DEMOGRAPHIC VITALITY IN ITALIAN MUNICIPALITIES: MEASUREMENT AND FEATURES OF THE MOST DYNAMIC AREAS[1]

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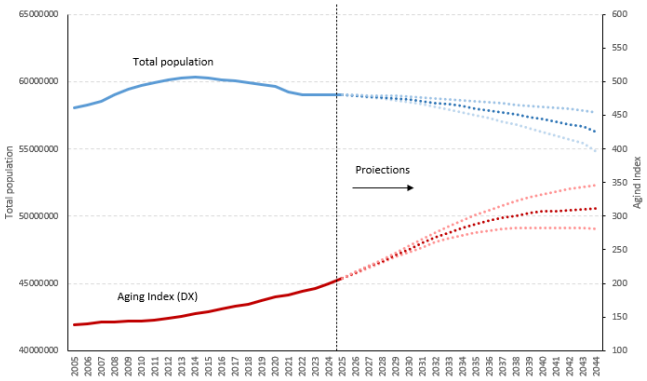
Abstract. The population living in Italy has fallen by 1.4 million over the last 10 years. According to the most likely scenario of recent demographic forecasts, the decline will continue in the near future leading to a further decrease of 1.1 million people by 2030. At the same time, the population is ageing: over the last 20 years, the aging index has risen from 136 to 200; the index will exceed 250 in 2030. This trend, however, is not homogeneous in all the territories. The main aim of this work is to identify the most dynamics areas, namely those municipalities where the tendency to population decline and aging is less marked.
At this scope, a synthetic index named as Demographic Vitality Index (DVI), was introduced. DVI measures the degree of "demographic vitality" for each municipality. The index is composed by 8 indicators representing different aspects of demographic vitality: dynamics of population and changes in age structure. DVI represents therefore a new and powerful tool to implement the most appropriate anti-decline and anti-aging policies of the population.
The conceptual framework is the following: i) DVI assumes higher values in municipalities where in the meanwhile the demographic balance tends to be better and the aging process slows down; ii) the national average of DVI is imposed to be equal to 100 for the first year of observation (2019); iii) DVI ranges between 0 and 200. The source of data is the Istat dataset DEMO (demography in figures) for the years 2019-2024 (Permanent census data). Municipality borders are those at 1st January 2025.
According DVI results, demographic vitality tends to reduce during the period of analysis. Differences between the dynamic and the structural components are significant during the years of Covid; in the most recent period they narrow down to almost converge.
The index is higher in large areas of the northeast (especially in Trentino-Alto Adige, along the Po plain, and the Via Emilia) and in coastal areas, particularly along the Lower Tyrrhenian. Vice-versa DVI is very low in Sardinia, Liguria, and in the Apennine interior areas. In the territories, there are differences depending on the distance to the main services (transport, health, education). Demographic vitality is relatively higher in the Polo areas, followed by the Intermunicipal centre and Belt areas. The worst vitality is accounted in the peripheral and ultra-peripheral municipalities.

[1] The work is the joint result of the two authors that shared the working methodology (Paragraph 2). However, Paragraphs 1, 3 and 4.2 are attributable to Alessandro Valentini; Paragraphs 4.1 is attributable to Francesca Paradisi.

1. Demographic context

The population living in Italy at the beginning of 2005 was around 58 million of inhabitants. In the following ten years, the number of residents increased until the top of 60,345,917 at the 1st January of 2014. From this point, the population started to diminish, and actually (1st January 2025) is less than 59 million. In the meanwhile, the aging process, already in place for several years, accelerates. The Aging index has risen from 131.7 in 2005 to 158.3 in 2015 and to 207.6 in 2025. According to the most recent demographic projections, in the next future (2025-2044) decline and aging will continue in all forecast scenarios (Figure 1).

Figure 1 – *Total population (left) and Aging index (right). Observed values and forecasts at 1st January. Italy. Years 2005-2044.*



Source: Istat, Resident population by age, gender and civil status (2005-2018); Permanent Census of population (2019-2024); Population projection (2025-2044).

This negative demographic trend has been the subject of many studies for several years in terms of depopulation of rural areas (Macchi Janica, 2016; De Rubentis, 2019), and more in general in terms of demographic alert (Guarracino, 2016) and analysis of territorial resilience (Keck and Sakdapolrak, 2013; Salvia and Quaranta, 2020).

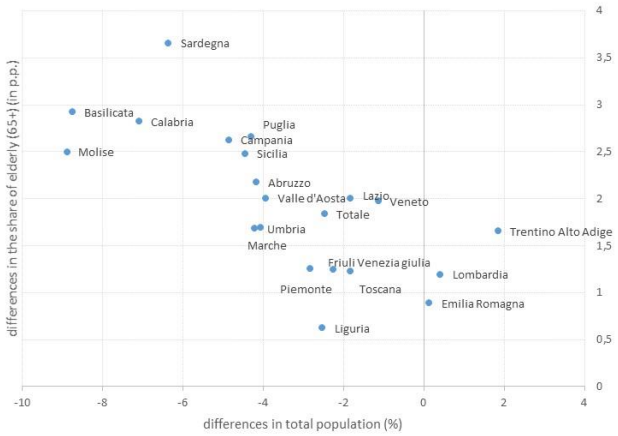
A focus on the different Italian regions has been realised for the most recent period (2019-2025) using results of the permanent census. It should be noted that the change in the total population and in the age structure is not homogeneous between the different regions (Figure 2). These two indicators are inversely correlated: the more the population decline, the more it ages.

The share of elderly (65 years and over) increased in all regions: between 0.62 p.p. in Liguria and 3.65 p.p. in Sardinia (the increase in Italy was of 1.84 p.p.). The total population declined in quite all regions; the drop was particularly significant in Molise (-5.2%), Basilicata (-5.1%) and Calabria (-4.2%). Vice-versa the population

has grown only in South Tyrol (+1.12%), Lombardy (+0.25%) and Emilia-Romagna (+0.09%). Those three regions were the only ones with a demographic trend relatively better in terms of both total population and evolution of demographic structure. On the opposite side Molise, Basilicata, Calabria and Sardinia were the regions with a relatively worst trend both for evolution of the total population and for the increase of elderly.

Peculiar is the case of Liguria: the region with the lowest increase of elderly. This positive figure actually underlies a paradoxical effect linked to the fact that the region has the highest proportion of older people at national level. On the other hand, in this study it is not the level reached by age structure that matters, but how much it changes over time. This approach is useful to understand the level of resilience with regard to aging.

Figure 2 – *Differences in total population (%) and in the share of elderly (65+) (in p.p.) between 2019 and 2025 (data at 1st January) by Italian region.*



Source: Istat, Permanent Census of population.

2. Method

In recent years, a large bibliography has been devoted to analysing the characteristics of the Italian population and its territories, with particular reference to the relationship between decline and aging. See for example Gesano and Strozza (2011), Blangiardo (2013). Particular attention was deserved to the local consequences of these trends, especially in indoor areas of the country or in rural territories (Rizzo 2015; Cipolloni 2021). A further analysis was focused on the resilience of population in terms of the ability to cope with the shocks caused by the dynamics in progress. The writings of Salone (2017), Colantoni *et al.* (2020) are

interesting at this regard. Bottazzi and Puggioni (2013) introduced a composite *index of demographic malaise* for the municipalities of Sardinia. This index is composed by two parts: the first takes into account episodes of depopulation (for the period 1951-2011), the second refers to some population characteristics, expressive of its structure and its natural movement.

In the present paper, a new composite index is introduced, the index is named Demographic Vitality Index (DVI). The work is inspired by the pioneering study concerning the index of demographic malaise. The proposed methodological advancements of DVI are: i) it is linked to a specific reference year to allow temporal comparisons; ii) the structural and dynamic components are treated separately; iii) the structural component is expressed as annual changes in the age composition.

As in the preliminary studies of Paradisi and Valentini (2024), conceptual framework of DVI is the following: a) the level of demographic vitality is represented by a synthetic figure (Maggino, 2006; OECD, 2008; Mazziotta and Pareto, 2024) measured on a scale between 0 (theoretical minimum) and 200 (theoretical maximum). The value 100 represents the reference point (goalpost). In case of the present paper 100 is DVI for Italy in 2019;

- demographic vitality is a relative concept. Tends to be higher in places where the population increases (or diminishes less in relation to the context) and where age structure is rejuvenated (or gets less older than elsewhere); vice-versa is lower in places where the population declines and the age structure of it is ageing (compared to other territories);
- base indicators are representatives of two aspects of a population (dimensions): dynamic (in terms of rates of birth, death, immigration and emigration) and changes in the age structure (in terms of share of youngers, share of elders, structure of active population, structure of elders).

According to the framework, indicators to calculate DVI, for a specific year and place (for instance at municipality level) are the followings:

- I.1 *birth rate*
- I.2 *death rate*
- I.3 *immigration rate* (from abroad and other Italian municipalities)
- I.4 *emigration rate* (to other Countries and to other Italian municipalities)
- I.5 *changes in the share of Youngers* (0-14 years), between 1st January and 31th December;
- I.6 *changes in the active population index* (15-39 younger working ages; 40-64: older working ages), between 1st January and 31th December;
- I.7 *changes in the share of elderly* (65 years and over), between 1st January and 31th December;
- I.8 *changes in the old population index* (65-84 less old; 85+ very elderly) between 1st January and 31th December-

Table 1 shows in detail the formulas to calculate the different indicators (*I.x* the generic indicator, where x = 1 to 8) for municipality *c* and year *t*. More specifically:

Table 1 – *Basic indicators of Demographic Vitality Index.*

Code	Dimension	Indicator	Formula
I.1	Dynamic	Birth rate	$\frac{B_{c,t}}{0.5(Pop_{c,TOT,t} + Pop_{c,TOT,t+1})}$
I.2	Dynamic	Death rate	$\frac{D_{c,t}}{0.5(Pop_{c,TOT,t}+Pop_{c,TOT,t+1})}$
I.3	Dynamic	Immigration rate	$\frac{IM_{c,t}}{0.5(Pop_{c,TOT,t}+Pop_{c,TOT,t+1})}$
I.4	Dynamic	Emigration rate	$\frac{EM_{c,t}}{0.5(Pop_{c,TOT,t} + Pop_{c,TOT,t+1})}$
I.5	Evolution of structure	Changes in the share of youngers	$\frac{Pop_{c,0-14,t+1}}{Pop_{c,TOT,t+1}} - \frac{Pop_{c,0-14,t}}{Pop_{c,TOT}}$
I.6	Evolution of structure	Changes in active population index	$\frac{Pop_{40-64,t+1}}{Pop_{c,15-39,t+1}} - \frac{Pop_{40-64,t}}{Pop_{c,15-39,t}}$
I.7	Evolution of structure	Changes in the share of elderly	$\frac{Pop_{c,65+,t+1}}{Pop_{c,TOT,t+1}} - \frac{Pop_{c,65+,t}}{Pop_{c,TOT,t}}$
I.8	Evolution of structure	Changes in the old population index	$\frac{Pop_{c85+,t+1}}{Pop_{c,65-84,t+1}} - \frac{Pop_{c85+,t}}{Pop_{c,65-84,t}}$

Notes:
$Pop_{c,GR,t}$ is the population of municipality *c* on 1 January for age group GR. Where GR is TOT for the total population; 0-14 for ages not yet active (lower than 15 years); 15-39 for the younger group of active population; 40-64 for the older group of active population; 65+ for the no more active population; 85+ for the oldest people.
$B_{c,t}$ and $D_{c,t}$ respectively are the total number of births and the total number of dead in the municipality *c* year t.
$IM_{c,t}$ and $EM_{c,t}$ respectively are the total number of immigrants (immigration from abroad and immigrations from other italian municipalities) and the total number of emigrants (emigration to other countries and emigration to other Italian municipalities) in the municipality c during year t.

Each indicator is standardised using the min-max procedure with goalpost. Defining:

- *Rif (I.x)* as the goalpost (Italy 2019)
- *Max (I.x)* and *Min (I.x)* as, respectively, absolute maximum and minimum of the indicator I.x for all municipalities and years of the time series.
  Max (I.x)= Max (I.x,c,t) $\forall c, t$; *Min (I.x)= Min (I.x,c,t)* $\forall c, t$

Formulas for the standardization are the followings:

$$Sup(I.x) = Rif\ (I.x) \quad + [Max(I.x) - Min(I.x)]/2 \tag{1}$$

$$Inf(I.x) = \quad Rif\ (I.x) \quad - [Max(I.x) - Min(I.x)]/2 \tag{2}$$

$$I.x_{c,t}^{ST} = 200\frac{I.x_{c,t} - Inf(I.x)}{\mathrm{Sup}(I.x) - \mathrm{Inf}(I.x)} \quad (3a) \text{ or } \qquad I.x_{c,t}^{ST} = 200\frac{-I.x_{c,t} + Sup(I.x)}{Sup(I.x) - Inf(I.x)} \quad (3b)$$

The formula is (3a) if *I.x* is positively correlated with DVI (indicators I.1, I.3, I.5); (3b) in case of inverse correlation (indicators I.2, I.4, I.6, I.7, I.8).

The dynamic component (DY), the component representing evolution of structure (EV) and DVI are calculated as the arithmetical mean of the standardized indicators, the most intuitive and most used method of synthesis. The average is unweighted in order to attribute the same importance to each indicator.

$$DVI_{c,t}^{DY} = \frac{\sum_{i=1}^{4} I.i_{C,T}^{ST}}{4} \quad (4) \qquad DVI_{c,t}^{EV} = \frac{\sum_{i=5}^{8} I.i_{C,T}^{ST}}{4} \quad (5) \quad DVI_{c,t} = \frac{DVI_{c,t}^{DY} + DVI_{c,t}^{EV}}{2} \quad (6)$$

Indicators (4), (5) and (6) range between 0 and 200.

3 Data

The implementation of the indicators dataset described in Table 1 was a significant part of this work. Indicators are calculated for the period between 2019 and 2025 (1st January) using the permanent census data warehouse. As well known, census data are perfectly aligned with administrative data of demographic registrations. The geographical detail of the dataset is that of municipalities (LAU 2), for the 7,896 actually existing municipalities (boundaries at the 1st January 2025). During the period of analysis, several administrative changes occurred in the borders because of various processes of aggregation and disaggregation. To have an idea, the total number of municipalities was 7,954 at the end of 2018; 7,914 at the end of 2019; 7,903 at the end of 2020; 7,904 at the end of 2021 and 2022; 7,900 at the end of 2023.

Changes in territorial borders have been managed as follows: a) in case of aggregation, adding together the data of extinct municipalities. For instance the municipality of Mornago was established in 2023 thanks to the fusion between Sella Giudicarie, Fondo, Malosco; b) in case of disaggregation by subtracting known data from the total population transferred and applying a proportional statistical model for the other variables. This is the case of separation of Missiliscemi from Trapani.

For each municipality (borders at 1st January 2025) and year, the dataset includes the following variables: births, deaths, immigrations and emigrations (from other Italian municipalities and from abroad); total population and population by age (classes 0-14; 15-39; 40-64; 65-84; 85+) at 1st January and at 31st December.

Each municipality data is then linked to a set of covariates, functional to the analysis of DVI results: region, geographical repartition (North-West, Northeast, Centre, South, and Islands), provincial capital (not capital; capital); typology of

indoor area (Polo, Intermunicipal center, Belt, Intermediate, Peripheral, Ultra-peripheral).

4 Main results

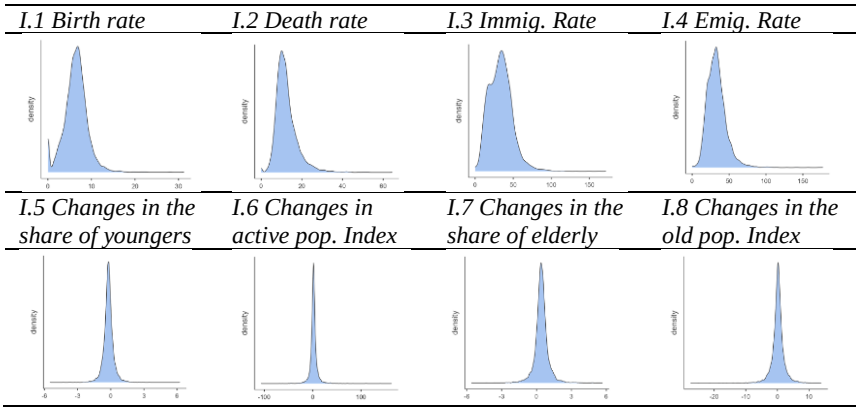
The approach of analysis followed in this paper is twofold. On one side, a preliminary study on the indicators at the basis of DVI was able to identify the main features of the different demographic components. The univariate approach allowed knowing the form of the different distributions and the value of the main representative indexes. Bivariate approach was suitable to evaluate correlations between indicators.

On the other side, the synthetic index DVI was studied in greater detail, in terms of distribution form, historical trend (2019-2024), analysis of the different territorial areas (geographical repartition, type of municipality, typology of indoor area).

4.1. Analysis of base indicators of DVI

Figure 3 shows the frequency distribution of the basic indicators of DVI for the base year 2019; this is the first year for which the results of the permanent census are available at 1st January. Indicators representing components of the structure (I.1, I.2, I.3, I.4) have 0 as the minimum value and have no upper end. The means values are 6.3 and 12.4 for respectively birth and death rate; 33.4 and 33.2 for immigration and emigration rate.

Figure 3 – *Frequency distribution of the basic indicators of DVI. Year 2019.*



Source: elaboration of authors.

Note that those two distributions (in particular distribution of immigration rate) are bimodal. It depends on the fact that they are the sum of two distinct components

with distinct distributions: domestic and foreign. Indicators representing evolution of the structure (I.5, I.6, I.7, I.8) have no theoretical limits; their means are: -0.2 (I.5), 2.2 (I.6), 0.4 (I.7) and 0.2 (I.8) and are relatively symmetric.

The base indicators are almost uncorrelated. According to the correlation matrix (not reported here), the only two significant exceptions are the strength of the linear relation between I.3 and I.4 (r=0.628) and between I.1 and I.5 (r=0.349).

The distribution of each indicator and the correlation between indicators do not change significantly over time.

4.2. Analysis of DVI

Application of the method introduced in § 2 to the dataset illustrated in § 3 allows to calculate the composite index DVI for all Italian municipalities in the period 2019-2024. Figure 4 shows the frequency distribution of DVI (year 2019) in the range between 90 and 110 (cases of DVI lower than 90 and upper then 110 are very limited and ignored in this figure).

Despite a slightly skewness to the right, the form of the distribution is almost normal. The arithmetic mean of the distribution is 99.40; the median is 99.58. The value for Italy in 2019 (goalpost) is equal to 100; the same for both components: dynamics (DY) and evolution of structure (EV). Figure 5 shows the historical trend of DVI and that of the two components DY and EV for the period 2019-2024. The value of DVI tends to decrease over time. It reaches the value 99.38 in 2024 (-0.62 points). This diminishing depends on distinct effects. In 2020 it was accounted a significant slope, of opposite sign, both on the EV (+0.87 points) and on the DY components (-1.14 points). The reasons are contingents, and mainly related to the Covid consequences, which caused an increase in deaths, particularly for elderly people, with a rejuvenating effect. In the following years, DY grows slightly but always remains below the 2019 initial value; EV decreases according to a linear model falling below 100 in 2023.

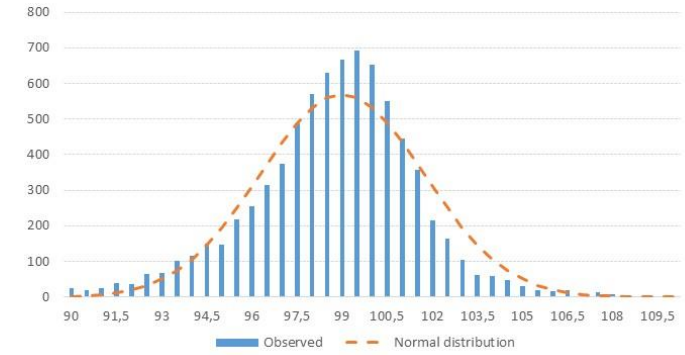
The value of DVI is not homogeneous in the different areas of the country. It tends to change according to different territorial characteristics. Table 2 illustrates the value of DVI (years 2019 and 2024) aggregated according to three variables: territorial placement from North to South (in terms of geographical partitions), distance from the main services (type of indoor area) and administrative features (to be or not to be provincial capital). For each variable, differences between the various modalities are statistically significant ($p<0.001$ based on the Anova test). Considering the geographical partitions, DVI assumes higher values in the North, especially in the Northeast, where the highest value is recorded both at the beginning of the period (100.27) and at the end (99.59). The distinction by type of municipality shows for both years a higher demographic vitality in the provincial capitals (100.25

vs 99.89 in 2019; 99.50 vs 99.33 in 2024). Focusing on the different indoor areas, the population is more demographically lively in areas next to the services (of instructions, health and transport), and less lively in more peripheral areas. In any case, in 2024 compared to 2019 there seems to be a recovery of the less central and more peripheral areas. The rate of decrease in Peripheral (-0.11%), Intermediate (-0.28%) and Ultra-peripheral (-0.48%) areas is lower than the rate of decrease in the more central ones (upper than -0.70%).

Figure 6 shows the level of DVI by municipality (quintiles 2019). It is relevant to note that population living in critical municipalities (1st and 2nd quintile, DVI below 98.5) is only 13.7%. In particular, population of the 1st quintile is solely 3.2%. Vice-versa population living in more vitality municipalities (4th and 5th quintile, DVI over 99.7) is 61.6% of the total. Specifically 21.7% of population lives in the municipalities with the highest vitality. Looking at the different territories, the liveliest region is Trentino-Alto Adige with the highest number of municipalities (54.6%) and the highest quota of inhabitants (70.6% of population) that belongs to the 5th quintile. Following Lombardia (28.8% of municipalities; 42.3% of population); Campania and Valle D'Aosta in terms of municipalities (both around 27.0%); Emilia-Romagna in terms of population (32.7%). It is worth to note that Liguria has a very limited quota of inhabitants in the liveliest areas (2.1%). Regions with the worst situation in terms of vivacity (1st quintile) are Molise, Basilicata and Sardinia both in terms of municipalities (respectively 44.1%; 35.9% and 35.5%) and population (17.8%; 12.0% and 9.8%). Worthy of interest the cases of Liguria (33.8% of municipalities and 6.1% of population) and Piemonte (respectively 33.6% and 8.0%).

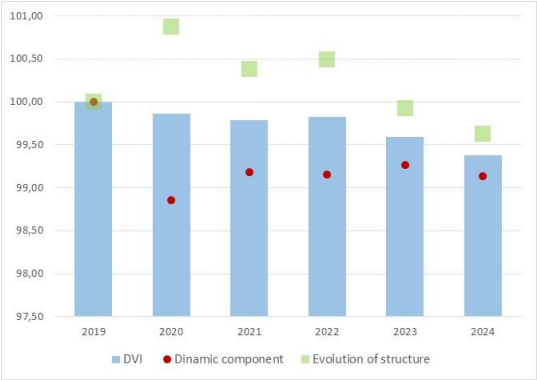
The comparison between 2019 and 2024 shows a significantly worsening situation: at national level the population living in critical municipalities (1st and 2nd quintiles) reaches a peak of 18.4%, increasing of almost 5 p.p. Similarly, the quota of population of the most demographically lively municipalities (5th quintile) drops by 10 points contracting to 11.9%. The worsening is broadly homogeneous in all regions, with a progressive population shift in the lowest quintiles. Trentino-Alto Adige continues to be the most demographically lively region with over half of the municipalities (51.1%) falling into the 5th quintile. However, the population share in this quintile (40.4%) almost halved compared to the previous five-year period due to the relocation of the two capitals of Trento and Bolzano. A significant loss of population from the 5th quintile is also accounted in Lombardia (- 15.8 p.p. because of the outing of Milano), Emilia-Romagna (-14.1) and Veneto (-11.1). Similarly the population of the 1st quintile grows in almost all regions; in particular in Sardegna (+ 20.5) and in Valle d'Aosta (+10.3).

Figure 4 – *Frequency distribution of DVI. Year 2019 (base Italy=100).*



Source: elaborations of authors.

Figure 5 – *DVI, Dinamic and Evolution of structure. Years 2019-2024 (base 2019=100).*



Source: elaborations of authors.

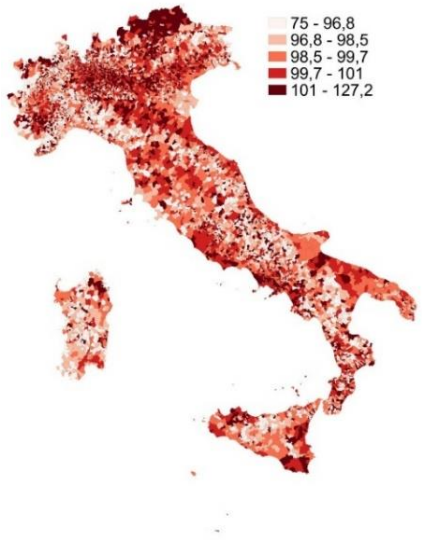
Directions of future work for this subject could be the followings: analysis of spatial correlations in composite index values; estimation of covariate effects using quantitative models.

Table 2 – *DVI by geographical partitions, type of municipality, type of indoor area. Years 2019-2024 (base Italy 2019=100)*

Territory	2019	2024
Italy	100.00	99.38
Geographical partitions		
North-Ovest	100.13	99.43
North-Est	100.27	99.59
Centre	99.84	99.15
South	99.96	99.47
Islands	99.67	99.16
Type of municipality		
Non provincial capital	99.89	99.33
Provincial capital	100.25	99.50
Type of indoor area		
Polo	100.27	99.51
Intermunicipal Centre	100.07	99.24
Belt	100.09	99.38
Intermediate	99.59	99.31
Peripheral	99.19	99.09
Ultra-peripheral	99.07	98.59

Source: elaborations of authors

Figure 6 - *DVI by municipality. Year 2019 (base Italy 2019 = 100)*



Source: elaborations of authors

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