial dimensions of access identified by Penchansky and Thomas (1981), alongside accessibility (i.e. travel effort). PPRs are straightforward to compute with standard demographic and health facility data, and their results are immediately interpretable by policy makers and planners (Guagliardo 2004; Wang 2012).

While more sophisticated approaches have been developed to account for travel impedance, demand side dynamics, and services attractiveness (Luo and Wang 2003; Tao et al. 2020), these models typically require high-resolution spatial and behavioral data, including real-world travel times or individual-level service use patterns. Such data are often unavailable or inconsistently collected at the subnational level in Italy.

Despite the recognized importance of spatial inequality in healthcare provision, the literature on this issue remains relatively limited. A key constitutional factor contributing to territorial imbalances is the structure of the Italian National Health System (NHS), established in 1978. As Turati (2014) emphasizes, the NHS operates through a multilayered governance model that involves national, regional, and local health authorities. While it ensures universal coverage and freedom of provider choice, this framework also allows significant discretion to regional governments in the allocation of resources and service delivery. As a result, regions with higher-quality services often attract patients from elsewhere, potentially exacerbating disparities and weakening the resilience of under-resourced areas, particularly in rural and inner territories.

Nonetheless, the spatial organization of hospital services in Italy is shaped not only by regional health institutions but also by national regulatory standards. Importantly, the Levels of Essential Care (Livelli Essenziali di Assistenza, LEA), first defined in 2001 and subsequently updated, establish the minimum service guarantees that all regions must provide to citizens, regardless of residence, in order to ensure a basic uniformity of access across the national territory, even within a decentralized governance model. A significant reorganization of hospital services was introduced by Ministerial Decree DM 70/2015, which defined structural and organizational standards for the hospital network and established a hierarchical classification of hospitals based on catchment population thresholds and levels of service complexity. This framework explicitly adopts a hub-and-spoke logic, in which specialised services are concentrated in a limited number of referral centres (hubs) while peripheral facilities (spoke) provide basic care and ensure initial access and patient stabilization before transfer (Mauro and Giancotti 2023). Clearly, this institutional architecture has important implications for interpreting spatial inequality in hospital capacity. Some degree of concentration is not only expected but actually mandated by regulatory standards, as the Decree 70/2015 establishes that certain high-complexity services (e.g., trauma centres, cardiac surgery, and neurosurgery) should only be provided by facilities serving sufficiently large populations. Consequently, observed spatial disparities in bed distribution may partly reflect regulated functional specialization rather than unplanned fragmentation or failure of network cohesion. As a result, this consideration cautions against treating all measured inequality as evidence of systemic disfunction. Yet, the effectiveness of such a hub-and-spoke system depends critically on interconnectivity, that is, the capacity to transfer patients rapidly and safely from spokes to hubs. For instance, a province with relatively few beds may provide adequate access if it is well-connected to centres via efficient emergency transport and clear referral pathways. Conversely, high nominal capacity offers limited resilience if facilities operate in isolation. Building on that structural duality, the present study is based on bed numbers as the representative healthcare supply and captures the structural distribution of capacity, although does not directly measure network, connectivity or patient flow dynamics.

On the regional scale, several empirical studies have shed light on these imbalances. Using Piedmont as a case study, Perucca et al. (2019) found that potential access to healthcare is highly uneven within the region. Peripheral and mountainous areas, characterized by lower income levels and sparse populations, exhibit the lowest degrees of access. The study also shows that individuals in these areas are less likely to utilize healthcare services and tend to be less mobile, reinforcing the idea that potential access alone is insufficient for achieving equitable outcomes. Socioeconomic conditions, such as education, income, and mobility, act as crucial mediators between infrastructure and healthcare use.

In Southern Italy, Bruzzi et al. (2022) applied the OECD Health Care Quality Indicators framework using a non-compensatory Adjusted Mazziotta-Pareto Index to construct composite measures of performance. Their findings reveal a paradox: high levels of healthcare expenditure coexist with relatively poor performance. This suggests that spatial inefficiencies and institutional fragmentation may undermine the effective use of resources in vulnerable regions. Recent contributions in health economics emphasize that resilience is not an intrinsic property of individual hospitals or regions, but rather emerges from the configuration of healthcare networks and the capacity to manage interdependencies (Reich 2019; Kickbusch and Gleicher 2012). Network-oriented perspectives suggest that spatial inequalities create vulnerable nodes, which can propagate shocks through the system, reducing efficiency and equity (Reggiani et al. 2015; Barra et al. 2022): This suggests that measuring territorial disparities is not only a matter of equity, but also of understanding systemic vulnerability in health systems.

Further exploring regional disparities, Barra et al. (2022) assessed hospital efficiency across Italian regions from 2004 to 2019 using a decomposable Theil index. Their analysis reveals a persistent North-South divide in hospital performance, linked to broader inequalities in institutional effectiveness. These findings underscore how spatial fragmentation within national networks can generate long-standing vulnerabilities, weakening system-wide efficiency and equity.

From a methodological point of view, while the Gini coefficient remains the most widely used inequality measure due to its intuitive interpretation, it is not perfectly decomposable into subgroup components without generating a residual 'overlap' term (Pyatt 1976). This limitation is consequential when the analytical goal is to attribute inequality to specific territorial levels. The GE class indices, by contrast, satisfy the property of additive decomposability (Shorrocks 1980), ensuring that total inequality can be expressed exactly as the sum of within-group and between-group components. This property makes GE indices particularly suited for analysing healthcare networks, where understanding whether disparities originate at the provincial or sub-provincial level has direct implications for policy design. Moreover, incorporating measures of entropy in the GE class (as done in the present paper) allows to emphasize different parts of the distribution, ranging from underserved to concentrated areas, enabling a proper assessment of structural vulnerabilities. Recent methodological innovations have also contributed to this field. For example, Pecoraro et al. (2024) used an enhanced two-step floating catchment area (ESFCA) method to analyze the spatial dynamics of hospital catchment areas across regions. Their results confirm a concentration of high-quality healthcare infrastructure in certain regions, which drives patient mobility and reinforces regional disparities. The study highlights how connectivity between paces – conceptualized by patient flows – is shaped by uneven access to quality services, and how this connectivity, in turn, contributes to the systemic resilience or vulnerability of regional healthcare systems.

3 Data and Methods

3.1 Data

The analysis relies on data from the Italian Ministry of Health, which provides information on the number of beds in both public and accredited private hospitals. Accredited private hospitals consist of private facilities which, in light of a formal agreement with the Italian National Health System (NHS), are considered an integral part of the public health system, despite being managed by private entities. Both public and accredited private facilities provide most services for free. These free services include primary care services, such as emergency services and vaccinations. Both public and accredited private facilities require citizens to make a copayment for some specialized services, such as nonemergency procedures, with exemptions based on income, health conditions and other criteria. Private facilities that are not accredited require citizens to pay for all health care services received; the NHS does not cover any costs.

The data reports on the total number of beds per hospital, disaggregated by type of care, including rehabilitation care, long-term care, and curative (or acute) care.

Hospitals are spatially identified by their civic address, which has been geocoded using UTM (universal transverse Mercator) coordinates. The geocoding was performed with the sf library in R, retrieving spatial information from OpenStreetMap.

The dataset provided by the Italian Ministry of Health is merged with demographic data at the provincial level, sourced from the Italian National Institute of Statistics (Istat). Specifically, we use provincial population size to compute the number of hospital beds per 10,000 inhabitants, which serves as a key measure of healthcare infrastructure availability. To better capture the demographic context and potential demand for health services, we also include the percentage of elderly residents (aged 65 and over), the birth rate, and the mortality rate. In addition to reflecting underlying health needs, the mortality rates serve as proxy for assessing the severity of the COVID-19 pandemic's impact across provinces, providing a useful lens through which to interpret spatial differences in health system strain and outcomes.

Descriptive statistics are set out in Table 1.

Table 1 Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
N. beds per 10,000 inhab	13,262	3.515	5.353	0.009	39.094
N. beds per 10,000 inhab for acute care	11,373	3.436	5.211	0.007	36.506
N. beds per 10,000 inhab for rehabilitation	6,972	0.793	1.443	0.003	18.202
N. beds per 10,000 inhab for long-term care	4,368	0.461	0.618	0.002	6.667
Socio-demographic variables (NUTS-3)					
N. Covid cases per 10,000 inhab.	1,284	487.16	219.05	90.65	1,334
Mortality rate	1,284	10.614	1.699	0.8	20.9
Percentage of elderly population	1,284	21.685	2.692	14.473	29.585
Birth rate	1,284	8.055	1.199	4.6	11.3
GDP	1,284	27371.05	9480.115	13,600	59,900
Unemployment rate	1,284	11.524	6.370	2.923	30.794

Figures A1 and A2 in Appendix show the distribution of the total number of beds per 10,000 inhabitants across provinces in the first and last sample period also distinguished by type of care. They reveal clear and persistent spatial heterogeneity in the distribution of beds. While the overall pattern of concentration remains visible in both years, the maps suggest a relative stability in the geographical clustering of better-equipped provinces, with northern and some central areas generally exhibiting higher bed availability per 10,000 inhabitants. The disaggregation by type of care (Figure A2) highlights that these territorial imbalances are evident across acute, rehabilitation, and long-term care, with acute care beds showing the most uniform distribution and rehabilitation and long-term care displaying more pronounced spatial concentration.

3.2 Methodology

Let the unit of observation be the hospital. Index hospitals by $i = 1, \ldots, N$, and provinces by $j = 1, \ldots, J$. Each hospital i belongs to one province j.

Let y_i denote the number of hospital beds per 10,000 inhab. in hospital i, and $\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$ the corresponding national mean. This quantity captures the average hospital bed availability per 10,000 inhab. in Italy.

Inequality indices of the Generalized Entropy (GE) class can be formulated as follows:

$$E(\alpha) = \frac{1}{N(\alpha^2 - \alpha)} \sum_{i=1}^{N} \left[\left(\frac{y_i}{\bar{y}} \right)^{\alpha} - 1 \right] \quad (1)$$

where $\alpha \in (-\infty; \infty)$ is the parameter that determines the specific form of the entropy index.

When $\alpha = 0$, Eq. (1) becomes:

$$E\left(0\right)=\frac{1}{N}\sum{}_{i=1}^{N}ln\frac{\overline{y}}{y_i}, \tag{2}$$

and it is called the mean logarithmic deviation or Theil's second measure.

When $\alpha=1$, Eq. (1) becomes:

$$E\left(1\right)=\frac{1}{N}\sum{}_{i=1}^{N}\frac{y_i}{\overline{y}}ln\frac{y_i}{\overline{y}}, \tag{3}$$

and it is called Theil index.

Equations (2) and (3) are obtained by using a rule by de l'Hopital.[1] Notice that both indexes are not defined if there are zero hospital beds per 10,000 inhab. The following index, called one-half of the squared coefficient of variation and obtained with $\alpha=2$, can handle zero hospital beds:

$$E\left(2\right)=\frac{1}{2N}\sum{}_{i=1}^{N}\left[\left(\frac{y_i}{\overline{y}}\right)^2-1\right], \tag{4}$$

The indices of the Generalized Entropy Class differ in their sensitivity to changes in different parts of the bed distribution. Indices with a value of α close to zero are more sensitive to differences in the lower tail of the bed distribution; the Theil index $(\alpha=1)$ is equally sensitive to changes across the whole distribution; indexes with a value higher than 1 are more sensitive to differences in the upper tail.

Let consider one of these indices from the Generalized Entropy Class, for instance the Theil index, to show the decomposability according to a spatial criterion, the provincial level in our case. The J provinces are mutually exclusive and completely exhaustive. Let s_j be the share of total beds of each province; let T_j be the Theil index of province j, with $j=1,\ldots,J$; let $\overline{y}_j$ be the average hospital bed availability per 10,000 inhab. in province j. Equation (3) may be rewritten as follows (Haughton and Khandker 2009):

$$E\left(1\right)=\sum{}_{j=1}^{J}s_jT_j+\sum{}_{j=1}^{J}s_jln\frac{\overline{y}_j}{\overline{y}}, \tag{5}$$

The first term of Eq. (5) is the weighted sum of the provincial Theil indices, where weights correspond to each province's share of total beds per 10,000 inhab. This term represents the within-province component, i.e. the part of overall inequality attributable to disparities in bed endowment among hospitals within the same province. The second term reflects differences in average bed endowment across provinces. It measures the inequality that would arise solely from variation in provincial mean beds per 10,000 inhab., abstracting from disparities among hospitals within each province. Hence, it represents the between-province component of overall inequality.

[1] For further details, see Bellù and Liberati (2006, p. 50).

From a resilience perspective, this decomposition captures specific dimensions of systemic vulnerability. The between-province component reflects disparities in aggregate capacity across administrative units, which constrain the reallocation of patients and resources across provincial boundaries during emergencies. By contrast, the within-province component captures the degree to which hospital capacity is concentrated or dispersed among facilities within the same territory. High within-province inequality may indicate that a few large hospitals absorb most capacity, leaving surrounding areas dependent on inter-facility transfers. While such concentration may be efficient under normal conditions, it can create single points of failure during shocks, when transfer capacity is constrained and local surge response becomes critical.

The empirical implementation of this methodology proceeds as follows. First, we compute y_i, i.e. the number of beds per 10,000 inhab., for each hospital. Second, using hospital-level data, we calculate the overall GE indices for each year according to Eqs. (2), (3), and (4). Third, we decompose the Theil index following Eq. (5).

As mentioned in Sect. 2, the Gini index is not additively decomposable according to (1), unless a specific condition is met, i.e. the relative position of each statistical unit in the subgroup is exactly the same in the total bed distribution. In all other cases, the Gini coefficient may be decomposed in a between component, in a within component and in a third term called interaction or stratification term, which is due to the overlapping of provincial bed distributions (Pyatt 1976; Yitzhaki and Lerman 1991). Although the Gini index is not perfectly decomposable, we compute it nonetheless as a benchmark for the GE class indices. This choice is motivated by the fact that the Gini index is easily interpretable, as it ranges between 0 and 1, whereas GE indices all share a lower bound of 0 (indicating perfect equality) but have no upper limit. The comparison with the Gini index, presented in the following section, allows us to better contextualize the magnitude of inequality captured by the GE class indices.

4 Results

This section presents the results of empirical analysis. Table 2 reports the evolution of inequality in the distribution of hospital beds per 10,000 inhabitants using GE class indices and the Gini index. Before turning to the numerical results, it is important to clarify the rationale for reporting multiple inequality measures. As discussed in the previous section the Generalized Entropy (GE) indices differ in their sensitivity to various parts of the distribution: GE(0) gives relatively more weight to disparities at the lower tail, GE(2) is more sensitive to concentration at the upper tail, while GE(1) (the Theil index) assigns equal weight across the distribution. The Gini coefficient, although not perfectly decomposable, provides a widely used benchmark. Comparing these indices allows us to verify whether the observed dynamics are driven by specific segments of the distribution or reflect a more generalized structural pattern. All these indices consistently indicate a persistently high level of spatial inequality. The Gini coefficient remains relatively stable, fluctuating between 0.626 and 0.641 (about a 2.4% variation). Among GE indices, GE(0) averages 0.838 and shows a moderate upward trend after 2016. The Theil index GE(1) rises from 0.719 in 2016

Table 2 Inequality in the distribution of hospital beds per 10,000 inhab., measured using Generalized Entropy (GE) indices and the Gini coefficient

Time period	GE(−1)	GE(0)	GE(1)	GE(2)	Gini
2010	2.531	0.831	0.735	1.158	0.630
2011	2.780	0.840	0.734	1.143	0.631
2012	2.641	0.829	0.732	1.146	0.629
2013	2.655	0.829	0.726	1.124	0.628
2014	2.696	0.834	0.732	1.135	0.630
2015	2.700	0.830	0.729	1.131	0.629
2016	2.663	0.820	0.719	1.099	0.626
2017	2.669	0.841	0.749	1.186	0.635
2018	2.610	0.836	0.750	1.187	0.634
2019	2.787	0.849	0.755	1.192	0.637
2020	2.800	0.850	0.756	1.198	0.637
2021	2.984	0.869	0.766	1.207	0.641
2010–2021	2.707	0.838	0.740	1.160	0.632

to 0.766 in 2021, indicating a gradual intensification of inequality. GE(2), more sensitive to upper-tail concentration, increases from 1.099 to 1.207 over the same period, suggesting growing concentration of capacity in a few provinces. At the same time, GE(−1), which emphasizes the lower tail, also peaks in 2021 (2.984), pointing to persistent under-served areas.

Overall, the evidence indicates worsening spatial equity in healthcare infrastructure after 2016, with disparities becoming more pronounced during and after the COVID-19 pandemic.

The correlation among the various GE measures is relatively high, with coefficients ranging from 0.47 to 0.98 (see Table A1 in the Appendix). This strong co-movement should be interpreted primarily as evidence of robustness: inequality trends are not sensitive to the choice of the measure and do not depend on emphasizing either the most underserved or the most concentrated provinces. At the same time, the high correlation implies that the indices are largely redundant in detecting temporal patterns. For this reason, after documenting their consistency, the subsequent analysis focuses on the Theil index (GE(1)).[2]

To provide an intuitive interpretation of the magnitude of the observed inequality dynamics, we perform a counterfactual redistribution exercise focusing on the Theil index. Starting from the 2021 distribution of hospital beds per 10,000 inhabitants across hospitals, we construct a counterfactual distribution by proportionally compressing the deviations of each hospital's capacity from the national mean.

Formally, the counterfactual distribution is defined as $y_i^{cf} = \bar{y} + (1 - \lambda)(y_i - \bar{y})$, where λ represents the proportional reduction in the deviation of each hospital's capacity from the mean. The value of λ is calibrated so that the Theil index computed on the counterfactual distribution matches the level observed in 2010.

The simulation suggests that $\lambda = 0.019$, implying that a 1.9% compression of deviations from the national mean would be sufficient to restore the level of spatial inequal-

[2] The results with the other GE indices are available upon request.

ity observed in 2010. Importantly, this result does not represent the share of hospital beds that would need to be physically reallocated. Instead, it reflects a proportional reduction in the dispersion of hospital capacity relative to the national average, since the analysis is conducted using beds per 10,000 inhabitants rather than absolute numbers of beds. The simulated redistribution is geographically concentrated, with a limited number of large metropolitan provinces accounting for a substantial share of the adjustment required to restore the 2010 level of inequality. In particular, provinces hosting major urban hospital systems, such as Rome, Milan, Naples, and Turin, account for the largest shares of the simulated redistribution (respectively 7.46%, 4.03%, 3.41%, and 2.93%), reflecting the strong influence that hospitals located in highly populated metropolitan areas exert on the national distribution of beds per capita.

Table 3 decomposes the Theil index of hospital bed inequality into its between- and within-province components for the period 2010–2021. Over the entire period, the within-province component exceeds the between-province component, highlighting that most of the inequality in hospital bed distribution arises within provinces rather than across them. The within component ranges from 0.38 (2012) to 0.41 (2021), while the between component fluctuates in a narrower band, between 0.33 (2016) and 0.35 (2012). The W/B ratio (within-to-between) is always greater than 1, reaching its peak in 2021 at 1.19, confirming the dominant role of within-province disparities. Another way to express the within component in relative terms is through the W/Total ratio, which indicates the proportion of overall inequality that is attributable to disparities within provinces. It remains above 50% throughout the entire period, increasing from 0.51 in 2012 to 0.54 in 2021. This upward trend confirms that intra-provincial disparities have become slightly more pronounced over time, particularly after the onset of the COVID-19 pandemic.

The analysis can be further deepened by identifying the provinces contributing most to national GE(1) inequality in each year. The top ten contributors are shown in Table A2 in Appendix.

The results reveal a strong persistence in the provinces driving national inequality. Isernia and Verbano-Cusio-Ossola systematically rank among the largest contributors

Table 3 Decomposition of Theil index for the distribution of the total number of beds per 10, 000 inhab. into Between- and Within-Province Components (2010–2021)

Time period	Between component	Within component	W/B	W/Total
2010	0.341	0.395	1.158	0.537
2011	0.347	0.388	1.118	0.528
2012	0.353	0.380	1.075	0.518
2013	0.342	0.384	1.124	0.529
2014	0.346	0.386	1.114	0.527
2015	0.345	0.385	1.116	0.527
2016	0.333	0.386	1.157	0.536
2017	0.349	0.400	1.145	0.534
2018	0.345	0.405	1.176	0.540
2019	0.349	0.406	1.166	0.538
2020	0.349	0.406	1.163	0.538
2021	0.349	0.416	1.191	0.544

throughout the period, while Aosta, Belluno, and Trieste also appear consistently in the top positions. This stability suggests that spatial disparities in hospital bed availability are largely shaped by structural territorial characteristics rather than short-term fluctuations.

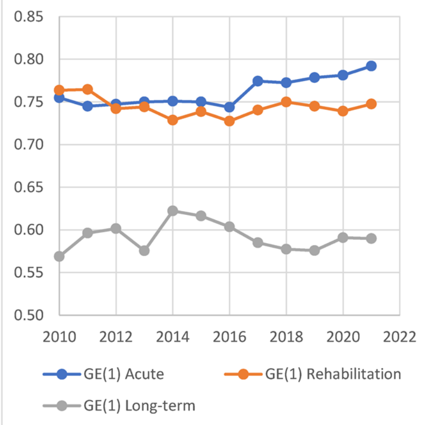
Two main mechanisms appear to underlie these patterns. First, several of the provinces contributing most to inequality are small or mountainous territories characterized by low population density and geographical fragmentation. In these contexts, healthcare systems must maintain a minimum hospital infrastructure to guarantee territorial coverage and emergency care. Given the relatively small resident population, this tends to generate comparatively high bed-to-population ratios, which mechanically increases their contribution to national inequality measures. Second, some provinces appearing in the ranking (e.g., Pisa, Ancona, Ferrara, and Trieste) host major referral hospitals within regional healthcare systems, reflecting strategies of service concentration aimed at improving efficiency and specialization.

Notably, the set of provinces contributing most to inequality remains largely unchanged over time, including during the COVID-19 years. This persistence indicates that the spatial distribution of hospital infrastructure is highly path-dependent and only weakly responsive to short-term shocks. From a policy perspective, these findings suggest that territorial inequalities in healthcare capacity primarily reflect long-standing planning choices and institutional arrangements, highlighting the importance of coordinated regional strategies when designing policies aimed at strengthening the resilience of healthcare systems.

At the same time, the interpretation of GE indices in geographically heterogeneous contexts requires some caution. In several small or mountainous provinces, relatively high bed-to-population ratios reflect the structural need to guarantee minimum territorial coverage and emergency care rather than a welfare-relevant excess of healthcare capacity. As a consequence, part of the observed variation in the Theil index may capture demographic dynamics and the mechanics of measurement associated with geographically fragmented territories, rather than a genuine deterioration in the equity of healthcare provision. The GE indices presented in this study should therefore be interpreted primarily as indicators of spatial dispersion in healthcare infrastructure, whose policy relevance lies in identifying the territorial and institutional factors shaping uneven healthcare resilience across provinces.

Figure 1 shows the evolution of the Theil index for acute, rehabilitation and long-term care from 2010 to 2021. Inequality is consistently highest in acute care and lowest in long-term care. Acute care remains stable until 2016, then rises to a peak of 0.792 in 2021. Rehabilitation begins slightly above acute care in 2010–2011 but declines modestly, fluctuating between 0.727 and 0.765. Long-term records the lowest levels, with a slight increase until 2014 followed by a gradual decline and stabilization. The persistent acute-long-term gap indicates structural disparities with the post-2016 acute care increase signals emerging inequalities.

Table 4 presents the decomposition of Theil index for acute, rehabilitation, and long-term hospital care into between- and within- province components from 2010 to 2021. Acute care shows a stable dominance of within-province disparities consistently exceeding 55% of total inequality, suggesting that local service configurations, rather than interprovincial gaps, drive most heterogeneity. Rehabilitation



Time period	GE(1) Acute	GE(1) Rehabilitation	GE(1) Long-term
2010	0.755	0.764	0.569
2011	0.745	0.765	0.596
2012	0.747	0.742	0.602
2013	0.750	0.744	0.576
2014	0.751	0.729	0.622
2015	0.750	0.739	0.616
2016	0.744	0.727	0.604
2017	0.774	0.740	0.585
2018	0.773	0.750	0.577
2019	0.779	0.745	0.576
2020	0.781	0.739	0.591
2021	0.792	0.748	0.590
2010-21	0.762	0.745	0.593

Fig. 1 Theil index of acute, rehabilitation, and long-term care beds per 10,000 inhabitants, 2010–2021

displays a more balanced structure, with between-province share decreasing from about 0.47 to 0.42 over the period, pointing to a gradual convergence across province. Long-term care is marked by persistent between-province dominance (0.32 or higher), revealing spatially entrenched disparities that are less susceptible to intra-provincial network effects.

Figure 2 shows the ratio of the within-province component to total inequality, measured by the Theil index, for total beds, and by type of care. Across the period, within-province disparities prevail in the overall distribution, largely driven by acute care beds, whose within/total ratio remains close to 0.55–0.60. Rehabilitation and long-term care display lower ratios, confirming the stronger role of between-province differences, especially for long-term care. Taken together, Table 4; Fig. 2 indicate that the spatial network of healthcare provision mediates inequality differently across care types, shaping whether disparities emerge primarily within or between provinces. Inequality in acute care beds is mainly within provinces because almost all provinces have a comparable overall supply, but the distribution among hospitals within each province varies significantly. Differences in hospital size, specialization, and historical development may contribute to this variation.

For rehabilitation and long-term care beds, inequality is largely between provinces. These services are less evenly distributed across the territory, as their availability often depends on demographic factors, historical planning decisions, and regional priorities. Some provinces are much better equipped than others, while differences among hospitals within the same province are relatively smaller.

Table 5 represents a correlation matrix showing the relationships between several demographic, economic, health, and COVID-related variables across different provinces. The variables observed include the number of COVID-19 positive cases per 10,000 inhabitants, total hospital beds per 10,000 inhabitants, beds for acute care, rehabilitation beds, and regular ward beds. It also includes provincial mortality and natality rates, the percentage of elderly residents, GDP per province, and the unemployment rate. The matrix quantifies how strongly these variables are related to

Table 4 Decomposition of Theil indices into Between- and Within-Province Components for Acute, Rehabilitation, and Long-term Care (2010–2021)

Time period	GE(1) Acute			GE(1) Rehabilitation			GE(1) Long-term		
	Between component	Within component	W/Total	Between component	Within component	W/Total	Between component	Within component	W/Total
2010	0.321	0.434	0.590	0.475	0.289	0.378	0.327	0.241	0.425
2011	0.322	0.423	0.576	0.472	0.292	0.382	0.375	0.222	0.372
2012	0.336	0.412	0.562	0.467	0.275	0.370	0.390	0.212	0.352
2013	0.319	0.431	0.594	0.470	0.275	0.369	0.370	0.205	0.357
2014	0.331	0.420	0.560	0.450	0.278	0.382	0.398	0.224	0.360
2015	0.327	0.423	0.564	0.461	0.278	0.376	0.416	0.201	0.326
2016	0.323	0.421	0.566	0.449	0.278	0.382	0.414	0.190	0.315
2017	0.346	0.429	0.553	0.463	0.278	0.375	0.415	0.170	0.291
2018	0.344	0.428	0.554	0.470	0.279	0.373	0.407	0.171	0.296
2019	0.349	0.429	0.552	0.453	0.292	0.392	0.403	0.173	0.306
2020	0.354	0.427	0.546	0.444	0.295	0.399	0.415	0.176	0.321
2021	0.349	0.443	0.559	0.423	0.324	0.434	0.400	0.190	0.398

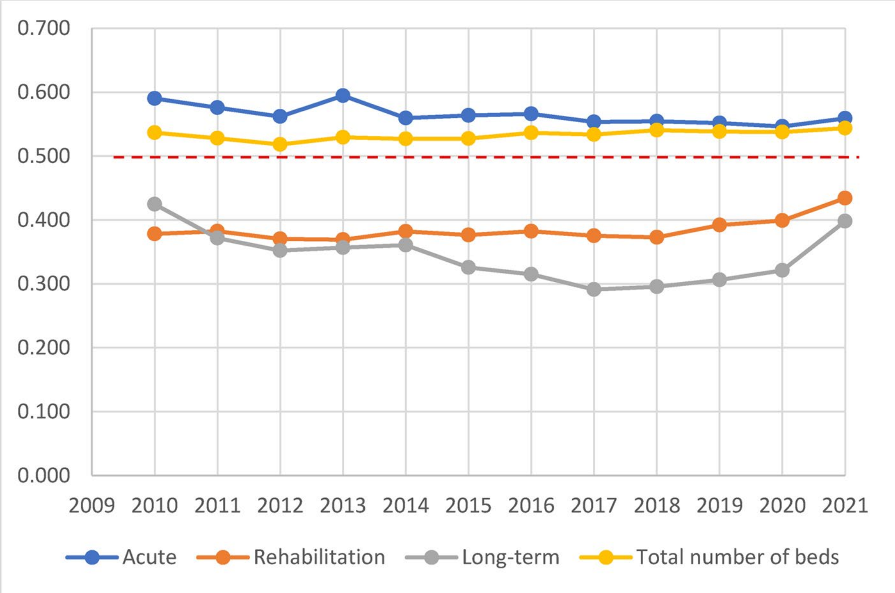


Fig. 2 Ratio of the within-province component to total inequality, measured by CE(1), for total beds per 10,000 inhab. and by type of care (2010–2021)

each other, with values ranging from −1 (strong negative correlation) to +1 (strong positive correlation). This allows us to identify clusters of related indicators, such as those describing hospital capacity, demographic structure, and economic conditions. The correlation analysis suggests that COVID-19 incidence was more closely tied to economic and demographic structures - positively with GDP (0.45) and negatively with unemployment (−0.29) - than to hospital infrastructure, which shows only weak associations with case numbers.

Hospital bed supply variables are strongly correlated with each other and moderately with aging and mortality patterns, indicating that capacity reflects long-term demographic pressures rather than acute shocks. These patterns highlight persistent spatial inequalities: provinces with greater exposure to COVID-19 were not necessarily those with stronger hospital capacity, underscoring the uneven preparedness of the Italian health system to absorb health shocks. These persistent differences align with the idea, emphasized in Modica et al. (2019), that certain regions carry structural burdens—intrinsic characteristics—that reduce resilience independently of external shocks. Thus, policy responses must account not only for shocks but for these embedded features of healthcare network infrastructure.

To further explore the implications of hospital capacity inequality, we examine whether disparities in bed endowment across hospitals within provinces are associated with pandemic outcomes. For each province-year, we compute the Theil index, GE(1), which measures the dispersion of hospital bed endowment across hospitals within the same province, independently of differences in average provincial capacity. We then relate this measure of within-province inequality to provincial excess

Table 5 Correlation matrix

Variabile	Total Covid-19 positive cases per 10,000 inhab.	Total hospital beds per 10,000 inhab.	Acute care beds per 10,000 inhab.	Rehabilitation beds per 10,000 inhab.	Long stay beds per 10,000 inhab	Deaths	Birth rate	Mortality rate	Share of elderly population	GDP per province	Un-empl. rate
Total Covid-19 positive cases per 10,000 inhab,	1,0000	0,0338	0,0324	−0,0291	0,0221	0,0865	0,1255	−0,0562	0,0288	0,4517	−0,2894
Total hospital beds per 10,000 inhab,	0,0338	1,0000	0,9815	0,3092	0,5018	−0,3301	−0,2225	0,2273	0,2806	−0,0773	−0,1416
Acute care beds per 10,000 inhab,	0,0324	0,9815	1,0000	0,1541	0,5000	−0,3188	−0,2236	0,2311	0,2899	−0,0528	−0,1592
Rehabilitation beds per 10,000 inhab,	−0,0291	0,3092	0,1541	1,0000	0,5150	−0,2549	−0,1612	0,1722	0,1525	−0,1571	0,0032
Long stay beds per 10,000 inhabitants	0,0221	0,5018	0,5000	0,5150	1,0000	−0,3076	−0,1608	0,1903	0,2263	−0,0582	−0,1188
Deaths	0,0865	−0,3301	−0,3188	−0,2549	−0,3076	1,0000	0,1984	−0,0772	−0,1888	0,5031	−0,0388
Birth rate	0,1255	−0,2225	−0,2236	−0,1612	−0,1608	0,1984	1,0000	−0,5735	−0,7426	0,0248	0,3511
Mortality rate	−0,0562	0,2273	0,2311	0,1722	0,1903	−0,0772	−0,5735	1,0000	0,7141	0,0308	−0,2435
Share of elderly population	0,0288	0,2806	0,2899	0,1525	0,2263	−0,1888	−0,7426	0,7141	1,0000	0,2995	−0,4814
GDP per province	0,4517	−0,0773	−0,0528	−0,1571	−0,0582	0,5031	0,0248	0,0308	0,2995	1,0000	−0,7178
Unempl. rate	−0,2894	−0,1416	−0,1592	0,0032	−0,1188	−0,0388	0,3511	−0,2435	−0,4814	−0,7178	1,0000

mortality during the pandemic. Specifically, we examine whether within-province inequality in hospital-bed availability was associated with the mortality gap observed during 2020–2021, defined as the difference between the mortality rate recorded during the pandemic and the average mortality rate observed in the same province during the pre-pandemic period. The estimated coefficients, reported in Table A3 in the Appendix, are consistently positive across specifications and statistically significant in the fixed-effects model including socio-demographic controls. Quantitatively, the estimates imply that a 0.01-point increase in the within-province GE(1) index is associated with an approximately 2.7% increase in the mortality gap. While these results should not be interpreted as establishing a causal relationship, they are consistent with the view that greater disparities in the spatial distribution of healthcare resources may have been associated with less favourable pandemic outcomes.

Taken together, these results indicate that spatial inequality in hospital capacity is not merely a structural feature of the hospital network but may also be related to differences in the ability of local health systems to absorb and respond to sudden surges in demand.

5 Conclusion

The analysis reveals persistent and increasing inequality in the distribution of hospital beds across Italian provinces, particularly accentuated after 2016 and during the COVID-19 pandemic. Importantly, most of this inequality originates from disparities within provinces rather than between provinces themselves. However, this overall result is actually driven by the dynamics related to the availability of beds for acute care services, which account for the majority of total beds. Acute care facilities are generally more evenly distributed because emergency and intensive treatments require widespread accessibility and are usually planned to ensure a minimum level of coverage in all provinces. On the other hand, when looking at non-acute care services (rehabilitation and long-term care), inequalities between provinces prevail.

While inequality between provinces in the number of hospital beds per 10,000 inhabitants is inherently undesirable, as it reflects uneven resource allocation across territories, inequality within provinces - that is, across hospitals located in the same province - is not necessarily negative. Such disparities may stem from legitimate differences in healthcare needs and from the intentional design of the hospital network, for example to combine large, highly specialised referral centres with smaller general-purpose facilities serving local communities. As discussed in previous sections, the Decree 70/2015 reform explicitly encourages functional differentiation through a hub-and-spoke model, in which specialized referral centres coexist with smaller facilities providing basic services. As a such, some degree of within-province concentration is therefore an expected outcome of this regulatory design, rather than evidence of planning failure. However, high within-province inequality may also signal imbalances in resource distribution or inefficiencies in service planning. Recent research suggests that disparities in healthcare accessibility often correlate with socio-spatial attributes such as income levels, population density, and urbanization, indicating that within-province inequalities may also reflect broader issues rather than merely administrative choices (Su et al. 2024).

Moreover, the intentional design of hospital networks to balance specialized and general services can lead to disparities in service quality and accessibility. While this design aims to optimize healthcare delivery, it can inadvertently create inequalities if not carefully planned and monitored. Therefore, it is crucial to assess whether the existing hospital network effectively meets the diverse healthcare needs of the population, considering both acute and non-acute services, and to ensure that all communities have equitable access to necessary care.

Overall, our findings confirm that resilience and vulnerability in the Italian healthcare system stem from the healthcare network infrastructure. Persistent inequalities – both between and within provinces – reflect structural vulnerabilities that weaken the capacity of the system to withstand shocks. A network perspective highlights that resilience cannot be secured by strengthening individual hospitals alone but requires policies that improve connectivity and coordination across territorial nodes, ensuring redundancy ad flexibility. Addressing inequalities in hospital capacity is therefore crucial not only to promote equity but also to safeguard the resilience of the healthcare system as a whole.

In conclusion, addressing healthcare inequalities in Italy requires a nuanced understanding of both between- and within-province disparities. It necessitates a comprehensive approach that considers not only the distribution of hospital beds but also the socio-economic and spatial factors that influence healthcare accessibility. By aligning hospital capacities with population health needs and ensuring equitable access to all levels of care, policymakers can work towards a more equitable healthcare system that serves the diverse needs of the population.

Clearly, some limitations of this study should be acknowledged. First, our analysis focuses on the spatial distribution of hospital beds, which captures potential capacity but does not account for the interconnectivity of healthcare networks. Nonetheless, inequalities in bed capacity can be compensated by strong network linkages in emergency systems. A province with fewer beds but excellent connectivity to regional hubs may achieve better health outcomes than a province with greater nominal capacity but fragmented services. As such, future research should complement infrastructure-based measures with indicators of network integration, like inter-hospital patient flows, emergency response times, or completion rates. Second, our interpretation of inequality trends must be tempered by recognition of the national/regional institutional framework. Notably, the hub-and-spoke logic embedded in Decree 70/2015 implies that some spatial concentration is by design. Our analysis therefore reports the spatial configuration of healthcare capacity but does not test it against an efficiency benchmark, that is, against the level of within-province concentration that efficient functional specialisation would imply. Developing such a benchmark for physiological inequality under hub-and-spoke organization is a priority for future research. Notwithstanding these limitations, our findings document significant and increasing disparities that warrant policy attention, particularly in light of the strains revealed by the COVID-19 pandemic.

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Data Availability The data are available on request from the authors.

Declarations

Competing interests The authors declare no competing interests.

References

Alam K, Mahal A (2014) Economic impacts of health shocks on households in low and middle income countries: a review of the literature. Globalization Health 10(21):1–18

Barra C, Lagravinese R, Zotti R (2022) Exploring hospital efficiency within and between Italian regions: new empirical evidence. J Prod Anal 57:269–284. https://doi.org/10.1007/s11123-022-00633-4

Betti M, De Tommaso CV, Maino F (2023) Health inequalities in Italy: comparing prevention, community health services and hospital assistance in different regions. Soc Dev Issues 45(1):61–76

Briguglio L, Cordina G, Farrugia N, Vella S (2009) Economic vulnerability and resilience: Concepts and measurements. Oxf Dev Stud 37(3):229–247

Bruzzi S, Ivaldi E, Santagata M (2022) Measuring regional performance in the Italian NHS: Are disparities decreasing? Soc Indic Res 159(3):1057–1084

European Commission (2020) Building a European Health Union: Reinforcing the EU's resilience for cross-border health threats, COM/2020/724. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0724

Geurs KT, van Wee B (2004) Accessibility evaluation of land-use and transport strategies: Review and research directions. J Transp Geogr 12(2):127–140

Guagliardo MF (2004) Spatial accessibility of primary care: Concepts, methods and challenges. Int J Health Geogr 3(3):3–11

Handy SL, Niemeier DA (1997) Measuring accessibility: An exploration of issues and alternatives. Environ Plann A 29(7):1175–1194

Haughton JH, Khandker SR (2009) Handbook on Poverty and Inequality. World Bank Publications, Washington, D.C.

Joseph AE, Phillips DR (1984) Accessibility and utilization: Geographical perspectives on health care delivery. Harper & Row, London

Kickbusch I, Gleicher D (2012) Governance for health in the 21st century. WHO Regional Office for Europe, Copenhagen
Langford M, Higgs G (2006) Measuring Potential Access to Primary Healthcare Services: The Influence of Alternative Spatial Representations of Population. Prof Geogr 58(3):294–306
Luo W, and., Wang F (2003) Assessing spatial and non-spatial factors for healthcare access: Towards an integrated approach to defining health professional shortage areas. Health Place 11(2):131–146
Mao L, Nekorchuk D (2013) Measuring spatial accessibility to healthcare for populations with multiple transportation modes. Health Place 24:115–122
Mauro M, Giancotti M (2023) The 2022 primary care reform in Italy: Improving continuity and reducing regional disparities? Health Policy 135:104862
Modica M, Reggiani A, Nijkamp P (2019) Vulnerability, Resilience and Exposure: Methodological Aspects. Advances in Spatial and Economic Modeling of Disaster Impacts. Springer, pp 295–324. https://doi.org/10.1007/978-3-030-16237-5_12
Neutens T (2015) Accessibility, equity and health care: Review and research directions for transport geographers. J Transp Geogr 43:14–27
OECD (2023) Health System Resilience Toolkit. OECD Publishing, Paris
Pecoraro F, Cellini M, Luzi D, Clemente F (2024) Analysing the intra and interregional components of spatial accessibility gravity model to capture the level of equity in the distribution of hospital services in Italy: do they influence patient mobility? BMC Health Serv Res 24:973
Penchansky R, Thomas JW (1981) The concept of access: definition and relationship to consumer satisfaction. Med Care 19(2):127–140
Perchoux C, Chaix B, Cummins S, Kestens Y (2013) Conceptualization and measurement of environmental exposure in epidemiology: accounting for activity space related to daily mobility. Health Place 21:86–93
Perucca G, Piacenza M, Turati G (2019) Spatial inequality in access to healthcare: evidence from an Italian Alpine region. Reg Stud 53(4):478–489
Pyatt G (1976) On the Interpretation and Disaggregation of Gini Coefficient. Econ J 86:243–254
Reggiani A, Nijkamp P, Lanzi D (2015) Transport resilience and vulnerability: the role of connectivity. Transp Res Part A 81:4–15
Reich MR (2019) Resilient health systems: visions, values, and strategies. Health Syst Reform 5(3):191–199
Shorrocks AF (1980) The Class of Additively Decomposable Inequality Measures. Econometrica 48(3):613–625
Su R, Wang L, Liu X (2024) Spatial and social inequality of hierarchical healthcare accessibility in urban system: A case study in Shanghai, China. Sustainable Cities Soc 109:1055540
Tao Z, Cheng Y, Liu J (2020) Hierarchical two-step floating catchment area (2SFCA) method: Measuring the spatial accessibility to hierarchical healthcare facilities in Shenzhen, China. Int J Equity Health 19(1):1–16
Thomas S, Sagan A, Larkin J, Cylus J, Figueras J, Karanikolos M (2020) Strengthening health systems resilience: Key concepts and strategies. Copenhagen (Denmark): European Observatory on Health Systems and Policies; 2020. PMID: 32716618
Turati G (2014) The Italian servizio sanitario nazionale: A renewing tale of lost promises. In: Costa-Font J, Greer S (eds) Federalism and decentralization in European health and social care. Palgrave MacMillan, London, pp 47–66
Wang F (2012) Measurement, optimization, and impact of health care accessibility: a methodological review. Ann Assoc Am Geogr 102(5):1104–1112. https://doi.org/10.1080/00045608.2012.657146
World Health Organization (2024) *WHO Coronavirus Dashboard*
Yitzhaki S, Lerman R (1991) Income Stratification and Income Inequality. Rev Income Wealth 37(3):313–329

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