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Indicators of accessibility and travel times

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January 7, 2025

Abstract

The next three chapters move to the notion of accessibility and tackle the question of how correctly measuring it, a prerequisite for any policy to improve it. This study builds indicators of accessibility in terms of travel times and applies them a grid of one-by-one kilometer cells for the Italian territory. This analysis allows to have a map of accessibility in Italy that is completely detached from administrative boundaries. The results show the complex interaction between *first-nature* and *second-nature* geography in shaping the accessibility of the various territories.

Keywords: Accessibility; Travel times; Spatial analysis; Transport geography

JEL codes: R41, R12, O18

1. Introduction

Over the last decade, both economic and transportation literature have shown a growing interest in the ease with which people can reach desired destinations, and the time they spend in reaching these locations.

Accessibility is typically quantified through a variety of indices that reflect the proximity of goods, services, and employment opportunities to individuals or firms. It encompasses different meanings, depending on whether the focus is on access to public services, employment, recreational and cultural activities, public transport, transport infrastructure, high-speed services, or information and communication technologies. Accessibility is closely tied to concepts like proximity (referring to reduced distance, where distance measurement goes beyond basic geometry), mobility (the ability to move using transportation systems), and connectivity (the links within a network).

Travel times are the other side of the coin. They are a proxy of transport costs and an important feature of market potential (Matas et al., 2018), reflecting time costs and the flows of people, goods, and information. Since the eighteenth century, technological advancements have led to reduced costs and faster speeds, resulting in greater volumes and more intricate patterns of flows. These developments have significantly influenced urban mobility patterns, the spatial distribution of activities, and location choices.

The discussion of accessibility and travel times is not always straightforward, as both concepts encompass a wide range of dimensions and intersect with various fields. In this research, we try to keep things as simple as possible, focusing on selected measures of accessibility and travel times. Without the use of engines, traveling across a territory is purely a matter of topography, what in the economic literature is called *first-nature* geography. In this sense, walking travel times offer a representation of the physical landscape. The endowment and quality of transport infrastructure, instead, provide a different perspective on travel times, also reflecting the *second-nature* geography of an area. This distinction implies that when we focus on a specific form of mobility, such as motorized travel times, we exclude other factors related to the movement of people and goods, such as delays, waiting times for public transportation, and intermodal mobility.

We aim to provide a clear overview of both travel times and accessibility in Italy at different territorial units, taking advantage of the availability of newly detailed data. We also aim to understand whether this granular information offers a more accurate representation compared to data aggregated at administrative levels.

Adopting a grid cell perspective introduces a novel approach to country-level analyses. Typically, accessibility and travel time assessments are conducted using smaller administrative divisions, such as municipalities (LAU) or NUTS 3 regions, and are shaped by governance frameworks. However, important details can be obscured by the aggregation required at these levels, potentially leading to biased results. A grid cell approach allows for capturing significant internal variability within municipalities, often overlooked by more aggregated data, and provides more balanced findings that account for both geographical and human-driven factors.

In recent years, advancements in geospatial techniques and models, the use of geocoded data on transportation infrastructure, and the availability of satellite data on topographical, geographical, and demographic features have significantly elevated the importance of travel times and costs, as well as market access, in the assessment of socio-economic development and in improving access to public and private services. In this research, we compute and investigate travel times and accessibility for Italy using different indicators. We want to take advantage of this very granular decomposition of the Italian territory, completely detached from administrative boundaries, measuring travel times *within* grid cells of one-by-one kilometer, and computing accessibility to cities and ports at the same territorial level. We examine these measures relating them to geography, main transport infrastructure endowment, and urbanization. We also expand our view and analyze the same indicators for the Italian municipalities (LAU) and for NUTS 3 regions, providing a perspective more linked to institutional considerations.

The results show a large variability across Italy. Favorable geography is a key factor in determining lower travel times and higher accessibility. However, our findings suggest that *second-nature* geography plays a crucial role in traveling using the motorized transport infrastructure and, in turn, in accessing cities and ports. Although more disadvantaged topography in some areas of northern Italy, accessibility and time costs are not as negatively impacted. This contrasts with the South and the Islands, where more favorable geography, like the proximity to the sea, is not supported by an adequate infrastructure, resulting in less efficient access.

2. Outline of literature background

Although interest in accessibility and travel times has gained renewed emphasis in recent years, particularly in economic literature, the importance of measuring and accounting for ease of access to various locations within reduced travel times is a well-established concept in transportation and land-use planning literature. Early studies, such as those by Harris (1954) and Hansen (1959), demonstrate that areas with good accessibility are more likely to be developed and at higher densities compared to remote locations, making the latter less attractive. The freedom of individuals to choose whether to engage in different activities (Burns, 1979), facilitated by a specific transport system (Dalvi and Martin, 1976), and the advantages offered by integrated transportation and land-use systems (Ben-Akiva and Lerman, 1979), are just a few of perspectives used to analyze accessibility. Other research concentrated specifically on the measurement of accessibility itself. Geurs and van Wee (2004) offer a comprehensive review of accessibility measures, according to various factors and components. Ingram (1971) uses the concept of relative accessibility, i.e. the extent to which two locations or points on the same surface are connected. Similarly, indexes based on the number of opportunities that can be accessed within a specified travel time, distance, or cost— along with the time or cost required to reach a fixed number of opportunities— have been developed starting from Wickstrom (1971) and Wachs and Kumagai (1973). Since then, a large number of studies have contributed to the understanding and analysis of a topic that is both complex and ever-relevant.

Research belonging to the urban economic literature focused mainly on accessibility and travel times at the regional level, examining how and whether transportation systems optimize resources and achieve intended goals, such as improving mobility, reducing travel time, and enhancing connectivity.

Analyses at the subregional level were not so common until recent times. In 2008, the Joint Research Center released the first global map of travel times to major cities. The accessibility map, along with corresponding raster data at a resolution of 30 arc-seconds, was developed by Nelson (2008) in collaboration with the World Bank's Development Research Group. Travel times to cities with a population of at least 50,000 inhabitants, referring to 2000, were quantified considering geographical frictions, national borders, and the type and quality of transport infrastructure. This pioneering work was later followed by an updated map and data by Weiss et al. (2018), who computed travel times to cities for 2015 at a spatial resolution of approximately one-by-one kilometer. In 2020, Weiss and coauthors produced a global map of travel times to healthcare facilities. The map is combined with walking-only and motorized friction surfaces that compute and provide the geographical barriers and infrastructural facilities that make the movement within the grid cell easier or costlier. Similar to these works, the contribution by Christodoulou et al. (2020) accounted for urban accessibility and congestion, constructing a dataset for European cities with populations of at least 250,000 people. Their findings indicate that congestion is negatively correlated with access to cities, and that accessibility serves as a good proxy for congestion and traffic.

Research on commuting has long attracted the interest of scholars from various fields. In economics, the primary goal is to save costs. For policymakers, understanding how individuals react to increased travel times and costs or switch to other transport modes due to congestion is fundamental for adopting the correct strategies to avoid costs in commuting. Additionally, understanding commuting goes beyond the central need to find policies aimed at reducing costs. Inequality is one of the dimensions that commuting involves: differences in accessibility and travel times exacerbate disparities in societies, making the cost of travel and access to services an extra burden for individuals. Jacob et al (2019) show how the increase in commuting times reduces female well-being, but does not affect men. Differences relate also to race. Bunten et al. (2024) provide evidence of significant differences between Black and White workers' commute times: although during the last 40 years the gap has narrowed, in large cities the time to reach the workplace is higher for Black people. Recently, city-level and census data have been used to assess the burden of commuting. Devin et al. (2024) exploit ZIP-code-level data on residential and workplace locations to measure differences in commuting between Black and White workers. Fuchs et al (2024) explore the gender commuting gap using geocoded administrative data about the residence and workplace for each worker.

The availability of newly collected and constructed geocoded data has made possible a further improvement of research at the subregional level. Smartphones' circulation and apps for mobile phones created novel sources of data for recent empirical research. In the seminal work by

González et al. (2008), the authors use geocoded data from mobile phones to analyze human mobility patterns, demonstrating the utility of mobile-generated data for fine-grained geographic research. Akbar et al. (2023) and Couture et al. (2018) rely on the Google Maps route-finding feature to estimate car travel times at different hours of the day in the US and India. Miyauchi et al. (2021) and Kreindler (2024) use smartphone GPS records to measure urban traffic in Japan and Bangalore, respectively.

3. Data and descriptive statistics

We make use of geocoded data in raster (geotiff) format (1x1 km, 30 arc-second cells) for the entire Earth's surface to implement a *within* territories analysis in Italy.

The raster data derives from six different global accessibility maps generated using a GIS (Geographic Information System) model by Weiss, Nelson, Vargas-Ruiz et al. (2020) and by Weiss, Nelson, Gibson et al. (2018).

Our first source of data is represented by a global walking-only friction surface, as in the paper by Weiss, Nelson, Vargas-Ruiz et al. (2020). The authors compute the time to walk across a pixel of one-by-one kilometer, providing speeds in minutes per meter. The friction surface considers the geography of each pixel and the endowment in terms of transportation infrastructure in 2019. They assume a walking speed of 5 km per hour if the grid cell is endowed with roads, and a swimming speed of 1 km per hour to cross a territory with water bodies.

The second source of data is represented by a global friction surface including land-based travel speed, expressed in minutes per meter, with access to motorized transport. Weiss, Nelson, Vargas-Ruiz et al. (2020) compute all travel times to cross each cell of the Globe using roads and/or other motorized transport infrastructure in 2019. The global friction surface accounts for the geographical features (landscape characteristics, land cover types, elevation, slope, waterways and bodies of water), transport infrastructure (roads, railways, navigable rivers), and countries' borders.[1]

Our third source of data is a raster file linked to a paper by Weiss, Nelson, Gibson et al. (2018) and consists of travel times (in minutes) needed to access the nearest city of at least 50,000 inhabitants from each pixel of the Earth's surface using the motorized transport infrastructure in 2015. Travel times have been computed after constructing a friction surface, representing the cost in terms of time associated with moving through different geographies and transport infrastructure endowments. The difference between the friction surface used in Weiss, Nelson, Vargas-Ruiz et al. (2020) and the one constructed by Weiss, Nelson, Gibson et al. (2018) lies in

[1] We downloaded the data about the "Global Walking Only Friction Surface" and "Global Motorized Friction Surface" linked to research paper by Weiss, Nelson, Vargas-Ruiz et al. (2020) from the Malaria Atlas Project (MAP, https://data.malariaatlas.org/maps).

the accuracy of the number of roads and road speeds for developing countries included: the former is more detailed, updating the friction surface used for travel times to cities in 2015. Both raster data use OpenStreetMap and Google Roads to extract information about roads and railways and their speed. The fastest road in each cell determines the speed at which that specific pixel can be traversed. Unlike roads, railways are not differentiated by type, and a uniform speed is assigned for movement.

The fourth source of data is represented by three global accessibility maps to ports. Weiss, Nelson, Gibson et al. (2018) compute travel times (in minutes) using the motorized transport infrastructure to the nearest large, medium and of any size port in 2015.[2] Information about ports has been sourced from "World Port Index 26th edition" by NGA (2017).[3]

The analysis *within* grid cells is completed by other four main sources of data about geography, urbanization, and transport infrastructure. Nunn and Puga (2012) provide the data about the ruggedness of the territory. Elevation has been computed using the information from Jarvis et al. (2008). Data about the population at the grid cell level has been sourced from Istat. The information about motorways, railways and primary roads in 2019 comes from OpenStreetMap.

4. Methodology

Our analysis aims to understand and describe accessibility and travel *within* territories. We focus on territorial units of one-by-one kilometer, creating a grid composed of 306,929 equally-sized areas completely detached from administrative and institutional boundaries. To ensure that our research is comparable and can be integrated with other analyses, we use the grid cell shape file by Eurostat.[4] We also analyze the same indicators for the Italian municipalities (LAU) and NUTS 3 regions, providing a perspective more linked to institutional considerations.

Starting from the raster image files constructed by Weiss, Nelson, Vargas-Ruiz et al. (2020) and by Weiss, Nelson, Gibson et al. (2018), we use a GIS methodology based on the zonal statistics of the raster analysis in QGIS[5] to compute territorial averages for all Italian grid cells, municipalities and provinces (NUTS 3) and provide accessibility and travel times as minutes per one kilometer.

Raster files data is stored in TIFF format (Tagged Image File Format), which requires GIS tools to extract meaningful information and convert the pixel-based data into usable, quantitative

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[2] The authors also compute travel times to small and very small ports. We don't take into account these data in our analysis.

[3] Data about travel times to cities and ports have been downloaded from https://figshare.com/articles/dataset/Travel_time_to_cities_and_ports_in_the_year_2015/7638134.

[4] https://ec.europa.eu/eurostat/web/gisco/geodata/grids.

[5] The same elaboration can be performed using ArcGIS.

insights. Each pixel within a raster file contains specific information, allowing researchers to analyze and manipulate the data at various scales, depending on the requirements of their study. This flexibility is particularly advantageous when researchers aim to perform geographical analyses that differ from those initially intended by the data's original authors. Raster files can also be overlaid with an unlimited number of shape files, enabling the integration of different geographical boundaries and layers to suit the specific research objectives.

In this study, we start with the raster files from Weiss, Nelson, Vargas-Ruiz et al. (2020) and Weiss, Nelson, Gibson et al. (2018), and we combine them with a detailed polygonal shape file of grid cells of one kilometer by one kilometer sourced from Eurostat. This high-resolution enables us to extract and compute averages with a high degree of precision, move beyond traditional administrative boundaries, such as municipalities, and perform a more refined geographical analysis.

A key advantage of using raster data combined by with a grid cell decomposition lies in the ability to conduct a novel spatial research for Italy, independent of administrative divisions or governance-driven considerations. Administrative-level statistics, such as those at the municipal level, often mask important variations. This is particularly true in geographically diverse regions, where mountainous or rural areas may face significantly longer travel times compared to urban centers, despite being part of the same administrative unit. Even in regions that appear homogenous, with generally high population density and well-developed transport infrastructure, there may still be pockets of reduced accessibility that are overlooked by more aggregated data.

By adopting a grid-based analysis, we can identify and address such disparities with much greater accuracy. This approach is especially valuable for identifying rural or underserved areas that may require targeted interventions, such as infrastructure improvements. Ultimately, grid-level analysis can lead to transport policies that are more closely aligned with local needs, promoting transport equity and ensuring that policy decisions are made with a nuanced understanding of accessibility at a finer geographic scale. This method allows policymakers to respond more effectively to the specific challenges faced by different regions, fostering more inclusive and balanced development across both urban and rural landscapes.

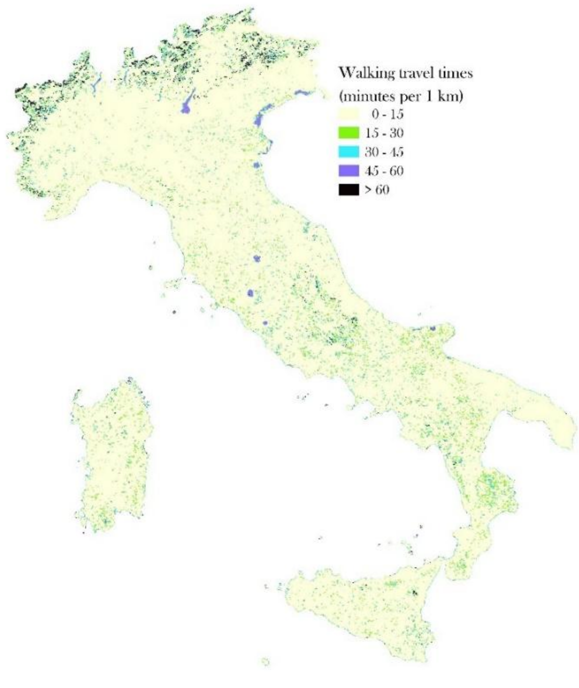
Due to the large number of observations, we represent our computations using maps. Results are discussed in the following section.

5. Findings and discussion

On average, in Italy, the time to walk one kilometer is about 15 minutes. However, there exists a large variability across the territory: walking travel times range from a minimum value of 12 minutes, that is predominant in many areas of the peninsula, to a maximum value of 1143 minutes (about 19 hours) in the province of Verbano-Cusio-Ossola, in northwestern Italy. Is geography the key factor determining this variability? Italian geography is quite diverse; it ranges from towering mountains to vast plains and long coastlines. The Alps in the North separate Italy from France, Switzerland, Austria, and Slovenia. The Apennines, instead, running down the length of the peninsula, divide Italy into its western and eastern parts. 35% of the territory is mountainous, 42% hilly, and 23% flat. The coastline consists of more than 7,600 km and two NUTS 2 regions are large islands in the Mediterranean Sea, Sicily and Sardinia. In these terms, Italian geography can be considered neither advantageous nor easy.

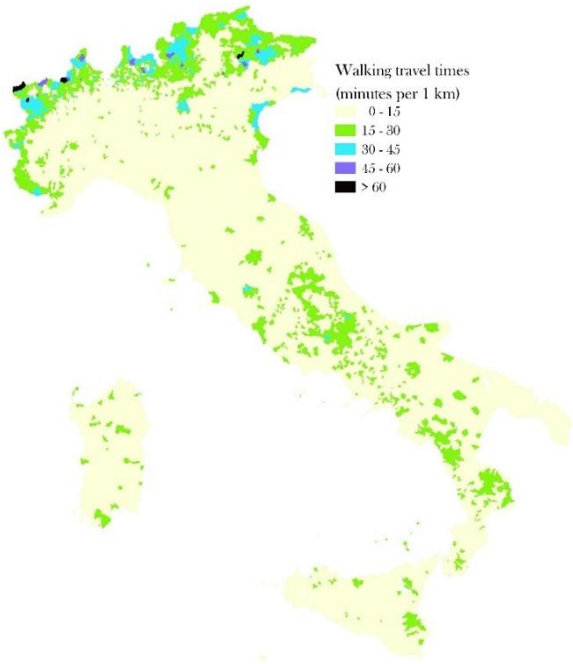
Figure 3.1 provides a clear picture of the time needed to cross one kilometer inside an area of one square kilometer. Most grid cells lie in the first category: 12 minutes is the predominant walking travel time in Italy, covering 87.7% of the peninsula. Mountainous areas are those registering the highest times to walk 1 km: in 3,486 cells (1.1% of Italy) more than 1 hour is needed to travel 1 km. Elevation and ruggedness are good proxies of walking travel times; water bodies, instead, act as obstacles slowing down movement. Differences across grid cells become clearer in Figure 3.2, where walking travel times are averaged at the LAU level. Green spots are widespread in many regions. Municipalities, where more than 30 minutes are needed to travel one kilometer, are, instead, concentrated in northern Italy. However, the overall picture is favorable. Despite vast differences between flatter and rougher areas, almost 90% of the Italian territory shares the same pedestrian time estimates, suggesting the importance of geography, but the relative effect it has.

Figure 3.1. Walking travel times in 2019 (minutes per km), grid cells



Source: own elaboration on Weiss, Nelson, Vargas-Ruiz et al. (2020) data

Figure 3.2. Walking travel times in 2019 (minutes per km), municipalities

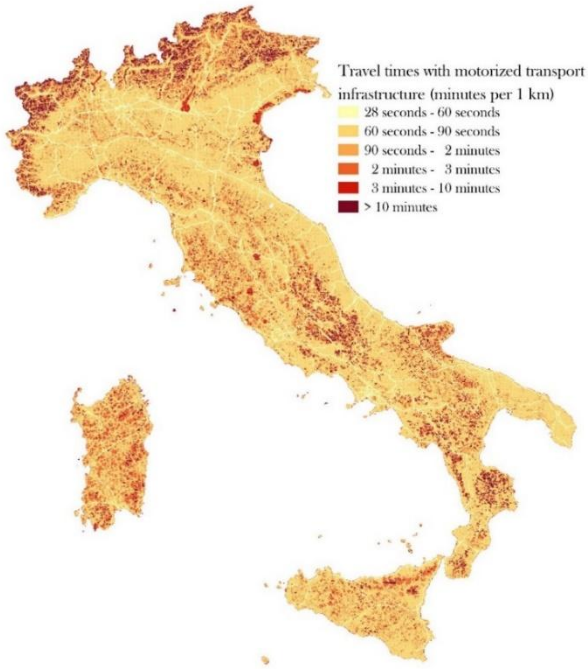


Source: own elaboration on Weiss, Nelson, Vargas-Ruiz et al. (2020) data

Incorporating the motorized transport network, and thus the possibility of using vehicles, introduces an extra element to the analysis. On average, in Italy, the minutes required to cross 1 km of territory using motorized means of transport are 3.7. This means more than 3 and a half minutes. However, as for pedestrian travel durations, there is a huge variability across the territory: travel times range from a minimum value of 0.46 minutes (about 28 seconds) to a maximum of 1143 minutes (about 19 hours), where the main factors determining this variability are the geographical features of the land and the land transport infrastructure. In this case, geography affects, on the one hand, the time of travel and, on the other hand, it affects the construction of the motorized network. The Italian motorway system is extensive, with over 6,700 km of highways, and a high-speed rail network. In terms of grid cells of one-by-one kilometer, 9,451 and 22,894 out of 306,929 cells are crossed by the motorways and railways, representing 3% and 7.5% of the total number of cells, respectively. Grid cells crossed by a primary road are 32,994, representing 10.7% of all grid cells.

Figure 3.3 shows the time needed to travel one kilometer with the transport infrastructure *within* a grid cell of one-by-one kilometer in 2019. About 5% of the Italian territory (16,501 grid cells) lies in the first category: less than one minute is used to travel one kilometer. However, unlike walking travel times for which geography was important, but didn't completely rule pedestrian journey durations, for motorized travel times, there seems to exist greater importance linked to geographical features. Moreover, differences between more and less developed areas as well as the presence and placement of the main transport infrastructure (the *second-nature* geography) seem to be key factors in making travel times higher. It immediately emerges how the island of Sardinia consists of several dark areas, suggesting that there is indeed challenging geography, but also an infrastructure deficit. This scenario is confirmed, focusing also on municipalities. Figure 3.4 maps travel times involving the use of motorized transport infrastructure at the LAU level. What becomes clearer is the difference between northern and southern Italy. If in the North the correlation between ruggedness, elevation, and travel times with the motorized infrastructure is 0.34 and 0.37, respectively; in the South, these correlations are 0.25 and 0.27,[6] suggesting that geography plays a larger role in northern Italy, and that longer travel times in the South or central Italy may be less due to disadvantageous geography. Table 1.1 in the Appendix averages travel times at the NUTS 3 level. The first 14 ranks, except for L'Aquila at the foothills of the Gran Sasso in the South, are all northern provinces in the Alpine region. Following these are the provinces of Cosenza (rank 15) and Crotone (rank 17) in Calabria, despite their average elevation being lower and their geography being less challenging compared to the mountainous NUTS 3 regions at the top positions.

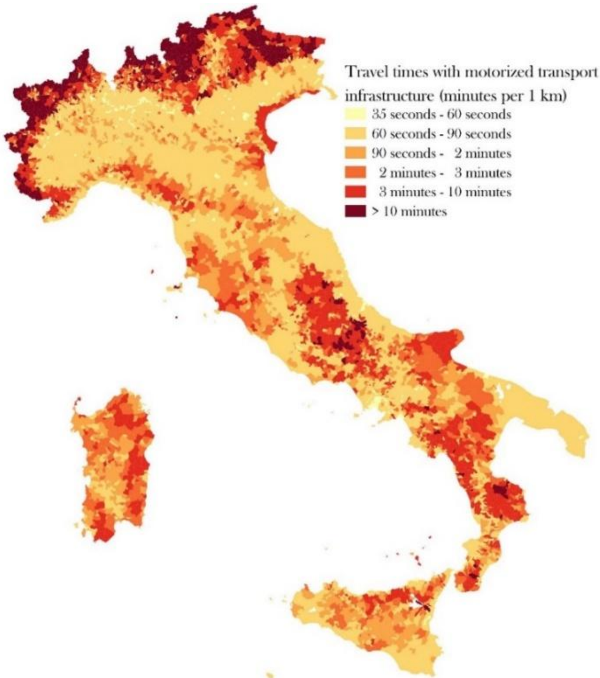
Figure 3.3. Travel times with motorized transport infrastructure in 2019 (minutes per km), grid cells



Source: own elaboration on Weiss, Nelson, Vargas-Ruiz et al. (2020) data

[6] In the Center they are 0.26 for ruggedness and 0.25 for elevation.

Figure 3.4. Travel times with motorized transport infrastructure in 2019 (minutes per km), municipalities



Source: own elaboration on Weiss, Nelson, Vargas-Ruiz et al. (2020) data

We add a further piece of information to the puzzle of travel times in Italy, considering travel times to cities of at least 50,000 inhabitants in 2015. This measure, compared to the previous ones, is less tied to geographical considerations and can be considered a measure of accessibility and market potential. Moreover, it allows for an assessment of accessibility to a broad range of services, such as schools, universities, hospitals and healthcare facilities, public offices, financial institutions, sports, and recreational centers.

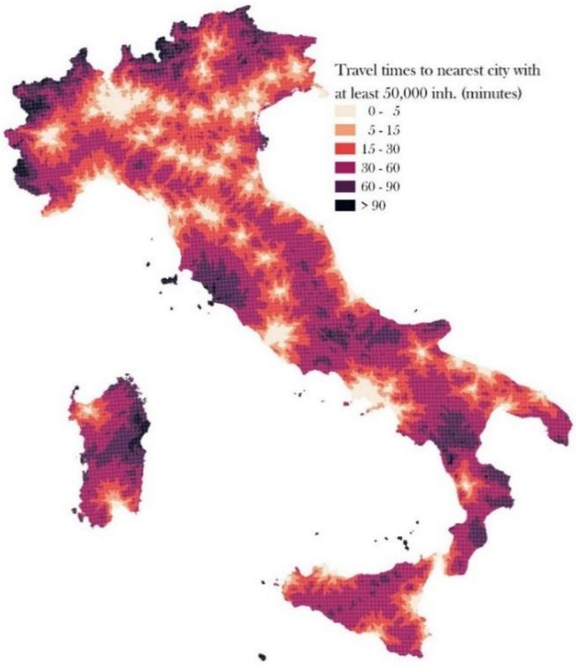
On average, in Italy, more than 35 minutes are needed to reach a large urban center, with peaks of 633 minutes (more than 10 and a half hours) in some areas. This large variability is represented in Figure 3.5. In lighter grid cells, the maximum time to reach a city is 5 minutes. Darker areas range from a minimum time of 60 minutes to more than 10 and a half hours.[7] Northern Italy, again, and coastal areas present higher accessibility to cities, while some areas lack a large city as a provider of services and facilities.[8] According to the 2021 census, 140 cities

[7] Since the measure pertains to geospatial data, the actual degree of urbanization in some populated areas does not perfectly align with census data. As a result, the population of urban centers with more than 50,000 inhabitants is underestimated in some cases: we are aware of this issue.

[8] Despite some urban centers exceed 50,000 inhabitants, the source data does not classify them as large cities. This underestimation in the source data does not compromise the analysis but rather strengthens it by considering only the largest cities as providers of public

in Italy are populated by more than 50,000 inhabitants; they were 141 in 2011. 35% of these urban centers are in the North, 33% in the South, 20% in the Center, and 13% in the Islands. Indeed, on average, the NUTS 1 area registering the shortest travel times to the nearest urban center is the North-East, with 28 minutes. In the North-West, instead, 36 minutes are needed. Central Italy registers an average travel time of 34 minutes; in the South and in the Islands, instead, the required minutes to reach a city with at least 50,000 people are 38 and 42, respectively. However, if we consider as a large urban center a city with at least 100,000 inhabitants, travel times increase and the number of municipalities drops to 46: 50% are in the North, 20% in the South, 17% in the Center, and 13 in the Islands. Table 3.1 in the Appendix lists travel times to urban centers for the 107 Italian NUTS 3 regions, ranked in descending order.

Figure 3.5. Travel times to the nearest city with at least 50,000 inhabitants in 2015 (minutes), grid cells



Source: own elaboration on Weiss, Nelson, Gibson et al. (2018)

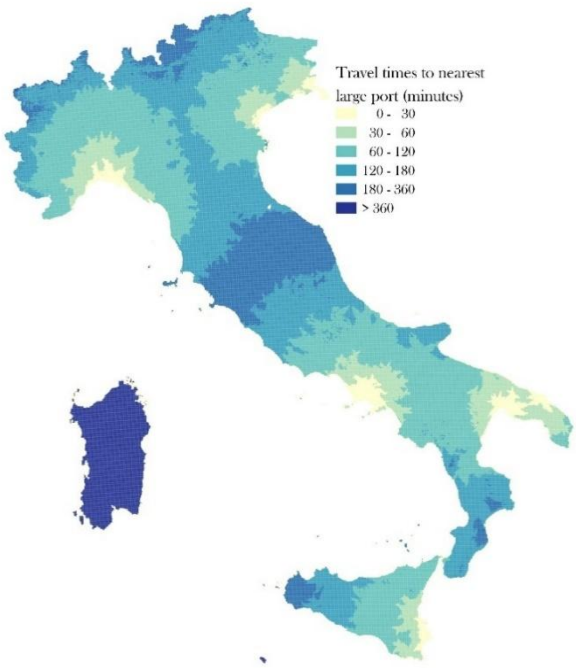
Travel times to ports are our last measure under scrutiny. According to Assoporti,[9] Italy has a total of 62 ports of national interest. On the one hand, ports serve as critical nodes in global trade by enabling the movement of goods across countries and acting as hubs for logistics and supply chains. On the other hand, ports contribute to regional connectivity by improving access to markets and integrating rural and urban areas into the global economy. We compute travel

and private services, which are known to offer a broader and more diverse range of activities and opportunities.

[9] Assoporti is the Association of Italian Ports.

times at the grid level to large, medium, and all categories of ports in Italy. Whether a port can be defined as large, medium, small, or very small depends on the definition provided by NGA (2017) in the "World Port Index". The index consists of different factors, including area, facilities, and wharf space, and considers 79 Italian ports. According to the index, Italy has 12 large ports: Genova and La Spezia in the North-West; Venezia and Trieste in the North-East; Civitavecchia and Livorno in central Italy; Brindisi, Gioia Tauro, Napoli, and Taranto in the South; Messina and Siracusa in Sicily. In Sardinia, the second island of the country, there are no large ports; Cagliari is categorized as a medium port. This important result is apparent in Figure 3.6, which shows travel times to the nearest large port in 2015. Sardinia, much of central Italy, certain areas in Sicily, and Calabria in the South experience high travel times to ports, comparable to those of landlocked regions in the North.

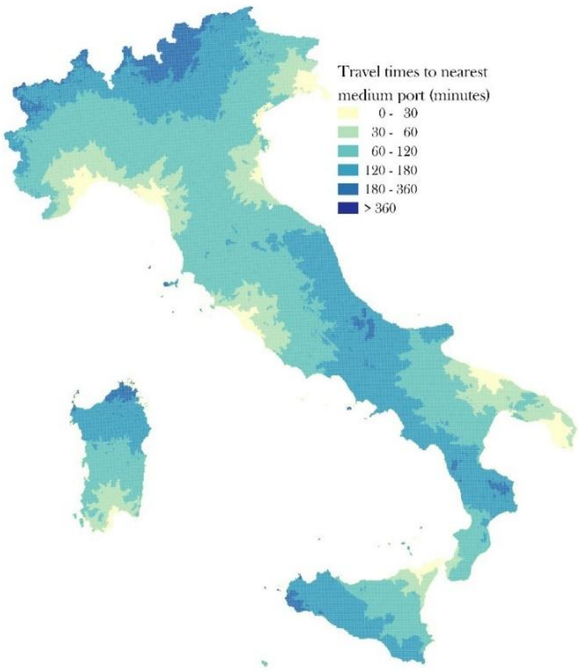
Figure 3.6. Travel times to the nearest large port in 2015 (minutes), grid cells



Source: own elaboration on Weiss, Nelson, Gibson et al. (2018)

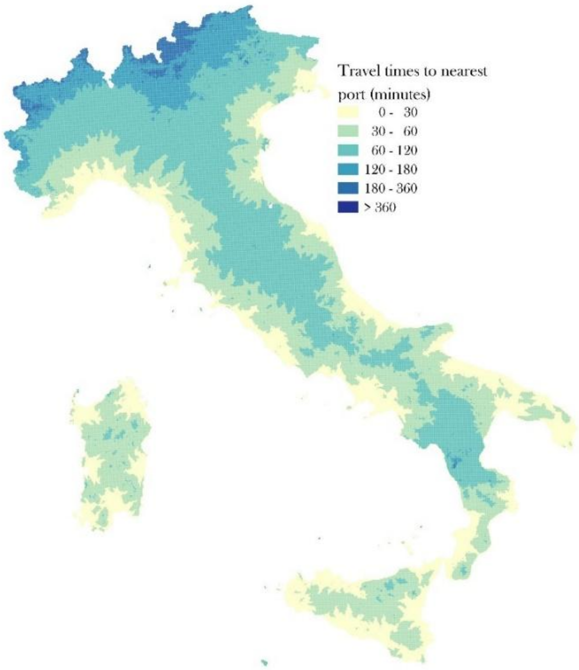
Considering medium-sized ports provides a more favorable picture for some regions. Italy has 10 medium ports: Rada di Vado in the North-West; Monfalcone in the North-East; Porto Corsini in the Center; Bari and Gallipoli in the South; Augusta, Catania, and Milazzo in Sicily; Cagliari and Sarroch in Sardinia. Figure 3.7 shows that now grid cells in northern Italy are those experiencing the highest travel times to reach a port. However, many southern territories and very large areas in the two islands still have travel times similar to those of northern areas, suggesting that being close to the coast does not mean having access to maritime facilities. This is an important result that highlights how the favorable geography of South Italy, in terms of access to the sea, is not supported by adequate access to infrastructure. Figure 3.8, which includes all types of ports, reconnects Italy's physical geography to the *second-nature* geography: grid cells closer to the coast are those closer to the maritime infrastructure.

Figure 3.7. Travel times to the nearest medium port in 2015 (minutes), grid cells



Source: own elaboration on Weiss, Nelson, Gibson et al. (2018)

Figure 3.8. Travel times to the nearest port of any size in 2015 (minutes), grid cells



Source: own elaboration on Weiss, Nelson, Gibson et al. (2018)

6. Policy implications and recommendations

The stark differences in travel times between northern and southern Italy, and in specific regions, point to infrastructure deficits. In some areas, rugged geography has hindered infrastructure development, but even flatter regions may face long travel times due to underdeveloped transport networks. In terms of policy, while natural geography cannot be changed, infrastructure can be developed to overcome geographical limitations. In this sense, solutions must be calibrated with the specific issues raised by different areas of the country. For example, where ruggedness and elevation significantly impact travel times, innovative engineering solutions are mostly required. Regions that lag well behind and experience high travel times, despite the less impacting geography, need clear strengthening interventions. The correlations between geography, infrastructure, and travel times identified in this paper can be used to inform infrastructure planning and prioritize areas that will benefit most.

Starting from the bigger picture - the national level - with only a small percentage of grid cells crossed by motorways (3%), railways (7.5%), and primary roads (10.7%), the analysis shows that there is an urgent and undeferrable need to expand the network. Severely underserved areas are concentrated mainly in the South and Sardinia. In this part of the country, motorized travel times to major cities and ports suggest a need for targeted infrastructure development, even when coastal municipalities are considered. Despite their proximity to the sea, southern regions lack effective port access, particularly to large ports, a condition that hinders economic development, market integration, and access to services. For this reason, infrastructure development must be intended as a tool to reduce economic disparities within Italy. The same infrastructure projects can create employment opportunities, stimulating local economies.

The fine-grid descriptive analysis suggests a final important consideration. Coordination among national, regional, and local governments is essential to ensure infrastructure development strategies. The real potential for creating cohesive conditions is met when local geographical and economic conditions are considered. In some instances, also investing in secondary roads and local transport networks or modernizing existing infrastructure to complement the major one can assure an improvement in overall accessibility.

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8. Appendix

Table 3.0.1. Travel times with motorized transport infrastructure in 2019 (minutes per km) and travel times to nearest city with at least 50,000 inh. in 2015(minutes), NUTS 3 regions

Rank	NUTS 3 region	Motorized travel times	Rank	NUTS 3 region	Travel times to nearest city
1	Aosta	26.04	1	Aosta	83.08
2	Sondrio	21.46	2	Sondrio	78.95
3	Verbano-Cusio-Ossola	19.62	3	Grosseto	73.20
4	Belluno	13.35	4	Nuoro	72.67
5	Bolzano	11.79	5	Verbano-Cusio-Ossola	68.52
6	Pordenone	9.63	6	Crotone	61.60
7	Trento	7.80	7	Campobasso	58.93
8	Torino	7.68	8	Oristano	58.40
9	L'Aquila	6.08	9	Vibo Valentia	56.28
10	Udine	5.16	10	Livorno	55.67
11	Bergamo	5.00	11	Potenza	55.45
12	Cuneo	4.78	12	L'Aquila	54.86
13	Vercelli	4.63	13	Isernia	54.73
14	Brescia	4.62	14	Belluno	54.54
15	Cosenza	4.50	15	Cuneo	51.53
16	Como	4.19	16	Agrigento	51.39
17	Crotone	3.96	17	Catanzaro	50.76
18	Rieti	3.89	18	Frosinone	50.35
19	Frosinone	3.73	19	Bolzano	47.43
20	Pescara	3.48	20	Viterbo	46.40
21	Ascoli Piceno	3.38	21	Macerata	45.08
22	Teramo	3.35	22	Mesina	45.05
23	Isernia	3.34	23	Cosenza	44.29
24	Massa Carrara	3.18	24	Lecce	43.34
25	Lecco	3.13	25	Sassari	42.76
26	Biella	3.11	26	Matera	41.40
27	Matera	3.05	27	Siena	40.56
28	Foggia	2.96	28	Biella	39.79
29	Salerno	2.90	29	Reggio di Calabria	39.71
30	Potenza	2.88	30	Latina	39.70
31	Imperia	2.83	31	Enna	39.63
32	Reggio di Calabria	2.81	32	Sud Sardegna	38.61
33	Catania	2.79	33	Chieti	37.75
34	Catanzaro	2.72	34	Torino	36.68
35	Mesina	2.71	35	Ragusa	36.09
36	Lucca	2.71	36	Trapani	35.90
37	Rovigo	2.63	37	Rieti	34.63
38	Nuoro	2.62	38	Foggia	34.51
39	Venezia	2.59	39	Vercelli	34.42
40	Cagliari	2.51	40	Rovigo	34.27
41	Gorizia	2.49	41	Trento	32.99
42	Sud Sardegna	2.49	42	Fermo	32.54
43	Ferrara	2.44	43	Caltanissetta	31.92
44	Sassari	2.40	44	Parma	31.29
45	Chieti	2.39	45	Palermo	30.96
46	Grosseto	2.34	46	Benevento	30.59
47	Livorno	2.24	47	Alessandria	30.57
48	Palermo	2.20	48	Salerno	30.36
49	Latina	2.18	49	Asti	30.16
50	Perugia	2.17	50	Udine	29.80
51	Viterbo	2.15	51	Teramo	29.63
52	Barletta-Andria-Trani	2.13	52	Brescia	28.95
53	Roma	2.06	53	Ancona	28.67
54	Caserta	2.00	54	Pesaro e Urbino	28.52
55	Terni	1.92	55	Pisa	27.95
56	Caltanissetta	1.91	56	Ascoli Piceno	27.38
57	Pisa	1.91	57	Perugia	27.36
58	Oristano	1.88	58	Pordenone	27.19
59	Macerata	1.87	59	Siracusa	26.23
60	Siena	1.87	60	Pavia	25.89

61	Avellino	1.86	61	Mantova	25.16
62	Benevento	1.85	62	Piacenza	25.11
63	Verona	1.84	63	Avellino	24.01
64	Enna	1.84	64	Catania	23.94
65	Campobasso	1.81	65	Pescara	23.15
66	Savona	1.78	66	Bergamo	22.97
67	Genova	1.77	67	Terni	22.89
68	Arezzo	1.77	68	Caserta	22.65
69	Pistoia	1.76	69	Arezzo	22.53
70	La Spezia	1.68	70	Gorizia	22.51
71	Vicenza	1.67	71	Forli'-Cesena	21.82
72	Agrigento	1.67	72	Modena	21.72
73	Forli'-Cesena	1.66	73	Taranto	20.99
74	Vibo Valentia	1.65	74	Massa Carrara	20.96
75	Piacenza	1.64	75	Ferrara	20.77
76	Ravenna	1.61	76	Brindisi	20.24
77	Bari	1.60	77	Imperia	20.19
78	Parma	1.59	78	Reggio nell'Emilia	19.40
79	Siracusa	1.59	79	Cagliari	19.20
80	Varese	1.58	80	Como	19.06
81	Firenze	1.57	81	Venezia	18.96
82	Prato	1.54	82	Lucca	18.76
83	Trapani	1.50	83	Firenze	18.65
84	Novara	1.49	84	Vicenza	18.58
85	Pesaro e Urbino	1.49	85	Bari	18.36
86	Alessandria	1.48	86	Verona	18.23
87	Cremona	1.47	87	Barletta-Andria-Trani	18.02
88	Reggio nell'Emilia	1.45	88	Savona	17.67
89	Mantova	1.44	89	Bologna	17.35
90	Modena	1.40	90	Cremona	16.90
91	Bologna	1.40	91	Genova	16.74
92	Treviso	1.39	92	Roma	16.41
93	Fermo	1.38	93	Rimini	16.04
94	Taranto	1.38	94	Ravenna	15.99
95	Pavia	1.37	95	La Spezia	15.82
96	Ragusa	1.33	96	Treviso	15.02
97	Rimini	1.32	97	Lecco	14.27
98	Lodi	1.31	98	Padova	13.78
99	Padova	1.30	99	Lodi	13.76
100	Trieste	1.29	100	Pistoia	12.71
101	Ancona	1.28	101	Novara	12.57
102	Brindisi	1.25	102	Prato	9.26
103	Lecce	1.24	103	Varese	8.47
104	Napoli	1.24	104	Trieste	4.57
105	Asti	1.23	105	Napoli	3.92
106	Milano	1.16	106	Milano	3.12
107	Monza e della Brianza	1.11	107	Monza e della Brianza	0.91

Source: own elaboration on Weiss, Nelson, Vargas-Ruiz et al. (2020) and Weiss, Nelson, Gibson et al. (2018) data

Table 3.0.2. Travel times to ports in 2015 (minutes), NUTS 3 regions

Rank	**NUTS 3 region**	**Travel times to large ports**	**Rank**	**NUTS 3 region**	**Travel times to medium ports**	**Rank**	**NUTS 3 region**	**Travel times to any port**
1	Sud Sardegna	682.41	1	Sondrio	215.94	1	Sondrio	197.58
2	Cagliari	664.42	2	Aosta	172.81	2	Aosta	169.42
3	Nuoro	641.83	3	Verbano-Cusio-Ossola	170.83	3	Verbano-Cusio-Ossola	164.81
4	Oristano	635.89	4	Bolzano	169.48	4	Bolzano	163.13
5	Sassari	561.88	5	Chieti	169.23	5	Brescia	138.68

6	Ancona	213.32	6	Isernia	163.71	6	Bergamo	136.75
7	Macerata	212.11	7	Trento	162.98	7	Como	130.75
8	Perugia	204.02	8	Crotone	158.62	8	Trento	129.65
9	Sondrio	198.53	9	Caserta	155.54	9	Lecco	124.27
10	Pesaro e Urbino	194.41	10	Pescara	155.31	10	Torino	114.20
11	Fermo	193.16	11	Bergamo	154.70	11	Varese	113.65
12	Viterbo	191.25	12	Trapani	153.58	12	Biella	112.05
13	Grosseto	189.43	13	Como	149.52	13	Belluno	106.70
14	Terni	187.29	14	Fermo	149.32	14	Vercelli	104.61
15	Arezzo	186.43	15	Agrigento	149.20	15	Cremona	98.29
16	Trapani	181.24	16	Brescia	148.81	16	Monza e della Brianza	98.11
17	Siena	180.57	17	Campobasso	147.70	17	Mantova	97.55
18	Ascoli Piceno	178.20	18	Sassari	145.72	18	Novara	96.60
19	Aosta	171.76	19	Cosenza	143.50	19	Verona	96.00
20	Bolzano	168.95	20	Lecco	143.03	20	Arezzo	90.87
21	Verbano-Cusio-Ossola	164.81	21	Teramo	142.62	21	Lodi	86.48
22	Catanzaro	164.55	22	Ascoli Piceno	141.70	22	Milano	86.41
23	Rimini	157.56	23	Benevento	139.74	23	Perugia	86.13
24	Teramo	156.77	24	Napoli	137.69	24	Modena	79.36
25	Forli'-Cesena	155.82	25	Macerata	134.50	25	Vicenza	77.81
26	Vibo Valentia	155.38	26	Salerno	132.68	26	Potenza	74.63
27	Rieti	152.57	27	L'Aquila	130.44	27	Cosenza	74.39
28	Firenze	150.76	28	Caltanissetta	128.01	28	Bologna	73.64
29	Crotone	148.04	29	Varese	126.95	29	Rieti	73.18
30	Brescia	142.28	30	Verona	126.53	30	Pordenone	71.49
31	Reggio di Calabria	140.59	31	Palermo	125.17	31	Piacenza	71.11
32	Palermo	139.10	32	Ragusa	123.85	32	Terni	69.01
33	Prato	137.27	33	Vicenza	122.42	33	Siena	68.96
34	Bergamo	136.75	34	Avellino	120.05	34	Cuneo	67.82
35	Roma	136.67	35	Biella	117.98	35	L'Aquila	67.79
36	Trento	136.54	36	Catanzaro	117.38	36	Pavia	67.49
37	Agrigento	134.97	37	Ancona	117.36	37	Prato	66.03
38	Bologna	134.05	38	Monza e della Brianza	116.92	38	Firenze	65.43
39	Como	130.75	39	Frosinone	116.41	39	Parma	65.43
40	Ravenna	130.56	40	Torino	114.82	40	Reggio nell'Emilia	63.60
41	Torino	129.29	41	Belluno	113.73	41	Pesaro e Urbino	63.46
42	Pescara	128.54	42	Nuoro	112.17	42	Ascoli Piceno	62.52
43	Modena	127.26	43	Vercelli	110.44	43	Treviso	61.80
44	Pisa	124.66	44	Cremona	107.60	44	Rimini	61.08
45	Lecco	124.27	45	Lodi	107.01	45	Matera	60.91
46	Mantova	124.16	46	Foggia	104.84	46	Forli'-Cesena	58.35
47	Pistoia	120.94	47	Milano	104.69	47	Asti	57.62
48	Cosenza	119.53	48	Novara	103.47	48	Macerata	56.91
49	L'Aquila	119.02	49	Perugia	103.29	49	Udine	56.83
50	Livorno	117.58	50	Mantova	102.19	50	Isernia	56.50
51	Varese	113.65	51	Potenza	101.26	51	Frosinone	55.74
52	Reggio nell'Emilia	113.18	52	Siracusa	101.12	52	Fermo	54.81
53	Verona	112.39	53	Arezzo	101.05	53	Pistoia	53.63
54	Biella	112.06	54	Enna	100.94	54	Ferrara	53.23
55	Foggia	111.18	55	Siena	98.86	55	Benevento	51.35
56	Belluno	110.85	56	Rieti	96.57	56	Rovigo	51.35
57	Chieti	109.15	57	Pesaro e Urbino	95.43	57	Salerno	48.59
58	Ferrara	105.17	58	Latina	95.14	58	Campobasso	48.44
59	Vercelli	104.81	59	Padova	94.21	59	Padova	48.12
60	Cremona	103.85	60	Piacenza	90.65	60	Avellino	46.96
61	Parma	101.07	61	Oristano	89.47	61	Foggia	45.23
62	Cuneo	99.99	62	Prato	87.78	62	Alessandria	44.91
63	Caltanissetta	99.98	63	Firenze	86.79	63	Grosseto	42.98
64	Monza e della Brianza	98.11	64	Pavia	85.24	64	Enna	42.73
65	Novara	96.60	65	Vibo Valentia	85.19	65	Teramo	42.61
66	Lucca	95.94	66	Modena	83.12	66	Viterbo	42.06
67	Potenza	95.28	67	Treviso	81.71	67	Nuoro	41.62
68	Barletta-Andria-Trani	94.06	68	Catania	80.47	68	Catanzaro	39.58
69	Campobasso	93.02	69	Livorno	79.26	69	Ravenna	37.87
70	Mesina	87.91	70	Bologna	75.91	70	Caserta	36.77
71	Vicenza	86.53	71	Pisa	75.78	71	Lucca	35.93
72	Lodi	86.48	72	Grosseto	75.03	72	Roma	35.13

73	Milano	86.41	73	Matera	73.83	73	Venezia	34.60
74	Enna	86.26	74	Cuneo	73.12	74	Mesina	34.20
75	Latina	84.79	75	Pistoia	72.55	75	Ancona	33.93
76	Frosinone	84.10	76	Pordenone	71.49	76	Oristano	33.93
77	Imperia	84.03	77	Reggio di Calabria	71.31	77	Sud Sardegna	32.88
78	Pordenone	83.65	78	Terni	69.34	78	Latina	31.54
79	Rovigo	81.23	79	Rovigo	68.75	79	Palermo	30.55
80	Massa Carrara	73.93	80	Reggio nell'Emilia	67.99	80	Sassari	30.31
81	Isernia	73.84	81	Parma	66.10	81	Pescara	29.93
82	Salerno	73.55	82	Rimini	62.30	82	Catania	29.71
83	Piacenza	72.03	83	Asti	60.27	83	Bari	29.65
84	Udine	69.03	84	Sud Sardegna	58.40	84	Reggio di Calabria	29.56
85	Pavia	67.49	85	Forli'-Cesena	58.35	85	Chieti	29.02
86	Asti	66.30	86	Roma	57.25	86	Pisa	28.61
87	Padova	66.14	87	Udine	56.83	87	Crotone	28.32
88	Catania	63.58	88	Alessandria	56.75	88	Brindisi	27.04
89	Matera	62.70	89	Imperia	55.21	89	Caltanissetta	26.97
90	Treviso	62.34	90	Venezia	53.76	90	Ragusa	26.92
91	Avellino	57.65	91	Ferrara	53.74	91	Siracusa	26.05
92	Bari	57.46	92	Brindisi	52.83	92	Taranto	25.63
93	Ragusa	55.80	93	Barletta-Andria-Trani	51.95	93	Massa Carrara	25.42
94	Benevento	53.09	94	Taranto	51.34	94	Agrigento	25.13
95	La Spezia	49.34	95	Lucca	48.80	95	Barletta-Andria-Trani	23.85
96	Lecce	48.92	96	Mesina	43.23	96	Genova	22.96
97	Alessandria	47.04	97	Viterbo	42.53	97	Cagliari	22.19
98	Savona	44.31	98	Genova	42.52	98	Lecce	21.85
99	Venezia	42.52	99	Ravenna	37.87	99	Trapani	21.22
100	Caserta	38.22	100	Cagliari	34.96	100	La Spezia	20.16
101	Siracusa	33.15	101	Bari	34.29	101	Vibo Valentia	19.92
102	Brindisi	29.05	102	Massa Carrara	29.00	102	Imperia	18.65
103	Taranto	25.96	103	Lecce	25.08	103	Savona	17.25
104	Gorizia	23.62	104	La Spezia	20.70	104	Livorno	15.71
105	Genova	23.26	105	Savona	19.91	105	Gorizia	13.59
106	Napoli	13.49	106	Trieste	15.86	106	Napoli	9.77
107	Trieste	6.93	107	Gorizia	13.59	107	Trieste	6.12

Source: own elaboration on Weiss, Nelson, Gibson et al. (2018) data