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Revitalizing marginal areas: A foundational economy approach

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ABSTRACT

This study presents a novel data-driven methodology to assess service provision and territorial fragility in Italy's marginal areas, focusing on the Piedmont region. Based on the foundational economic theory, this research emphasizes the role of essential services in sustaining daily life and territorial cohesion. We develop a Foundational Economy Index (FEI) that maps the availability of key services including healthcare, education, food, transportation, and civic infrastructure at the local level. Leveraging ISTAT data and over 17,000 geolocated service points through the Google Maps API, we identify distinct service configurations across 372 municipalities using hierarchical clustering techniques. We further introduce the concept of multi-service hubs, defined as multi-functional facilities that emerge in response to service scarcity and evaluate their capacity using the Economic Service Coverage (ESC) metric. Results reveal pronounced intraregional disparities, with most municipalities exhibiting critically low levels of foundational service availability. Hierarchical clustering identifies three distinct territorial profiles, with most municipalities concentrated in the low-service group, reflecting widespread structural under-provision. By operationalizing the foundational economy through a spatial analytical framework, this study provides a replicable and scalable approach for monitoring service equity in marginal territories worldwide. It offers actionable insights for policymakers, community leaders, and stakeholders aiming to reverse structural decline and promote sustainable development.

1. Introduction

Territorial disparities in access to essential services remain a significant and growing problem in advanced economies [1,2]. Unequal territorial growth poses rising issues for both developed and developing regions throughout the world, including unequal access to infrastructure, education, healthcare, and economic prospects [3–5].

In Italy, the so-called "marginal" or "inner" areas comprise more than 4000 municipalities, approximately 48.5% of the total towns of the country, which are characterized by demographic decline, infrastructural fragility, and institutional undercapacity [6,7]. These areas, often located in mountainous or remote regions of northern, central, and southern Italy, are defined by their distance from major urban centers and their limited access to essential services such as healthcare, education, and transportation [8,9]. As of January 1, 2024, approximately 13.3 million people, 25% of Italy's population, live in these inner areas. Between 2014 and 2024, these territories experienced a population decline of 5%, with peripheral and ultraperipheral municipalities suffering reductions of 6.3% and 7.7%, respectively [10]. Long-term structural issues, such as decades of underinvestment and centralization of services, which have reduced the economic and social resilience of these regions, are responsible for this trend [11]. Limited access to employment and professional growth accelerates youth outmigration, further weakening the demographic and economic structure, with more than 330,000 young graduates leaving these areas between 2002 and 2022 and an additional 45,000 moving abroad [10].

Traditional development policies have been largely based on frameworks centered on territorial competitiveness and innovation-driven agglomeration [12,13]. Although these models have proven effective in supporting growth in dynamic urban cores, they often fail to address the complex challenges faced by declining rural and mountain areas. Recognizing these limitations, Italy has introduced specific policy initiatives aimed at rebalancing territorial inequalities. One of the most prominent is the National Strategy for Inner Areas (SNAI) [6], which

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seeks to support marginal territory [7,8].

Despite these structural challenges, many residents express a strong desire to remain in their native territories, valuing local identity, community bonds, and social cohesion [14]. However, progressive closure of essential services undermines these aspirations, further exposing these areas to the risks of socioeconomic exclusion and functional decline [7,15,16].

This situation calls for a comprehensive and place-based approach to revitalization. Interventions must prioritize accessibility, strengthen local economies, and enhance connectivity. Investing in foundational infrastructures and leveraging digital tools to bridge service gaps can help reverse these trends and improve livability in underserved regions [17,18,19].

Building on these conceptual foundations, this paper adopts the *Foundational Economy* (FE) perspective, a concept introduced by Bentham et al. [20] to describe the network of essential goods and services that sustain daily life and social well-being [8,21]. Unlike growth-oriented models that focus on innovation and competitiveness, the foundational economy prioritizes universal access to essential infrastructures, viewing them as key elements of territorial cohesion, social justice, and democratic participation [21–23].

Recent studies have highlighted the resilience of foundational sectors during economic crises, their role in reducing territorial inequalities, and their potential to anchor sustainable development pathways [24–26]. Other contributions have also emphasized the prescriptive strength of the foundational economy framework, highlighting its capacity to guide concrete policy action more effectively than other sustainability-oriented models, which often remain at a more abstract or normative level [24,25,27].

To operationalize this framework, this study adopts a novel data-driven methodology to map and assess the availability of essential services in marginal areas, using the Google Maps API as a dynamic proxy and integrating it with official national data [28,18]. This approach enables the construction of a *Foundational Economy Index* (FEI) that captures the territorial distribution, density, and diversity of foundational services, including healthcare, education, food, transport, and civic infrastructure across 372 municipalities in the Piedmont region [3,29].

A key methodological innovation lies in the identification and classification of *Multiservice Hubs*: single facility that centralizes different services under one roof, emerging as adaptive responses to service withdrawal in marginal areas. Their functional capacity is assessed through the *Economic Service Coverage* (ESC) metric, which quantifies the variety of services provided by each facility across different economic domains.

To complement the service mapping, a cluster analysis based on service configurations was applied to identify service patterns across municipalities. This was combined with regression models to investigate the influence of demographic and geographic factors, such as population dynamics, altimetric zones, and local economic activity on service availability.

This multiscale analytical framework captures the heterogeneous geography of foundational infrastructures and reveals patterns of local adaptation to service scarcity. It also demonstrates the potential of spatial digital data as a proxy for service monitoring. By producing spatially sensitive and actionable insights, the proposed methodology supports differentiated policy responses and offers a scalable model applicable to marginal territories beyond the Italian context.

2. Review of literature

2.1. Foundational economy: concepts and principles

The concept of Foundational Economy (FE), first introduced by Bentham et al. [20], is based on Braudel's [30] recognition that 'there are no one but multiple economies' and refers to the set of economic activities that provide essential goods and services necessary to sustain daily life and social well-being [21,30]. These include critical sectors such as education, healthcare, transport, food systems, water, energy, and civic infrastructure, which are often overlooked in traditional growth-oriented economic models but are vital for community resilience and territorial cohesion [31,32]. The foundational economy emphasizes the strategic importance of ensuring universal access to these services while promoting environmental sustainability, social justice, and inclusion [33,34]. Within this framework, the foundational economy is typically categorized into three domains: the material economy, the providential economy and the overlooked economy [23,24], Table 1 provides an overview of dimensions and areas.

The material economy: This area includes the physical infrastructure and utilities necessary for daily life. It encompasses sectors such as transportation networks (roads, rails, public transit), energy supply systems (electricity generation and distribution, gas networks, renewable energy infrastructure), water and waste management systems, and telecommunication infrastructure (internet and communication networks). Transport networks deserve special attention, as they represent the vital system of territorial life, connecting communities with essential services, employment opportunities, and social networks [35]. In marginal areas, the quality and accessibility of the transportation infrastructure often determines whether residents can access healthcare, education, and economic opportunities, making transportation a foundational service rather than merely a technical utility. The lack of reliable public transport in remote areas creates cascading effects on social inclusion, economic participation, and territorial cohesion [36]. These sectors are capital-intensive and require significant investment, yet are crucial for supporting economic activities and ensuring a high quality of life. The fundamental material economy is characterized by its stability and the essential nature of its services, which are less susceptible to market fluctuations [33].

The Providential Economy: This sector focuses on the provision of welfare services that support individuals throughout different stages of their lives. This domain includes healthcare services, such as hospitals, clinics, doctors, and pharmacies; education, which includes schools, universities, and vocational training; social care services, including elderly care, childcare, and social work; civic infrastructure such as local government and police stations; as well as social hubs like bars, cafes, and squares, where people can socialize and support community cohesion. It is important to note that *civic infrastructure* represents a particular foundational service category that includes local government offices, police stations, fire stations, courthouses, and municipal administrative centers. Typically, municipalities allow private service providers to develop infrastructures needed for energy, water, waste management, and internet services, thus facilitating access to these essential services [37,38]. This institutional arrangement reflects the principle of municipal responsibility for essential services, positioning these infrastructure utilities within a governance framework that bridges material and providential services [20].

The Overlooked Economy: This area includes sectors and activities

Table 1
Foundational economy dimensions.

Dimensions	Focus	Examples
Material Economy	Physical infrastructure and utilities managed or regulated by local governments	Food access, transportation networks, energy supply, water and waste management systems, telecommunications, banks, postal services
Providential Economy	Welfare services and civic infrastructure supporting individuals and communities	Healthcare services, education, social care services, civic centers, local government support
Overlooked Economy	Community well-being, social capital, and local provisioning initiatives	Small local businesses, informal care work, community initiatives, local food production

crucial to community well-being but often underappreciated or overlooked in economic policies and analyses. The overlooked economy encompasses small local businesses such as family-owned stores and local artisans, community initiatives such as local food production, and cooperative enterprises [23,27]. It also includes tourist attractions, such as enogastronomic experiences and museums. The literature on social economics emphasizes the crucial role of cooperative enterprises, mutual aid societies, and community organizations in sustaining territorial life [39,40]. In marginal territories, the overlooked economy often becomes particularly vital as market-based services are removed and formal institutional support weakens. Small family-owned businesses often serve multiple functions beyond their primary commercial purpose, acting as informal community centers, information centers, and social gathering spaces [41]. Local artisans and craftspeople not only preserve traditional skills and cultural knowledge but also contribute to territorial identity and place-based distinctiveness that can support tourism and the development of the cultural economy [42]. Community initiatives such as local food networks and cooperative enterprises represent innovative responses to market failures and institutional gaps in marginal territories. These initiatives often emerge from what Gibson-Graham term "community economies": diverse economic practices that prioritize social reproduction and environmental sustainability over profit maximization [43].

Recognizing the overlooked economy underscores the importance of small business activities and the social capital that contributes to the resilience and cohesion of communities [11,12]. This recognition is particularly crucial for foundational economy approaches, as it reveals how territorial well-being depends not only on formal service provision but also on the dense networks of reciprocity, mutual support, and community capacity that often substitute or complement market provision [44].

Although the *tradeable economy* is not always classified as the foundational economy, it is important to recognize its interaction with the foundational sectors. The tradable economy includes industries that produce goods and services for export and are exposed to global competition, such as manufacturing and certain service industries. A strong foundational economy supports the tradeable economy by providing the necessary infrastructure and skilled workforce, highlighting the interdependence between these sectors [45].

The foundational economy challenges conventional economic models by arguing that prosperity should be measured not just by GDP growth or market output but by the accessibility and quality of essential services available to all members of society. Investing in the foundational sectors can lead to more resilient and sustainable communities, reduce social inequalities, and promote inclusive and regionally balanced economic development [9,31–34]. Rather than prioritizing market competitiveness and short-term profitability, this approach shifts the focus toward long-term societal well-being and the infrastructures that enable equitable living standards [45].

FE intersects with the literature on commons and community economies, which emphasize collective agencies, care, and reciprocity [42–46]. Although community economies emphasize grassroots and cooperative forms of provisioning [40–44,47], FE seeks to translate such ethical orientations into scalable institutional policies, such as multi-service centers, public procurement strategies, and territorial contracts [22,23,48,49]. The foundational economy specifically draws attention to the territorial dimension of service provision. Peripheral and rural areas are often structurally disadvantaged because essential services tend to be concentrated in urban centers, generating spatial inequalities that undermine social cohesion [33,34]. The concept emphasizes that universal service provision should not merely be a goal within dense metropolitan regions, but a fundamental right extended throughout the national territory, ensuring equitable living standards regardless of geographical location [50]. Scholars argue that investing in foundational sectors is a strategic response to multiple contemporary challenges, from demographic decline and territorial inequalities to climate change and economic instability [21–23]. By prioritizing accessibility and quality of essential services, the FE framework promotes more resilient and sustainable communities, reducing social disparities and anchoring economic activities locally to counter the volatility of global markets. From a governance perspective, the FE calls for participatory models that involve local communities in service planning, strengthening democratic legitimacy and social trust [26,33,34].

2.2. Access to essential services and foundational economy

Access to essential services has long been recognized as a fundamental determinant of territorial cohesion, social equity, and regional development. A substantial body of literature in regional studies, economic geography, and spatial planning has examined how disparities in service provision contribute to processes of peripheralization, demographic decline, and socio-economic marginalization [14–16]. In rural and inner areas, the progressive withdrawal or centralization of key services such as healthcare, education, public transport, and financial infrastructure has increasingly been identified as both a symptom and a driver of territorial fragility [17,20,51].

Early contributions in this field focused on the development of spatial methods for measuring service accessibility. Studies employing Geographic Information Systems (GIS) introduced analytical techniques such as travel-time analysis, gravity models, and service catchment areas to evaluate the ability of residents to reach essential services [52,53,54]. Building on these methodological foundations, more recent European research has systematically mapped accessibility to services of general interest across countries and regions, highlighting persistent structural disparities between urban cores and peripheral territories. Kompil et al. [55], for example, develop a market-potential approach to measure access to generic services across Europe, revealing significant spatial inequalities in service availability. Ortega-Reig et al. [56] propose a diagnostic framework for identifying well-being inequalities among rural areas through service accessibility indicators, demonstrating how deficits in essential services correlate with broader socio-economic disadvantages. Similarly, Šišak and Lukić [57] analyze the spatial distribution of services within functional urban regions in Zagreb (Croatia), showing that intra-regional disparities in service provision persist even within relatively integrated metropolitan systems.

Comparable dynamics have been documented beyond the European context, particularly in regions experiencing demographic shrinkage and territorial restructuring. In Australia, McGuirk and Argent [53] demonstrate how population decline undermines the viability of local service provision in rural regions, generating feedback loops of depopulation, economic contraction, and infrastructural erosion. In Japan, Feldhoff [58] shows that shrinking rural communities increasingly rely on local ownership and community-based management of services and infrastructures to compensate for the withdrawal of public provision, although structural inequalities remain. Similar trends have been observed in North America, where the spatial concentration of essential services in metropolitan areas has been accompanied by the progressive loss of services in rural and small-town communities [59,60]. These processes are frequently reinforced by market-driven consolidation and public sector restructuring, which prioritize efficiency and economies of scale over territorial equity [61].

Across these diverse contexts, the literature converges on a common finding: the decline of service provision in peripheral areas cannot be explained solely by geographic remoteness. Rather, it reflects cumulative demographic, economic, and institutional dynamics that reshape territorial opportunity structures and reinforce spatial inequalities. The progressive erosion of everyday infrastructures in rural and marginal territories contributes to processes of territorial marginalization, whereby declining accessibility to essential services further accelerates demographic shrinkage and economic decline [53,58–60]. Most accessibility studies focus primarily on measuring travel times or service density, without fully embedding these infrastructures within a wider understanding of how everyday services sustain local economies and social cohesion [52,55–57]. While this literature has provided robust tools for measuring spatial accessibility and identifying service gaps, it often remains analytically separated from broader debates on economic restructuring and regional development.

It is precisely at this intersection that the Foundational Economy (FE) perspective offers a valuable conceptual framework [11,21–23]. Rather than treating services merely as spatial amenities, the FE approach emphasizes their role as essential infrastructures that underpin everyday life, social well-being, and territorial resilience [45,27]. From this perspective, sectors such as healthcare, education, food provision, mobility, and civic infrastructure constitute the economic foundations of communities and play a critical role in sustaining both social reproduction and local economic activity.

In recent years, several empirical studies have examined the role of foundational sectors in regional development. In Sweden, Martynovich et al. [25] provide the first systematic mapping of foundational employment at the subnational level, showing that during the Great Recession (2007–2009) foundational sectors proved more resilient than tradeable sectors and contributed significantly to post-crisis recovery. Similarly, Nygaard and Hansen [26] analyze planning strategies across all Danish municipalities, demonstrating that foundational sectors are often prioritized in local development strategies, particularly in rural municipalities with limited economic alternatives. In these contexts, foundational services function less as drivers of economic growth and more as pragmatic anchors of local well-being and territorial stability. Complementary evidence is provided by Riepl et al. [24], who develop a Foundational Accessibility Indicator for 250 census districts in Vienna. Their results reveal that wealthier districts systematically enjoy higher access to essential infrastructures such as healthcare, education, nature, and care services, demonstrating that foundational service accessibility remains socially and spatially unequal even within affluent urban contexts.

These studies highlight how the foundational economy provides an alternative perspective to growth-centered regional development strategies [62,63]. Whereas conventional development models often emphasize innovation, competitiveness, and investment concentration in urban centers, the FE perspective focusses the importance of everyday infrastructures and service provision in sustaining territorial cohesion and social welfare. By focusing on sectors that directly support daily life, the FE framework offers a place-based approach to addressing territorial fragility and inequality.

Despite these advances, the empirical operationalization of the foundational economy remains relatively limited. The quantitative literature has focused primarily on employment structures and economic output within foundational sectors [25], rather than on the spatial distribution and real-time accessibility of foundational services themselves. Similarly, studies such as Nygaard and Hansen [26] rely largely on planning documents and qualitative interviews, offering valuable insights into governance strategies but providing limited measurement of service provision on the ground. Even recent efforts to map foundational infrastructures spatially, such as the study by Riepl et al. [24], remain dependent on official datasets such as census data, which often lack the temporal granularity needed to capture dynamic changes in service availability, particularly in rapidly transforming or declining territories. More broadly, existing frameworks for measuring territorial fragility and rural development, such as the Italian National Strategy for Inner Areas (SNAI) [6,64] or the OECD Rural Policy Framework [61], rely predominantly on static administrative classifications. While these approaches provide important institutional benchmarks, they are less suited to capturing the dynamic, multidimensional, and spatially embedded nature of everyday service provision.

By integrating the conceptual framework of the foundational economy with a data-driven approach based on digital geographic information, this study contributes to bridging the gap between spatial accessibility research and contemporary debates on territorial resilience and place-based development. The proposed methodology provides a more dynamic and fine-grained perspective on the distribution of foundational services, offering new opportunities for evidence-based territorial planning in rural and marginal regions.

Building on this framework, the study poses the following research questions to explore the structural and spatial dimensions of marginality in Piedmont. These questions assess the relevance of the foundational economy framework, the role of dynamic mapping tools, and the design of evidence-based strategies to revitalize underserved territories.

The core research questions are as follows:

1. How can a Foundational Economy Index (FEI) reveal spatial disparities in foundational service provision and inform territorial planning for cohesion in marginal municipalities?
2. Can multiservice hubs be identified through digital mapping, and what is their role in supporting local resilience in marginal areas?
3. Can digital data (e.g. Google Maps) serve as a valid proxy for measuring service availability in underserved areas?

This study addresses these gaps by introducing a novel methodological approach: the use of Google Maps data, parsed and categorized through the API, to dynamically map essential services across the foundational economy (material, providential, overlooked) and tradeable economy [20,23]. The mapping methodology developed here not only improves the temporal resolution of the analysis but also expands the conceptual boundaries of what constitutes 'essential services' in marginal territories. It incorporates a wide spectrum of foundational functions, including civic infrastructure, social centers, food access, and education, and integrates them into a synthetic foundational index (FEI) and territorial service networks.

2.3. Marginal areas of Italy

In Italy, marginality is not merely the result of geographical remoteness or low population density. Rather, it is the outcome of historically uneven development, long-term political neglect, and structural underinvestment in non-metropolitan territories [5,14,16,17]. These dynamics have led to persistent spatial inequalities, particularly in rural, mountainous, and inner areas where access to essential services remains fragile and demographic decline is accelerating [6,7,65]. Contemporary international literature reinforces this systemic reading of marginality. Rodríguez-Pose [62] refers to the "revenge of places that don't matter" as a reaction to decades of spatial exclusion under growth-centric models. Davezies [66] emphasizes the symbolic and functional disconnect of peripheral territories from national economic flows, while Mayaud et al. [15] highlights the compounding role of digital exclusion and infrastructural decay in limiting access to rights and opportunities, particularly for the elderly, youth, and migrants. In this light, marginality should be understood as a multidimensional and relational condition, encompassing demographic shrinkage, infrastructural fragility, weak institutional capacity. Closely linked is the notion of peripheral citizenship, in which access to public goods, political voice, and future opportunities is structurally constrained by geography and policy design [65].

Since the 1990s, Italy has attempted to address these disparities through various legislative and regional development initiatives. The most ambitious and coherent among them is the National Strategy for Inner Areas (SNAI), launched in 2012 and formalized in 2014. SNAI redefined marginality not in morphological or demographic terms, but through accessibility to three essential services: healthcare, education, and mobility [5,6]. Based on travel time thresholds to service centers, municipalities were functionally classified into six categories (Fig. 1) [6,67]:

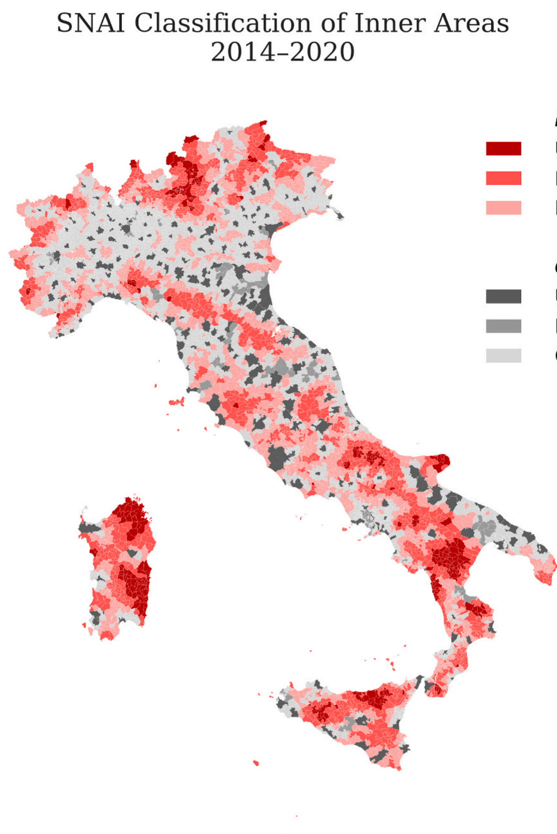

Fig. 1. SNAI Inner Areas: 2014–2020 vs 2021–2027.

- *Urban Poles* – Municipalities that directly provide all three essential services: hospital with emergency care, upper secondary school, and a Silver-class railway station.
- *Intermunicipal Poles* – Groups of nearby municipalities that, together, ensure access to the essential services.
- *Outlying Areas* – Municipalities located up to 20 min from a service pole. These are not considered inner areas and usually form the surrounding belts.
- *Intermediate Areas* – Municipalities located more than 20 min from a service pole, marking the beginning of Inner Areas as defined by SNAI.
- *Peripheral Areas* – Municipalities located more than 40 min from a pole.
- *Ultraperipheral Areas* – Municipalities located more than 75 min from a pole, often mountainous or remote, facing the highest accessibility challenges.

The updated SNAI classification for the 2021–2027 programming period shows a clear expansion of marginal territories ("Inner Areas") compared to the 2014–2020 framework. This is evident from the increase in municipalities categorized as intermediate, peripheral, or ultra-peripheral areas. These changes reflect an enhanced recognition of territorial disparities in service accessibility and infrastructure. In our study, we adopt the most recent classification (2021–2027) as the baseline for identifying and analyzing marginal municipalities in the Piedmont region.

3. Methodology

Fig. 2 outlines the four main stages of the research design: identification of marginal municipalities based on the 2021–2027 SNAI classification; data collection through national statistics and Google Maps API; classification of services within the Foundational Economy framework; and finally, analysis through the calculation of the Foundational Economy Index (FEI) and clustering of municipalities by service profiles. The following sections provide a detailed explanation of each methodological step.

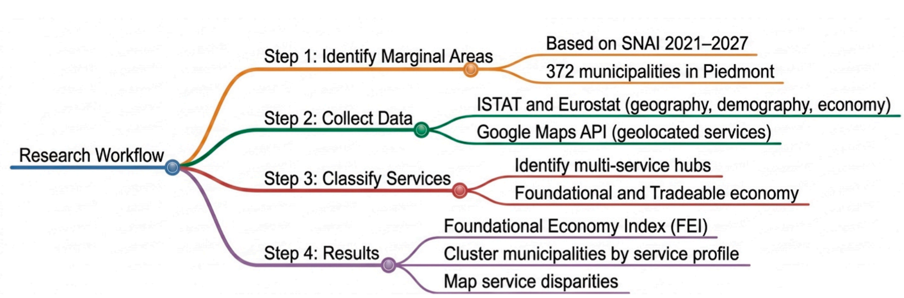

Fig. 2. Research workflow.

3.1. Case selection: Marginal Municipalities in Piedmont

The study focuses on 372 municipalities in the Piedmont region of northwest Italy, identified as intermediate, peripheral, or ultra-peripheral under the latest classification of the National Strategy for Inner Areas (Fig. 3). Piedmont was selected for its pronounced territorial diversity, 43% of its area is mountainous and the presence of highly urbanized and deeply marginalized areas within the same regional context. The choice of Piedmont as the study area is motivated by several factors that make it a particularly representative and analytically productive case for the study of marginality in Italy and Europe. First, Piedmont encompasses a wide spectrum of territorial configurations, from highly urbanized plains (Turin metropolitan area) to deeply peripheral Alpine municipalities, within a single administrative region, making it an ideal laboratory for comparative analysis of foundational service provision. Second, with 372 SNAI-classified marginal municipalities, Piedmont hosts one of the largest concentrations of inner area municipalities in northern Italy, accounting for approximately 10% of all Italian marginal municipalities, and offering a statistically meaningful sample for the development and testing of the proposed methodology. Third, in terms of demographic dynamics, economic structure, and service withdrawal patterns, Piedmont's marginal municipalities display characteristics broadly comparable to those of other European mountain and rural regions undergoing similar transitions (e.g., Alpine regions in France, Austria, and Switzerland; Apennine regions in central Italy; rural regions of Spain and Portugal). However, the analytical pipeline, the service classification and Foundational economy index computation, is designed to be replicable across any territorial context. Since Google Maps API provides global coverage, the same data collection approach can be applied to other mountain and rural regions beyond the Alpine context.

The spatial configuration of Piedmont clearly highlights a structural divergence between marginal and central municipalities in terms of both physical geography and environmental characteristics. As illustrated in Fig. 3, marginal areas are located in inner mountain regions, with more than 52% of municipalities classified within the highest altimetric category, compared to only 17% among central areas. In contrast, central areas are significantly more represented in hills (49%) and plains (34%), reflecting a more accessible and infrastructurally integrated landscape. The environmental variables displayed in Fig. 4 further reinforce this spatial difference.

The demographic trajectories of marginal areas in Piedmont present a clear picture of long-term structural decline, characterized by population loss, aging, and limited in-migration [7]. The marginal areas show a significantly population change, while central areas exhibit a more balanced trend, with several municipalities experiencing mild demographic growth [10]. This divergence is largely explained by the sustained outmigration of younger cohorts from marginal territories to

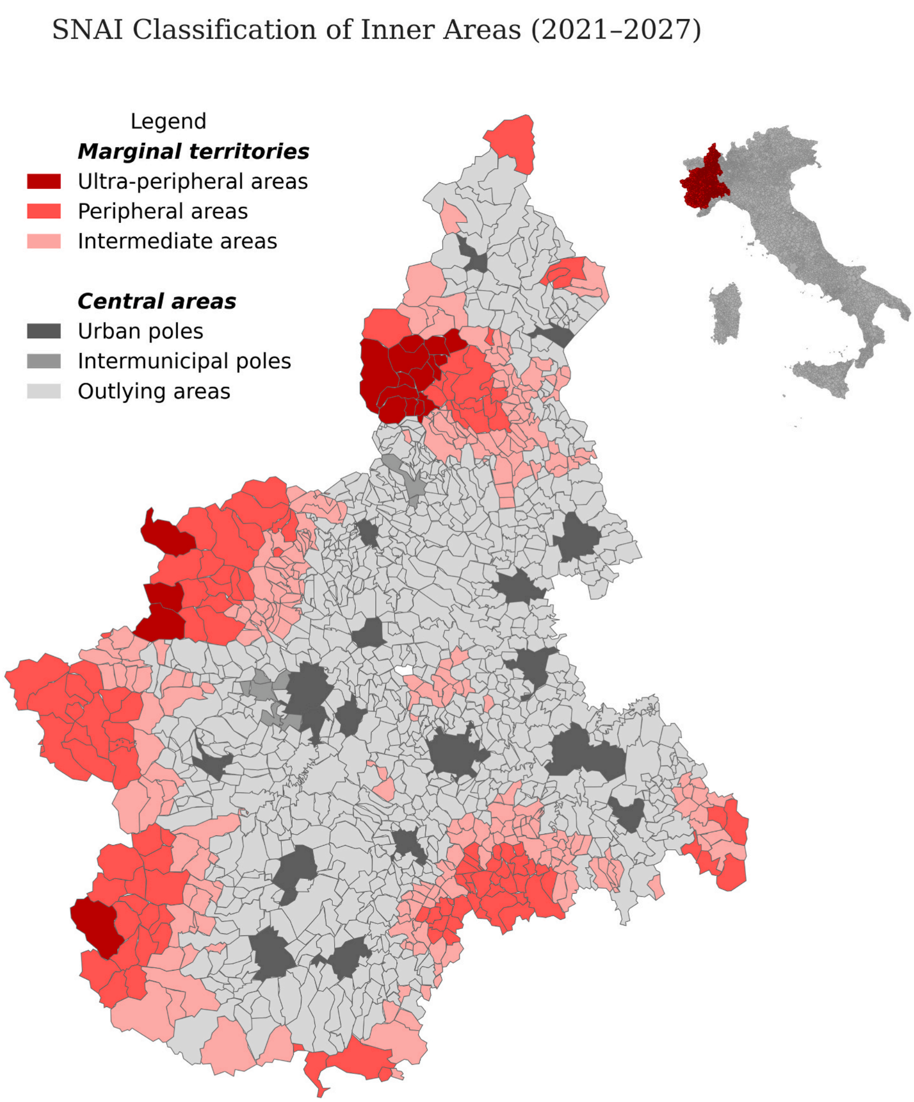

Fig. 3. Marginal Municipalities in Piedmont region.

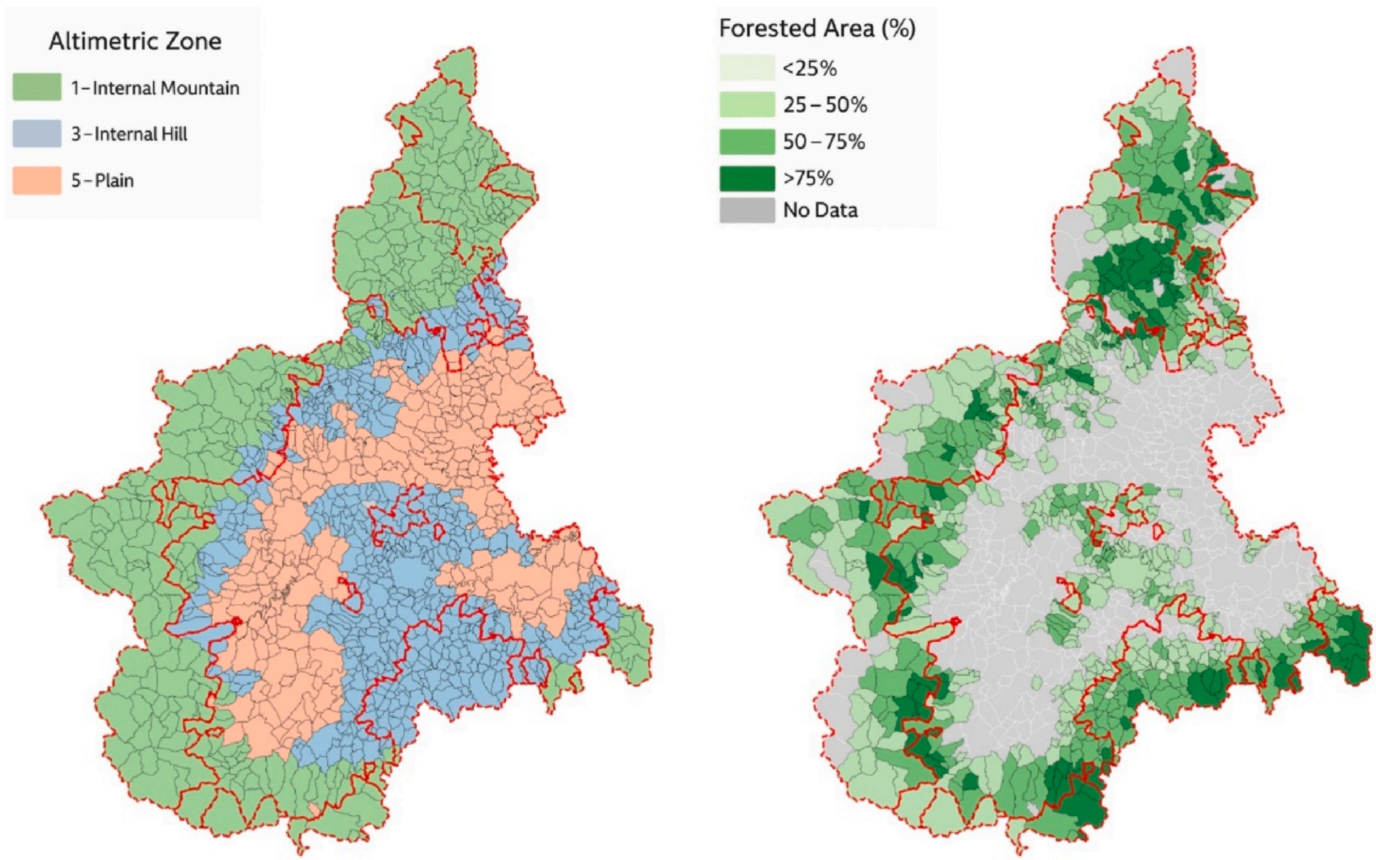

Fig. 4. Altimetric zones and forest coverage in Piedmont. The red dashed line delineates the marginal areas (classified as D, E, and F according to the SNAI classification). The gray municipalities on the right panel indicate missing data for forest coverage. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

larger urban centers, a process driven by the search for employment, education, and higher-quality services [7,10]. The phenomenon reflects a broader demographic polarization in which the most accessible and economically dynamic areas retain or attract working-age populations, while remote and less connected territories are left with shrinking, older, and more dependent populations [8,9].

3.2. Data sources

A dual-source data strategy was employed:

Official statistics: Data from the ISTAT, Eurostat, MIPAAF and ASIA registers were used to describe the structural profile of the 372 marginal municipalities in Piedmont. The indicators covered geographic configurations (such as altitude zones and forest coverage), demographic trends (population dynamics, urbanization levels), and labor market characteristics (employment structure, unemployment rate, and business density). These variables allowed comparison with central municipalities and provided information on the socioeconomic vulnerabilities of marginal areas. Table 2 summarizes the key indicators used.

Geospatial Service Data: We collected over 17,145 geolocated facilities using Google Maps Places API, including a wide array of facilities such as grocery stores, pharmacies, healthcare centers, schools, public transport stops, and other essential local services. For each services point, the data set includes metadata such as name, address, geographic coordinates, user rating, number of reviews, service categories, and operational status. A key element of this data set is the "category type" variable provided by Google, which classifies each service based on its primary function (e.g., grocery store, school, cafe). This classification was used to map services into broader functional domains aligned with the foundational economy framework, such as material services (e.g. grocery store, public transport), providential services (e.g. schools, healthcare) and other sectors regarding overlooked services like hospitality, retail, and parks. The "*status*" field further allows verification of whether a service is currently operational or permanently closed, providing a dynamic view of service availability across municipalities. Table 3 provides a descriptive overview of a small sample of services identified in the Pettenasco municipality.

This geospatial data collection not only provided a detailed map of the services available in marginal municipalities but also allowed their functional classification into different economic domains. Using the *category* feature provided by Google, each service was systematically mapped to the foundational and tradeable economy domains.

3.3. Service classification and foundational economy domains

Mapping services according to the domains of the foundational economy (material, providential, and overlooked) involves the use of dynamic spatial data from Google Maps API. This process enables a detailed assessment of the availability and accessibility of essential services in municipalities. Services are categorized into three principal domains of the foundational economy. Table 4 delineates the classification of services within the Foundational Economy and Non-Fe areas, highlighting their prole in maintaining physical infrastructure and improving community well-being.

Material services include access to food, transportation, and financial services, essential for functioning and daily life. *Providential services* encompass healthcare and education systems, civic infrastructure, as well as public and cultural amenities that promote social interaction and development. The *Overlooked economy* includes activities related to leisure, tourism, and personal services whose consumption is typically

Table 2
Overview of socio-economic and geo-environmental indicators.

Dimension	Variable	Description	Year	Source
Geography and Environment	Altimetric Zone	Mountain, Hill, Plain Classification	2022	ISTAT
	Forest Area	Share of forested land on total area	2020	MIPAAF
Demography and Urbanization	Degree of Urbanization	Densely populated, Intermediate, Rural classification	2018	Eurostat
	Current Population	Resident population in the municipal level.	2022	ISTAT
	Population Change	Percentage change in total population (2011–2021)	2011–2021	ISTAT
	Change in Foreign Residents	Absolute change in the foreign population (2011–2021)	2011–2021	ISTAT
Economy and Territory	Business Activity	Number of active businesses (industrial and services sectors).	2020	ASIA Register
	Employees by Sector	Employment Distribution across Economic Sectors	2021	ISTAT
	Unemployment Rate	Job seekers as a percentage of the labor force (2018–2022)	2018–2022	ISTAT
	SNAI Classification	(A) Urban poles, (B) Intermunicipal poles, (C) Outlying areas, (D) Intermediate, (E) Peripheral, and (F) Ultra-peripheral	2021-2027	National Strategy for Inner Areas

Table 3
Example of geolocated services (Pettenasco Municipality).

Service Name	Category type	Operational status
Municipality of Pettenasco	Local Government Office	Operational
Pettenasco Nursery School	School	Operational
Skipper	Cafe, Grocery Store, Liquor Store, Lodging	Operational
Church of Saints Audentius and Catherine	Place of Worship	Operational
Conad City Supermarket	Supermarket, Grocery Store	Operational
Pettenasco Primary School	School	Operational

Note: Not an exhaustive representation of all metadata provided by the Google Maps API.

occasional and can be postponed, such as hospitality, restaurants, or personal care services. While these activities are not strictly part of the core foundational provisioning system, they contribute to the cultural and social vitality of local communities and therefore remain relevant for territorial well-being [68].

Some services may perform multiple functions within local economies. For instance, *restaurants, bars* and *cafés* provide food services but also act as informal social hubs that facilitate everyday social interaction and community life. Similarly, lodging facilities contribute to tourism economies while also reinforcing local identity and place attractiveness.

Table 4
Overview of Foundational Economy (FE) and Non-FE Areas, with Corresponding Service Domains and category types.

FE Area	Service Domains	Example Types
Material	Food Access	Grocery stores, supermarkets, bakeries, take-out meals …
	Transportation	Bus stations, train stations, gas stations, parking …
	Bank & Postal Services	Banks, ATMs, post offices, finance services …
Providential	Health & Medicine	Hospitals, pharmacies, physicians, dentists, and physiotherapists …
	Education	Schools, Universities, Preschools, Secondary Schools …
	Civic Infrastructure	Local government offices, police, fire stations, courthouses …
	Social Hubs & Public Spaces	Libraries, parks, bars, cafés, places of worship, community centers …
Overlooked	Cultural Necessities	tourist attractions, restaurant, lodging, hair salons …
Non-FE Area	Service Domains	Example Types
Tradeable	Aspirational Purchases	car dealers, electronics stores, jewelry, real estate, florists …

Note: The services listed are not exhaustive but represent the most illustrative examples for each category within the Foundational and Non-Foundational Economy areas.

Recognizing these functional overlaps is important when mapping local service ecosystems, as it highlights how certain activities can simultaneously support consumption, social interaction, and territorial cohesion.

In addition, *civic infrastructure* services, as outlined in the theoretical section, serve as a link between material and providential services by providing administrative support to residents, ensuring safety, and facilitating essential infrastructure services such as renewable energy, waste management, water treatment, and internet services.

The data mapped and collected are cross-validated using official national statistics and Google Maps platform checks, ensuring the reliability of the presence of the service for each municipality. This integrated mapping allows for a clearer understanding of how foundational services meet the daily needs of residents in marginal territories. This classification follows the literature on foundational economics [20,22] and was operationalized using Google category tags.

3.4. Measuring multi-service provision: the Economic Services Coverage (ESC) metric

In marginal areas facing population decline and limited access to essential services, *multiservice hubs* have emerged as adaptive and strategic responses. These facilities, often small family-owned stores, combine different services under one roof, such as groceries, bar, accommodation, and other activities. In doing so, they help maintain access to key services despite the closure of specialized businesses, while also acting as important social and economic anchors within the community.

To better understand the functional role of these hubs, we introduce the *Economic Services Coverage* metric, which captures both the number and the types of services provided by individual facilities or shops located in marginal areas. Each service is then classified according to its economic domain: *Foundational Economy (FE)* or *Tradable Economy (TE)*.

$$\mathrm{ESC}(s_i) = \sum_{d\in\{\mathrm{FE},\mathrm{TE}\}} \sum_{t_k\in d} \delta(t_k \in \mathrm{types}(s_i))$$

Where:

- ESC (s_i) : total number of services offered by shop s_i, grouped by economic domain
- dFE, TE : *economic domains* : FE = foundational economy, TE = tradeable economy
- $t_k \in d$: individual service type (e.g., grocery, lodging, clothing) within domain d
- $\delta(\cdot)$: indicator function, returns 1 if $t_k \in \text{types}(s_i)$, 0 otherwise

The service profile of each store is operationalized using a binary matrix that records the existence or absence of services within each economic domain. The ESC captures the multiservice nature of many facilities in marginal areas, where a single store may simultaneously provide grocery, postal, and bar services (see Supplementary Fig. S1 for an illustrative example of the service network of Skipper, a multiservice hub located in Pettenasco city). This comprehensive mapping serves two purposes. First, it provides a granular overview of service provisioning across the study area, distinguishing between foundational and tradeable economy functions at the facility level. Second, it constitutes the necessary input for the second stage of the analysis, the computation of the Foundational Economy Index (FEI), in which only the foundational economy service types are retained and aggregated at the municipal level.

3.5. Aggregating foundational services: The Foundational Economy Index (FEI)

The construction of the Foundational Economy Index (FEI) follows a two-stage procedure. In the first stage, each Point of Interest (POI) retrieved from the Google Places API was classified into one of eight foundational service categories based on a predefined mapping of Google Places types to service domains (ESC metric). Each POI was assigned to a category if its Google Places type matched one of the type codes associated with that category (e.g., *hospital, pharmacy, doctor* → Health and Medicine; *school, university* → Education). This classification step was necessary to aggregate the raw and heterogeneous POI data, which contains over 90 distinct Google Places category types, into eight meaningful foundational service domains. These eight categories constitute the set C of foundational service categories: *food access, transportation, bank and postal services, health and medicine, education, civic infrastructure, social hubs & public spaces, cultural necessities*.

In the second stage, the FEI for each municipality i was computed as the unweighted sum of service counts across all categories in C:

$$FEI_i = \sum_{c \in C} S_{i,c}$$

Where:

- FEI_i: Foundational Economy Index for municipality i
- C: the set of eight foundational service categories listed above
- $c \in C$: an individual Google Places service type (e.g., *pharmacy, doctor, hospital*) belonging to one of the eight foundational categories in C
- $S_{i,c}$: number of POIs of service type c present within municipality i, as classified through the Google Places type mapping described in Stage 1

This formulation directly reflects the total stock of foundational service units present in each municipality. To ensure comparability across municipalities, the raw FEI was subsequently normalized using min-max scaling, generating the Foundational Economy Score (FES), which ranges from 0 to 1:

$$FES_i = \frac{FEI_i - \min(FEI)}{\max(FEI) - \min(FEI)}$$

Where:

- $\min(FEI)$ and $\max(FEI)$: minimum and maximum FEI values observed across all municipalities in the study area
- $FES_i = 0$: municipality with the lowest foundational service provision
- $FES_i = 1$: municipality with the highest foundational service provision

3.6. Spatial autocorrelation and econometric modelling

Before exploring the factors associated with variation in the Foundational Economy Index (FEI), we first assessed whether the dependent variable exhibited spatial dependence. In spatial datasets, observations located close to each other may display correlated outcomes, potentially violating the independence assumption of classical regression models [69,70].

To account for this possibility, a spatial weights matrix W was constructed using a *K-Nearest Neighbours (KNN)* specification (k = 5) based on geographic distances between municipal centroids [71]. This approach ensures that each municipality is linked to its five closest spatial neighbours regardless of administrative boundaries and is particularly appropriate in morphologically heterogeneous regions such as Piedmont, where contiguity-based matrices may generate disconnected units in mountainous areas. Row-standardized weights were applied so that the spatial lag of each observation reflects the average value of its neighbours [69,70]. Global spatial autocorrelation in the FEI was assessed using *Moran's I statistic*, which measures whether similar values of a variable cluster spatially or are randomly distributed across space [72].

To explore the structural characteristics associated with variation in foundational service provision, we first estimated a baseline *Ordinary Least Squares (OLS)* model:

$$\begin{aligned} FEI_i = \; & \beta_0 + \beta_1 \log(Population_i) + \beta_2 ForeignResidents_i + \beta_3 UnemploymentRate + \\ & \beta_4 Hill_i + \beta_5 Mountain_i + \beta_6 ActiveWorkers_i + \beta_7 SNAI\_E_i + \beta_8 SNAI\_F_i + \varepsilon_i \end{aligned}$$

where FEI_i represents the Foundational Economy Index for municipality i, and ε_i is the error term.

The explanatory variables capture geographic, demographic, and economic characteristics of marginal municipalities. Geographic constraints are represented by two dummy variables *Altimetric Zone* (*hill, mountain*), while demographic structure is captured by *Log Population* and *Foreign Residents*. Local economic conditions are proxied by *Unemployment Rate* and *Active Workers*. Finally, two dummy variables identify municipalities classified as *Peripheral* (SNAI category E) and *Ultra-Peripheral* (SNAI category F).

Because spatial dependence may influence both the dependent variable and the explanatory variables, we additionally estimated several spatial econometric models, including the Spatial Lag Model (SLM), the Spatial Error Model (SEM), and the Spatial Durbin Model (SDM), which represent standard approaches for modelling spatial spillovers and spatially correlated disturbances [69,73].

Among these models, the *Spatial Durbin Model (SDM)* provides the most general specification, allowing both the dependent variable and the explanatory variables to exhibit spatial spillovers:

$$FEI_i = \rho WFEI_i + X_i\beta + WX_i\theta + \varepsilon_i$$

where $WFEI_i$ represents the spatial lag of the dependent variable, WX_i captures spatially lagged explanatory variables, and ρ measures the strength of spatial dependence.

Model comparison was conducted using standard spatial econometric diagnostics, including the Akaike Information Criterion (AIC) and tests for spatial autocorrelation in the regression residuals [74]. Moran's I was computed on the residuals of all estimated models to assess whether spatial dependence remained after accounting for the observed covariates [72].

3.7. Clustering municipalities by service profiles

To identify patterns in the configuration of services across municipalities, we applied a hierarchical clustering technique based on cosine similarity [75,76]. This method allowed us to group municipalities according to their service profiles, considering nine categories that span both foundational and tradeable domains, such as food access, transportation, health, education, and civic infrastructure. First, a pairwise cosine similarity matrix was generated using normalized service counts, capturing the degree of similarity between each pair of municipalities. This matrix formed the basis for the subsequent clustering analysis. We then applied hierarchical agglomerative clustering using Ward's linkage method, which is particularly suited for high-dimensional data and tends to produce compact and interpretable groupings. To determine the optimal number of clusters, we tested different distance thresholds (ranging from 5 to 50) and evaluated the modularity of each resulting configuration using the networkx library [77]. The configuration that maximized *modularity*[1] at a threshold of 20, was selected as the most meaningful grouping, resulting in three distinct clusters. Finally, we visualized the clustering structure through a reordered *cosine similarity* heatmap, which highlighted the internal cohesion and separation between clusters. This approach enabled the identification of territorial patterns in service provision, offering a more nuanced understanding of spatial disparities.

4. Results

The 372 marginal municipalities included in the analysis are predominantly small settlements. The average population is about 1221 inhabitants, but this value is influenced by a few larger municipalities. The median population is only 528 residents, and 25% of municipalities have fewer than 230 inhabitants. The smallest municipality has 41 residents, while the largest reaches 21,383. This wide range highlights the strong heterogeneity within the category of "marginal" territories. The high standard deviation (2,335) compared to the mean also indicates a right-skewed distribution: most marginal municipalities are very small rural or mountain villages, while a small number of larger towns meet the marginality criteria mainly due to economic conditions or limited access to services rather than population size.

Economically, marginal areas show a limited presence of productive structures. The spatial distribution of local industrial and service units (Fig. 5) highlights a marked territorial divide between central and marginal municipalities. Service enterprises are clearly more widespread than industrial ones, particularly concentrated in central urban areas, as detailed in Table 5. On average, central municipalities host three to four times more service and industrial enterprises than marginal ones. This imbalance reflects stronger agglomeration economies, higher population density, and better market accessibility in central territories. Turin city stands out as an extreme case, with over 40,000 service enterprises, while most marginal municipalities are sparsely populated and economically less dense.

Looking beyond enterprise numbers, employment data further emphasizes this divide. Central areas register substantially higher levels of employment across commerce, services, and transportation, with figures often three to five times greater than in marginal municipalities. Although overall unemployment rates appear to be comparable, marginal regions exhibit higher fluctuation and have concentrations with persistent unemployment - up to 18.5% in certain towns. This emphasizes the structural fragility of periphery economies and the importance of specialized measures to promote job creation and local company growth.

These data illustrate not only quantitative disparity but also a concentration of employment in fewer sectors in marginal areas. The broader and more diversified occupational structure in central zones ensures greater resilience and flexibility, while marginal territories remain exposed to vulnerability due to their limited labor base and specialization. Together, these patterns reveal a compounding disadvantage for marginal areas: the simultaneous loss of native youth and the limited arrival of newcomers. Without targeted policies aimed at improving local living conditions, accessibility to services, and employment opportunities, these areas risk entering a vicious cycle of demographic and economic stagnation. Addressing this requires not only spatial redistribution of resources but also imaginative strategies to make peripheral living a viable and desirable choice, especially for younger generations and families.

4.1. Spatial patterns of foundational service provision

Table 6 presents the descriptive statistics of service availability across the 372 marginal municipalities analyzed in this study, distinguishing between foundational economy domains and tradeable economy. The values reported represent the number of service units (i.e., individual facilities or points of service) identified within each municipality using Google Maps API. The results highlight substantial variation in the presence of essential services across municipalities. Among foundational services, social hubs and public spaces show the highest average availability (mean = 9.94 service units), followed by cultural necessities (mean = 7.77) and food access services (mean = 7.35). In contrast, key infrastructures such as education (mean = 1.42), transportation (mean = 1.85), and health services (mean = 2.16) display relatively low average values, indicating limited local provision in many municipalities. High standard deviations across several categories further suggest strong territorial disparities, with some municipalities concentrating on a large number of services while others lack even basic facilities.

These disparities become more visible when examining their spatial distribution. As shown in Fig. 6, foundational services are unevenly distributed across marginal municipalities. Most municipalities, represented in lighter shades of blue, exhibit relatively low levels of service availability, while only a limited number of municipalities (dark blue) show higher concentrations of services. This spatial pattern reveals significant territorial inequalities in access to everyday infrastructures, highlighting how many marginal communities face structural limitations in the provision of basic services.

The histogram reveals a highly skewed distribution of FEI scores, resembling a log-normal pattern. The vast majority of municipalities group below 0.15, confirming a widespread under-provision of foundational services across marginal areas. Only a limited number of municipalities reach moderate to high FEI values, representing localized concentrations of stronger service capacity or historically more structured territories (e.g. tourist-oriented municipalities) may exhibit comparatively strong foundational service levels despite their geographically peripheral position.

Taken together, the spatial and statistical evidence highlights

[1] networkx.algorithms.community.quality.modularity.

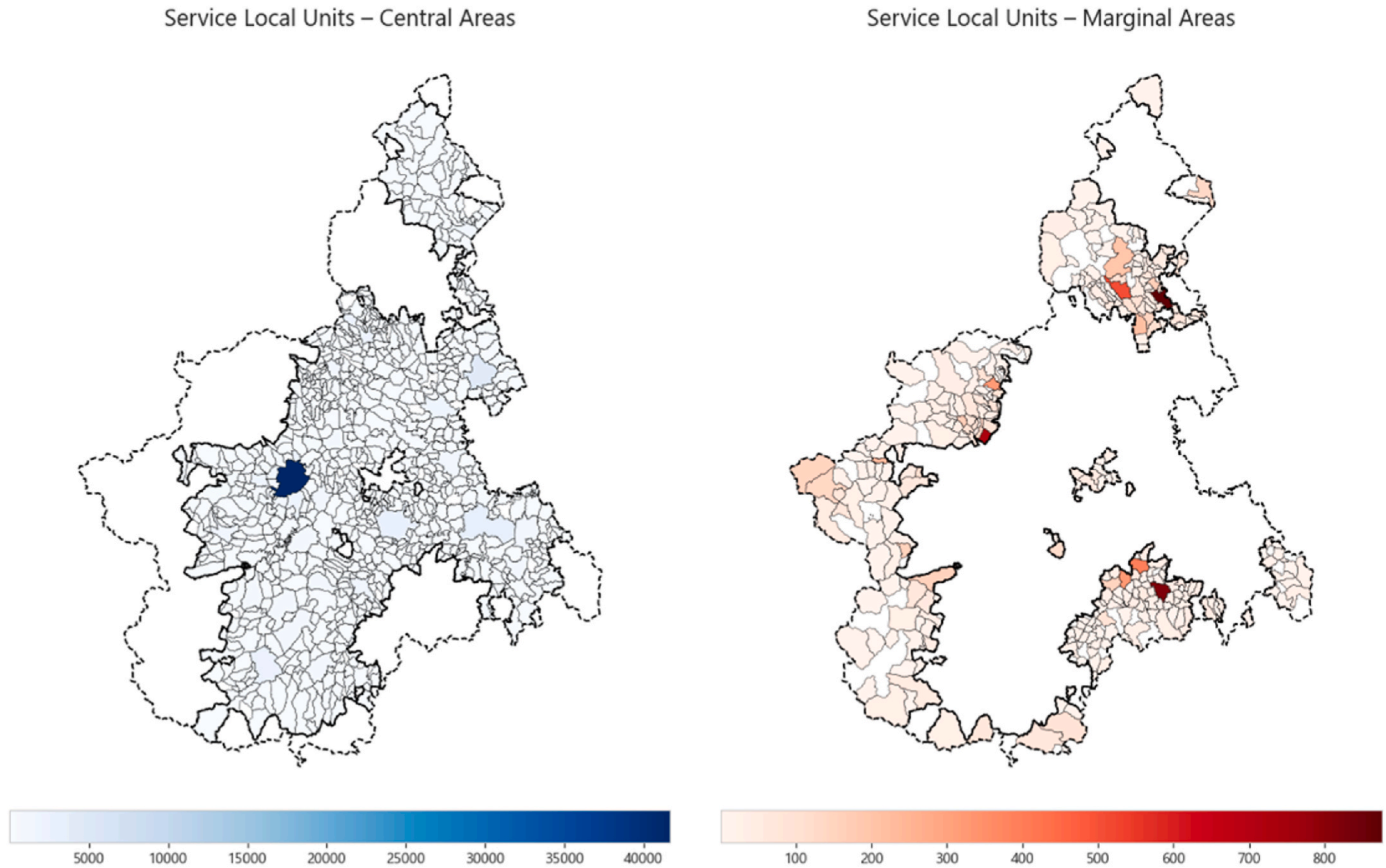

Fig. 5. Spatial distribution of service enterprises in central and marginal municipalities.

Table 5
Descriptive statistics by area type and indicator.

Dimension	Indicator	Area	Count	Mean	Std. Dev.	Min	Median	Max
Geography and Environment	Altimetric	Central	807	3.33	1.38	1.00	3.00	5.00
	Zone	Marginal	372	1.98	1.07	1.00	1.00	5.00
	Forested	Central	377	47.91	12.34	37.50	37.50	62.50
	Area (%)	Marginal	257	51.61	12.42	37.50	62.50	62.50
Demography and Urbanization	Degree of Urbanization	Central	807	2.76	0.44	1.00	3.00	3.00
		Marginal	372	2.88	0.33	2.00	3.00	3.00
	Population	Central	797	−4.58	6.20	−31.1	−4.54	19.54
	Change (%)	Marginal	367	−8.04	8.86	−36.6	−8.05	73.81
	Change in Foreign Population	Central	797	70.9	670	−145	5.00	17424
		Marginal	367	3.92	35.7	−146	1.00	309
Economy and Territory	Industrial Local Units	Central	769	33.66	184.54	1.00	10.00	4881
		Marginal	303	11.00	18.83	1.00	5.00	148
	Service Local Units	Central	769	170.91	1534.72	1.00	31.00	41686
		Marginal	303	42.03	95.00	1.00	16.00	876
	Employment in Agriculture	Central	806	63.62	114.39	1.00	30.00	1751
		Marginal	372	28.32	48.18	0.00	15.00	521
	Employment in Transport & Comm.	Central	806	182.09	1419.05	1.00	40.00	39100
		Marginal	372	30.69	60.63	0.00	13.00	552.00
	Employment in Commerce & Hosp.	Central	806	376.60	2308.92	3.00	103.00	62877
		Marginal	372	93.31	181.02	0.00	38.00	1656
	Employment in Services & Fin.	Central	806	351.85	2908.29	2.00	72.50	80639
		Marginal	372	65.29	140.67	0.00	21.00	1454
	Employment in Other Sectors	Central	806	496.00	3788.75	3.00	116.50	104295
		Marginal	372	111.35	241.41	0.00	47.00	2477
	Unemployment Rate (%)	Central	806	6.55	1.76	1.99	6.51	16.39
		Marginal	372	6.38	2.19	0.98	6.20	18.54

significant inequalities in the distribution of foundational services.

To formally assess the degree of spatial clustering in the FEI, Global Moran's I was computed on the FEI distribution across the 372 marginal municipalities using a K-Nearest Neighbours spatial weights matrix ($k = 5$, row-standardised), based on geographic distances between municipal centroids. The result (Moran's $I = 0.0598$, $p = 0.031$) indicates a low but statistically significant level of spatial autocorrelation, formally ruling out spatial randomness in the distribution of the FEI (See Supplementary Figure S2 A). Results are robust to the choice of bandwidth, with Moran's I remaining low and significant at $k = 3$ ($I = 0.061$, $p = 0.047$) and $k = 7$

Table 6
Descriptive statistics of service availability in marginal areas categorized by foundational and tradeable economy domains.

Dimension	Service area	Count	Mean	SD	Min	25%	Median	75%	Max.
Foundational Economy	Food Access	372	7.35	7.38	0.0	2.0	6.0	11.0	58.0
	Transportation	372	1.85	3.98	0.0	0.0	1.0	2.0	55.0
	Bank and Postal Services	372	2.98	2.69	0.0	2.0	2.0	4.0	18.0
	Health and Medicine	372	2.16	5.87	0.0	0.0	1.0	2.0	63.0
	Education	372	1.42	2.82	0.0	0.0	1.0	2.0	33.0
	Civic Infrastructure	372	5.97	2.11	0.0	5.0	6.0	7.0	12.0
	Social Hubs & Public Spaces	372	9.94	7.05	0.0	6.0	9.0	12.0	78.0
	Cultural Necessities	372	7.77	8.09	0.0	3.0	6.0	10.0	89.0
Tradeable Economy	Aspirational Private Purchases	372	4.85	6.78	0.0	0.0	2.0	7.0	57.0

Note: Data on categorized services were collected using Google Maps API.

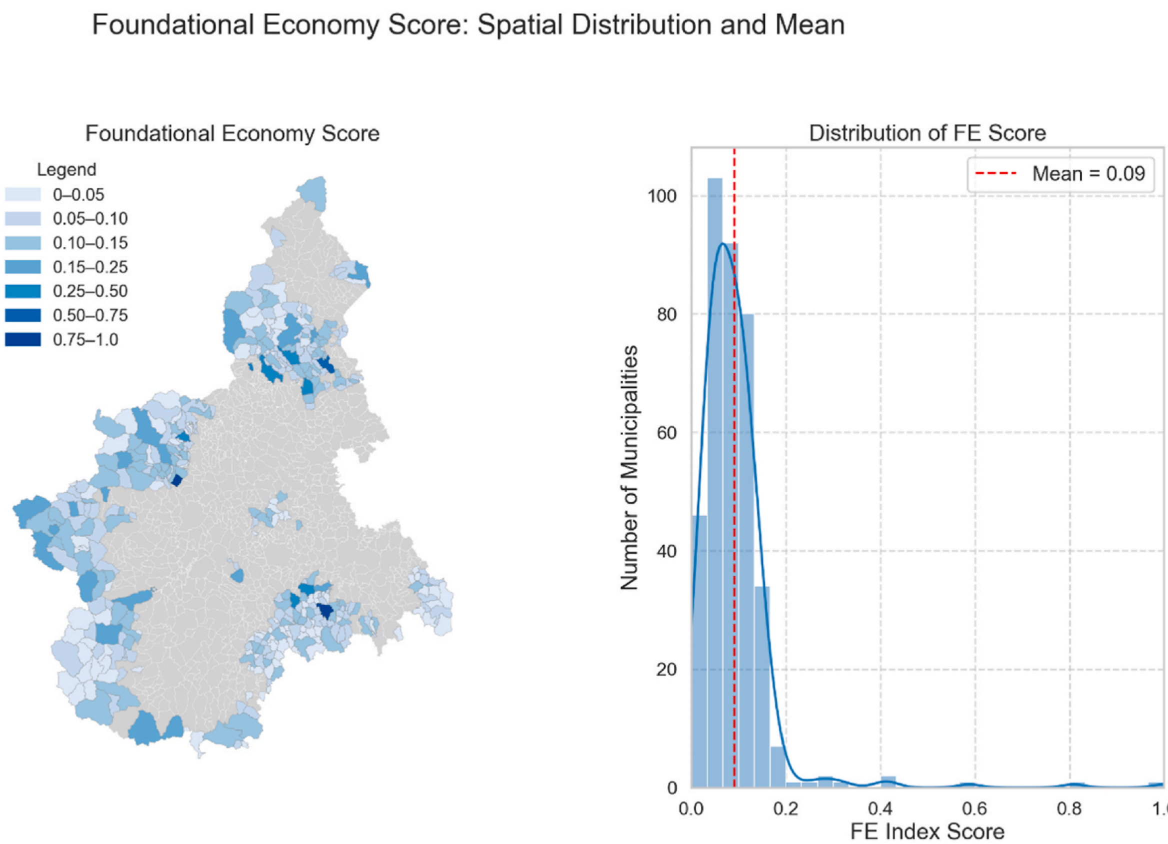

Fig. 6. Spatial distribution of the Foundational Economy Score (FES) across marginal municipalities in Piedmont.

(I = 0.046, p = 0.040). The low magnitude of the statistic is consistent with the polycentric structure of service provision in Piedmont's marginal areas, where a small number of high-service municipalities act as isolated poles surrounded by low-service territories, generating localised rather than global spatial clustering.

Given the weak but statistically significant spatial autocorrelation detected in the FEI distribution, we estimated a set of spatial econometric models in addition to the baseline OLS specification to verify whether spatial dependence affects the estimated relationships.

Table 7a reports the results of the regression models estimating the determinants of the Foundational Economy Index (FEI). The findings are consistent across the different model specifications (OLS, Spatial Lag Model, Spatial Error Model, and Spatial Durbin Model), indicating a robust relationship between socio-economic characteristics and the spatial distribution of foundational services. Population size emerges as the strongest predictor of FEI, with the coefficient of log population remaining positive and highly significant across all models. This suggests that larger municipalities benefit from stronger economies of scale in the provision of essential services. Similarly, the share of foreign residents and the number of active workers show positive and statistically significant effects, indicating that more economically dynamic and demographically diverse communities tend to sustain a broader network of foundational services.

In contrast, the unemployment rate does not appear to significantly influence the FEI, suggesting that the availability of foundational services is more closely related to structural demographic and territorial characteristics than to short-term labour market conditions. Territorial morphology also plays a role: municipalities located in hill areas display significantly lower FEI values compared to lowland municipalities, reflecting the challenges of service provision in more geographically fragmented territories. Interestingly, municipalities classified as ultra-peripheral under the SNAI framework show a positive and significant coefficient in several model specifications, suggesting that some remote municipalities may still function as local service centers within wider rural territories.

The post-estimation Moran's I test on OLS residuals returns I =

Table 7a
OLS and Spatial Regression results for the FEI.

Variable	OLS	SLM	SEM	SDM
Log Population	4.746***	5.020***	4.775***	5.376***
	(1.057)	(1.089)	(1.054)	(1.171)
Foreign Residents	0.0567***	0.0563***	0.0562***	0.0515***
	(0.0089)	(0.0088)	(0.0088)	(0.0090)
Unemployment Rate	0.178	0.184	0.170	−0.037
	(0.408)	(0.403)	(0.409)	(0.455)
Hill Zone	−5.295***	−5.296***	−5.290***	−5.682
	(1.908)	(1.883)	(1.959)	(5.100)
Mountain Zone	10.418	11.042	10.286	10.886
	(6.850)	(6.788)	(6.816)	(8.578)
Active Workers	0.0127***	0.0126***	0.0128***	0.0140***
	(0.0026)	(0.0026)	(0.0026)	(0.0026)
Peripheral (SNAI E)	2.107	2.131	2.021	−1.220
	(2.158)	(2.129)	(2.180)	(3.073)
Ultra-Peripheral (SNAI F)	9.496**	9.558**	9.532**	6.867
	(4.485)	(4.426)	(4.548)	(6.861)
Spatial lag (ρ)	–	−0.053	–	0.016
Spatial error (λ)	–	–	0.047	–
Model statistics				
Log-Likelihood	−1575.93	−1575.59	−1575.80	−1571.82
AIC	3169.87	3171.19	3169.60	3179.64
R^2/Pseudo-R^2	0.726	0.726	0.726	0.732
Moran's I residuals	0.015	–	–	0.000

Notes: Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Variance Inflation Factors (VIF) were calculated to test for multicollinearity; all values are below the conventional threshold of 10 (maximum VIF = 4.63), indicating no serious multicollinearity issues.

0.0154 (p = 0.275), confirming the absence of statistically significant residual spatial autocorrelation. This result indicates that the spatial dependence observed in the raw FEI is fully absorbed by the included covariates, validating the independence assumption of the OLS (See Supplementary, Fig. S2 and B). To formally account for the feedback effects inherent in models with a spatially lagged dependent variable, Table 7b shows the average Direct, Indirect, and Total effects for the SLM and SDM, computed in accordance with LeSage and Pace (2009) [70]. Direct effects are almost comparable to the raw coefficients in Table 7b. In both models, indirect effects are negligible across all variables. For example, the indirect effect of log population is −0.255 in the SLM and 0.089 in the SDM, compared to direct effects of 5.022 and 5.376, respectively, confirming that service provision does not generate meaningful spillovers across neighboring municipalities. The full set of spatially lagged covariate estimates (θ) for the SDM is reported in Supplementary Table S3; none of the coefficients reach conventional significance thresholds, further confirming that the characteristics of neighboring municipalities do not directly drive local service provision.

The spatial econometric models reveal only weak spatial dependence. The spatial lag (ρ) and spatial error (λ) parameters are small and not statistically significant, the AIC of the OLS (3169.87) is comparable to or lower than that of all spatial specification, while Moran's I statistics for the residuals are close to zero across all models. Taken together, the marginal effects and the non-significant spatial parameters consistently indicate that the spatial distribution of foundational services is primarily determined by local socio-economic characteristics rather than by spillover effects from neighboring municipalities.

4.2. *Service profiles and degrees of marginality*

Fig. 7 presents a comprehensive cluster analysis aimed at identifying structural patterns in the distribution of services (*foundational economy* and *tradeable economy*) across marginal municipalities in the Piedmont region. The clustering procedure is entirely attribute-based: municipalities are grouped according to the similarity of their service profiles, independently of their geographical location. Two municipalities may therefore belong to the same cluster regardless of whether they are adjacent or hundreds of kilometres apart.

The left-hand *Panel A* displays a cosine similarity heatmap, where each cell indicates the degree of similarity between a pair of municipalities based on their service profiles. A hierarchical clustering algorithm was applied to the full similarity matrix, resulting in the distinct blocks of similarity that are visually delimited by colored squares corresponding to cluster partitions (High Service – dark green, Intermediate – light green, Low Service – yellow). The dendrogram was partitioned into three clusters, a decision based on modularity optimization, resulting in a modularity score of 0.62,[1] which indicates a relatively strong community structure within the similarity network. The three clusters represent municipalities characterized respectively by high, intermediate, and low levels of service availability.

Panel B illustrates the geographical projection of the three clusters across the Piedmont region. The clusters, represented by *dark green*, *light green*, and *yellow* colors, correspond respectively to municipalities characterized by *high*, *intermediate*, and *low* levels of service availability. The spatial distribution of these categories reveals a heterogeneous territorial pattern of service capacity among marginal municipalities.

Municipalities belonging to the *High Service* cluster (dark green) are not concentrated exclusively around major urban centers but instead display a relatively dispersed spatial configuration. Many of these municipalities appear near economically dynamic zones or regional service corridors. While several benefit from proximity to mid-sized metropolitan areas or key infrastructure networks, others are located in more peripheral territories where tourism activity or historical local centrality has likely contributed to maintaining a relatively dense network of basic services (see Table 7a).

The *Intermediate Service* cluster (light green) includes municipalities that occupy a transitional position in terms of service provision. These areas are typically semi-rural or located in zones situated between plains and more mountainous territories. They represent an intermediate level of service availability, generally maintaining access to some essential infrastructures such as education facilities, healthcare services, civic institutions, and food-related services. However, these municipalities often lack the demographic scale, economic dynamism, or institutional investment required to sustain a more diversified service ecosystem.

Table 7b
Average direct, indirect, and total effects - SLM and SDM.

Variable	SLM			SDM		
	Direct	Indirect	Total	Direct	Indirect	Total
Log Population	5.022	−0.255	4.767	5.376	0.089	5.465
Foreign Residents	0.056	−0.003	0.053	0.052	0.001	0.052
Unemployment Rate	0.184	−0.009	0.175	−0.037	−0.001	−0.037
Hill Zone	−5.298	0.269	−5.029	−5.682	−0.094	−5.776
Mountain Zone	11.047	−0.561	10.487	10.887	0.180	11.067
Active Workers	0.013	−0.001	0.012	0.014	0.000	0.014
Peripheral (SNAI E)	2.132	−0.108	2.024	−1.220	−0.020	−1.240
Ultra-Peripheral (SNAI F)	9.562	−0.485	9.077	6.868	0.113	6.981

Notes: Effects computed following LeSage & Pace (2009) using the spatial multiplier $(I - \rho W)^{-1}$. Direct effects capture own-municipality impacts; Indirect effects measure average spillovers to neighboring municipalities; Total = Direct + Indirect.

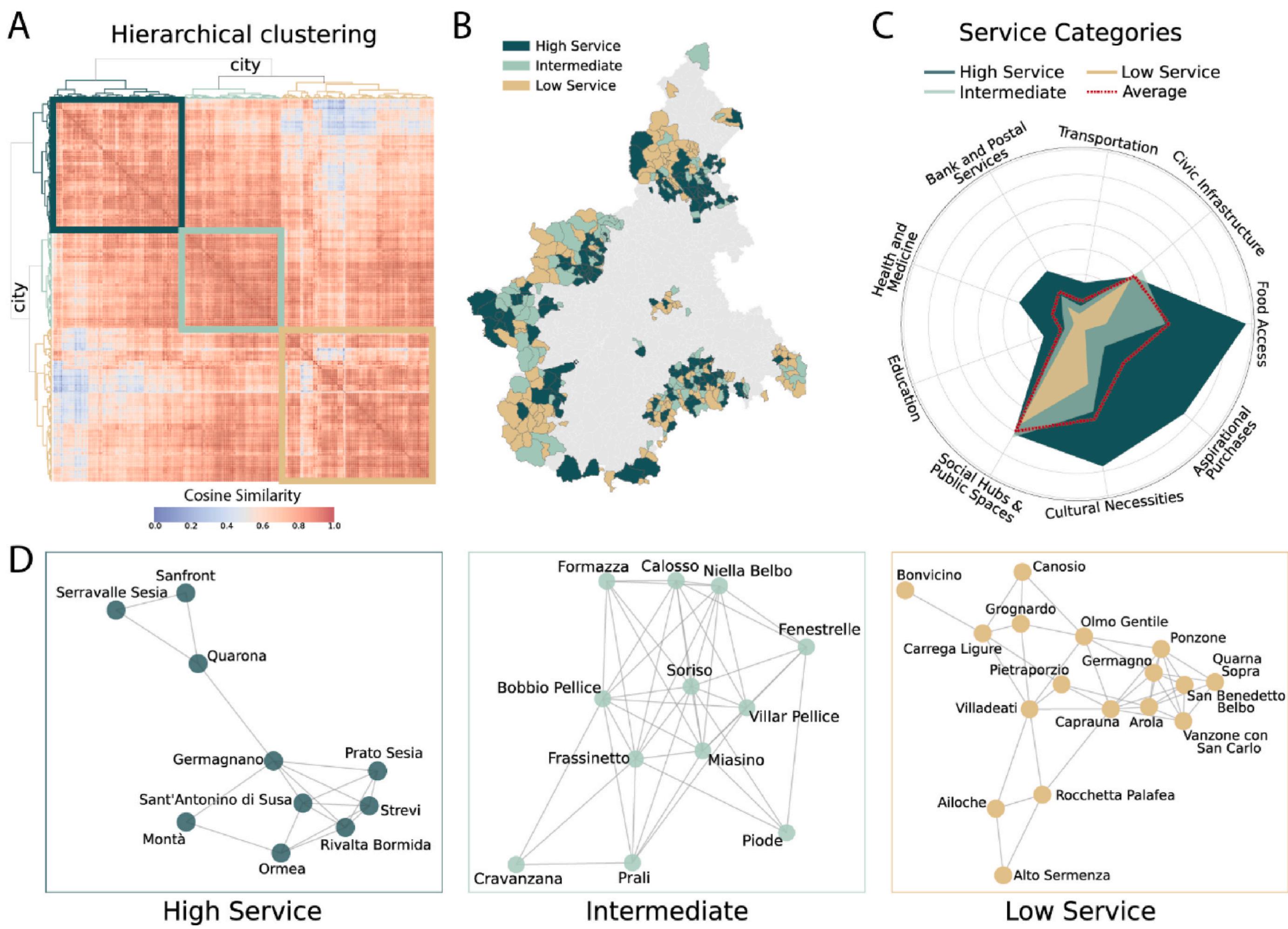

Fig. 7. (A) Hierarchical clustering with cosine similarity highlights service similarities across municipalities. (B) Spatial distribution of clusters: High (dark green), Intermediate (light green), and Low Service (yellow). (C) Radar chart compares service profiles across economic domains. (D) Network diagrams show internal connectivity within each cluster based on service-profile similarity. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Finally, the *Low Service* cluster (yellow) comprises municipalities characterized by particularly limited access to foundational services. Many of these municipalities are located in geographically remote areas, particularly within the inner Alpine and Apennine regions. However, geographical remoteness alone does not fully explain their lower service provision. Some mountainous municipalities appear in higher service clusters, suggesting that additional factors such as tourism-driven demand, or historical infrastructure investments can significantly influence the local availability of services.

To look more closely at the internal structure of each cluster, we constructed a similarity network in which municipalities are connected by a link if their service profiles are extremely similar, specifically, if they share at least 97% cosine similarity across all service categories 78. The resulting networks, displayed in Panel D of Fig. 7, allow us to identify which municipalities sit at the structural heart of each cluster and which ones occupy a more peripheral position.

Within the *High Service cluster* (dark green), a cohesive core of municipalities emerges, connected by strong mutual similarity across all service categories. Germagnano lies at the center of this core. Its balanced mix of services, including food access, healthcare, civic facilities, and transport connections such as a railway line, makes it similar to many other municipalities in the cluster and explains its central position in the network. By contrast, Serravalle Sesia and Sanfront appear more peripheral. This is not because they are poorly served in absolute terms, but because their service profiles are skewed toward a higher share of aspirational private services relative to foundational ones. This compositional difference reduces their similarity with the core municipalities below the connection threshold, placing them at the edges of the network rather than at its centre.

The *Intermediate Service cluster* (light green) forms a compact and coherent network. Municipalities in this group are quite similar, with basic services such as food shops, healthcare, and civic infrastructure available but limited. The network's compactness shows that these territories are structurally similar: they are neither well-served nor severely deprived, but share a common condition of partial and uneven service

Table 8
Average number of services per category across clusters.

Service Areas	Clust 1 (High)	Clust 2 (Interm.)	Clust 3 (Low)
Food Access	13.53	7.02	2.29
Civic Infrastructure	5.87	6.73	5.56
Transportation	3.37	1.45	0.81
Bank and Postal Services	4.92	2.61	1.57
Health and Medicine	5.00	1.23	0.33
Education	2.90	1.11	0.36
Social Hubs & Public Spaces	10.22	10.53	9.32
Cultural Necessities	11.61	7.15	4.91
Aspirational Purchases	11.19	2.81	0.77

Note: *Clusters are based on the level of service availability in marginal areas.*

provision.

The *Low Service cluster* (yellow) shows a very different pattern. The network is fragmented, with many municipalities weakly connected or isolated from the central group. Ailoche, Alto Sermenza, and Bonvicino are the most peripheral nodes. Their isolation reflects a near-total lack of basic services: with populations between about 100 and 320, these municipalities have no food shops, healthcare facilities, or schools. While other low-service municipalities retain at least a minimal service provision, these three cases represent an extreme condition of service deprivation, what may be characterized as service deserts [63,79]. The structural distance observed in the network therefore directly mirrors the severity of service shortages in the most marginal areas of Piedmont, offering a spatially grounded representation of peripheral vulnerability.

Panel C shows a radar chart that summarizes the service composition of the three clusters identified by the similarity analysis. The figures shown represent the average number of service units for each category within each cluster, as shown in Table 8. These cluster-level averages can be compared with the overall municipal averages shown in Table 6 to see how each cluster differs from the general distribution of services provision across Piedmont's rural towns. Together, the radar chart and the summary statistics provide a concise comparison of how foundational and tradeable services are distributed across municipalities with high, intermediate, and low levels of service availability. Interpreted through the lens of the foundational economy, Cluster 1 shows the high service coverage, Cluster 2 displays a more intermediate configuration with partial service provision, while Cluster 3 reflects a generalized scarcity of foundational services.

4.3. Robustness and sensitivity analysis: validating google POI data

In order to validate the use of Google-derived Points of Interest (POI) data as a proxy for local economic structure, a robustness analysis was conducted by comparing the number of service-related POIs mapped via Google with the number of registered service units from the official statistical register ASIA (Archivio Statistico delle Imprese Attive). This validation focused on marginal municipalities, which are typically underrepresented in formal datasets and where the need for alternative data sources is most acute.

To better capture the distribution of services across municipalities of varying sizes, the analysis was conducted using a log-log scale, which is particularly effective when data are heteroskedastic and span multiple orders of magnitude. Two complementary statistical techniques were applied: Spearman's rank correlation and log-log linear regression. Spearman's correlation coefficient between the total number of Google-mapped service POIs and ASIA-registered service units was $\rho = 0.81$ ($p < 0.001$), indicating a strong monotonic relationship. This suggests that municipalities with more services mapped on Google also tend to have more officially registered service firms.

A log-log linear regression model was also estimated to assess explanatory power. The resulting coefficient of determination (R^2) was 0.64, meaning that 64% of the variance in registered service units can be statistically explained by the number of Google-mapped services in log space. The model suggests a scaling relationship consistent with a power-law form between the two indicators, further supporting the use of Google POI data as a viable proxy for local service economies in data-sparse territories (Fig. 8).

The scatter plot in Fig. 8 visualizes this relationship, with a fitted regression line and annotations for the ten marginal municipalities with the highest number of service availability. Although some outliers exist, typically small towns that serve as local economic hubs, the overall alignment supports the methodological choice of using Google data in contexts where up-to-date administrative registers may be limited, outdated, or unavailable at granular levels.

5. Discussions and conclusions

This study proposes a replicable and scalable methodology that integrates dynamic geospatial data with a theoretically grounded index. In doing so, it contributes to applied economics by operationalizing the foundational economy in marginal territories through the development of the Foundational Economy Index (FEI) and the Economic Service Coverage (ESC) metrics as quantitative tools for assessing territorial service distribution.

Drawing on the conceptual framework of the Foundational Economy (FE), this study reframed marginality not just as a demographic or economic deficit, but as a condition of infrastructure scarcity. FE consists of goods and services essential for 'civilized life' for all citizens, regardless of income or location – from material infrastructure such as

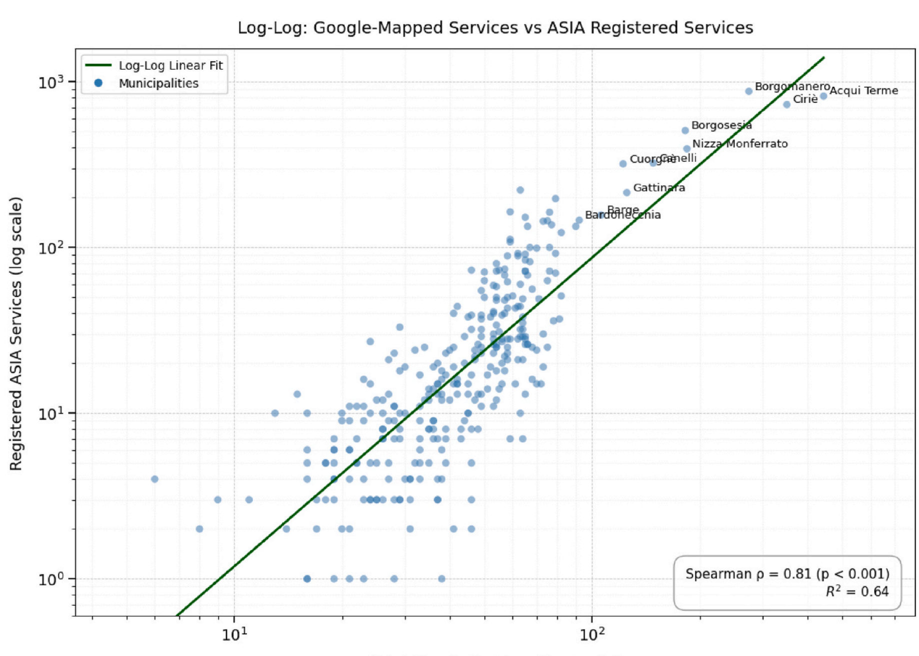

Fig. 8. Google-mapped POIs and ASIA-registered service units in marginal municipalities.

utilities and public transport to providential services such as education, health care, and care for the elderly [11,20,23]. Orthodox development policies have often overlooked these basic principles, instead focusing on high-tech industries or large infrastructure projects [21–25,64]. On the contrary, this study has argued that strengthening the foundational economy in marginal territories is essential to reverse the decline. This aligns with a growing recognition in the literature on regional development that improving basic goods and services should be a central concern of policymaking, as it supports inclusive and sustainable growth in lagging regions [80].

Methodologically, the study introduces an innovative, data-driven approach to mapping foundational services by integrating geospatial data from Google Maps. This allows for the quantification of the presence and diversity of essential services across 372 marginal municipalities in the Piedmont region. By using Google Maps to identify facilities such as grocery stores, pharmacies, schools, banks, and transit stops, the study overcomes the limitations of infrequently updated census data [7,10]. The outcome is a granular and up-to-date picture of service provision in areas often classified as 'peripheral'. The Foundational Economy Index (FEI), along with the associated mapping techniques, fills this critical gap by enabling digital monitoring of service availability and helping to detect emerging weaknesses in local infrastructure.

Empirical results confirm significant disparities in foundational service provision. Many municipalities exhibit a fragile infrastructure of everyday life, with limited or absent presence of key services. In several cases, communities suffer from acute service gaps: for example, the average small community has roughly seven food-related services, yet some have zero local grocery stores or markets, while others (often larger or tourism-rich towns) have dozens. Key services like banking, postal services, and healthcare are similarly irregular, with mean availability around 2 to 3 units per town, but entire municipalities that lack a doctor's office or pharmacy. Even basic education facilities show critical issues, as some remote municipalities do not have schools.

These findings underscore that marginalization manifests itself in everyday infrastructure: residents of these areas face considerable difficulty in accessing fundamental goods and services that urban populations take for granted [2,9]. On a more positive note, the data also showed that certain categories of foundational provision, especially civic and social infrastructure (community centers, public spaces, cultural amenities) tend to be maintained even in small communities, indicating local efforts to preserve social life. Meanwhile, the tradeable or non-essential consumer economy (e.g., retail stores for luxury or specialized goods) is predictably underdeveloped in these areas (low average presence), reflecting limited market demand. This aligns with broader European evidence that rural areas suffering from service withdrawal are also those most vulnerable to demographic shrinkage and economic stagnation [62,81]. These findings also reflect what Rodriguez-Pose (2018) described as the “revenge of places that do not matter”, regions where cumulative neglect fosters social and political disaffection [62,61].

Using hierarchical clustering the study grouped communities into high, intermediate, and low service clusters. This revealed that marginal areas are not monolithic – there is significant heterogeneity within Piedmont's inner areas, reflecting what Rodriguez-Pose [62] describes as the need for 'place-sensitive' approaches to development rather than one-size-fits-all interventions [81,61,82]. Some rural municipalities (the 'high service' group) have managed to retain a relatively dense network of basic services, often thanks to specific local assets such as tourism or historical significance that draw resources. Others fall into an intermediate group, with a moderate but not comprehensive service provision – these are typically semi-rural towns or those in transitional zones rather than the remotest locations. Finally, a substantial number of municipalities emerge as ’low service’ areas, characterized by severely limited access to most foundational services (a few shops, schools or clinics). These are often the most geographically isolated or demographically depleted villages, consistent with the findings of studies on the decline of rural services in southern Europe [62,64].

From an academic perspective, this approach bridges the conceptual framework of the foundational economy with practical spatial analysis, advancing current debates on how to measure and visualize territorial fragility. It also contributes to the foundational economy literature by operationalizing its core concepts, translating the abstract idea of foundational services into measurable, location-based indicators.

From policy makers perspective, evidence suggests that transformative revitalization of marginal areas will require a reorientation of policy priorities toward basic services, infrastructure, and social well-being. By adopting a 'Foundational Economy' lens, policy makers should explicitly recognize foundational services, such as local grocery stores, schools, health facilities, public transport, and utilities, as critical infrastructure for community resilience. Rather than treating these as residual or secondary concerns, they must be made a strategic priority. Ensuring universal access to these essential services is not merely a social policy issue, but a precondition for economic revival and citizen equality.

The clustering analysis showed that not all marginal communities are alike in their needs, therefore, a one-size-fits-all policy will be inefficient. Stakeholders should develop place-sensitive strategies tailored to different service clusters, resonate the call by Rodriguez-Pose [62] for development approaches that reflect spatial heterogeneity [81]. For high-service clusters (including some remote but tourism-rich areas), policies could focus on supporting the existing service, such as protecting heritage industries or seasonal transport links. For intermediate clusters, interventions could aim to upgrade key missing services (e.g., adding a pharmacy or improving school access). In low-service, critically underserved areas, a more ambitious approach is needed. For example, multi-service hubs may sometimes emerge from the efforts of remaining residents. However, where such multifunctional shops do not arise on their own, local governments should prioritize investments to establish them, ensuring that the remaining population continues to have access to essential services [48–50,83].

The use of Google Maps data in this study demonstrates how digital tools can support planning, policy makers should consider establishing live dashboards or regional geo-databases to track foundational service coverage. These systems could help monitor closures, identify underserved communities, and trigger policy responses in near real-time.

Together, these implications set out a plan for transformative territorial policy. This aligns with Rodriguez-Pose's [62] assertion that effective place-based development requires 'better, not just more, policies' that are tailored to local capacities and aspirations [61,82]. The foundational economy approach embodies this principle by identifying essential services, pinpointing gaps, and exploring ways to implement universal provision without erasing local specificity. By adopting this agenda, policymakers and communities can work together to reverse the narrative of decline and restore the conditions necessary for a decent life in peripheral areas.

This study has several limitations. Firstly, while the FEI is a useful indicator of the presence of foundational services, it does not reflect the quality of these services, nor does it account for informal services or community-run initiatives that could be crucial for local resilience. In addition, the index relies on an equal-weighting scheme across service categories. While this assumption reflects the foundational economy literature's premise that different everyday services collectively contribute to basic territorial welfare and preserves the interpretability and replicability of the index, it may not capture potential variations in the relative importance of specific services across different demographic contexts. Future research could therefore explore alternative weighting approaches, such as principal component analysis (PCA) or other data-driven techniques and incorporate municipal-level demographic indicators, such as age structure, to develop demand-informed weighting schemes that better reflect the relative importance of different service categories across marginal territories. Furthermore, the FEI is modelled as a raw count variable with a right-skewed distribution. While the OLS residuals show no significant spatial dependence and the model fit is satisfactory ($R^2 = 0.726$), a spatial Poisson or Negative Binomial specification might theoretically better capture the data-generating process; this remains a direction for future methodological refinement.

Secondly, the analysis is limited to a cross-sectional snapshot; future studies are required to evaluate the impact of changes in foundational infrastructure, whether through public investment or service closures, on demographic and economic outcomes over time. Thirdly, the research focuses solely on the supply of services, whereas demand-side factors such as population structure, preferences and income levels also influence the viability and use of services [84]. Finally, while the Piedmont case offers broader insights, contextual differences must be considered when generalizing to other EU and non-EU regions.

Moreover, further research is needed to explore the application of this integrated methodological framework to marginalized areas in other national contexts, particularly in Europe and the United States. Comparative analyses could help to identify common patterns of territorial decline, as well as cases where foundational services have been successfully preserved, thereby contributing to the resilience and retention of local populations.

CRediT authorship contribution statement

Giuseppe Varavallo: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Filippo Barbera:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Riccardo Di Clemente:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.seps.2026.102549.

Data availability

The methodology, analytical code, and an anonymised sample dataset used in this study are publicly available in the following GitHub repository: https://github.com/Varavallo/Foundational-Economy-Toolkit. The repository includes the data collection script for the Google Maps Places API, the service classification framework, and the code and formulas for computing the Foundational Economy Index and identifying multi-service hubs through the Economic Service Coverage metric. Raw POI data cannot be shared in full due to the Google Maps Platform Terms of Service; however, the collection pipeline is fully documented and replicable. As of March 2025, the Google Maps Places API provides 10,000 free monthly requests per SKU under the Essentials tier, sufficient to collect service data for small-to-medium municipality samples at no cost. The results can be explored on the dedicated project website https://www.riccardodiclemente.com/projects/marginal_areas.html

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