



Measuring Competitiveness: A Composite Indicator for Italian Municipalities

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Abstract

This study measures territorial competitiveness at the municipal level in Italy, by proposing a robust composite indicator based on variables not yet used in the literature. The underlying theoretical framework is identified based on the literature on regional competitiveness. The proposed indicator consists of the following seven dimensions of competitiveness: Education, Job, Economic Wellbeing, Territory and Environment, Entrepreneurship, Innovation, and Infrastructures and Mobility. Data are retrieved mainly from administrative sources, for 2014 and 2015. In the building process, three aggregation methods are compared: a compensatory method, the arithmetic mean, and two partially compensatory methods, the geometric mean and the Adjusted Mazziotta-Pareto Index (AMPI). The arithmetic mean turns out to be the most robust method among the three considered, but the AMPI is the most robust method among the two partially compensatory methods. All the methods considered agree in identifying Innovation and Entrepreneurship as the most influential pillars in 2014 and 2015, respectively. The detailed geographical focus provides specific insights into territorial competitiveness in Italy. It emerges a rather heterogeneous picture of municipal competitiveness within the Italian regions. Highly competitive municipalities are present in every region, though with different concentration levels.

Keywords Multidimensional phenomena · Data aggregation · Territorial analysis · Influence analysis

1 Introduction

Territorial competitiveness is a multidimensional phenomenon and has been studied at different levels. It is related both to the growth performance of a territory and to development and well-being of people living there (Meyer-Stamer, 2008; Resmini et al., 2011). Given its intrinsic complexity and variety of connotations, a single definition of territorial competitiveness is not available in the literature, and properly measuring territorial

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competitiveness is a challenging task that involves various dimensions besides the specific context of application.

With respect to spatial granularity, measuring territorial competitiveness at its most disaggregated level of detail, namely municipal level, could allow to take targeted actions towards improving growth performance and people well-being. In this respect, a proper measure of municipal competitiveness should be able to distinguish municipalities with different competitiveness levels.

Another characterising element is that competitiveness is a phenomenon that needs to be evaluated over time, also considering that it is strongly influenced by the economic policy. Thus, in order to be meaningful, a measure of competitiveness should allow for such evaluations and comparisons.

It is also interesting to notice that, given the multidimensional nature of competitiveness, the different dimensions may contribute to the overall phenomenon to varying degrees. In this respect, a measure of competitiveness should be *robust* in terms of the selected dimensions, namely it should not be influenced too much by one dimension only. Further, given an overall measure of competitiveness, it would be advisable to identify the most influencing dimension(s).

In this context, the main objective of this study is to measure municipal competitiveness in Italy over time. In Italy, a municipality is a basic public territorial entity that autonomously governs its own territory according to the modalities and limits set by the Italian Constitution (Istat, 2021). In terms of the Nomenclature of Territorial Units for Statistics (NUTS),¹ Italian municipalities correspond to a further subdivision of small regions (provinces) at NUTS 3 level. Italian municipalities are Local Administrative Units (LAU), like all the municipalities and communes of EU member states (Eurostat, 2021).

In the economic literature, competitiveness at this territorial level does not have a definition nor a corresponding theoretical framework and measure. Therefore, our research question is as follows:

RQ. Introduce a robust synthetic measure of municipal competitiveness in Italy, allowing comparisons over time and the identification of different levels of competitiveness. Based on this measure, understand which dimensions of competitiveness are the most relevant, determining and differentiating competitiveness the most among municipalities.

Answering the research question implies developing a proper strategy for measuring competitiveness and testing its robustness. To the purposes of measuring municipal competitiveness, the proposed approach is that of building a composite indicator. This is a valid technique for measuring multidimensional phenomena, as it enables reducing dimensionality while considering the different dimensions of a phenomenon, represented by one or more individual indicators, by aggregating them into a unique number (Mazziotta & Pareto, 2013). In this respect, an *individual* indicator is a quantitative or qualitative measure based on observations of real-world facts and capable of showing the relative positions of the observed units. On the other hand, a *composite* indicator involves aggregating two or more individual indicators into a unique index according to a specific model defined by

¹ “The NUTS classification subdivides the economic territory of the EU Member States and the UK into territorial units (regions), whereby the following principles apply: (a) The NUTS classification includes three hierarchical levels,” namely NUTS 1, NUTS 2 and NUTS 3; “(b) NUTS favours administrative units already existing in the Member States ...”; “(c) The NUTS Regulation lays down minimum and maximum thresholds for the population size of the regions ...”; “(d) The NUTS are complemented at the lower level by local administrative units (LAU)” (Eurostat, 2020, pp. 5–6).

the composite indicator builder (Freudenberg, 2003; OECD & JRC, 2008). The building process of a composite indicator is stepwise, entailing several phases (Freudenberg, 2003; Mazziotta & Pareto, 2013, 2017; OECD & JRC, 2008). Taking those and the specific aim of the present work into account, the proposed methodological steps that we plan to take in order to tackle our research question are the following: 1) Introduce a definition of municipal competitiveness; 2) Identify potential dimensions and factors of municipal competitiveness, on the basis of a properly defined theoretical framework; 3) Search for available and adequate data sources at municipal level, and identify and analyse individual indicators, for multiple time periods (if available); 4) Build the municipal-level competitiveness measure, by properly normalizing, weighting and aggregating the individual indicators; 5) Analyse the competitiveness indicator, in terms of scores, rankings, and geographical distribution; 6) Carry out an influence analysis to test the robustness of the composite indicator and to identify the most influent dimension on municipal competitiveness; 7) Analyse some specific municipalities to investigate the properties and characteristics of the proposed indicator and its capacity to distinguish different competitiveness levels.

Regarding the definition of municipal competitiveness, some implications can be derived from the literature on territorial and regional competitiveness, as a municipality shares some features with regions, while the adjustment mechanisms that operate at the national level do not apply. The definition of municipal-level competitiveness that we propose in this article is inspired by the definition underlying the Regional Competitiveness Index (RCI), a composite indicator computed at the NUTS 2 regional level for EU member states (Dijkstra et al., 2011). The RCI also functions as our main reference for the identification of competitiveness dimensions. In this respect, we identify the following seven dimensions: Education, Job, Economic Wellbeing, Territory and Environment, Entrepreneurship, Innovation, and Infrastructures and Mobility. It should be noted that, among the identified dimensions, social dimensions (e.g., Education) are also present. The data are mainly retrieved from *A Misura di Comune*,² an Italian statistical multisource system that collects data from different sources, both consolidated and experimental (Istat, 2018). Due to data availability issues, we only consider two time periods, namely 2014 and 2015. Recognizing that the economic context may not be greatly different consecutive years, the proposed indicator can be considered a prototype for measuring competitiveness that could be computed for other time periods whenever data become available.

The building process of a composite indicator entails specifying proper normalization, weighting, and aggregation strategies. As the aim is conducting an analysis at time series level, we use methodologies that allow to conduct time series analysis (e.g., we do not use standardization to normalize the individual indicators). With regard to aggregation, we apply and compare three different aggregation methods: the arithmetic mean, the geometric mean and the Adjusted Mazziotta-Pareto Index (AMPI). In this respect, the differences between the three methods need to be kept in mind when interpreting the results, as the arithmetic mean is a totally compensatory method, while the AMPI and the geometric mean are partially non-compensatory methods.

The contribution of this study is two-fold. First, it introduces a measure of competitiveness at municipal level, which is not available in the Italian literature. An innovative aspect of the proposed measure is that it is based on variables not yet used in the literature, being the result of an experimental program that links traditional surveys with state-of-the-art

² <http://amisuradicomune.istat.it/aMisuraDiComune/>

data production methods and allows the dissemination of data at a highly disaggregated territorial level. Second, from the substantive point of view, the proposed composite indicator enables comparing the competitiveness of all Italian municipalities.³ The detailed geographical focus of the proposed measure makes it possible to obtain precise insights into territorial competitiveness in Italy, not only in terms of overall competitiveness but also in terms of relative positions in the rankings and the specific strengths and weaknesses of each municipality.

The rest of this article is organised as follows. Section 2 surveys the literature on competitiveness, focusing on regional and territorial competitiveness. Section 3 provides the theoretical framework underlying the proposed composite indicator at the municipal level, introduces the proposed definition of municipal competitiveness and identifies competitiveness dimensions, providing the reasons behind their inclusion. Section 4 presents the methodology, the data and the results derived from the application of the proposed composite indicator to the 2014–2015 period. Section 5 concludes by summarising the main findings and suggesting further potential applications for the proposed composite indicator.

2 Literature Review

The existing literature does not provide a specific theoretical framework for competitiveness at the municipal level that could be applied when constructing a composite indicator at this geographical detail. However, regions and municipalities share certain features due to being subnational, local entities. Therefore, this section focuses on regional-level and territorial-level competitiveness. In this respect, the strategy of considering competitiveness at the regional level as a starting point for the municipal context was also used in other studies – for instance, by Kurek et al. (2020) and Balestrieri (2014) – in which the authors analysed municipal competitiveness in relation to two specific cases, namely the impact of geothermal resources on municipal competitiveness in Poland and the linkage between competitiveness and rurality, respectively.

Sect. 2.1 provides an overview of the definitions of competitiveness at the regional level employed in the literature, while Sect. 2.2 discusses factors of regional competitiveness as described in the literature. Finally, Sect. 2.3 presents the most relevant strategies for measuring regional competitiveness using composite indicators.

2.1 Defining Competitiveness

Regional competitiveness may be considered from two different perspectives, either as an aggregate of firm competitiveness or as a derivative of macroeconomic competitiveness, though both perspectives involve certain limitations (Cambridge Econometrics et al., 2003). Therefore, regional competitiveness lies between firm competitiveness and national competitiveness (Cambridge Econometrics et al., 2003). Different definitions of regional competitiveness and territorial competitiveness can be found in the literature. A synthetic selection is provided below.

³ This is subject to data availability. As we explain in Sect. 4.2, some municipalities were excluded due to missing data. However, the purpose of the proposed composite indicator was to compare the competitiveness scores for all Italian municipalities.

According to the European Commission (1999, p. 75), “[Regional competitiveness is defined as] the ability to produce goods and services which meet the test of international markets, while at the same time maintaining high and sustainable levels of income or, more generally, the ability of (regions) to generate, while being exposed to international competition, relatively high income and employment levels.” This definition describes competitiveness not as a goal but as an ability, specifically the ability to generate high incomes and employment while facing competitors in the open market. This is a broad definition of competitiveness, which is valid not only at the regional but also at the national, industry and firm levels.

Huggins (2003) provided an intermediary definition of regional competitiveness between national competitiveness and firm competitiveness, citing Storper (1997), who defined the competitiveness of an area as “the capability of a sub-national economy to attract and maintain firms with stable or rising market shares in an activity, while maintaining increasing standards of living for those who participate in it” (Huggins, 2003, p. 89). This definition was then adopted by Huggins (2003) in the construction of a UK regional competitiveness composite indicator.

A different definition was proposed by Meyer-Stamer (2008), who focused on the residents’ perspective, defining “(systemic) competitiveness of a territory as the ability of a locality or region to generate high and rising incomes and improve the livelihoods of the people living there.” This definition shares some key elements with the previous ones, claiming that competitiveness is linked to improving living standards and generating high incomes. Annoni and Dijkstra (2019) noted that this definition refers only to the benefits of the people living in a region and not to those of firms.

With reference to the Italian context, a different perspective was adopted by Pacetti (2008) and Ciccarelli (2003, 2006). Pacetti (2008) identified the competitiveness of a territory with the competitiveness of the firms situated in that territory – in other words, as an aggregate of firms’ competitiveness. Ciccarelli (2003) studied the competitiveness of Italian provinces (NUTS 3) in terms of their ability to retain existing firms and attract external ones. The study by Ciccarelli (2006) was based on a definition of area competitiveness that focused on firms, as in Ciccarelli (2003), in which the competitiveness of an area was defined as its capacity to provide the basic factors needed for firms to operate in an effective and efficient manner. On the basis of this definition, Ciccarelli (2006) built a composite indicator measuring provincial competitiveness in Italy.

The last definition to be presented here is the one underlying the Regional Competitiveness Index (RCI), a composite indicator developed by the European Commission for measuring regional competitiveness at the NUTS 2 level in the EU (Annoni & Kozovska, 2010). The RCI definition states the following: “Regional competitiveness can be defined as the ability to offer an attractive and sustainable environment for firms and residents to live and work” (Dijkstra et al., 2011). This definition involves a point in time, which also implies that the selected individual indicators involve a point in time. Differently from Meyer-Stamer (2008), Pacetti (2008), and Ciccarelli (2003, 2006), the RCI definition takes into account both firms’ and residents’ perspectives. More specifically, the authors stated that they “strive to balance the most important aspects of an attractive environment by combining the goals of commercial success with personal well-being” (Dijkstra et al., 2011, p. 4), in both the short and the long term, as implied by the term “sustainable.” The definition proposed by Dijkstra et al. (2011), which underpins the RCI, has inspired our own definition of municipal competitiveness and the corresponding theoretical framework proposed in this article.

2.2 Identifying Competitiveness Factors

Once regional competitiveness is defined, the factors that comprise it need to be further identified in order to structure the various dimensions of the phenomenon and to identify a list of selection criteria for the underlying variables (OECD & JRC, 2008). This section provides an overview of some of the factors that are relevant to regional competitiveness according to the literature.

In this context, the reports published by the European Commission are important. More specifically, the *Second Report on Economic and Social Cohesion* (European Commission, 2001), which focuses on assessing the degree of cohesion in the EU, also introduces the factors that are assumed to affect regional competitiveness (Cambridge Econometrics et al., 2003). As reported by Cambridge Econometrics et al. (2003), the factors considered by the *Second Report* include employment, investments, productivity, demographic trends, education level, infrastructure and innovations. The *Seventh Report* (European Commission, 2017) represents the latest edition of these reports by the European Commission. In this edition, economic cohesion among EU regions is evaluated by studying GDP per capita, employment and productivity, and the factors that affect regional competitiveness according to the European Commission, which comprise, for instance, entrepreneurship (e.g. firm density), research and innovation (e.g. patents), educational attainment (e.g. tertiary education), factors that improve market access (transport infrastructure), and digital networks.

The UK's Department of Trade and Industry (DTI) produced a study on the indicators of regional competitiveness in the UK (DTI, 2001), in which it identified 14 indicators. Some indicators, such as the employment level, the education level, innovation factors and infrastructures, coincide with the factors pointed out by the European Commission (2001, 2017).

An overview of another study, the *Competing with the World* report by Barclays Bank PLC et al. (2002), has been provided by Cambridge Econometrics et al. (2003). In the report, a group of 15 competitive regions was selected, with 10 of them located in the EU, and common factors crucial for the competitiveness of the whole group identified. Those included a clear international orientation and specialisation as well as the presence of deep-rooted cultural and/or geographic factors (Cambridge Econometrics et al., 2003). These factors do not coincide with the ones identified in previous studies—for instance, innovation was not included. In addition, different factors are included, such as the presence of long-established cultural/governmental/geographical factors.

OECD Regions at a Glance reports are another relevant group of studies. In the first edition, productivity, industry specialisation, employment rates, participation rates, age activity rates, and population were identified as factors that affect regional competitiveness (OECD, 2008). Productivity, employment and population were also considered by the European Commission in the aforementioned reports, while the specialisation factor was also present in the *Competing with the World* report. Furthermore, in the 2016 edition, the OECD analysed how regions contribute to the economic growth of their countries and discussed the factors that foster regional competitiveness (OECD, 2016). These factors include GDP, employment, labour productivity growth, venture capital and highly skilled workers.

The last group of studies to be discussed in this section represents a selection of Italian studies on regional competitiveness. Brioschi et al. (2005) studied the development path of some European knowledge economies and identified the following main

Table 1 Summary of the main factors that affect regional competitiveness according to the literature

Overview of regional competitiveness factors

Infrastructures and accessibility	Human resources	Productive environment
<i>Basic infrastructure</i>	<i>Demographic trends</i>	<i>Entrepreneurial culture</i>
Road	Migration of skilled workers	Low entry barriers
Rail	Diversity	Risk-taking culture
Air	<i>Highly skilled workforce</i>	<i>Sectoral concentrations</i>
Property	Knowledge-intensive skills	Balance/dependency
<i>Technological infrastructure</i>		Employment concentration
Ict		High value-added activities
Telecoms		<i>Internationalisation</i>
Internet		Exports/global sales
<i>Knowledge infrastructure</i>		Investment
Educational facilities		Business culture
		Nature of FDI
<i>Quality of place</i>		<i>Innovation</i>
Housing		Patents
Natural surroundings		R&D levels
Cultural amenities		Research institutes and universities
Safety		Linkages between companies and research
		<i>Governance and institutional capacity</i>
		<i>Capital availability</i>
		<i>Specialisation</i>
		<i>Nature of competition</i>

Source: Cambridge Econometrics et al. (2003, p. 32, Table 2.8)

factors that are relevant to regional economic development and territorial attractiveness: the capacity to innovate, skilled human capital and R&D in high-technology industries. Resmini et al. (2011) argued that territorial competitiveness may be affected by different factors in different territories. Some of the competitiveness factors cited in the study are innovation, productive resources, inflows of foreign capital and people, natural and cultural resources, and infrastructures. Natural and cultural resources were discussed in the study by Mariotti and Biondi (2018), which focused on tourism and touristic policies, linked territorial competitiveness to the former and analysed the case of Emilia-Romagna. Dal Bianco and Fratesi (2020) analysed resilience and competitiveness policies in the 2007–2013 regional programming of the cohesion policies for Lombardy. They discussed some factors as being important for both resilience and competitiveness, such as innovation, human capital, the presence of urban areas, and the production structure. In their study, they also included a descriptive analysis at the municipal level. In terms of measuring resilience and competitiveness, the authors proposed the use of employment to measure both phenomena. Later in their work, they also used the annual growth of the IRPEF taxable income to measure the territorial competitiveness and resilience of the local labour systems.

Table 1 summarises the main regional competitiveness factors according to the literature. It should be noted that these are micro-economic factors. The presence of stability at the macro level is usually assumed to be a precondition for regional competitiveness; therefore, macro-economic factors tend not to be considered in this kind of study (Cambridge Econometrics et al., 2003).

2.3 Regional competitiveness indexes proposed in the literature

Scholars have adopted different strategies to study regional competitiveness. This section provides an overview of the most relevant strategies that use composite indicators.

Some studies have developed national composite indicators to measure regional competitiveness in specific countries. For instance, Huggins (2003) created a composite indicator to measure the competitiveness of regions and localities in the UK. The author adopted a two-step aggregation technique: first, individual indicators are aggregated into three sub-indices; then, these are combined to create the final composite indicator. The individual indicators selected by Huggins (2003) included the following: GDP per capita, which measures economic activity; business density, which indicates the possibility of sustainable economic growth by the emergence of new firms; and knowledge-based business, which fosters economic growth.

Other studies investigate provincial competitiveness building an indicator at the provincial level in Italy. Ciccarelli (2006) and Scuola di Governo del Territorio (2016) measure the competitiveness of the Italian provinces. Similar to Huggins (2003), both studies used a two-step aggregation technique. Ciccarelli (2006) identified eight dimensions of provincial competitiveness, which were then combined to measure competitiveness. The eight dimensions included, for instance, the endowment of infrastructures, the propensity to innovate and human capital. In the study, a method inspired by the taxonomic method was used to aggregate individual indicators into the eight synthetic indicators and to create the final composite indicator. Differently from Ciccarelli (2006), the composite indicator developed by Scuola di Governo del Territorio (2016) consists of two pillars, an indicator of production activity development and an indicator of the local context, with arithmetic mean being applied to aggregate the two pillars. In the study by Scuola di Governo del Territorio (2016), the composite indicator was applied to a selection of metropolitan cities, too.

Other composite indicators have been proposed for measuring competitiveness across the entire EU. The European Competitiveness Index (ECI) published in 2004 and 2006, measures NUTS 1 competitiveness in the EU (Huggins & Davies, 2006). ECI follows a two-step aggregation technique similar to that of Huggins (2003), Ciccarelli (2006) and Scuola di Governo del Territorio (2016): individual indicators are combined into three pillars, namely creativity, economic performance and infrastructure, which are then combined to generate the ECI (Annoni & Kozovska, 2010).

The Regional Competitiveness Index (RCI) is the first composite indicator that enables measuring regional competitiveness at the NUTS 2 level in the whole EU (Dijkstra et al., 2011).⁴ The RCI is built using multiple-step aggregation; at each step, the simple arithmetic mean is applied to satisfy the key principle of simplicity set by its builders. In the

⁴ Another study, the *Atlas of Regional Competitiveness*, provides an analysis of regional competitiveness at the NUTS 2 level as well but uses a dashboard approach and does not build a composite indicator (Eurochambres, 2008).

first step, more than 70 normalised individual indicators are combined into 11 pillars of competitiveness. The candidate individual indicators are selected based on the literature while avoiding the inclusion of redundant information (Annoni & Kozovska, 2010). Only the candidate individual indicators that are appropriate according to both a univariate analysis of each individual indicator and a multivariate analysis at the pillar level are retained. In the second step, the pillars are combined into three subindices of competitiveness factors: Basic, Efficiency and Innovation. The Basic group, which represents the enablers of regional competitiveness (Annoni & Dijkstra, 2019), includes the following five pillars: Institutions, Macroeconomic Stability, Infrastructures, Health, and Quality of Primary and Secondary Education. The Efficiency group combines three pillars (Higher Education, Training and Lifelong Learning; Labour Market Efficiency; and Market Size), which measure the skills of the workforce and the extent to which the labour market is efficient (Annoni & Dijkstra, 2019). Finally, the Innovation group includes Technological Readiness, Business Sophistication, and Innovation. In the last step, these three subindices are combined into the final composite indicator, by applying a differential weighting scheme based on a region's development stage (Annoni & Kozovska, 2010). The RCI is particularly relevant in the context of this article, and we use it as a reference point to identify competitiveness dimensions and select individual indicators.

3 Municipal Competitiveness

The first step to take in order to answer our research question implies defining municipal competitiveness and a theoretical framework (Step 1). On the basis of the literature review presented in Sect. 2, we propose to define *municipal competitiveness* as a municipality's ability to offer an attractive and sustainable environment for firms and residents to live and work in. The proposed definition takes into account both firms' and residents' perspectives and includes the element of sustainability.

The identification of competitiveness dimensions and individual indicators to be included in the proposed composite indicator represents the second step to take in the analysis (Step 2). This was a complex process that involved a careful analysis of the literature. Based on that, especially referring to the RCI, we identified the following seven competitiveness dimensions: Education, Job, Economic Wellbeing, Territory and Environment, Entrepreneurship, Innovation, and Infrastructures and Mobility. Some of these dimensions are also present in the RCI, and they are included in the proposed composite indicator for the same reasons as those underlying their inclusion in the RCI (Annoni & Kozovska, 2010). Other dimensions are different, namely *Territory and Environment*, *Entrepreneurship* and the *Mobility* aspect in the last pillar. Their inclusion in our proposal is justified by their relevance to municipal competitiveness according to the regional competitiveness literature.

Therefore, the seven pillars included in the municipal competitiveness index are as follows:

1. *Education*, which measures the quality of the education possessed by the municipalities' residents.
2. *Job*, which measures the status of the labour market in each municipality, a factor linked to the economic development of territories.

3. *Economic Wellbeing*, which measures the wellbeing of the municipal population from an economic perspective.
4. *Territory and Environment*, which measures the environmental dimension of competitiveness. Indeed, the quality of the environment is a relevant component of an attractive area, also from a sustainability point of view. Therefore, one avenue for future research on competitiveness is related to its environmental dimension (Bhawsar & Chattopadhyay, 2015).
5. *Entrepreneurship*, which captures the firm-related dimension of municipal competitiveness. We included this pillar because business density is a factor of regional competitiveness according to the literature and may be relevant at the municipal level as well, as firms contribute to wealth generation and innovation.
6. *Innovation*, which consists of measuring both the spread of innovation and the potential to innovate in each municipality.
7. *Infrastructures and Mobility*, which measures the quality of infrastructure and the mobility flows within the municipality and directed to the municipality for study and work purposes. The greater the flows, the more a municipality is capable of attracting people from other areas and avoiding its residents moving to work and study in other areas, signalling that such a municipality is competitive. Furthermore, efficient infrastructure enables easier transportation of people and goods and, more broadly, increases an area's economic efficiency levels (Annoni & Kozovska, 2010).

4 Case Study

This section describes the data sources considered and the selected individual indicators (Step 3), the methodology adopted for building the municipal-level competitiveness measure (Step 4), and the results obtained (Steps 5–7). More specifically, Sect. 4.1 introduces our data sources, Sect. 4.2 details the individual indicators selected for the construction of the proposed composite indicator, Sect. 4.3 presents the methodology used for the composite indicator, and Sect. 4.4 discusses the results and an influence analysis at pillar level.

4.1 Data Source

Individual indicators were mostly retrieved from *A Misura di Comune*, a multi-source system in which sources of experimental nature are presented alongside other more consolidated ones. Among the experimental sources, a prominent place belongs to the databases created by the ARCH.IMEDE project, which deals with the construction and maintenance of databases for territorial analysis in the Integrated System of Microdata (SIM) of the Italian Institute of Statistics (Istat). The databases used were as follows: Socio-Economic Conditions of Households, Populations That Use a Territory and Mobility, and Job Insecurity. They enabled the development of many individual indicators at the municipal level that were related to both important structural aspects and the phenomena observed in the context of measuring Equitable and Sustainable Well-being (Italian BES). A significant contribution to the construction of *A Misura di Comune* came from the Open Data made available by other organisations in the Italian National Statistical System (Sistan), such as the Ministry of Internal Affairs, the Ministry of Economy and Finance, the Ministry of Economic Development, and the Higher Institute for Protection and Environmental Research (ISPRA). Other sources were part of Istat's current statistical production, such as

demographic statistics (deaths and causes of death; the movements and annual calculations of the resident populations; resident population by sex, year of birth and marital status; and population censuses), Statistical Registers of Active Companies (ASIA), the survey Environmental Data in Cities, and other surveys on industry, services and agriculture. Moreover, data from several Italian registers created by the Institute for the Evaluation of the Education and Training System (INVALSI), Institute for Occupational Accident Insurance (INAIL), and the Automobile Club of Italy (ACI) were also used to construct other individual indicators (Mazziotta, 2017).

4.2 Indicators' selection

The selection of the individual indicators was based on a formative measurement approach (Diamantopoulos et al., 2008). This selection method is subjective, with competitiveness factors identified on the basis of the adopted definition of municipal competitiveness. Individual indicators were selected according to the following two criteria: relevance to municipal competitiveness based on the theoretical framework and data availability at the same time periods. In this respect, the selected pillars and indicators represent an acceptable compromise between the literature and the issues related to the specific features of the municipal context, which also imply difficulties in terms of data availability. The following explains in detail the individual indicators included in the proposed composite indicator, pillar by pillar.

1. *Education*: Three indicators were identified for measuring education: the percentage of 25–64 years-old people who graduated from upper secondary school (*Grad.sec.sch*), the percentage of 30–34 years-old people who graduated from university (*Grad.uni*) and the percentage of children cared for by childcare services (*Childcare*).

The first two indicators are related to educational achievement, which is considered to positively affect development and prosperity; in addition, educational achievement increases employability (European Commission, 2017) and can be used to measure a region's capacity to both use and create innovation (OECD, 2016). However, these aspects are only partially captured by the second indicator, which is related to the 30–34 years-old population. The third indicator, related to childcare services, is less traditional than the previous ones. It may be relevant to the competitiveness of a municipality because childcare services are important for children and help parents organise their working life.

2. *Job*: The indicators considered were the percentage of 20–64 years-old people employed in October (*Empl*), the percentage of 20–64 years-old people in non-stable employment in October (*Not.stabl.empl*) and the percentage of shifts from non-stable to stable employment (*T.not.stabl.stabl*).

Traditionally, indicators related to employment and unemployment levels have been used for measuring job related dimensions. In this context, we considered two indicators that measure employment: the first indicator, the percentage of the employed, is more generic, while the second indicator captures a more specific aspect related to non-stable employment. The third indicator, shifts from non-stable to stable employed, is considered to be positively related to competitiveness at the municipal level.

3. *Economic Wellbeing*: The indicators included were gross income per capita (*G.inc.p.cap*) and low working intensity of the registered households (*Low.work.int.*).

Regarding the first indicator, unlike the RCI, we did not consider disposable income per capita due to data unavailability. The second indicator, the percentage of households with low working intensity, is supposed to be linked to municipal competitiveness, in particular with negative polarity,⁵ because it indicates a potential that is not completely used.

4. *Territory and Environment*: The indicators considered were the percentage of circulating cars with an emissions standard inferior to Euro 4 class (*Cars < Euro4*) and the recycling of urban waste (*Recycling*).

The two indicators included in this fourth pillar were meant to capture characteristics related to the quality of the environment. The first indicator measures a municipality's air pollution, though in a limited manner.

5. *Entrepreneurship*: The indicators included were the entrepreneurship rate (*Entr.rate*) and the density of local units, namely local units per square kilometre (*Loc.units.Kmq*).

According to the literature, business density is relevant to regional competitiveness. Business density was included, for instance, in the composite indicator of regional competitiveness in the UK by Huggins (2003). Firms contribute to the generation of new jobs and foster growth and innovation, especially when firms are geographically concentrated. This may also apply at the municipal level. The two indicators in this pillar measure business density from two different perspectives.

6. *Innovation*: The indicators included were the percentage of real estate units with 30 Mbps Ultra broadband (*Ultra.broadband.units*) and productive specialisation in high-tech sectors (*High.tech.spec*).

At the regional level, telecommunication networks and ICT infrastructures are relevant to competitiveness (Annoni & Kozovska, 2010; European Commission, 2017). Municipal competitiveness could be positively affected by the degree of penetration of Ultra broadband, as this factor increases the efficiency of firms and institutions and improves residents' perceived wellbeing. Regarding the second selected indicator, the percentage of people employed in high-tech sectors affects competitiveness by positively influencing innovation potential.

7. *Infrastructures and Mobility*: The indicators included were road accident rate (*Road.acc.rate*), attraction index (*Attr.index*) and self-containment index (*Self.cont.index*).

The quality of infrastructure can be measured by considering accessibility of different transport infrastructures, as in the RCI. However, data for considering transport accessibility are not available at the municipal level. Therefore, the measurement of infrastructures is pursued only partially, by means of the first indicator, which may contribute to measuring the quality of the road infrastructure; however, it should be noted that the first indicator can measure road infra-

⁵ The polarity of an individual indicator is the sign of the relation between the indicator and the studied phenomenon (Mazziotta & Pareto, 2017).

structure quality only in a limited manner, as road accidents do not necessarily happen due to poor road infrastructure. The measurement of mobility is related to mobility flows: a municipality is a particularly attractive environment if it can attract people from outside for study- and work-related reasons and if, for the same reasons, the municipality's residents decide to stay in the municipality. This implies that the municipality provides good study and/or work opportunities and, therefore, is an attractive environment, which corresponds to the idea behind the underlying definition of competitiveness adopted in the proposed composite indicator.

Overall, we considered 17 indicators, subdivided almost equally across the seven pillars. Most of these individual indicators have positive polarity, with the only exceptions being in non-stable employment, the percentage of households with low work intensity, cars with emissions lower than Euro 4 class and road accident rate.

The data were retrieved from *A Misura di Comune*.⁶ Only the 2014 and 2015 periods were considered due to data availability reasons: more recent data could be retrieved from *A Misura di Comune* only for some of the individual indicators. As for the Ultra broadband indicator, data were available only for 2015 and 2016. As this is a relevant competitiveness indicator according to the theoretical framework, as a first approximation, it was included in the dataset considering the two available periods as 2014 and 2015, respectively. The number of municipalities included in the dataset was 7,159. Considering that the total number of municipalities in the first part of 2014 (Istat, 2014) was 8,057, some municipalities are missing. In fact, the municipalities that had missing values both in 2014 and 2015 even for one indicator only were not included in the dataset, the reason being that all the individual indicators previously identified were deemed relevant to measuring municipal competitiveness. In total, 898 municipalities were removed from the dataset for this reason.

Tables 2 and 3 report some summary statistics for the individual indicators in 2014 and 2015, respectively. As Table 2 shows, very few missing values are present in the datasets, representing 1% or less of all observations for each individual indicator. Comparing the median and the mean values, the indicators for childcare services, the density of local units and the real estate units with 30 Mbps Ultra broadband are strongly right skewed, while the other indicators are quite symmetric. Finally, the evaluation of the coefficients of variation shows that a high degree of heterogeneity is present among the municipalities for many indicators, such as high-tech specialisation and attraction index. Similar comments also apply to the 2015 data, as reported in Table 3.

When values were missing for one year only, we decided not to remove the corresponding municipalities but to impute the missing values (de Waal et al., 2011). More specifically, we used a temporal imputation, a kind of donor imputation whereby for each statistical unit, the value of its non-missing period was imputed to the missing one. Whenever a municipality had a missing value for an individual indicator in 2014, this was imputed using the corresponding 2015 value. The same rule applied in reverse if a 2015 value was missing.

⁶ Only the two values for the Ultra broadband indicator at country level were retrieved from the Infratel website (<https://www.infratelitalia.it/>), the in-house society of the Ministero dello Sviluppo Economico which implements the Ultra broadband strategy (Ministero dello Sviluppo Economico, 2015). These values were needed when aggregating the individual indicators into the pillar subindices in the first aggregation step.

Table 2 Summary statistics of individual indicators, 2014

Pillar	Indicator	obs	Missing	Min	1° quartile	median	3° quartile	max	St. dec	mean	Coeff. of var	polarity
1. Education	Grad.Sec.sch	7159	0	18.1	47.7	53.45	59.2	85.02	8.96	53.17	0.17	+
	Grad.Uni	7159	2	0	17.58	22.19	27.16	100	8.28	22.53	0.37	+
	Childcare	7159	3	0	0	0	12.32	360	14.71	7.71	1.91	+
2. Job	Empl	7159	0	16.67	52.09	63.96	68.22	90.86	10.28	60.52	0.17	+
	Not.Stabl.Empl	7159	0	0	8.73	10.23	12.46	53.83	4.2	11.18	0.38	-
	T.not.stable.stabl	7159	54	0	18.75	24.32	30.23	335.87	12.95	25.63	0.51	+
3. Economic wellbeing	G.inc.p.cap	7159	0	3746.62	10,331.1	13,436.81	15,108.97	29,543.03	3048.37	12,954.84	0.24	+
	Low.work.int	7159	0	0	11.52	15.92	25.2	73.85	9.5	18.98	0.5	-
	Recycling	7159	52	0	32.36	55.77	67.28	100	22.96	49.51	0.46	+
4. Territory and environment	Cars < Euro4	7159	0	12.11	42.23	48.61	58.55	83.97	10.56	50.43	0.21	-
	Entr.rate	7159	0	11.48	48.34	60.01	73.23	411.05	23.05	62.69	0.37	+
	Loc.units.Kmq	7159	0	0.05	2.67	7.14	20.45	1067.43	45.41	21.77	2.09	+
6. Innovation	High.tech.spec	7159	0	0	0	0.69	1.71	62.66	3.65	1.63	2.23	+
	Ultra.broadband.units	7159	0	0	0	0	0	100	26.44	10.15	2.6	+
	Atr.index	7159	0	0	13.95	21.59	30.88	83.33	12.25	23.28	0.53	+
7. Infrastructures and mobility	Self.cont.index	7159	0	0	25.41	33.42	42.62	89.17	13.29	34.82	0.38	+
	Road.acc.rate	7159	0	0	0.46	1.39	2.54	34.65	1.9	1.77	1.07	-

Table 3 Summary statistics of individual indicators, 2015

Pillar	Indicator	obs	Missing	Min	1° quartile	median	3° quartile	max	St. dec	mean	Coeff. of var	polarity
1. Education	Grad.Sec.sch	7159	2	17.91	48.75	54.58	60.2	85.38	8.95	54.21	0.17	+
	Grad.Uni	7159	3	0	18.54	23.24	28.3	100	8.5	23.61	0.36	+
	Childcare	7159	15	0	0	0	11.92	450	15.29	7.65	2	+
2. Job	Empl	7159	2	14.18	50.77	62.71	67.28	91.49	10.36	59.41	0.17	+
	Not.Stabl.Empl	7159	2	0	11.49	13.89	17.97	72.42	7.73	16.16	0.48	-
	T.not.stable.stabl	7159	31	0	17.86	25.78	32.28	100	11.03	25.12	0.44	+
3. Economic wellbeing	G.inc.p.cap	7159	2	3845.32	10,610.2	13,799.84	15,511.84	30,427.92	3141.44	13,307.24	0.24	+
	Low.work.int	7159	2	0	13.52	18.64	28.51	80	10.04	21.58	0.47	-
	Recycling	7159	57	0	35.91	57.7	68.63	94.4	22.09	51.72	0.43	+
4. Territory and environment	Cars < Euro4	7159	0	9.34	38.76	45.4	55.5	81.44	10.85	47.19	0.23	-
	Entr.rate	7159	0	8.58	48.12	59.7	73.09	403.73	23.66	62.62	0.38	+
	Loc.units.Kmq	7159	0	0.05	2.63	7.07	20.23	1078.3	45.24	21.61	2.09	+
6. Innovation	High.tech.spec	7159	0	0	0	0.69	1.75	64.72	3.68	1.64	2.24	+
	Ultra.broadband.units	7159	0	0	0	0	0	104	29.87	12.68	2.36	+
	Attr.index	7159	0	0	14.19	21.87	31.16	100	12.64	23.62	0.54	+
7. Infrastructures and mobility	Self.cont.index	7159	1	0	24.82	32.66	42.03	100	13.35	34.28	0.39	+
	Road.acc.rate	7159	0	0	0.41	1.42	2.53	28.08	1.89	1.76	1.07	-

Next, we performed a principal component analysis (PCA) pillar by pillar. Differently from the RCI (Annoni & Kozovska, 2010), no individual indicator was removed on the basis of the results from the PCA. Within our proposal, the PCA is not a method for selecting individual indicators but rather an exploratory method used to understand the structure of the data and the relationships between the individual indicators within the same pillar. More specifically, we checked for the presence of two ideal conditions: the first principal component explaining a large percentage of the variance and the correlations between the first principal component and each individual indicator being approximately of the same size and sign. The interpretation of the sign must account for the fact that the individual indicators have different polarity, while the PCA does not take polarity into account, this being one of the reasons why PCA is not suitable for indicators selection. Generally, except in some cases, the PCA results showed that for each pillar, the first principal component explained a relevant percentage of variance; moreover, within each pillar, individual indicators were not always equally correlated with the first principal component.

As for outliers, differently from the procedure used for building the RCI (Annoni & Kozovska, 2010), outliers were not treated in the proposed composite indicator. Indeed, the municipal data were retrieved from administrative sources, which implies that it would not have been possible to know whether extreme values represented an error to be corrected or were truly extremely high or low values.

4.3 Composite indicators

In order to identify a robust competitiveness measure, we considered and compared three different aggregation techniques. In this respect, our choice of specific normalisation and aggregation methods was guided by the underlying objective of performing comparisons in absolute terms over time. Individual indicators were normalised using the min–max procedure, also known as rescaling (Mazziotta & Pareto, 2017). The aggregation methods considered involved a totally compensatory method, the simple arithmetic mean, and two partially compensatory methods, the geometric mean and the AMPI.

Denote x_{ij}^t the value for indicator j for unit i at time t and assume it to have positive polarity. The corresponding rescaled value y_{ij}^t according to the min–max procedure is obtained as follows (Mazziotta & Pareto, 2017):

$$y_{ij}^t = \frac{x_{ij}^t - \min_i (x_{ij})}{\max_i (x_{ij}) - \min_i (x_{ij})}, \quad (1)$$

where $\min_i (x_{ij})$ and $\max_i (x_{ij})$, known as goalposts, are the minimum and maximum values for indicator j . In this context, the goalposts are the minimum and maximum values for indicator j across all observations at both time periods considered (2014 and 2015). In case indicator j has a negative polarity, the numerator of the formula above becomes $\max_i (x_{ij}) - x_{ij}^t$. Clearly, the min–max is sensitive to highly skewed data, which was the case in our data. This means that more importance is given to outliers.

The proposed composite indicator was built according to a two-step aggregation procedure. In the first step, individual indicators were combined to form seven subindices, one for each pillar. In the second aggregation step, the subindices were combined into the final composite indicator. Normalisation had to be performed during the first aggregation only. The same aggregation method was used in the first and second steps. The proposed

municipal-level composite indicator was positive, which means that increasing values of the composite indicator correspond to improvements in municipal competitiveness.

The simple arithmetic mean was computed as follows (Mazziotta & Pareto, 2017):

$$M_i^t = \frac{1}{m} \sum_{j=1}^m y_{ij}^t \tag{2}$$

where y_{ij}^t is the value of either the normalised individual indicator j (in the first aggregation step) or of the pillar j (in the second aggregation step) for unit i and m is the number of normalised individual indicators or pillars to be aggregated. The geometric mean was obtained as follows:

$$IMG_i^t = \prod_{j=1}^m \left(y_{ij}^t \right)^{1/m}, \tag{3}$$

while the AMPI (Mazziotta & Pareto, 2017) for each unit i was given by:

$$AMPI_i^{t+/-} = M_{r_i} \pm S_{r_i} cv_{r_i}, \tag{4}$$

where M_{r_i} , S_{r_i} and cv_{r_i} are the arithmetic mean, the standard deviation and the coefficient of variation of r_i^t , which, in the first aggregation step, corresponds to:

$$r_{ij}^t = y_{ij}^t \cdot 60 + 70, \tag{5}$$

where y_{ij}^t is the value of indicator j , normalised using rescaling as in (1), while, in the second aggregation step, r_{ij}^t is the value (without further normalisation) of pillar j for unit i . The AMPI consists of the following two parts: the arithmetic mean, and the product of the standard deviation and the coefficient of variation. The product represents a penalisation, which aims “to reward the units that, mean being equal, have a greater balance among the indicator values” (Mazziotta & Pareto, 2017, p. 178); such units receive a lower penalisation. The penalisation is downwards when the composite indicator is positive; it is upwards if the composite indicator is negative.

We used an equal-weighting system in both aggregation steps, as there are no specific references in the literature regarding the most appropriate weights to be used in a differential weighting scheme, or, in other words, regarding the relative importance of each individual indicator/pillar. It has to be noticed though that other weighting strategies have been used in the literature, such as differential weighting procedures that allow the weights to be different across individual indicators/pillars. Such strategies involve, for instance, PCA or regression analysis (Alaimo & Maggino, 2020; Gan et al., 2017).

We carried out the first aggregation step using the COMposite Indicators Creator (COMIC) software (Massoli & Pareto, 2017).⁷ COMIC is a software for building composite indicators using different normalisation and aggregation methods for several dates and evaluating their robustness. A specific feature of COMIC is that normalisation and aggregation are performed jointly, and each available aggregation method already includes a specific normalisation method, which cannot be further customised or removed by the user. The second step was performed by means of a specific code written using the R software.

⁷ <https://www.istat.it/it/metodi-e-strumenti/metodi-e-strumenti-it/analisi/strumenti-di-analisi/comic>

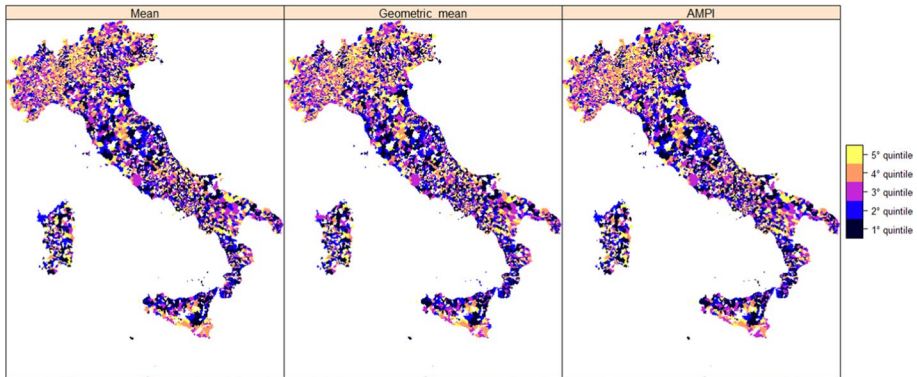


Fig. 1 Maps that represent the competitiveness of Italian municipalities, 2014

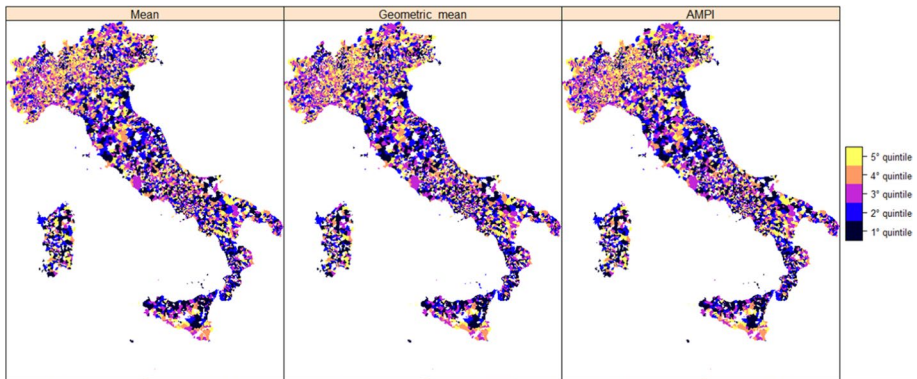


Fig. 2 Maps that represent the competitiveness of Italian municipalities, 2015

In fact, it was not desirable to use COMIC for the second aggregation step: if COMIC had been used again, the subindices would have been automatically normalised, leading to a double normalisation of the original data.

4.4 Results

The results are reported below, based on Scaccabarozzi (2021). To answer the research question, we present a detailed analysis of the computed indicators, compare the scores and the rankings (Sect. 4.4.1), discuss the most influential pillars associated with the three types of composite indicators and identify the most robust composite indicator among those under consideration (Sect. 4.4.2). Section 4.4.3 contains an analysis of the competitiveness of some specific municipalities to provide further insights into the properties of the proposed indicator, its capacity to distinguish different levels of competitiveness and hence the feasibility of building a composite indicator for measuring competitiveness at such a disaggregated level of detail.

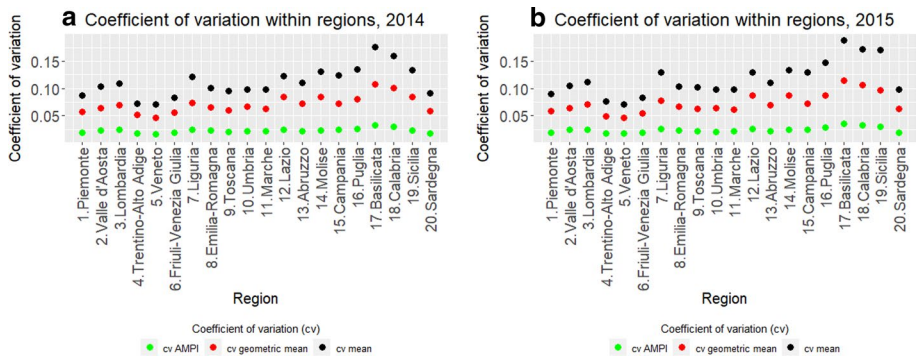


Fig. 3 Coefficients of variation of the three composite indicators in Italian regions, 2014 (left-side panel) and 2015 (right-side panel)

4.4.1 Scores and Rankings Comparison

We compared the scores using a geographical analysis and by considering their variability at the NUTS 2 regional level as well as the patterns between the initial competitiveness level and the observed changes in competitiveness according to the different methods. Rankings were compared by considering Spearman's co-graduation index and analysing the absolute differences of ranks. When interpreting the results, it should be taken into account that the arithmetic mean is a totally compensatory method, while the geometric mean and the AMPI are partially non-compensatory. Moreover, it should be recalled that the proposed composite indicator is positive, with higher scores corresponding to higher levels of municipal competitiveness.

The geographical distribution of municipal-level competitiveness scores is presented in Figs. 1 and 2 for 2014 and 2015, respectively, by comparing the three methods. The scores are divided into five classes (quintiles) to enable meaningful comparisons. The maps show that the three aggregation methods produce similar score distributions, which do not differ significantly between the two periods. Highly competitive municipalities, represented with the lightest colours (yellow and orange) in the maps, are identified in every region, though their concentration is quite different across regions: the concentration is visibly higher in the Northwest and Northeast regions, while several low-competitive municipalities are located in the regions of the South and the Islands.

Considering the scores' variability at the NUTS 2 regional level, Fig. 3 shows the coefficients of variation within each NUTS 2 region for 2014 and 2015. This analysis allows to measure the degree of within-region heterogeneity in municipal competitiveness and hence to identify the regions with higher internal variability in terms of municipal competitiveness and those showing more uniform levels. We preferred the coefficient of variation over other possible methods to measure variability, as the scores of the three aggregation methods are characterised by different ranges. Figure 3 shows that even though the three aggregation methods have different ranges for the coefficients of variation, they exhibit a similar behaviour within each time period. This also provides a robustness check: the AMPI is associated with the lowest values of the coefficient of variation for every region.

To investigate the patterns between the initial competitiveness levels and the observed changes in competitiveness based on the three methods, Fig. 4 shows velocity-acceleration score plots for each aggregation procedure. These plots report the initial competitiveness

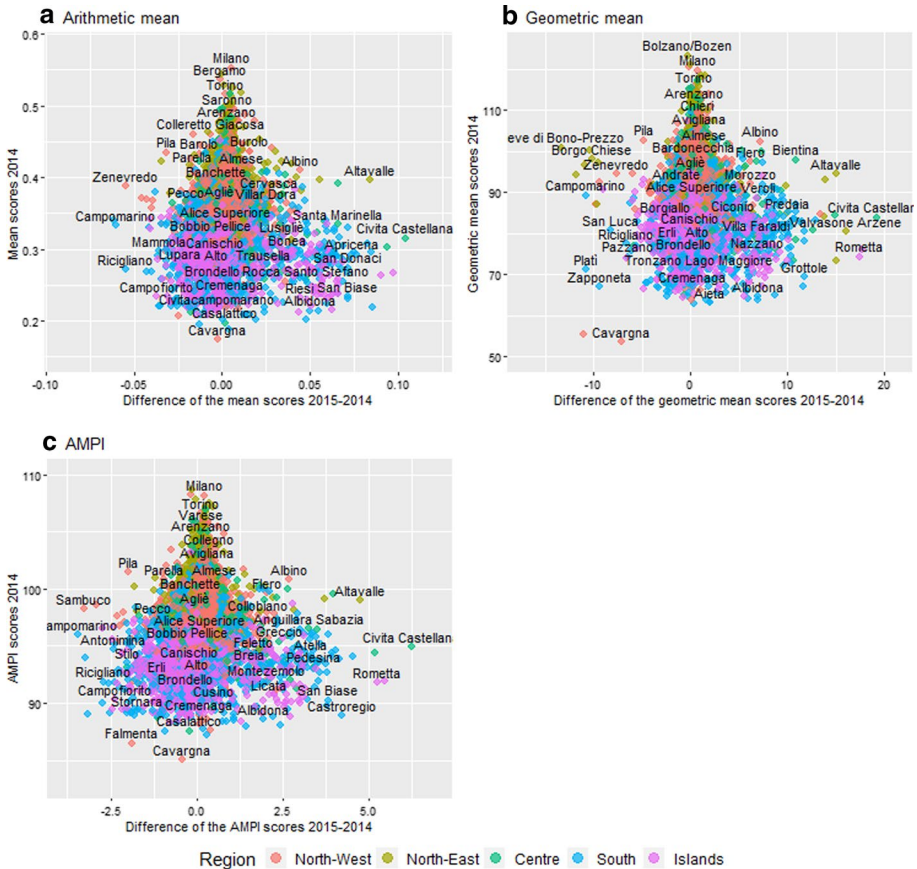


Fig. 4 Velocity-acceleration score plots of the arithmetic mean, the geometric mean and the AMPI (panels a–c, respectively)

Table 4 Spearman’s rank correlation matrix for the three composite indicators for 2014 and 2015

Method	2014			2015		
	Mean	Geometric mean	AMPI	Mean	Geometric mean	AMPI
Mean	1	0.984	0.996	1	0.983	0.995
Geometric mean	0.984	1	0.993	0.983	1	0.992
AMPI	0.996	0.993	1	0.995	0.992	1

level in 2014 on the y axis and the change in competitiveness between 2014 and 2015 on the x axis. Each point in the plots represents one of the 7,159 municipalities in the dataset, coloured according to the corresponding NUTS 1 region. The plots are slightly different in terms of the municipalities that exhibited the highest changes in competitiveness, but generally, the plots are very similar. Overall, the point clouds do not show a clearly increasing

Table 5 Summary statistics of the absolute differences of ranks, 2014 and 2015

Absolute differences of rank	Mean	Standard deviation	Coefficient of variation
2014			
Mean-geometric mean	251.675	272.167	1.081
Mean-AMPI	137.128	139.449	1.017
Geometric mean-AMPI	150.739	183.175	1.215
2015			
Mean-geometric mean	256.722	286.531	1.116
Mean-AMPI	148.036	140.254	0.947
Geometric mean-AMPI	159.563	209.843	1.315

or decreasing pattern and are concentrated around a change in competitiveness equal to 0 and roughly aligned along the y axis.

Regarding the comparison of the rankings associated with the three aggregation procedures, we first analysed their degree of correlation by computing Spearman's co-graduation indexes, calculated as Pearson's correlation for the ranks of each possible pair of the three aggregation methods. Spearman's co-graduation index takes values in the range $[0, 1]$, where the two extreme values indicate zero rank correlation and perfect rank correlation, respectively. Table 4 shows Spearman's rank correlation matrices for 2014 and 2015. The three rankings are strongly positively correlated, as all values are above 0.98.

Regarding the absolute differences of ranks between pairs of aggregation methods, Table 5 shows some basic summary statistics, namely the mean, the standard deviation and coefficient of variation for 2014 and 2015. Generally, the values reported in Table 5 are high and are justified by the high number of units that are included in the dataset. The mean of the rank shifts is always above 130, which means that for each pair of aggregation methods, on average, a municipality shifted more than 130 positions. The coefficient of variation enables us to conclude that, in terms of percentages, the variability of the absolute differences of ranks is above 100% of the mean for basically all the considered pairs of composite indicators. In terms of both the mean and the variability, the two closest methods are the arithmetic mean and the AMPI.

4.4.2 Influence analysis

We performed an influence analysis for two purposes: identify the most robust method among the three under consideration and the most influential pillars for municipal competitiveness in Italy in terms of the methods considered. The analysis involved seven leave-one-out simulations whereby each pillar was excluded one at a time. The composite indicator was computed after the removal of each pillar, and the absolute differences of ranks between the original ranking with all pillars and the new rankings with six pillars were then calculated for each municipality in the dataset. These steps were carried out for each aggregation method for the 2014 and 2015 periods.

The boxplots in Fig. 5 represent the distribution of the absolute differences of ranks related to the removal of each pillar, in relation to the simple arithmetic mean, the geometric mean and the AMPI, both in 2014 and in 2015. For each method, the seven distributions are clearly characterised by different ranges, interquartile ranges and skewness, which

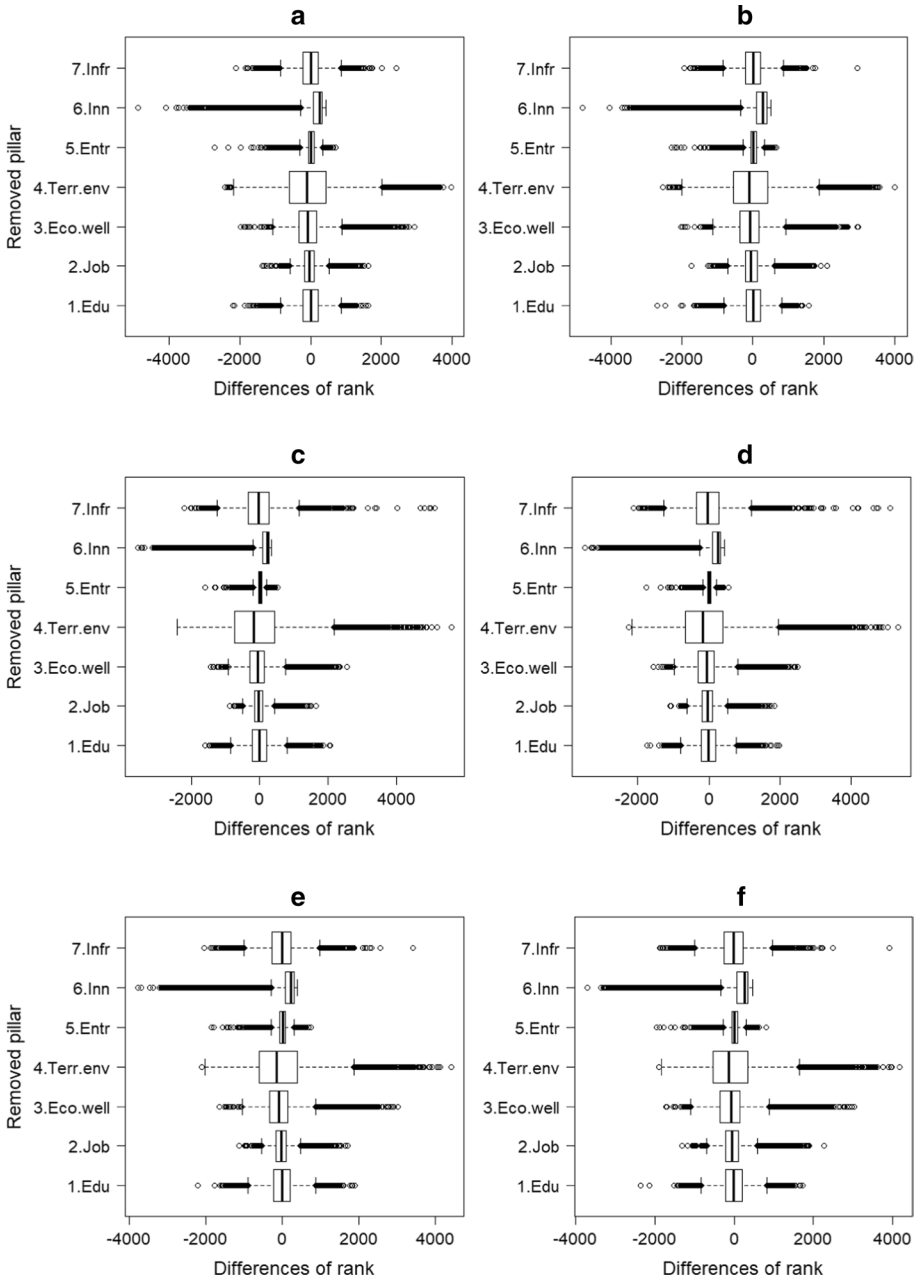


Fig. 5 Boxplots that show the distributions of the absolute differences of ranks (x axis) related to every excluded pillar (y axis) based on the arithmetic mean (panels a and b), the geometric mean (panels c and d), and the AMPI (panels e and f), for 2014 (left-side panels) and 2015 (right-side panels)

shows that the seven competitiveness dimensions affect the rankings in different ways once they are removed.

Table 6 Coefficients of variation for the absolute differences of ranks. Composite indicators: arithmetic mean, geometric mean and AMPI, 2014 and 2015

Removed pillar	Aggregation method		
	Arithmetic mean	Geometric mean	AMPI
2014			
6.Innovation	1.301	1.317	1.269
5.Entrepreneurship	1.216	1.211	1.179
3.Economic wellbeing	1.058	1.064	1.073
2.Job	1.019	1.062	1.039
7.Infrastructures and mobility	0.948	1.011	0.959
1.Education	0.918	0.946	0.921
4.Territory and environment	0.890	0.923	0.908
2015			
5.Entrepreneurship	1.231	1.224	1.189
6.Innovation	1.171	1.193	1.165
3.Economic wellbeing	1.027	1.040	1.050
2.Job	1.022	1.038	1.039
7.Infrastructures and mobility	0.940	1.004	0.956
1.Education	0.933	0.948	0.938
4.Territory and environment	0.898	0.931	0.921

The coefficients of variation for the absolute differences of ranks were computed for both 2014 and 2015 (Table 6). For each period, we considered the three aggregation methods. The most robust method, characterised by the lowest variability over the seven simulations, turned out to be the arithmetic mean, both for 2014 and 2015. However, a meaningful comparison should be made either between compensatory methods or between partially compensatory methods rather than between methods that belong to different categories. Regarding the two partially compensatory methods used, Table 6 shows that AMPI is more robust than the geometric mean for both periods.

Further, the study of the coefficients of variation helps in identifying the most influential pillar, which is the pillar that, once removed, leads to the highest coefficient of variation for the absolute differences of ranks. In general, within each period, the ranking of the removed pillars according to the coefficient of variation is the same, independently of the aggregation method used. However, the two time periods have slightly different rankings, with the most influential pillar in 2014 being Innovation and in 2015 Entrepreneurship, with respect to the three aggregation methods.

4.4.3 Competitiveness of specific municipalities

This section reports an analysis of specific municipalities to investigate some properties and characteristics of the proposed indicator and its capacity to distinguish different competitiveness levels. In this respect, as Northern regions exhibit higher competitiveness scores, it is interesting to consider the least competitive municipalities in this macro-region and to find out the most competitive municipalities in Southern Italy, as well as to explore the characteristics of these two groups. The general objective is to understand whether,

Table 7 Ten least competitive municipalities in Northern Italy and ten most competitive municipalities in Southern Italy, 2014, based on the arithmetic mean composite indicator

Ten least competitive municipalities in Northern Italy			Ten most competitive municipalities in Southern Italy		
Municipality	NUTS 1	Score	Municipality	NUTS 1	Score
Cavargna (CO)	Northwest	0.1736	Pescara (PE)	South	0.4741
Falmenta (VB)	Northwest	0.2074	Cagliari (CA)	Islands	0.4513
Gurro (VB)	Northwest	0.2166	Portici (NA)	South	0.4501
Cavaglio-Spocchia (VB)	Northwest	0.2191	Pomigliano d'Arco (NA)	South	0.4497
San Nazzaro Val Cavargna (CO)	Northwest	0.2231	Salerno (SA)	South	0.4486
San Bartolomeo Val Cavargna (CO)	Northwest	0.2270	Lagonegro (PZ)	South	0.4383
Cusino (CO)	Northwest	0.2351	San Sebastiano al Vesuvio (NA)	South	0.4346
Cremonaga (VA)	Northwest	0.2370	Bari (BA)	South	0.4339
Bene Lario (CO)	Northwest	0.2386	Piano di Sorrento (NA)	South	0.4336
Tronzano Lago Maggiore (VA)	Northwest	0.2416	Vallo della Lucania (SA)	South	0.4336

within each group of outliers, these municipalities are close to one another and to consider the possible reasons behind their performance.

To provide an example, we analysed the 2014 data by looking at the arithmetic mean composite indicator only, but a similar procedure could be performed on the 2015 data and, for both periods, using the other two aggregation methods.⁸ To this end, we computed the arithmetic mean composite indicator as described in Sect. 4.3. Then, starting from the 2014 global ranking that included all 7,159 municipalities in the dataset, the municipalities belonging to Northern Italy were filtered, arranged in ascending order based on the competitiveness scores and, finally, the first 10 municipalities were selected. The same procedure was applied to Southern Italy, but, in this case, the scores were arranged in descending order before the selection. Table 7 lists the 10 least competitive municipalities in Northern Italy and the 10 most competitive municipalities in Southern Italy in 2014.

A geographical pattern can be identified among the first group of outliers. Nearly all these municipalities are mountain municipalities, concentrated in a few provinces and a restricted area. They are either at the border with Switzerland or close to it. In this respect, administrative data can be partially misleading in relation to these municipalities, as a percentage of their residents can be expected to work in Switzerland. At the same time, the second group of outliers is more widespread in Southern Italy and belongs to a larger number of provinces.

To understand further specific strengths and weaknesses, the composite indicator was disaggregated into its dimensions. Table 8 shows the minimum and maximum scores of the arithmetic mean for each pillar for 2014 and provides, by way of example, the specific pillar scores of three municipalities selected from the two groups of outliers, namely Cavargna, Falmenta and Gurro in Northern Italy and Pescara, Portici and Pomigliano d'Arco in Southern Italy.

⁸ It should be noted that, as different methods lead to different rankings, the two groups of outliers are not perfectly equal among the three methods.

Table 8 Scores of the seven pillars for three municipalities from each group of outliers. Minimum and maximum values of the seven pillars from the 7,159 municipalities are reported in the last two rows. Composite indicator: arithmetic mean, 2014

Area	Municipality	1. Education	2. Job	3. Economic Wellbeing	4. Territory and Environment	5. Entrepreneurship	6. Innovation	7. Infrastructures and Mobility
Northern Italy	Cavargna	0.011	0.335	0.038	0.29	0.022	0	0.519
	Falmenta	0.018	0.344	0.104	0.558	0.007	0	0.421
	Gurro	0.092	0.267	0.087	0.525	0.016	0	0.529
Southern Italy	Pescara	0.424	0.478	0.561	0.416	0.309	0.479	0.652
	Portici	0.335	0.439	0.457	0.469	0.413	0.473	0.565
	Pomigliano d'Arco	0.295	0.444	0.444	0.438	0.142	0.711	0.674
	Minimum	0.011	0.267	0.038	0.023	0.004	0	0.181
	Maximum	0.567	0.725	0.889	0.858	0.654	0.755	0.753

Regarding the low-performing municipalities in Northern Italy, the three municipalities show low scores in nearly all pillars, especially in Education, Economic Wellbeing, Entrepreneurship and Innovation. More specifically, these municipalities take the minimum value in the Innovation pillar, and, in addition, Cavargna has the lowest value in the Economic Wellbeing pillar. It should be noted that Cavargna is a municipality in the Como province, which borders Switzerland. Some of Cavargna's residents work in Switzerland and pay taxes there; therefore, certain aspects related to these residents cannot be totally captured by administrative sources. Hence, the low competitiveness level observed possibly reflects a problem related to the use of administrative sources rather than real low level of competitiveness for the municipality.

As for the most competitive municipalities in Southern Italy, these municipalities exhibit high scores, particularly in the Infrastructures and Mobility pillar and, in the case of Pomigliano d'Arco, in the Innovation pillar. It should be noted that several departments of Gabriele d'Annunzio University are located in Pescara, that Portici hosts the Research Centre of ENEA, which also includes the Institute for Composite and Biomedical Materials (IMCB) of the CNR, and that an important industrial centre is located in Pomigliano d'Arco, which hosts, for instance, the Gian Battista Vico plant of Fiat Chrysler Automobiles. These factors may help explain, at least partially, these municipalities' performance in the aforementioned pillars.

5 Conclusions

The main aim of this study was to measure municipal competitiveness in Italy. The research question that guided our work was: finding a robust synthetic measure of municipal competitiveness in Italy, allowing comparisons over time and the identification of different levels of competitiveness; based on the proposed measure, understanding which dimensions of competitiveness are the most relevant to the overall phenomenon.

For measurement purposes, we decided to build a composite indicator of municipal competitiveness, as this method is particularly useful for studying multidimensional phenomena that cannot be properly measured using a single indicator.

The proposed theoretical framework was mainly inspired by the one underlying the Regional Competitiveness Index (RCI) (Annoni & Kozovska, 2010). Based on this and the extensive literature review, we identified seven dimensions (pillars) of municipal competitiveness: Education, Job, Economic Wellbeing, Territory and Environment, Entrepreneurship, Innovation, and Infrastructures and Mobility.

We retrieved municipal data from *A Misura di Comune*, a multi-source system of indicators at the municipal level that includes data from different sources, mainly administrative ones. The use of administrative based data has the advantage of allowing a very disaggregated analysis, providing a geographically detailed picture of municipal competitiveness in Italy. However, a detailed analysis on some specific municipalities (namely the 10 least competitive municipalities in Northern Italy and the 10 most competitive municipalities in Southern Italy) allowed us to identify issues associated with the use of administrative sources that may have affected the scores and hence the relative positions in the rankings. Particularly, we found that administrative sources cannot capture certain aspects related to municipal residents, such as the residents from Northern Italy who work in Switzerland. Despite this issue, the use of data retrieved

from administrative sources allowed for the construction of a composite indicator at the municipal level, a result that could not be achieved otherwise.

The methodology adopted for the construction of the composite indicator was guided by two main requirements: the proposed measure should be robust in terms of the mechanism for including or excluding single dimensions and it should allow for evaluations and comparisons of competitiveness over time. To this purpose, we considered rescaling as normalisation method and compared three versions of the composite indicator by applying three different aggregation techniques, namely the arithmetic mean, the geometric mean and the AMPI. The three methods were compared in terms of scores, rankings and the most influential pillars. The geographical distribution of the scores was similar among the three methods, with few differences between 2014 and 2015. The rankings based on the application of the three methods were not perfectly equal. Spearman's rank correlation was larger than 0.98 both in 2014 and in 2015. The mean of the absolute differences of ranks was high for both years, as, on average, a municipality shifted by at least 130 positions when two methods were compared, which means we should be cautious when interpreting the relative positions of the municipalities in the rankings, as the positions depend on the method used. We identified the most robust aggregation method by carrying out an influence analysis at the pillar level. Considering the coefficients of variation of the absolute differences of ranks (Table 6), the arithmetic mean turned out to be the most robust method. However, the arithmetic mean, being a compensative method, could not be directly compared to partially non-compensative methods. Among the latter, the AMPI proved to be more robust than the geometric mean. The influence analysis also allowed to identify Innovation and Entrepreneurship as the most influential pillars for municipal competitiveness in 2014 and 2015, respectively.

In terms of substantive results, the proposed competitiveness measure provides a geographically very detailed picture of competitiveness in Italy. Positioning the proposal with respect to the available literature, the competitiveness of Italian regions (NUTS 2 level) has been evaluated in the different editions of the RCI, with the 2016 edition (Annoni et al., 2017) showing that the regions of Northern Italy are either medium or highly competitive, with the highest scores belonging to Lombardy and Trentino-Alto-Adige, and the regions of Southern Italy, particularly Sicily and Calabria, being characterised by a lower level of competitiveness. Our proposed composite indicator at the municipal level offers further insights regarding territorial competitiveness in Italy. In this respect, it is important to recall that the municipal competitiveness indicator not only includes economic dimensions but also social ones. Municipal competitiveness turned out to be rather heterogeneous within each NUTS 2 region, particularly in the South and in the Islands (Fig. 3). Highly competitive municipalities were found in every NUTS 2 region, although their concentration was higher in Northern Italy than in Southern Italy (Figs. 1 and 2). Most of the municipalities did not exhibit a notable change in competitiveness between 2014 and 2015, regardless of their starting competitiveness level in 2014 or the NUTS 1 region to which they belonged (Fig. 4). However, the two periods were very close in time, and this factor should be taken into account. Furthermore, it is also interesting to note that the most influential pillar does not coincide in the two periods, with Innovation and Entrepreneurship being the two most influential pillars in 2014 and 2015, respectively (Table 6). Finally, the analysis of the least competitive municipalities in Northern Italy and the most competitive municipalities in Southern Italy, together with the disaggregation of the composite indicator into its dimensions, enabled us to obtain additional insights into the competitiveness of Italian municipalities also from a social perspective, thus completing the geographical

analysis and providing a more complex picture of territorial competitiveness in Italy (Tables 7 and 8).

Our analysis also entails certain limitations. First, the time frame is rather short and not very recent. The eventual update of the data available on *A Misura di Comune* would allow us to perform analyses in more recent time periods. Second, it is well known that there are pros and cons associated with the use of composite indicators (Mazziotta & Pareto, 2013; OECD & JRC, 2008; Saisana & Tarantola, 2002), and there exist two opposite schools of thought regarding their use (Sharpe, 2004). Considering the two opposite positions, it is clear that a composite indicator may be useful for measuring a multidimensional phenomenon, but builders must be aware that such indicators also have conceptual and methodological limits, which have to be identified and properly disclosed (Freudenberg, 2003). In this respect, future studies should explore the use of non-aggregative approaches to measuring municipal-level competitiveness. In this framework, the Partially Ordered Set (POSET) enables the development of non-aggregative synthetic indicators, which can measure a latent phenomenon without normalising and aggregating the scores of the individual indicators (Alaimo et al., 2021b; Fattore, 2017). This method is particularly useful in two situations: when the data are ordinal, which means they cannot be combined using linear combinations or other functions that are generally used with numerical indicators, and when the individual indicators are weakly interdependent, whether they are ordinal or cardinal (Fattore, 2017). While in the first situation a composite indicator approach is not possible, in the second situation, its results can lead to wrong interpretations. Recent applications of the POSET methodology have been discussed in Fattore (2017, 2018), Alaimo et al. (2021a), Alaimo et al. (2021b) and Fattore et al. (2015). Another method that could be considered non-aggregative is the one proposed by Mazziotta and Pareto (2020) to overcome some problems of the aggregative approach, namely the fact that the results of a composite indicator will differ across different aggregation methods and that a single value is used to measure a multidimensional phenomenon. Their method involves computing a range of values rather than a unique number for each statistical unit, and the results are independent of the aggregation method used (Mazziotta & Pareto, 2020).

Further developments of this study also include an analysis of the spatial dependence among the observed units, which is likely to exist among neighbouring municipalities.

Finally, with respect to the applicability of the proposed composite indicator to other contexts, the indicator may be extended beyond Italian borders. For example, it could be applied to other LAUs in the EU, provided data availability.

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