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Research article

Cities as innovation poles in the digital transition. The Italian case

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Abstract: Since the beginning of settled civilizations, cities have represented places of innovation and meeting points for flows of goods, services, people, ideas, and cultural expressions. Cities as places of interaction help to develop new ideas, solutions, and applications. If the spreading of innovation in the past appeared as a spontaneous process, nowadays it is inserted into more structured business models for enterprises and companies and in development policies at central, regional, and local levels. This also involves cities, as investing in innovation can represent opportunities for their growth. Urban geography literature, for instance, examines the urban life cycle, which has evolved into what Florida terms the "New Urban Crisis". Based on the "demographic winter" facing Italy and other industrialized countries, the present work aims to observe the most recent urban dynamics in spatial and demographic changes, innovation, and digital transitions. This research combined an analysis of innovative cities in Italy, based on the innovation index (ICity Rank) with demographic data, considering metropolitan cities and their functional urban areas (FUAs), along with a set of mid-sized cities identified as "innovative" and dynamic. Cities were ranked within the urban life cycle model, employing LISA (Local Moran's I) as a method for analysis and clustering. Using spatial analytical techniques, the work focused on the Italian urban system, its capital cities and mid-size innovative cities, considering urban dynamics in terms of population change, income, and innovation, observing their characteristics and recent evolution (2019–2023). The findings highlight the formation of urban "champions" and their characteristics in terms of ability to attract people and expertise. The results show that innovative metropolitan cities are able to maintain population levels, particularly in suburban rings, while populations in the core areas tend to decline. However, certain innovative metropolitan cities in Southern Italy maintained or increased the core population. In general, medium-sized cities present more interesting dynamics, showing either population stability or a slower rate of decline.

Keywords: cities; innovation; digital transition; demographic transition; sustainability; peripheries; urban planning; regional planning

1. Introduction

Since their origin, cities emerged as the outcomes and consequences of important innovations following the development of agriculture, which brought about a wealth of innovative by-products, such as the organization of societies, the introduction of writing, mapping for storage and warehousing purposes, and the creation of ad-hoc buildings for different purposes and functions played by the new organization of society and economy. These innovations in cities underscore their role and importance as nodal places of interaction, gathering flows of people, goods, ideas, and, more generally, novelties—including conflicts, wars, and epidemics. From a geographical perspective, innovation can either emerge from interactions between places, i.e., moving from one place of origin to a set of destinations and being therefore shaped by local differences, or as the outcome of local processes of interaction [1,2]. The relative scarcity of cities in space and their density have historically facilitated interaction, characterizing cities as expressions of human civilizations [3–5].

This research aimed to analyze population dynamics in the main Italian metropolitan cities (in administrative terms) and areas (in functional ones), along with the most dynamic and mid-sized cities in terms of innovation, observing the trend these areas witnessed in recent years (2019–2023). The research had two objectives: first, to explore urban population dynamics in Italy, affected by depopulation, population aging, and urban sprawl, starting with metropolitan cities; second, to analyze the concept of "innovation" as expressed in the 2019 Italian ICity Rank index. A parallel analysis was conducted on the innovation expressed by cities in 2019 and their more recent population dynamics to provide a first set of suggestions for further analysis and the development of urban policies aimed at reinforcing the role of cities in tackling upcoming challenges.

The paper focused on observations of population dynamics and innovation characteristics of metropolitan cities and average-sized cities to understand if and how innovation helps to mitigate the "demographic winter" Italy and its cities are facing and in which stage of the urban life cycle such cities and their surroundings are set. This is expected to help understand the urban dynamics and develop targeted policies aimed at limiting depopulation, including investments in innovation and population growth. The analysis combined a set of different principles, concepts, and methods, proposing an innovative and significant overview of the urban phenomenon and its dynamics. Florida's Urban Crisis concept was used as the research backbone, and the Urban Life Cycle model was used as a theoretical and comparison framework for the different cities. The study considered cities as administrative units (municipalities and regions in the Italian subdivisions) and functional urban areas, classified using the ICity Rank index. The analysis was further supported by local spatial analytical techniques such as LISA (Local Moran's I).

The rest of the paper is organized as follows: Section 2 provides a conceptual review of the urban life cycle and the demographic trends, as well as cities as places of innovation. Section 3 describes the study area analyzed (Italy), data sources (population and innovation indicators), and methods (application of the urban life cycle model and a local analysis based on spatial autocorrelation analysis of innovation). Section 4 presents the results and discussion, while Section 5 concludes with a general overview of the main findings of the paper, shedding light on the upcoming research agenda.

2. The urban lifecycle and demography: A review

Observing the evolution of cities over time, particularly regarding their relationship with human settlements, city territories, and wider areas, has led scholars to develop the Urban Life Cycle model [6,7]. This model helps to understand the basic elements of core–periphery—or core–ring—relationships, explaining urban dynamics [8–10]. The model is organized in the different stages that cities are likely to undergo in their evolution. The model takes into consideration the different parts of a city, namely its core and its ring (or inner periphery). In its expanded form, the model can focus on the city and include further elements such as urban extra-peripheral fringes. Van den Berg et al. [7] considered a city as an organism moving in its life cycle following four different stages, focusing on its core and fringe (or ring). The urban life cycle does not describe a required and unavoidable path that a city must follow; instead, it describes a potential progression that cities may experience, in stages not necessarily predetermined (Figure 1).

The initial stage, urbanization, is characterized by an increased concentration of people in the core and reduced density in the ring. This is the early stage of the creation and growth of cities as relevant settlements with increasing levels of agglomeration. This is also the stage in which density is increasing, both in the core and, in a second substage, in the ring.

The second stage, suburbanization, consists of slower growth in the core and increased development in the ring, with density growth decelerating in both areas. Most industrialized countries have gone through this stage, where private vehicle ownership influences the city's size and growth, reducing population density in the city center. The core becomes an area dedicated to daily/working-time activities. The process of suburbanization is generally coupled with rising rents in the city center, favoring residential relocation in the ring's suburbs.

The disurbanization stage marks a decline in agglomeration in both the city center and the external parts. The city and its first ring of suburbs lose population and density, explained by different reasons. For instance, mining cities lost their role when the mining industry collapsed; similarly, industrial cities struggled finding a new role following deindustrialization. Disurbanization can involve centrifugal movement of population toward farther neighborhoods, suburbs, or satellite cities in the second ring. According to the different patterns, disurbanization can either relate to rising rents and therefore a further relocation of people farther from the center, or reduced rents due to a lack of attractiveness of central locations.

Reurbanization covers the process of returning to the city center, initially driven by its rediscovery by the creative class, as theorized by Florida [11], and later substituted by affluent residents.

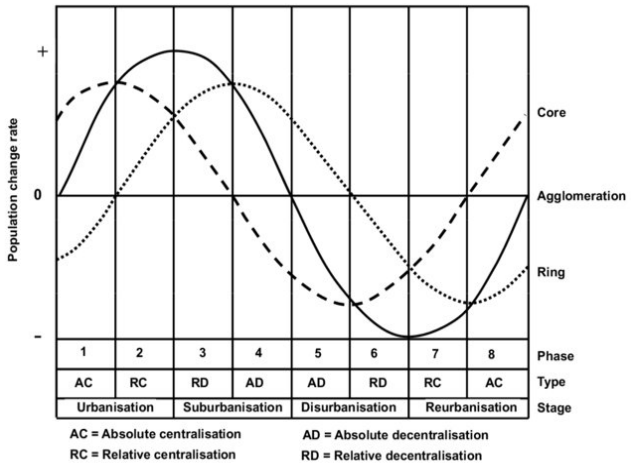


Figure 1. The urban life cycle. Source: [4,7,12].

A paradox related to the process of urbanization is the spreading of the urban lifestyle over a wider area, not necessarily considered as *urban* in the density sense (Figure 1). This expansion leads to a constant reduction of one of the main characters of the city itself—its density, agglomeration, or concentration of people, buildings, and activities that characterize the functions and reasons for the city itself. Such density reduction is coupled with an increase in flows and interactions, particularly in the sense of commuting from farther destinations to the city center, as well as an overall mix of residents and city users in the core [13–16].

Accessibility plays a fundamental role in the life cycle of a city, influencing every phase of its development and evolution. In the different stages, we can highlight the following processes:

During Stages 1 and 2 (urbanization and suburbanization), accessibility attracts new residents and activities, promotes social cohesion, and supports economic growth.

In Stage 2, described by maturity and consolidation, accessibility improves the quality of life (essential services such as school, work, health, and culture) and promotes tourism.

In Stages 3 and 4 (Disurbanization and Reurbanization), accessibility can facilitate the reconversion of abandoned urban areas into new residential neighborhoods or spaces for productive and commercial activities. Furthermore, it promotes urban regeneration and fosters urban resilience.

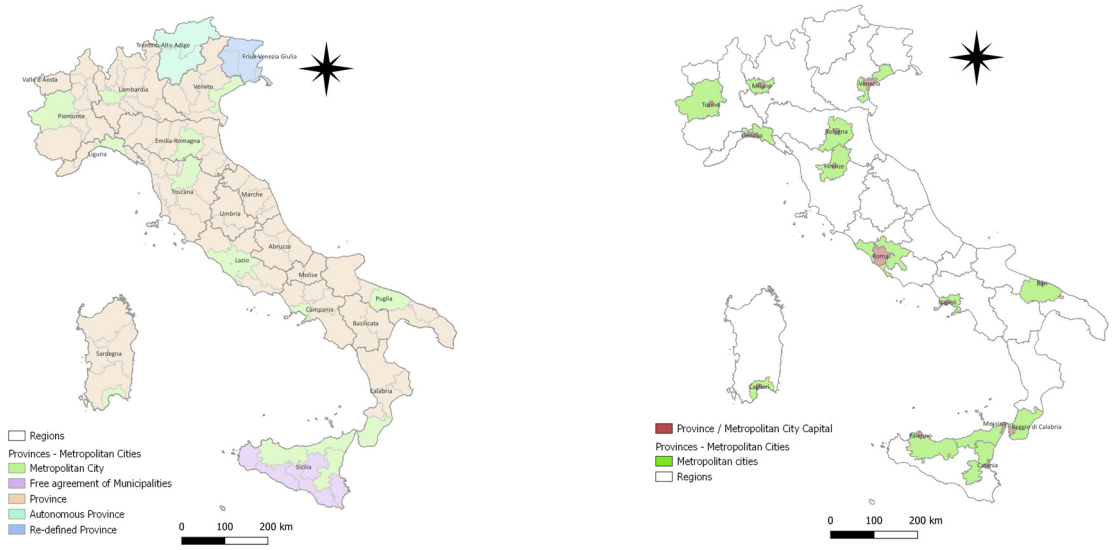
3. Study area, data, and methods

3.1. Study area

The analysis focused on the Italian administrative and statistical subdivisions, specifically provinces, metropolitan cities, and their capital municipalities. The analysis also considered the functional urban areas (FUAs) related to metropolitan cities and a selection of provinces, based on innovation values to consider both the administrative and functional principles of cities and metropolises [17,18].

Italy's administrative structure is organized into three different levels: macro, intermediate, and micro levels, corresponding to regions, provinces/metropolitan cities/aggregations of municipalities, and municipalities. Regions hold the highest level of autonomy, particularly on issues related to health,

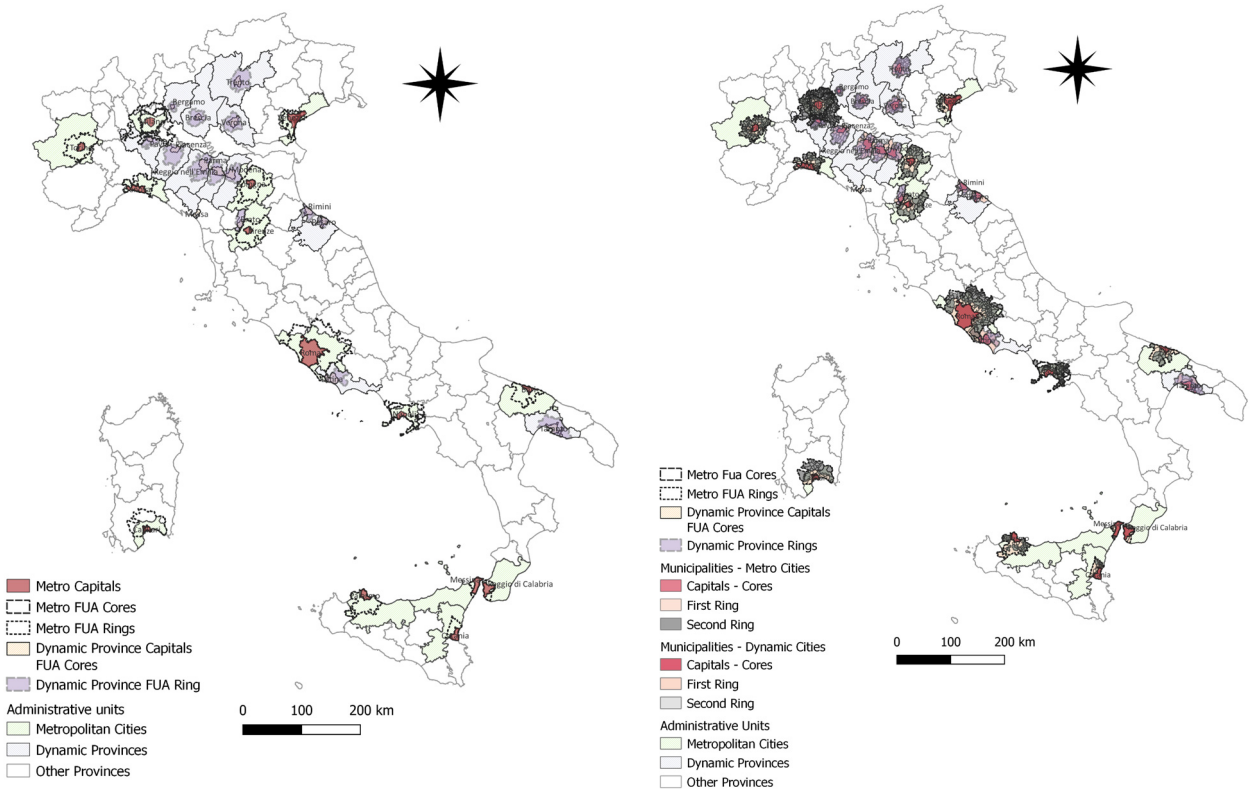
transport, and spatial planning. Municipalities deal with local taxation and services and plan at the municipal level, under national and regional guidelines and laws. Provinces, previously a part of the intermediate administrative level, now have intermediate strategic planning aligned with the lower and upper levels, with regional differences [19–21]. The main change in the intermediate level took place after 2015 with the transformation of provinces centered around main urban municipalities into metropolitan cities [22,23]. In most cases (Cagliari representing an exception), these units occupy the same areas of the former provinces, holding, therefore, more administrative than functional meaning. Fourteen metropolitan cities were defined by the national reform law, though the five autonomous regions (Sicily, Sardinia, Val D'Aosta, Trentino Alto Adige with the Autonomous Provinces of Trento and Bolzano, and Friuli Venezia Giulia) have the option to define regional metropolitan cities autonomously due to their autonomy in terms of spatial planning and internal administrative organization (Figure 2) [24–27]. Figure 2a shows the second-level administrative units in the Italian system: metropolitan cities, free agreements of municipalities in Sicily, provinces, autonomous provinces in Trentino Alto Adige Region, and re-defined provinces in Friuli Venezia Giulia Region. There remains a wide debate on metropolitan cities and their configurations [21,22,28–31]. Figure 2b shows the Metropolitan cities' boundaries together with their municipal capitals.



a) b)

Figure 2. a) Administrative divisions: regions and metropolitan cities and provinces; b) regions, metropolitan cities, and their capital municipalities. Source: our elaborations from ISTAT (2023).

The study also considered mid-sized cities with FUA, characterized by the highest values in terms of innovation as expressed by the 2019 ICity Rank. The metropolitan and dynamic cities were also considered in terms of their functional areas (FUAs); the municipalities included the core and ring areas (Figure 3). FUAs were obtained from Copernicus Data and according to the OECD methods proposed for defining homogeneous metropolitan areas at the international level, based on a minimal dimension (50,000 inhabitants), population density, and commuting [32,33].



a) b)

Figure 3. a) FUAs: metropolitan cities and their FUAs; b) metropolitan cities' FUAs and their municipalities. Source: our elaborations from ISTAT, OECD (2023), and Copernicus Data.

3.2. The data

Data used in this analysis were taken from different sources and focused on demographic changes through time, parameters and characters of innovation, and income/energy categorization, as highlighted in Table 1. The analysis considered Italian provinces and municipalities. Innovation data were attributed to provinces, while population data were attributed to municipalities; these considering metropolitan cities and areas. We evaluated a 5-year period, between 2019 and 2023. This timeframe was considered to observe changes over a narrow period distant from the national census of 2011 and 2021. Data were obtained from the Italian National Statistical Institute (ISTAT) [34,35], along with geographical data for the administrative units (municipalities, provinces/metropolitan cities/intermediate units, and regions [36]).

Table 1. The data used.

Data	Indicators	Spatial units	Source
Population	Population density Population change (2019–2023)	Municipalities; provinces/metropolitan cities; FUAs	ISTAT; OECD; Copernicus
Innovation	ICity Rank Economic solidity Sustainable mobility Environmental protection Social quality Governance capacity Digital transformation	Provinces Capital cities	ForumPA

Population data was standardized at the municipal level to the administrative divisions of 2023. The administrative geography of Italy has changed in recent years, with merging, splitting, or reassigning of municipalities to different provinces. Additionally, in recent years, the intermediate level of provinces has been subject to reforms and reconfigurations, shifting from administrative purposes to statistical ones, very often varying their borders. In such a framework, population data from 2019 were reconfigured and attributed to the 2023 administrative units. Doing so allowed us to accurately compare the two different periods.

Demographic analysis focused on population changes within metropolitan and urban areas. Another level of analysis considered innovation as categorized and classified within the ICity Rank, an index of innovation implemented in Italian provinces. Data were therefore attributed to this intermediate level, considering a comparison between provinces and metropolitan cities. The 2019 index and its components were considered due to recent changes occurring in the index computation. Until 2019, innovation was considered as an overall combination of different factors, including sustainability aspects, governance, digitalization, and welfare. More recently, the index's attention turned to digitalization, with an overall equivalence between *innovation* and *digitalization*.

The ICity Rank, developed every year by ForumPA (public administration board for innovation), ranks Italian cities (provinces or metropolitan city capitals), measuring their capacity to be more dynamic, functional, ecological, livable, manageable, innovative, and capable of promoting sustainable development by reacting to changes with new technologies. The ICR 2019 index and ranking consists of six dimensions of urban quality, based on a wide set of articulated and defined datasets (Table 2).

Table 2. ICity Rank 2019 index and its dimensions (ForumPA, 2019).

ICR 2019 Dimensions	Main characteristics
Economic solidity	The index measures the potential capacity of Italian cities to adapt intelligently and sustainably to economic changes that will be able to invest in the near future.
Sustainable mobility	The index is a measurement of the city's capacity to adapt quickly to problems and opportunities determined by ongoing changes with the aim of increasing sustainability in medium- and long-term urban mobility.
Environmental protection	The index has the primary purpose of highlighting the path that cities are taking to reach greater levels of sustainability.
Social quality	The index unifies into a one-dimensional index of social quality the indicators that were in previous editions divided between the areas of poverty/social exclusion, education/human capital, and tourist-cultural attractiveness to emphasize the fact that, in the face of changes expected for the next decade, the three aspects must be kept together because they are destined to interact increasingly in influencing the fate of our cities, in line with what should make a truly "smart" city.
Governance capacity	The index was built starting from the variables previously included in the indicators within the scope of "governance and participation" and "legality and safety", trying to consider three factors that appear crucial to face the challenges of the next decade in a balanced way: cohesive and innovative social fabric, innovation in public administration, and concrete conditions of legality and safety.
Digital transformation	The index was built with the aim of measuring the ability of municipal administrations to take full advantage of the potential offered by new technologies and large national projects. In particular, the ability to make the best use of intangible and enabling platforms, the ability to respond to the needs of technological infrastructure of the territories, and the ability to use innovative solutions were taken into consideration.

The six dimensions and their indexes are synthesized from 106 indicators and 250 variables. The overall ICR 2019 adopts the geometric average of all indexes [37].

3.3. Methods

This analysis applied the urban life cycle model to Italian cities, examining spatial population variations over a 5-year period across Italian municipalities, particularly in metropolitan cities and areas. This analysis focused on innovation, selecting cities categorized as "innovative" based on their level of innovation. The urban life cycle was analyzed in terms of the innovation performance of the different cities, trying to find possible relationships between innovation levels and the capacity of the city to attract people. When considering the urban life cycle, a set of assumptions were made regarding the core-ring dynamics of the different units considered. Data were collected and compared, in the selected timeframe, considering the different spatial aggregations. Three principals were followed, as expressed in Table 3.

Table 3. Municipality aggregation principles in the urban life cycle.

Aggregation principle	Core	Ring
Administrative	Municipal capital	Province /
FUA	Core municipality	External boundary
Spatial proximity	Municipal capital	First ring and second ring of adjacent municipalities
Mixed one	Municipal capital	First ring (when FUA boundary is smaller than first ring municipalities)

The ICity Rank was used at various stages. Initially, it obtained the values for metropolitan cities and mid-size cities. This allowed focusing on a selected set of cities for analyzing urban population dynamics. Then, the population dynamics of the innovative cities were considered and categorized according to the urban lifecycle model. All population data were attributed to municipalities in their 2023 configuration, and the analysis was performed on Italian metropolitan cities and their areas, as well as on a set of cities, related provinces, and FUAs, selected according to innovation parameters and indicators. Since metropolitan cities and provinces are generally defined by administrative principles, such spatial units were integrated with their FUAs, as defined by OECD-EU and derived by the Copernicus database [32,33,38].

Local indicators of spatial autocorrelation (LISA) techniques were also applied to innovation indicators from the ICity Rank, and further compared to the overall performance of the regions encompassing these urban areas. Spatial autocorrelation indicators were used to assess local behaviors of the different variables considered and to observe the possible formation of clusters among the regions considered, highlighting proximity and clustering of the areas observed, following Tobler's studies [39], such as Tobler's First Law of Geography, or spatial autocorrelation, considering the spatial relationships between geographic entities [40].

Spatial autocorrelation considers the correlation between observations at different locations in a geographical area, assuming that observations in space may be influenced by spatial processes, suggesting therefore possible similarities in certain phenomena among proximal areas. Many phenomena taking place in space can be therefore examined by means of spatial autocorrelation [41,42]. A standard method in this analysis is to assess groups of neighboring geographic units, such as administrative divisions. This method allows us to observe and analyze the behavior of a selected variable in reference to its position in space and to what happens in its proximity. In particular, the Local Moran Index, also known as Local Moran's I, is a statistical measure used in spatial analysis to assess the degree of spatial autocorrelation at the local level. It identifies clusters of similar values (high-high or low-low), outliers surrounded by dissimilar values (high-low or low-high), and areas with no significant autocorrelation. This helps in identifying spatial hot spots, cold spots, and spatial patterns within the dataset.

In analytical terms:

$$\sum_i^n I_i = \gamma * I \tag{2}$$

The index is calculated as follows:

$$I_i = \frac{(x_i - \bar{X})}{s_x^2} \sum_i^N (w_{ij}(x_j - \bar{X})) \tag{3}$$

where:

- N is the number of geographical units.
- x_i is the variable describing the phenomenon under investigation in region i.

- $\bar{x}$ represents the sample average, and $(x_i-\bar{x})$ is the variable's average deviation.
- s_x^2 is the standard deviation.
- w_{ij} is the weight matrix.

The neighborhood property is analyzed by means of the parameter weight w_{ij}, whose values indicate the presence or absence of neighboring spatial units to a given one. Weights w_{ij} are part of a weight matrix and assume values of 0 in cases in which *i* and *j* are not neighbors or 1 when *i* and *j* are neighbors. Neighborhood is computed in terms of contiguity such as, in the case of areal units, sharing a common border of non-zero length [43].

4. Results and discussion

The analysis was performed on the fourteen Metropolitan Cities as officially recognized from an administrative point of view by Italian law, together with other fourteen mid-sized cities, identified as "dynamic" innovative cities based on the ICity Rank 2019 and their classification as a functional urban area (FUA) by OECD-EU. Population changes in these cities were analyzed in different terms. We considered their population dynamics, as well as the characteristics of innovation as expressed in the ICity Rank, considering different official statistical units. In particular, the following assumptions and steps were followed:

- When considering population data, we referred to metropolitan cities and FUAs.
- Metropolitan city capitals were considered the "central" municipalities of the metropolitan city areas.
- When considering metropolitan cities, the homonymous administrative and statistical areas were considered.
- When considering metropolitan areas in functional terms, we considered the FUAs and the municipalities belonging to them.
- For each metropolitan city, we considered its homologous FUA.
- The external borders of FUAs were chosen to collect all the municipalities belonging to a certain metropolitan city/area.
- The analysis on the core/ring was done considering two different situations:
    - Based on administrative divisions: metropolitan capital, first-ring municipalities (adjacent to the metropolitan capital), and second-ring municipalities (adjacent to the first-ring municipalities).
    - Based on the FUA definition method: urban core ("central" municipalities, including metropolitan capital) and ring (other municipalities, external from the core and within the FUAs' border).
- A second set of mid-sized cities was selected, based on their innovative level. Mid-sized cities were chosen according to their ranking in the ICity Rank 2019 index and the presence of FUAs in their OECD classification.
- Province capitals were considered as the "central" municipalities of the provinces.
- When considering provinces, the homonymous administrative and statistical areas were considered.
- When considering province capitals in functional terms, we considered the FUAs' areas and the municipalities belonging to them.
- For each province capital, we considered its homologous FUA.

- The external borders of FUAs were chosen to collect all the municipalities belonging to a certain province.
- In the case of FUAs smaller than the provinces, the first and second rings of municipalities were also selected.
- The analysis on the core/ring was done considering different situations:
    - Based on administrative divisions: province capital, first-ring municipalities (adjacent to the province capital), and second-ring municipalities (adjacent to the first-ring municipalities.
    - Based on the FUA definition method: urban core ("central" municipalities, including province capital) and ring (other municipalities, external from the core and within the FUA's border).
- In the case of smaller FUAs, the province capital was considered the core. The first ring of municipalities around the province capital was considered as the ring.
- The ICity Rank was related to the provinces and metropolitan city capitals. The analysis was extended to the capital cities/provinces they belong to.

An initial consideration to be done regards the delimitation of metropolitan cities by the Italian law and its (lack of) relationship with their functions in metropolitan terms [44]. The 14 cities considered are the biggest in Italy; nonetheless, the delimitation of their "catchment areas" follows administrative principles rather than functional ones. Still, they represent an important share of the Italian population. Together, these 14 metropolitan capitals count for 9.2 million people over a total of 59 million people living in Italy in 2023, while their metropolitan city areas count for 21.3 million people (ISTAT, 2024). The administrative-based system of definition of the Italian metropolitan city areas was therefore integrated with the functional one, developed for the definition of European functional urban areas. A similar approach was followed for the dynamic cities' capitals and their administrative areas. Nearly 2.2 million people lived in the municipal capitals in 2023, and 8.4 million people in the province areas in 2023. Regarding the metropolitan cities' sample, in absolute terms, the population involved in the administrative and functional systems is quite similar—21.3 million people in metropolitan cities and 20.4 million people in FUAs in 2023—although their spatial patterns are dissimilar. Differences are more striking when one considers dynamic cities. Their provinces host 8.4 million people, while the FUAs are limited to 4.5 million people, de facto making the province a sort of small region containing a city, its urban ring, and a set of lower-density settlements. Examples can be seen in Figure 4, which shows a sample of the major metropolitan cities and areas considered, together with the neighboring, mid-sized dynamic cities. In some cases (i.e., Rome or Naples), the functional and administrative dimensions are quite similar. On the contrary, in the case of Milan, the metropolitan city is just part of the central core of the FUA; in the case of Bari, the metropolitan city area is much bigger than the functional one. In most cases, the municipality of the metropolitan city capital is also the core of the FUA, except in the cases of Milan and Naples, where the urban core includes other municipalities than the metropolitan city capital. Figure 4 also displays the spatial organization of the urban areas within wider systems, such as the Po Valley Megalopolis with Lombardy and Emilia Romagna cities and the dyads Rome and Latina and Bari and Taranto.

This analysis required data harmonization between 2019 and 2023 in terms of the population attributed to municipalities and their provinces/metropolitan cities. Furthermore, spatial analyses were performed to obtain the municipalities enclosed within the FUAs and assess their belonging to the first

and second rings of proximity (Figure 4, pink and grey areas) and to the core (dashed black line), as well as the external FUA's borders (dotted black line).

The population analysis highlighted an overall decrease (−1.37%) in Italian population from 2019 to 2023. Metro cities (administrative areas) displayed a similar decrease of −1.32%, while metro areas (FUAs) showed a lower decrease (−1.01%). These results are significantly different for the internal dynamics of the metro cities and areas (Table 4).

All metropolitan cities and areas decreased their population. Most metropolitan cities and areas presented an overall decrease in their center (metropolitan capital in administrative terms) and the first and second rings of municipalities, as well in the functional separation of core area and ring area (Turin, Genoa, Venice, Florence, Naples, Reggio di Calabria, Messina, and Cagliari). Milan, Bologna, Rome, and Palermo presented an important decrease in their central municipalities and functional cores and an increase in the first and second rings, as well as functional ring areas. Bari, in Southern Italy, presented a slight increase in the central municipality and core and a decrease in the external rings. Catania, albeit decreasing its overall metro population, witnessed an increase in the central municipality and rings. In functional terms, this was the only metro area to increase its population.

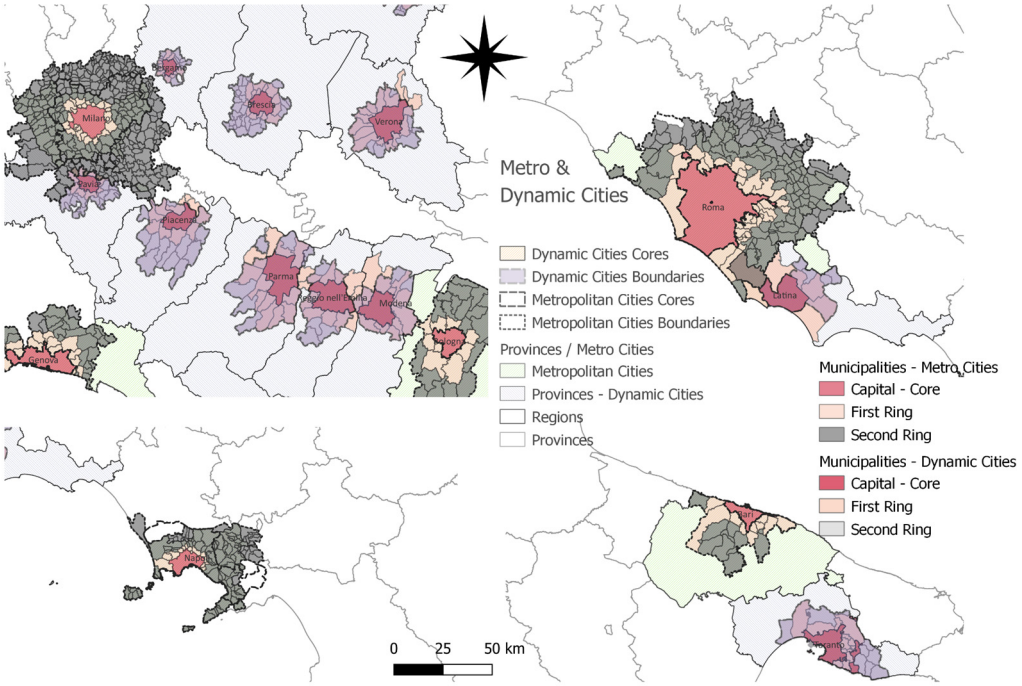


Figure 4. Overview of a selected set of metropolitan cities and their FUAs. From left to right, upper corner to lower corner: Milan, Po Valley Megalopolis; Rome, Latina; Naples, Bari-Taranto. Source: our elaboration on ISTAT, OECD, and Copernicus data.

It is worth stressing again that there is a difference in the shapes and areas of FUAs and metropolitan cities. As a matter of example, the metropolitan cities of Turin, Palermo, Catania, Messina, Reggio di Calabria, and Bari are considerably bigger than their FUAs. As such, many Italian metropolitan cities cover not only the cores and rings but also the municipalities external to such areas. On the contrary, cities such as Milan (the center of the Po Valley Megalopolis) and Cagliari (the most

important center of Sardinia Island and region) are characterized by metropolitan cities smaller in size than their FUAs.

Table 4. Metropolitan cities and areas. Population changes from 2019 to 2023 (based on municipalities data; positive values in green).

Metro city name	Metro city	Capital city	1st ring	2nd ring	FUA core	FUA ring	FUA total
Torino	−1.52	−1.56	−1.75	−0.77	−1.56	−1.23	−1.39
Genova	−1.75	−1.40	−3.17	−3.41	−1.40	−3.29	−1.74
Milano	*−0.68*	*−2.69*	*0.66*	*0.74*	*−0.66*	*0.62*	*−0.20*
Venezia	−1.78	−3.48	−0.38	−1.23	−3.48	−0.61	−2.08
Bologna	−0.34	−1.03	0.46	0.93	−1.03	0.70	−0.20
Firenze	−1.08	−1.93	−0.24	−0.84	−1.93	−0.53	−1.22
Roma	−0.86	−2.30	2.79	1.42	−2.30	2.08	−0.77
Napoli	*−2.23*	*−3.86*	*−1.42*	*−1.20*	*−2.25*	*−1.27*	*−1.99*
Bari	−0.81	0.08	−1.33	−1.16	0.08	−1.26	−0.68
Reggio di Calabria	−3.32	−2.90	−4.71	−6.14	−2.90	−4.78	−3.22
Palermo	−2.23	−3.10	1.48	0.21	−3.10	0.68	−1.77
Messina	−3.00	−4.31	−2.67	−3.51	−4.31	−2.97	−4.14
Catania	−0.26	0.66	0.62	2.43	0.66	1.30	1.00
Cagliari	−0.88	−2.12	−0.40	−1.14	−2.12	−0.67	−1.12

Source: our elaborations from ISTAT Data (2024) and OECD Data (2022).

Table 5. Dynamic cities and areas. Population changes from 2019 to 2023 (based on municipalities data; positive values in green). Source: our elaborations from ISTAT Data (2024) and OECD Data (2022).

Province city name	Province	Capital city/FUA core	1st ring	2nd ring	Total capital + rings	FUA ring	FUA total
Bergamo	−0.08	−0.63	0.39	−0.29	-0.17	0.12	−0.17
Brescia	0.23	0.56	−0.14	0.79	0.43	0.33	0.43
Pavia	−0.98	−1.44	0.61	0.05	-0.55	0.34	−0.56
Trento	-0.13	−1.12	1.07	1.33	0.05	1.2	0.05
Verona	0.3	−0.98	0.52	2.24	-0.05	0.85	−0.05
Piacenza	−0.71	−1.13	-0.21	−0.4	-0.72	−0.3	−0.72
Parma	−0.18	−0.8	1.44	−0.94	-0.05	0.91	−0.05
Reggio Emilia	−0.56	−0.26	-0.32	1.17	-0.19	−0.13	−0.19
Modena	−0.34	−2.21	0.16	1.82	-0.83	0.25	−0.84
Pesaro	−1.72	−0.96	-0.94	−0.31	-0.92	−0.87	−0.93
Prato	1.06	1.34	1.31	−0.25	0.99	0.2	0.9
Latina	0.66	0.6	1.46	−3.71	0.98	1.22	0.96
Taranto	−2.04	-2.32	-2.19	−1.64	-2.14	−1.99	−2.19
Rimini	−0.03	0.47	-0.19	−0.69	0.17	−0.22	0.17

When considering dynamic cities in terms of population change in the two selected years, the average decrease was −0.25% in the FUAs and −0.21% in the provinces. However, differences are visible in the internal area organization. Central municipalities lost −0.66% of the population, while both the proximal municipalities (first and second rings) and the FUA rings witnessed an increase of 0.12%, 0.06%, and 0.16%, respectively. The internal dynamics differ between dynamic cities and areas (Table 5).

Brescia, Verona, Latina, Prato, and Rimini (only province) increased their population in the FUAs and provinces. Of these, Brescia, Latina, Rimini, and Prato observed an increase in the core municipalities. Only Piacenza, Pesaro, and Taranto presented decreases in all different areas (core, rings, and total). The other cities showed a population increase in the external areas, either in the first and second rings of adjacent municipalities or in the overall FUAs' rings.

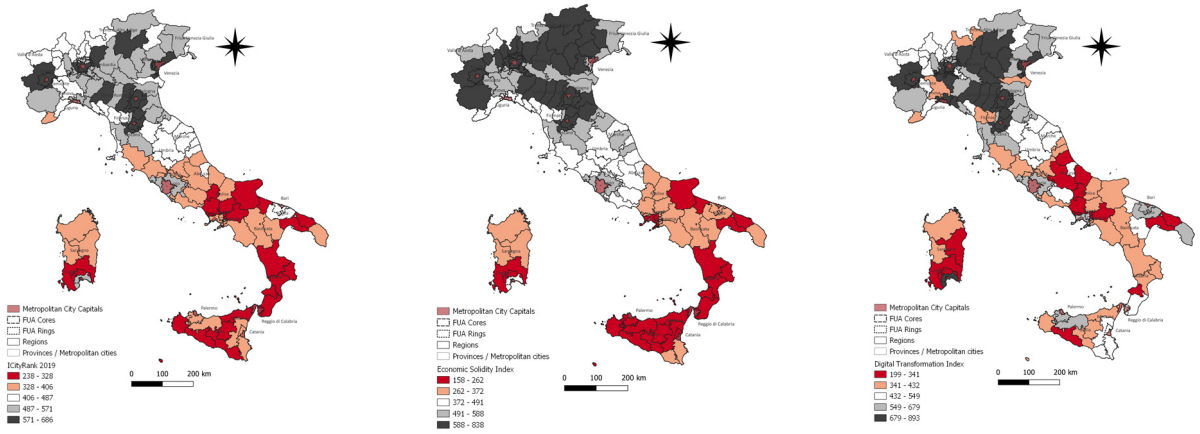
By synthesizing data according to the urban life cycle scheme, Italian metropolitan areas and dynamic areas can be observed as being mainly in the stages of disurbanization, except for the capital cities Milan and Bologna, along with Trento and Prato, which are still considered to be in the latest fringes of suburbanization, and Bari and Catania, with Brescia and Taranto, which are in the reurbanization stage (Table 6. Note that the '+' and '-' signs, as in [7], highlight the population increase and decrease in core and ring areas. Agglomeration is expressed as the sum of the ring and core dynamics).

The urban analysis was then considered along with innovation, based on the metropolitan cities' performances in terms of the ICity Rank 2019. It is worth noting that among all cities, Milan, Florence, Bologna, Turin, and Venice ranked 1st, 2nd, 3rd, 5th, and 7th, respectively. Southern Italian metropolitan cities were, on the contrary, clustered in the lowest sector of the rank. Apart from Cagliari (37th), the other capitals ranked under the 62nd position of Bari (Naples, Catania, Palermo, Messina, Reggio di Calabria; Table A1). The analysis of the ICity Rank, as well as its sub-indicators, presents interesting points for further reflection. Thematic maps on the sub-scores were performed, as well as LISA clustering. Of the 7 indexes (ICity Rank plus 6 sub-indicators), three indicators were selected to be mapped and commented on: the ICity Rank, the Economic Solidity, and the Digital Transformation indicators.

Figure 5a shows the analysis of the scores obtained in the different selected categories. Generally, the most innovative metropolitan cities and provinces are clustered in Northern Italy, with the exception of some provinces in Central Italy, including Rome, and Cagliari, in Sardinia Island. Similarly, the economic solidity indicator clearly separates Northern and Southern Italy (Figure 5b); at the same time, the digital transformation indicator highlights the importance of metropolitan city capitals as hotspots in innovation in the different parts of Italy, not only in Northern Italian (Figure 5c).

Table 6. Urbanization, urban life cycle, and Italian metropolitan cities and areas (2019–2023). Source: our elaborations from ISTAT Data (2024) and OECD Data (2022) and [7].

Stage	Sub-stage	Core	Ring	Agglomeration	City (Metro in capital letters)
Urbanization	1) absolute concentration	++	-	+	
	2) relative concentration	++	+	+++	
Suburbanization	3) relative deconcentration	+	++	+++	
	4) absolute deconcentration	-	++	+	MILAN, BOLOGNA, Trento, Prato
Disurbanization	5) absolute deconcentration	- -	+	-	ROME, PALERMO, Bergamo, Pavia, Verona, Parma, Modena
	6) relative deconcentration	- -	-	- - -	TURIN, VENICE, GENOA, FLORENCE, REGGIO DI CALABRIA, MESSINA, CAGLIARI, Piacenza, Reggio Emilia, Rimini
Reurbanization	7) relative concentration	-	- -	- - -	Latina
	8) absolute concentration	+	- -	-	BARI, CATANIA, Brescia, Taranto

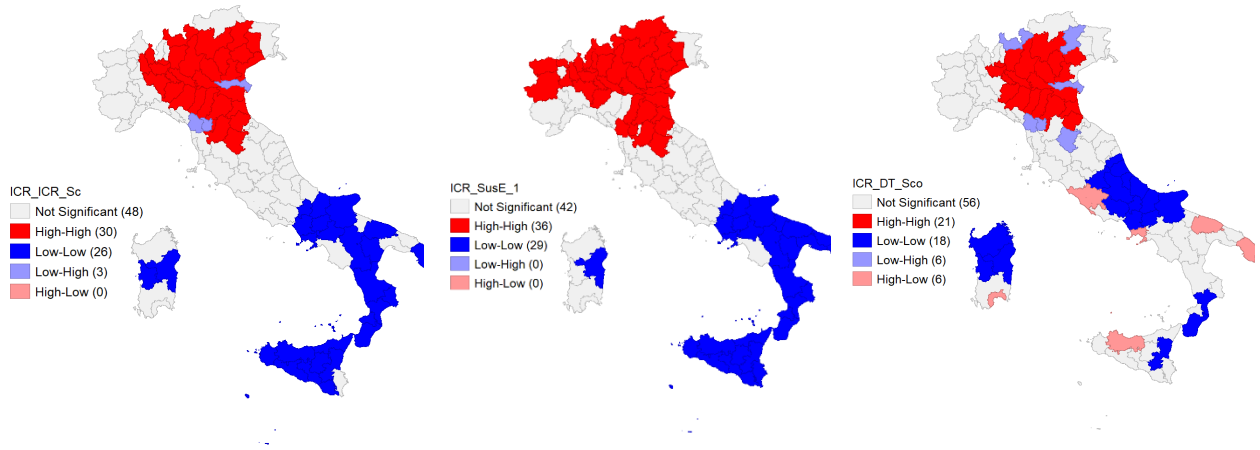


a) b) c)

Figure 5. Thematic map over a selected set of indicators. a) ICity Rank score; b) Economic Sustainability; c) Digital Transformation (Jenks & Caspall Method). Source: our elaboration on ICity Rank 2019.

These results were confirmed by the LISA analysis, as illustrated in Figure 6 (a–c). The clustering of provinces and metropolitan cities on the three indicators highlights a high-high, positive spatial autocorrelation, particularly in Northern Italy, and a negative, low-low spatial autocorrelation in Southern Italy, both in the case of the ICity Rank and the economic solidity indicator. The digital transformation indicator describes an important cluster of high-high spatial autocorrelation in the Po Valley area, while high-low values of metropolitan cities in Central and Southern Italy can be spotted

(Rome, Naples, Bari, Palermo, and Cagliari). These represent a unique, pivotal, and different role played by these areas when compared to the surrounding ones.



a) b) c)

Figure 6. LISA over a selected set of indicators. a) ICity Rank score; b) Economic solidity; c) Digital transformation. Source: our elaboration on ICity Rank 2019.

5. Conclusions

This research evaluated urban dynamics in terms of innovation in metropolitan cities and areas, as well as in mid-sized cities, considering, in particular, the functional urban areas (FUAs) related to such cities and their ranking in terms of innovation dynamics. The combined analysis—urban life cycle, LISA, administrative vs. functional division, demographic analysis, and innovation ranking—allowed an observation of urban dynamics from a different perspective, shedding light on the two-fold characteristics of depopulation and innovation.

The ongoing trends in Italian urban areas are described, from the dramatic phenomenon of depopulation to the difficulties of delimiting and defining urban areas in functional and administrative terms, together with the important consideration of innovation in urban areas as a potential driver of cities' performance and population attraction. One preliminary consideration, probably a full line of research in itself, refers to the relationship between the administrative and urban levels of metropolitan cities and provinces and their functional areas. The 14 metropolitan cities identified by the Italian law, with a few exceptions, follow their respective older provinces' borders and are very different in terms of surface covered. If the total amount of population living in metropolitan cities is close to that of their functional areas, important differences can be spotted. In cities like Milan and Cagliari, the metropolitan cities' surfaces—defined from an administrative point of view—are smaller than their functional urban areas, which correspond to the metropolitan areas, particularly from the commuting point of view. Many other metropolitan cities cover areas much wider than those covered by the FUAs, de facto including municipalities not strictly functionally related to the capital cities themselves. This happens in Northwestern Italian metro cities like Turin and Genoa, as well as in Palermo, Catania, Messina, and Reggio di Calabria in the South. The effect is two-fold. On one side, "natural" metropolitan areas, such as Milan and Cagliari, are underestimated in their administrative definition; on the other side, metropolitan cities govern over non-strictly urban areas, playing, therefore, a role as

micro-regions, albeit with a weaker level of governance based on the Italian administrative framework compared to those of regions and municipalities.

Population and innovation dynamics presented different behaviors and patterns in the selected period. In summary, metropolitan cities and areas present peculiarities considering the urban life cycle and considering the issue of depopulation currently affecting Italy. Even though overall metropolitan cities present a similar trend in population decrease, their FUAs limit this when compared to the national values. Most of the cities considered can currently be placed in the late stages of suburbanization and disurbanization. This is particularly reflected in the general decline of core populations, an increase in suburban rings for cities like Milan and Bologna, and declines for those in disurbanizing phases. A few cities, like Bari and Catania, exhibit signs of reurbanization. The dynamics within the Po Valley megalopolises remain to be evaluated, including cities like Milan, Bergamo, Brescia, Pavia, Piacenza, Parma, Reggio Emilia, Modena, and Bologna, where population dynamics need to be addressed in a more integrated way. Mid-sized cities, on the contrary, present interesting dynamics of reduced impact of depopulation when compared to the Italian average and capital cities' values. In such a sense, this average size dimension may foster more stable population dynamics. In terms of innovation, the 2019 values were considered to fix innovative patterns in space and time and observe how urban metro populations changed. Interestingly, the digital transformation indicator underscores the prominence of metro cities within the national context, while other indicators seem to be more affected by the traditional separation between Northern and Southern Italian provinces. This possibly influenced ForumPA's decision to concentrate on indicators of digital transformation to assess the level of innovation of cities, in the years following the 2019 edition.

The research is ongoing [45] and therefore still open and requires an in-depth analysis of different aspects. On one side, innovation analysis highlighted interesting dynamics of medium-sized cities, not just metropolitan ones. An extended analysis of these should therefore be carried out. On the other side, going more in-depth into the innovation side, such as considering more recent ICity Rank values and indicators, could help in better understanding the more articulated dynamics and possible evolutionary paths that cities will be likely to follow in the upcoming years. The role of the "optimal size of the city" emerges from this analysis. This depends on a series of factors, including economic and social goals. Economic goals relate to the fact that larger cities tend to offer greater economic opportunities due to economies of scale and a broader range of industries. However, very large cities can also face problems such as rising costs of living and infrastructure congestion. Social goals imply that mid-sized cities often offer a good balance between economic opportunities and a strong sense of community. Large cities (over 1 million people) offer greater economic opportunities, cultural diversity, and innovation hubs, while also presenting a high cost of living, traffic congestion, pollution, and potential social isolation. Medium-sized cities, on the other hand, ranging in size from 250,000 to 1 million people, present a good balance between economic opportunities and convenience, often a strong sense of community. In small cities, with less than 250,000 people, there is a lower cost of living and a strong sense of community but reduced economic opportunities and a low supply of services. In this sense, medium-sized cities, with a population between 50,000 and 250,000 inhabitants, play a fundamental role in the Italian urban system, representing a link between large metropolitan areas and FUAs and rural areas, and being responsible for the development of a more distributed and inclusive innovation model, to the benefit of the entire country. Smaller cities may be even more close-knit but have fewer job opportunities.

The results so far obtained appear interesting in terms of the possible implementation of specific urban policies. Both large and mid-sized centers can become resilient, tackling demographic shifts and fostering innovation. Metropolitan cities, particularly the most consolidated ones in Northern Italy, appear to be not so capable of maintaining residential population by "simply" investing in innovation and innovation hubs. In general, urban services and infrastructure should be implemented in metropolitan suburbs, where residents are more stable, to increase the attractiveness of these areas for businesses and residents. Recognizing mid-sized cities as innovation centers and addressing their urban innovation policies can be an option for urban revitalization. Furthermore, there is a need to continuously track demographic trends and adjust urban policies to address the changing needs of the population, incorporating strategies to attract young professionals and families to reduce the effects of the urban demographic winter and maintain urban livability and vitality in the long run.

Author contributions

Giuseppe Borruso and Ginevra Balletto: Conceptualization, Supervision, Validation, Writing – Original Draft Preparation (equal); Giuseppe Borruso: Data Curation, Formal Analysis, Investigation, Software, Visualization; Ginevra Balletto: Resources, Writing - Writing – Review & Editing.

More in particular, this paper is the outcome of an in-depth work of collaboration between the authors; however, Giuseppe Borruso has written Paragraph 1 – Introduction, Paragraph 2, Paragraph 3.2, 3.3 and Paragraph 4, while Ginevra Balletto has written the Abstract, Paragraph 3.1 and Paragraph 5 - Conclusions.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of Interest

The authors declare no conflict of interest.

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