Transport accessibility and demographic vibrancy:
Evidence from the high-speed railways in Italy

Mario Tartaglia[1], Andrea Fiduccia [1], Gianluigi Cisco[2]

[1] Ferrovie dello Stato Italiane [2] Parthenope University of Naples

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Background: Collapse of births in Italy

Source – Istat

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2
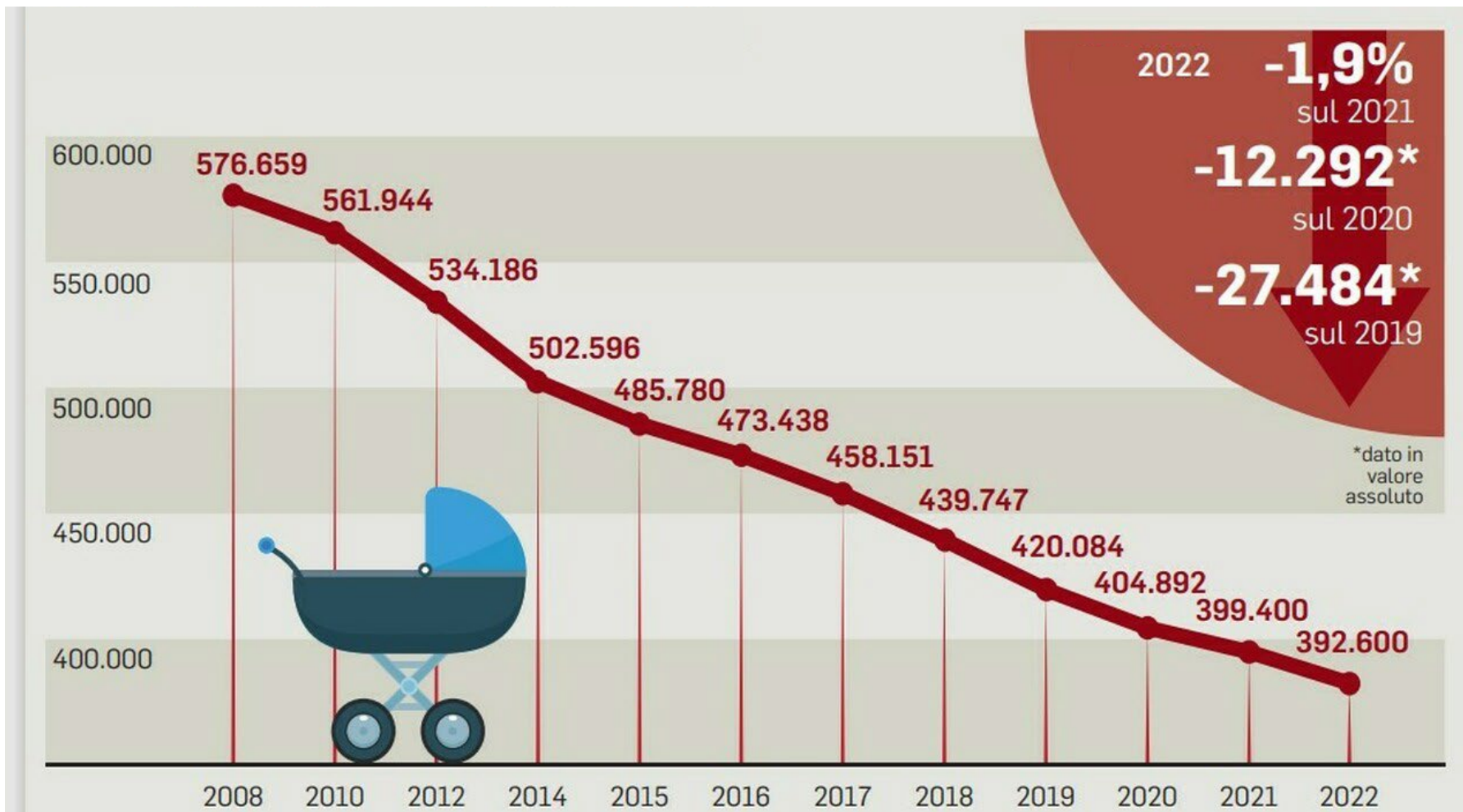
"Did high-speed railways affect demographics in Italy?"

Motivations

- **Aging Population:** Italy ranks third globally in terms of population aging, presenting unique challenges and opportunities for social, economic, and welfare systems.

- **Revolution in transportation:** High-speed rail represented a revolution in transportation, transforming travel experiences and connectivity in numerous countries, including Italy.

Goals

- Investigate the Influence of **High-Speed Railways on Demographic Vibrancy** in Italy.

- Examine the relationship between **accessibility and demographic composition** in Italy.

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Methodology
Data, Model and Variables

DATA

Periods: 2008 (Before HSR) – 2019 (After HSR)

Territorial Units: Catchment Areas

Model

Panel Regressions ***Fixed Effects***
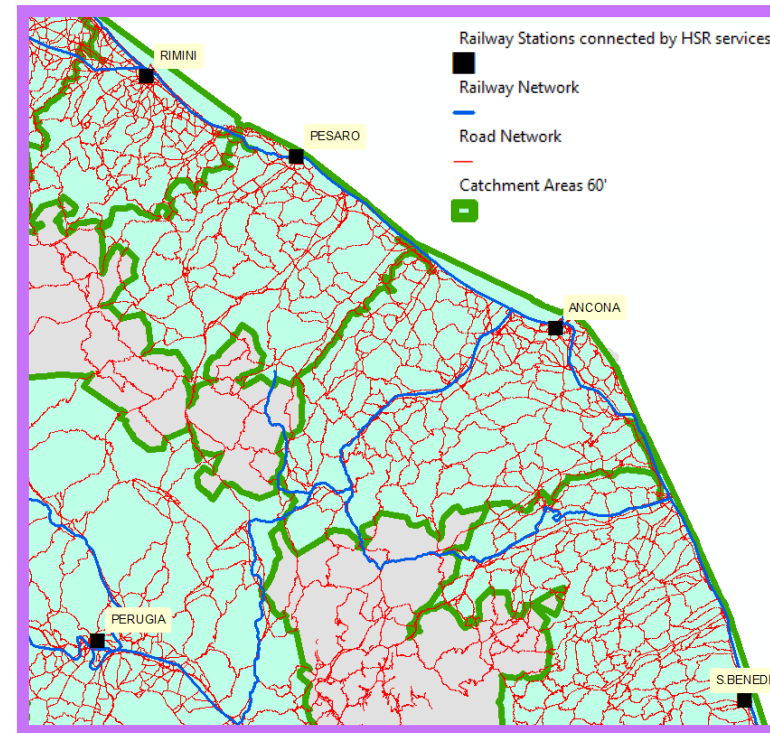
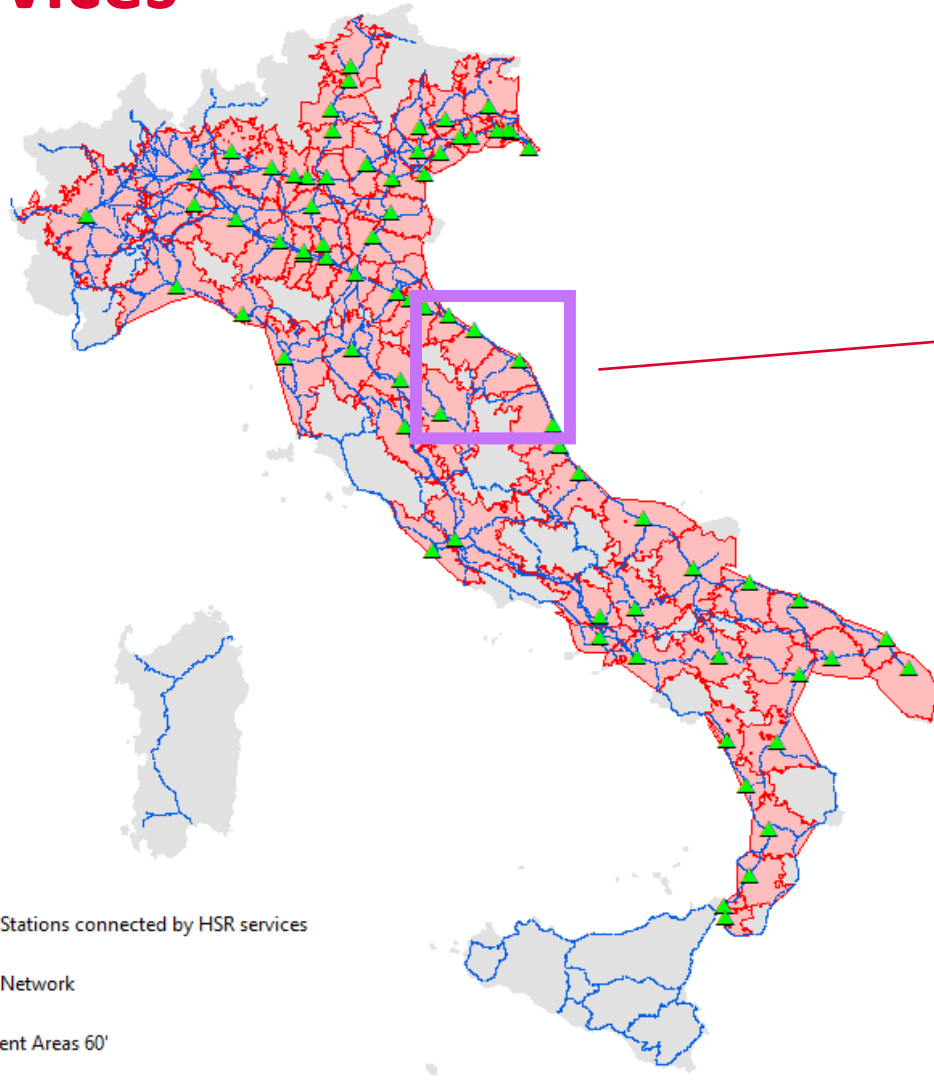**Variables**

Demographic Indicators

Accessibility index (from)

$$y_{i,t} = \beta_1 x_{i,t} + \varepsilon_{i,t}$$

Where:

- $y_{i,t} \rightarrow Demographic\ Indicators$
- $x_{i,t} \rightarrow Accessibility\ Index$

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# Catchment Areas of Railway Stations connected by HSR Services

- For each railway station connected by HSR services, the catchment area was calculated at 60 minutes of travel time on the road network.
- The road network graph characterizes each link with an average speed of its functional class. The travel time can be calculated from the speed and length of the link.
- Using the "service area" GIS function (Network data model), the catchment areas are determined for a given travel time (in our case 60 minutes).

Data aggregation in the Catchment Areas

Spatial Intersection of Municipalies and Catchment Areas
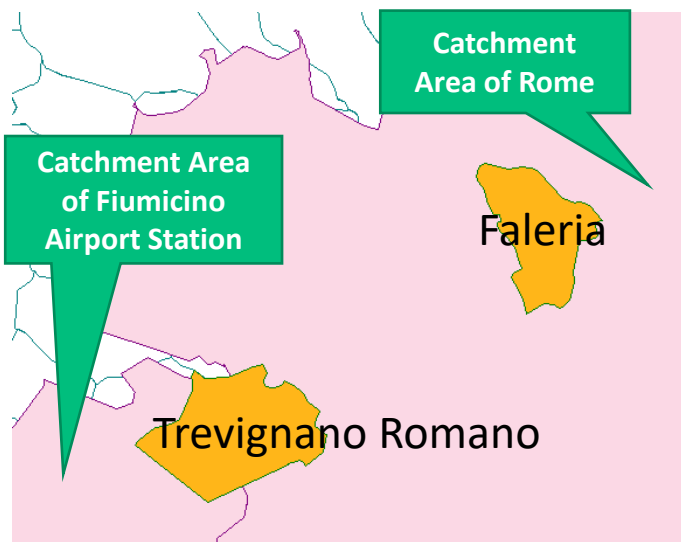
ISTAT Code	Municipality	AREA (Square Km)
56025	Faleria	25,59084572
58107	Trevignano Romano	38,89711804
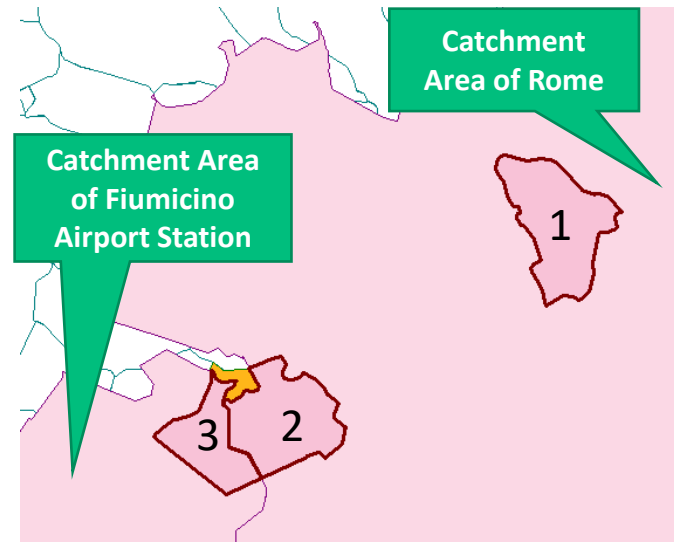
ID	Catchment Area	Municipality	AREA (Square Km)	INTERSECTION AREA (Square Km)	RATIO
1	ROMA : 0 - 60	Faleria	25,59084572	25,59084572	1
2	ROMA : 0 - 60	Trevignano Romano	38,89711804	22,85250498	0,587511521
3	FIUMICINO AIRPORT : 0 - 60	Trevignano Romano	38,89711804	13,75972775	0,353746715

C_i Municipalities intersecting the Catchment Area k (i = 1, ..., n)

D_i demographic data of Municipality C_i

S_i Surface of Municipality C_i

G_i Surface of the spatial intersection of Municipality C_i and Catchment Area k

$R_i = G_i / S_i$

$L_k = \sum_{i=1}^{n} R_i * D_i$ demographic data of Catchment Area k

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6

Variables

Aging Index

$$AI = \frac{Citizens\ age > 65}{Citizens(0,14)}$$

Migrant Citizens Index

$$MI = \frac{Migrant\ Citizens}{Tot\ Citizens}$$

Young (0-14) Citizens Index

$$YI(0,14) = \frac{Citizens\ (0,14)}{Tot\ Citizens}$$

Young (15-34) Citizens Index

$$YI(35,65) = \frac{Citizens\ (15,35)}{Tot\ Citizens}$$

Structural Dependence Index

$$SDI = \frac{Tot\ Citizens - Working\ age}{Working\ Age\ Citizens}$$

Accessibility Index

Accessibility via the **travel-time approach** (TtA_i) focuses on the performance of the transport connection in terms of supply and is the function of the **travel time** between the nodes i and j $(Tt_{i,j})$:
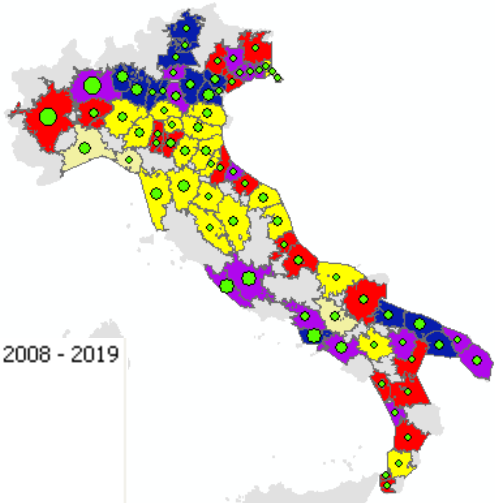
$$TtA_i = \sum_{j=1}^{n} \frac{1}{Tt_{i,j}}$$

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# Demographic Dynamics 2008-2019: derived indicators 1/5
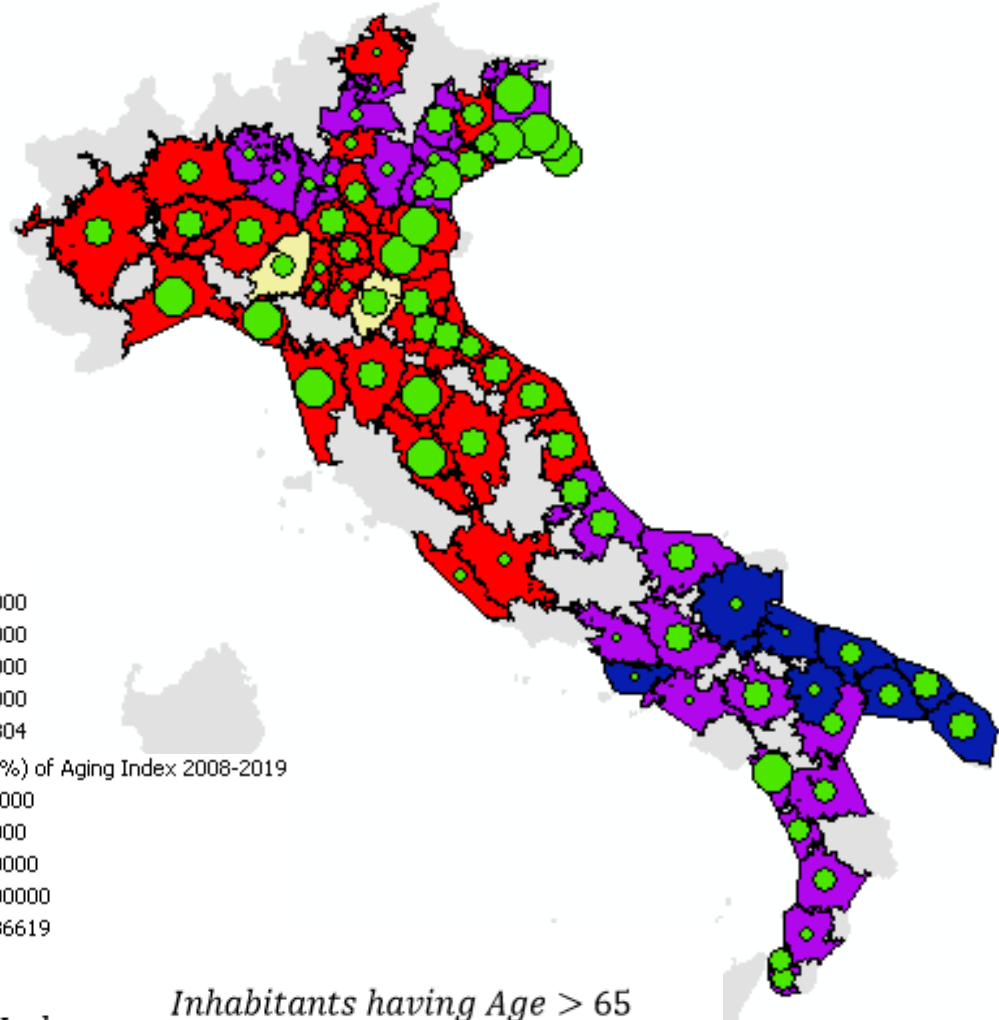
Relative Change of Population (%)
Age > 65

Aging Index

Citizens having age > 65 2019
- 10913.806397 - 96286.000000
- 96286.000001 - 209981.000000
- 209981.000001 - 375341.000000
- 375341.000001 - 714577.000000
- 714577.000001 - 1371364.990926

Relative Change (%) of Citizens having age > 65 2008 - 2019
- 2.131706 - 4.500000
- 4.500001 - 11.800000
- 11.800001 - 16.400000
- 16.400001 - 21.000000
- 21.000001 - 26.587610

Age 0-14
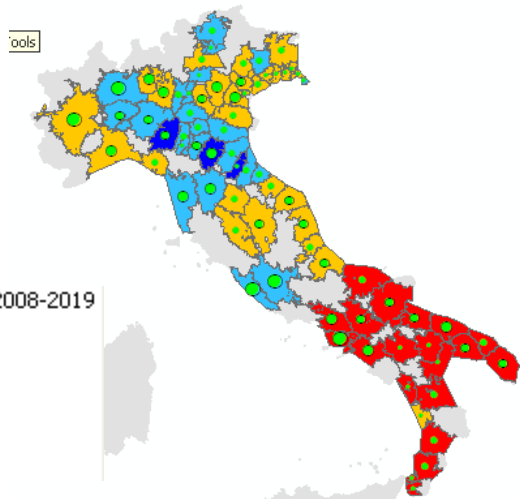
Young (0-14) Citizens 2019
- 4724.681563 - 29605.000000
- 29605.000001 - 55352.000000
- 55352.000001 - 98261.000000
- 98261.000001 - 234883.000000
- 234883.000001 - 808930.220812

Relative Change (%) of Young (0-14) Citizens 2008-2019
- -20.725890 - -13.000000
- -12.999999 - 0.000000
- 0.000001 - 0.000000
- 0.000001 - 7.000000
- 7.000001 - 13.932621

Aging Index 2019
- 1.135277 - 1.400000
- 1.400001 - 1.600000
- 1.600001 - 1.800000
- 1.800001 - 2.000000
- 2.000001 - 2.607304

Relative Change (%) of Aging Index 2008-2019
- -4.477619 - 0.000000
- 0.000001 - 0.000000
- 0.000001 - 20.000000
- 20.000001 - 40.000000
- 40.000001 - 52.786619

$$Aging\ Index = \frac{Inhabitants\ having\ Age > 65}{Inhabitants\ having\ Age \in [0,14]}$$

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Relative Change of Population (%)
Migrant Citizens

Migrant Citizens Index

Migrant Citizens 2019
- 3708.371419 - 25257.000000
- 25257.000001 - 64856.000000
- 64856.000001 - 127423.000000
- 127423.000001 - 333219.000000
- 333219.000001 - 684978.112966

Relative Change (%) of Migrant Citizens 2008 - 2019
- -0.625024 - 0.000000
- 0.000001 - 47.000000
- 47.000001 - 76.600000
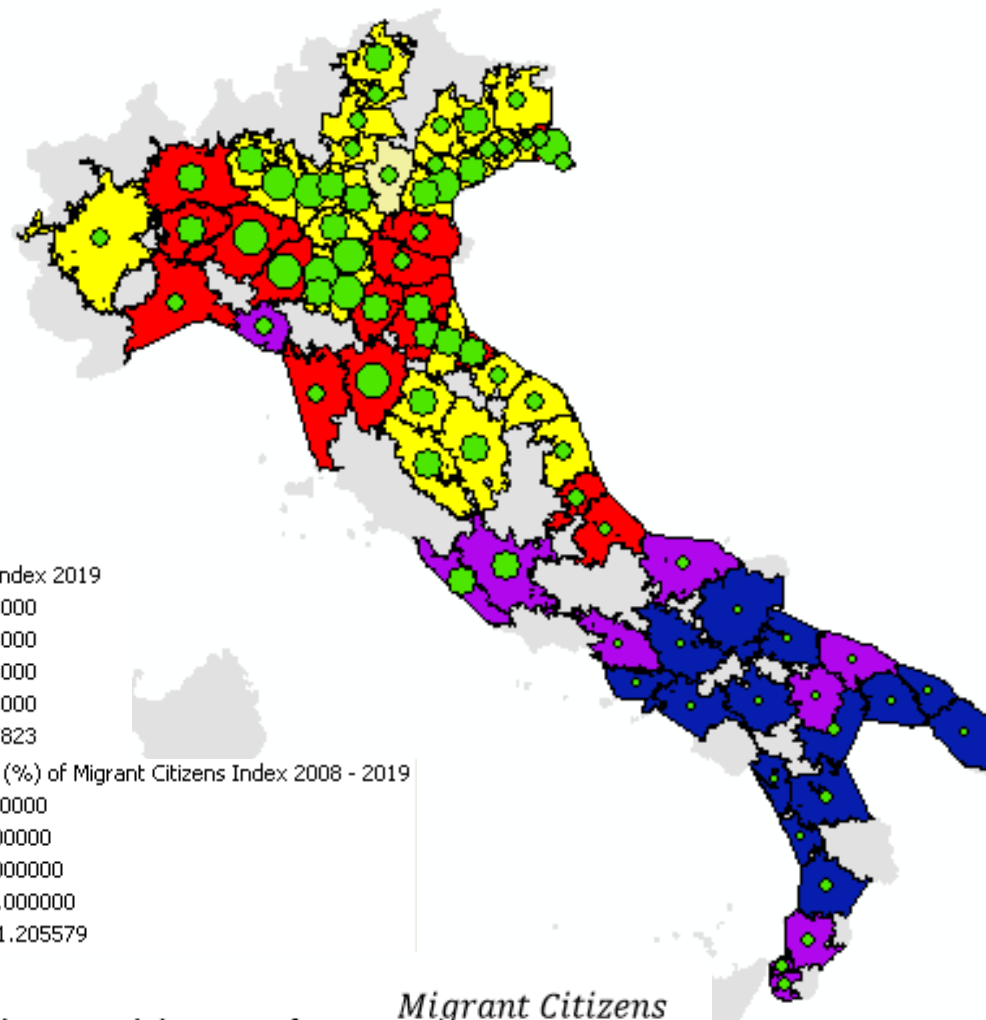- 76.600001 - 124.500000
- 124.500001 - 204.366966
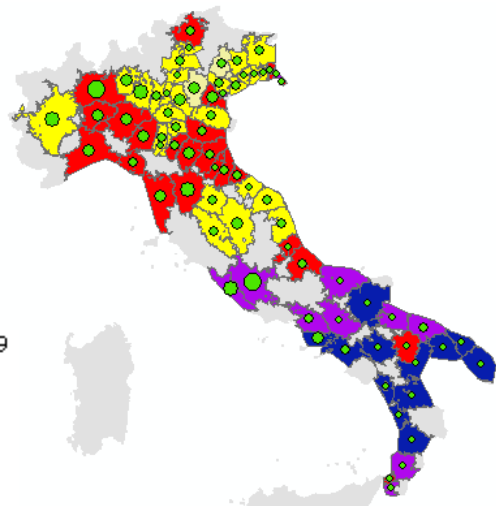
Total Citizens

Total Citizens 2019
- 39722.161878 - 227152.208011
- 227152.208012 - 526221.362512
- 526221.362513 - 937706.000402
- 937706.000403 - 1742717.566498
- 1742717.566499 - 5987358.880321

Relative Change (%) of Total Citizens 2008 - 2019
- -5.664497 - -3.077961
- -3.077960 - 0.000000
- 0.000001 - 1.600000
- 1.600001 - 5.500000
- 5.500001 - 9.603470
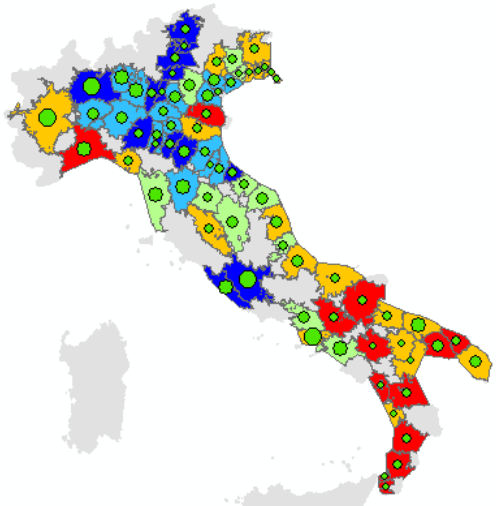
Migrant Citizens index 2019
- 0.023911 - 0.050000
- 0.050001 - 0.070000
- 0.070001 - 0.100000
- 0.100001 - 0.120000
- 0.120001 - 0.137823

Relative Change (%) of Migrant Citizens Index 2008 - 2019
- -1.966334 - 0.000000
- 0.000001 - 44.000000
- 44.000001 - 68.000000
- 68.000001 - 121.000000
- 121.000001 - 211.205579

$$Migrant\ Citizens\ Index = \frac{Migrant\ Citizens}{Total\ Citizens}$$

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9

Relative Change of Population (%)
Young (0-14) Citizens

Young (0-14) Citizens Index

Young (0-14) Citizens 2019
- 4724.681563 - 29605.000000
- 29605.000001 - 55352.000000
- 55352.000001 - 98261.000000
- 98261.000001 - 234883.000000
- 234883.000001 - 808930.220812

Relative Change (%) of Young (0-14) Citizens 2008-2019
- -20.725890 - -13.000000
- -12.999999 - 0.000000
- 0.000001 - 0.000000
- 0.000001 - 7.000000
- 7.000001 - 13.932621

Total Citizens

Total Citizens 2019
- 39722.161878 - 227152.208011
- 227152.208012 - 526221.362512
- 526221.362513 - 937706.000402
- 937706.000403 - 1742717.566498
- 1742717.566499 - 5987358.880321

Relative Change (%) of Total Citizens 2008 - 2019
- -5.664497 - -3.077961
- -3.077960 - 0.000000
- 0.000001 - 1.600000
- 1.600001 - 5.500000
- 5.500001 - 9.603470
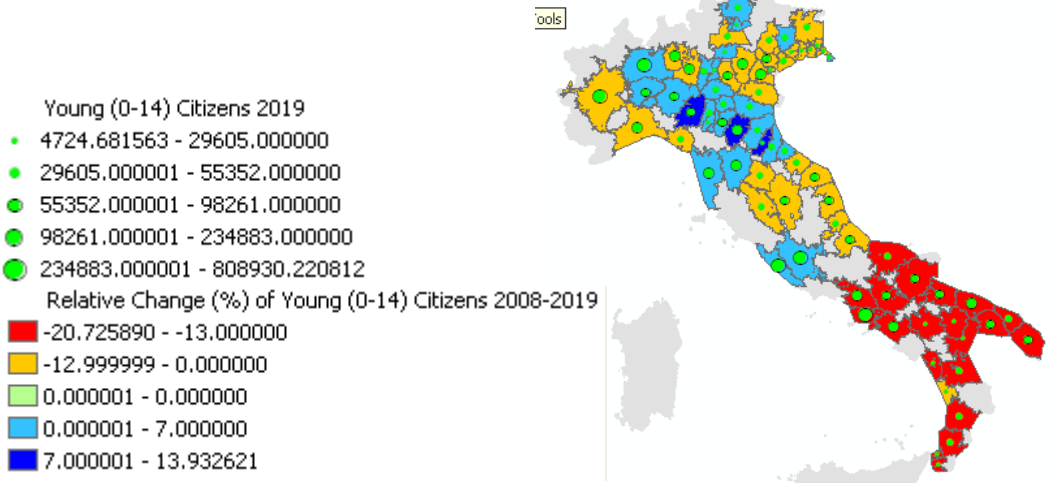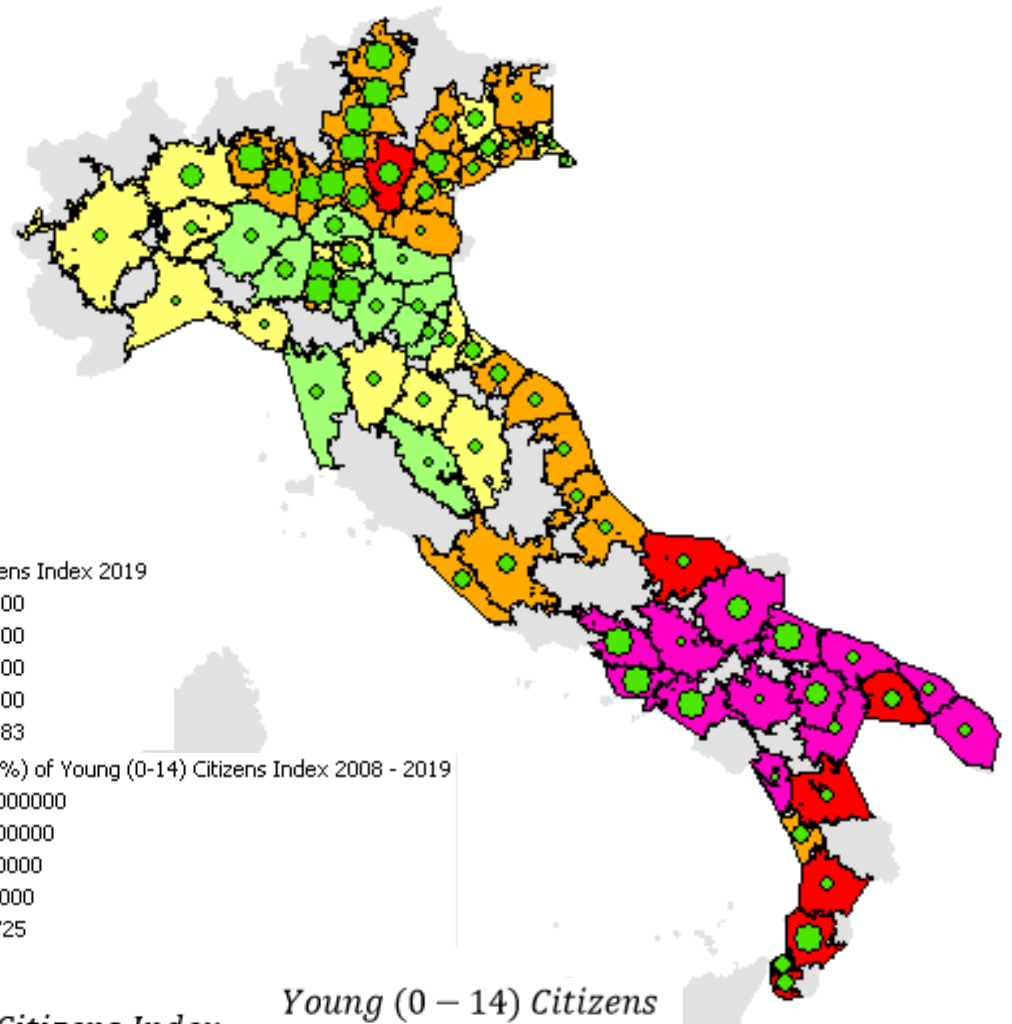
Young (0-14) Citizens Index 2019
- 0.110016 - 0.120000
- 0.120001 - 0.130000
- 0.130001 - 0.135000
- 0.135001 - 0.140000
- 0.140001 - 0.155883

Relative Change (%) of Young (0-14) Citizens Index 2008 - 2019
- -18.010492 - -13.000000
- -12.999999 - -8.000000
- -7.999999 - -3.000000
- -2.999999 - 0.000000
- 0.000001 - 5.281725

$$Young\ (0-14)\ Citizens\ Index = \frac{Young\ (0-14)\ Citizens}{Total\ Citizens}$$

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Relative Change of Population (%)
Young (15-34) Citizens

Young (15-34) Citizens 2019
- 7281.990447 - 38070.000000
- 38070.000001 - 94263.000000
- 94263.000001 - 182744.000000
- 182744.000001 - 343596.000000
- 343596.000001 - 1188042.226668

Relative Change (%) of Young (15-34) Citizens 2008-2019
- -21.532265 - -14.000000
- -13.999999 - 0.000000
- 0.000001 - 0.000000
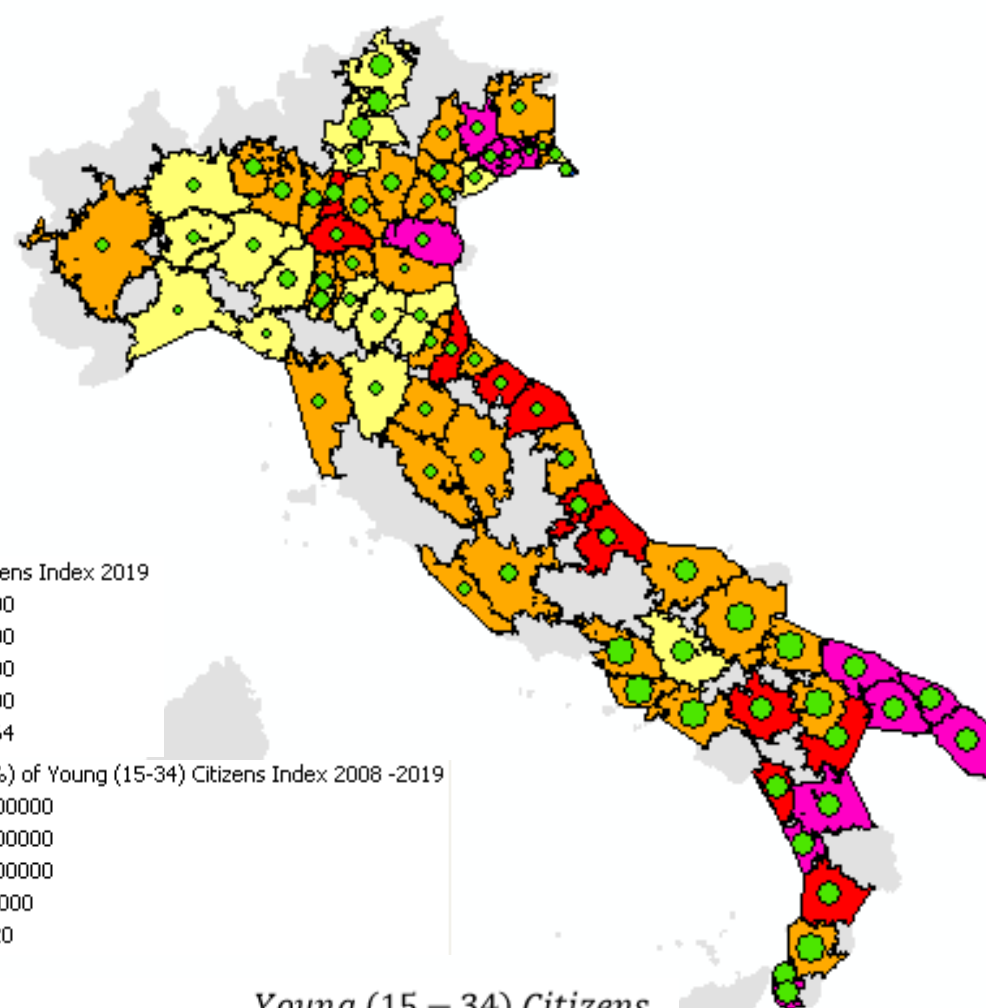- 0.000001 - 1.000000
- 1.000001 - 2.931699
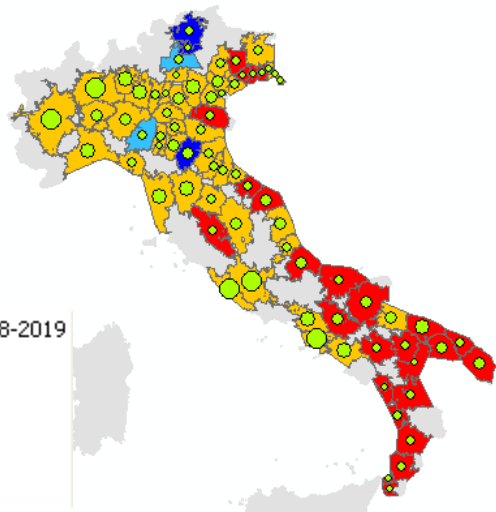
Total Citizens

Total Citizens 2019
- 39722.161878 - 227152.208011
- 227152.208012 - 526221.362512
- 526221.362513 - 937706.000402
- 937706.000403 - 1742717.566498
- 1742717.566499 - 5987358.880321

Relative Change (%) of Total Citizens 2008 - 2019
- -5.664497 - -3.077961
- -3.077960 - 0.000000
- 0.000001 - 1.600000
- 1.600001 - 5.500000
- 5.50001 - 9.603470

Young (15-34) Citizens Index
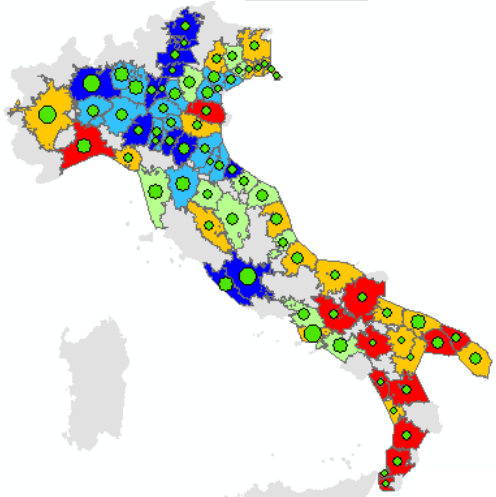
Young (15-34) Citizens Index 2019
- 0.171253 - 0.180000
- 0.180001 - 0.200000
- 0.200001 - 0.210000
- 0.210001 - 0.230000
- 0.230001 - 0.249364

Relative Change (%) of Young (15-34) Citizens Index 2008 -2019
- -19.090095 - -16.000000
- -15.999999 - -14.000000
- -13.999999 - -11.000000
- -10.999999 - 0.000000
- 0.000001 - 0.317620

$$Young\ (15-34)\ Citizens\ Index = \frac{Young\ (15-34)\ Citizens}{Total\ Citizens}$$

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11

Relative Change of Population (%)
Total Citizens in
no-working age

Structural Dependence Index


Total Citizens in no-working age 2019
- 15638.487960 - 89722.600000
- 89722.600001 - 183218.600000
- 183218.600001 - 365288.200000
- 365288.200001 - 610224.800000
- 610224.800001 - 2180295.211738

Relative Change (%) of Total Citizens in no-working age 2008 - 2019
- -6.084766 - -2.900000
- -2.899999 - 0.000000
- 0.000001 - 7.600000
- 7.600001 - 10.700000
- 10.700001 - 14.502523
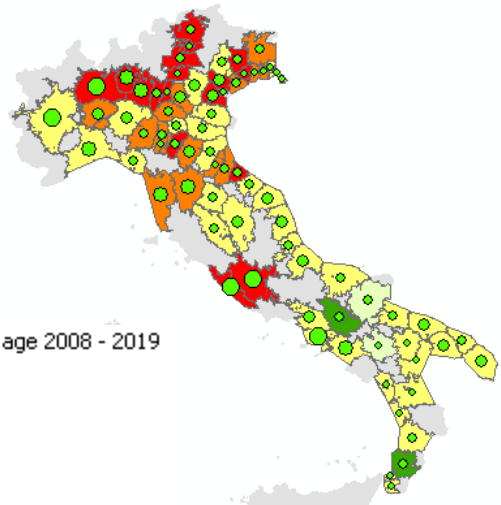
Total Citizens in working age

Total Citizens in working age 2019
- 24083.673919 - 148938.800000
- 148938.800001 - 306383.400000
- 306383.400001 - 566225.100000
- 566225.100001 - 1132492.700000
- 1132492.700001 - 3807063.668583

Relative Change (%) of Total Citizens in working age 2008 - 2019
- -8.140471 - -5.700000
- -5.699999 - -3.600000
- -3.599999 - 0.000000
- 0.000001 - 3.000000
- 3.000001 - 7.458369
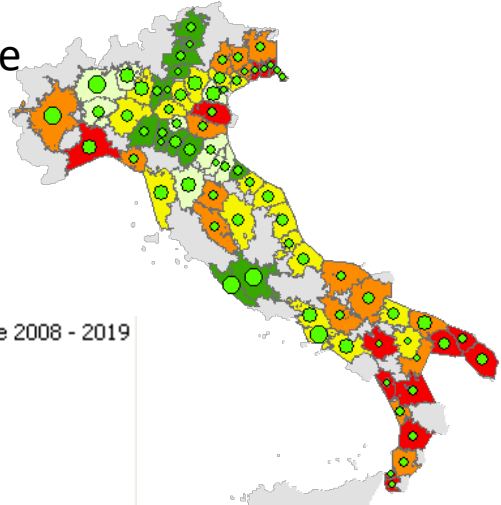
Structural Dependence Index 2019
- 0.487403 - 0.530000
- 0.530001 - 0.560000
- 0.560001 - 0.580000
- 0.580001 - 0.610000
- 0.610001 - 0.661978

Relative Change (%) of Structural Dependence Index 2008 - 2019
- -0.685225 - 0.000000
- 0.000001 - 8.000000
- 8.000001 - 10.000000
- 10.000001 - 14.000000
- 14.000001 - 17.984375
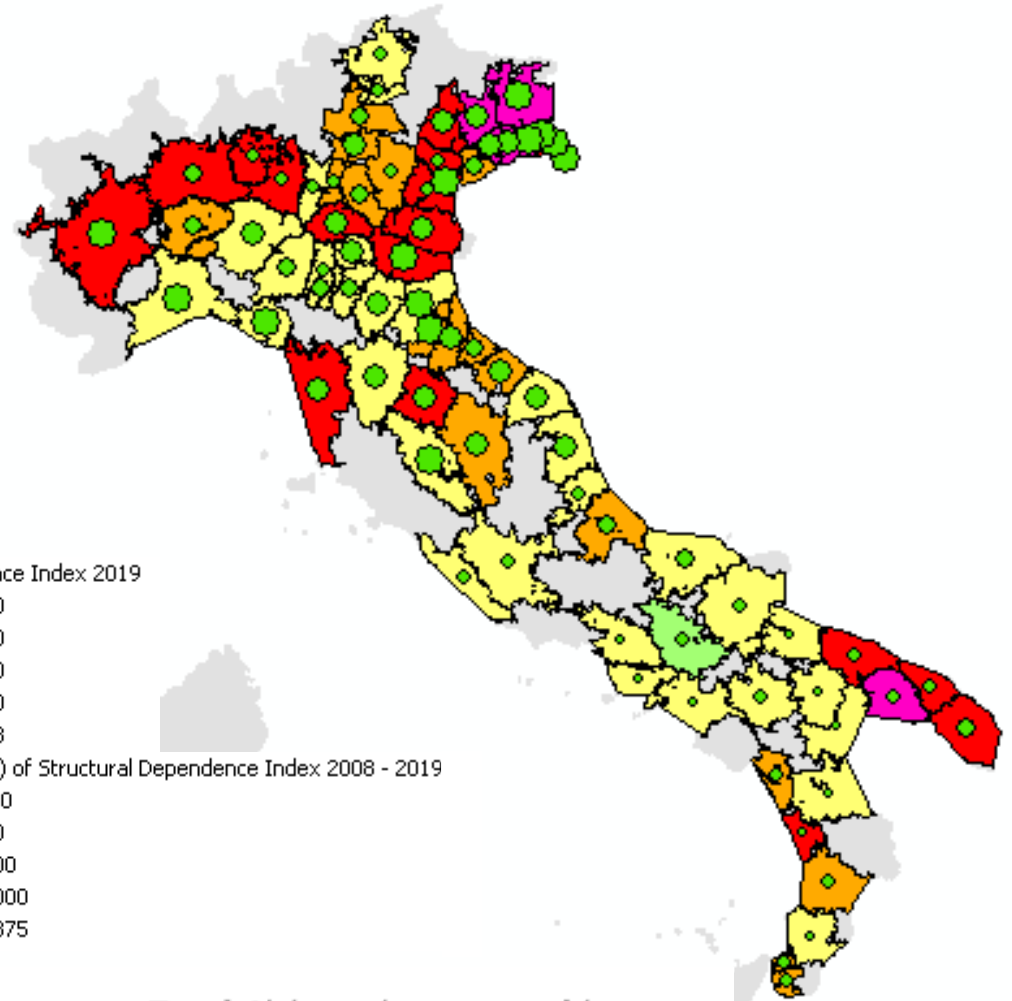
$$\text{Structural Dependence Index} = \frac{\text{Total Citizens in no} - \text{working age}}{\text{Total Citizens in working age}}$$

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12

Results

Did high-speed rail affect demographics in Italy?

	Accessibility Index	R-squared
Aging Index	$1,127^{***}$ $(0,113)$	$0,579$
Migrant Citizens Index	$2,919^{***}$ $(0,278)$	$0,605$
Young (0-14)Citizens Index	$-0,414^{***}$ $(0,074)$	0.362
Young (15-35)Citizens Index	$-0,682^{***}$ $(0,069)$	$0,489$
Structural Dependence Index	$0,358^{***}$ $(0,053)$	$0,336$

Table 1 – Regression Results

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Conclusions and Future Directions

Conclusions:

- The introduction of high-speed rail services alone is unable to change the course of **demographic trends**. Demographic changes are influenced by a complex **interplay of factors that extend beyond the realm of transportation infrastructure.**

- **The accessibility positively influences the dynamics of key demographic indicators**, namely the aging index, migrant citizens index, and structural dependency index.

- Accessible locations tend to attract **weaker demographic classes**, resulting in migration patterns that affect demographic composition.

Future Directions

- Analyze the relationship between accessibility and the **speed of the decline in births** (second derivative)

- **Alternative measures** of accessibility (e.g., potential);

- Adoption of **Multilevel models** to capture territorial clusters.

13 September, 2023

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