Measuring teachers' readiness to use ICT before the COVID-19 pandemic in Italy

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Abstract

This study seeks to measure teachers' readiness to use ICT in Italy by exploiting the data collected by the National Institute for the evaluation of education and training system (INVALSI) in 2018–2019. We propose a fuzzy set approach to provide a multidimensional picture of how much teachers were ready to integrate ICTs into educational practice. In addition, we use empirical bootstrap intervals to test whether significant differences exist in teacher readiness over several personal and socioeconomic characteristics. The study reveals that teachers' readiness for ICT is composed of three dimensions and varies by teachers' characteristics and regions. These results are a useful tool for understanding the relationship between teachers and ICTs so as to develop more appropriate educational policies.

Keywords

ICT in education; fuzzy logic; teacher readiness, INVALSI data

1. Introduction

In recent decades, the increasing pervasiveness of digital technologies in all areas of life, combined with the development of new communication languages, has required the innovation of education systems with the adoption of new training models that consciously integrate the use of digital technologies in teaching processes. The major international organisations have long recognised that new technologies are a catalyst for improving the quality of educational processes. In 2002, the United Nations Educational, Scientific and Cultural Organization (UNESCO) underlined that "*ICT adds value to the processes of learning and in the organisation and management of learning institutions. The Internet is a driving force for much development and innovation in both developed and developing countries*" (UNESCO, 2002). In 2010, the Organization for Economic Co-operation and Development (OECD) emphasised, "*a significant influence or effect of ICT on the measured or perceived quality of (parts of) education*" (OECD, 2010). In this context, ICT is perceived as an important tool in changing education (Blackwell et al., 2014). It is also for this reason that, since the 1990s, many countries have invested considerable resources in equipping schools with cutting-edge technological facilities (Witte and Rogge, 2014), to train and sensitise teachers to the issues connected with the digital revolution and to integrate technology into innovative educational projects, envisaging a comprehensive rethinking of the teaching process. Significant investments have enabled the implementation of new technologies in most schools in advanced countries. In the European context, the European Union has pushed its member states to invest in the digital revolution in education and has promoted, within the Strategic Framework for Education and Training (Eurydice, 2011), the integration of ICT in schools to improve technology-related competencies for all students and to enhance innovation and creativity. Additionally, in Italy, in line with other European countries, there has been exponential growth in the technological equipment of schools. The innovation in the school system and the digital educational opportunities have been considered key drivers of improving the Italian educational system and, thus, are one of the pillars of "La Buona Scuola" school reform (Law 107/2015). Operationally, in 2015 the Italian government launched the new edition of The National Plan for Digital Education (Piano Nazionale Scuola Digitale - PNSD), allocating €1.94 billion for new investments in ICT, financed by national and European funds and of which at least €511 million is for hardware and software technology. These investments, aimed at the transition towards the introduction of ICT in education systems, were interrupted by the COVID-19 pandemic with consequent school shutdowns. In a very short period of time, students, teachers, and school principals were forced to experiment with new types of educational practice. They all had to work outside their traditional educational environments, i.e., schools and classrooms, and adapt to working remotely using digital platforms. Thus, in the Italian context, it is of interest to measures the extent to which teachers were ready for the sudden and unexpected remote teaching triggered by the COVID-19 pandemic[1] and, in more general terms, it is relevant to assess the teachers' readiness to fully integrate information and communication technologies into educational practice.

We contribute to knowledge on this subject using a multidimensional perspective that contextually allows us to assess Italian teachers' "readiness to use ICT" as a matter of degree (a fuzzy concept). At least two considerations support this choice. We perceived teachers' readiness to use ICT as a phenomenon that needs to be assessed from several points of view. Therefore, a multidimensional approach is well suited for describing how this phenomenon is formed by different dimensions, which, in turn, are a summary of several aspects of it. Furthermore, we think that a fuzzy approach is generally very beneficial for problems with a high degree of complexity, as is the case with multidimensional phenomena.

A fuzzy approach in this regard can be considered a good choice because the measurement of teachers' ICT readiness is sensitive to how "teachers ready to use ICT" are identified. An approach based on a rigid dichotomy, namely, "ready/not ready" using a cut-off value for each aspect under study, could not be so immediate. In addition, such a clear-cut division results in a loss of information and removes the nuances that exist between the two extremes of substantial confidence in using ICT (teachers ready for

[1] There is a recent and increasing literature on the measurement of the degree of readiness of teachers for the online teaching and distance learning model triggered by the COVID-19 pandemic. Most of these research studies provides insights on the teachers' preparedness in emerging economies, as Philippine (Ocampo and Solina, 2021), Indonesia (Andarwulan et al., 2021), Pakistan (Makhdum and Khanam, 2021), and India (Paliwal and Singh, 2021). On studies reporting evidence from international samples, see, among others, Scherer et al. (2021).

ICT) on the one hand and those with distinct difficulties on the other. Currently, there are many applications of fuzzy statistical methods in various substantive domains, and many authors recognise their utility in several empirical contexts (see, among others, Belhadj and Limam, 2012; Neff, 2013; Betti et al., 2016; Pi-Alperin, 2016). For the purposes of our analysis, we use the fuzzy approach to poverty measurement, employed by Betti et al. (2006) and revised by Betti et al. (2016) to study the quality of life. This approach has a universal and interdisciplinary nature (Betti et al., 2020) and is considered a useful tool, even in education

Problem statement

The COVID-19 pandemic has accelerated ICT integration into educational processes. An in-depth assessment of the degree of teachers' ICT readiness can be a valuable tool for policy-makers and stakeholders of the educational system to support this integration process effectively. From this perspective and using a fuzzy set approach this study aims to understand teachers' ICT readiness using the data collected each year by the Italian National Institute for the evaluation of education and training systems (INVALSI). Our empirical strategy starts with the investigation of the dimensions that define teachers' readiness to use ICT, and then we attempt to answer the following research questions:

i) Do the dimensions vary by selected teacher characteristics?

ii) How are these dimensions distributed among the Italian regions?

The originality of our contribution to the literature is threefold. First, studies on this issue in Italy have received scarce attention, as we show in the following section. Second, as far as we are aware, this is the only empirical study that has addressed the issue of teachers' readiness to use ICT in a multidimensional framework and as a matter of degree. Third, in the empirical analysis, we identify the relevant dimensions of teachers' readiness to use ICT and, at the same time, we explore whether and how these dimensions vary with teachers' characteristics and regions. Our results allow us to learn more about the relationship between teachers and ICT and contribute to the development of more effective educational policies.

The paper is organised as follows. A literature review is presented in the next section, which is followed by the data and methods section, the core results and the discussion of our findings. The last section concludes the paper.

2. Literature review

Educational systems around the world are implementing digital competencies and skills in school curricula (Flórez et al., 2017; Siddiq et al., 2016). At the same time, teachers are encouraged to adopt technology in their teaching as a tool to facilitate learning or as a means for computer-based formative assessment systems (Shute and Rahimi, 2017; Straub, 2009). In recent years, integrating ICT into teachers' daily work with students has been considered an essential tool for improving the teaching and learning process (Bettinger et al., 2020). Many authors have pointed out that teachers play a crucial role in implementing ICT in the classroom, regardless of the quantity and quality of technology available in schools and classrooms (Williams et al., 2000). From this perspective, it is relevant to assess the degree of teacher ICT readiness, i.e., the extent to which teachers adopt technology and their confidence in using digital technologies (Fraillon et al., 2014; Petko et al., 2018). A large body of literature has investigated the factors affecting teacher readiness. In general, it is claimed that the choice of educational technology integration is related to teachers' beliefs and skills (Kim et al., 2013). From this perspective, teachers who are not fully convinced of the benefits and potential of ICT are reluctant to integrate technology into their teaching regularly and effectively (Badia et al., 2014). Ertmer et al. (2015) highlight that teachers who are accustomed to the traditional teaching approach are characterised by a pedagogical prejudice that leads them to not adopt technology in their classrooms. Fraillon et al. (2014) show that the main obstacle to ICT integration is teachers' self-efficacy. Teachers avoid the practical application of ICT in the classroom if they do not feel competent and lack sufficient skills. Different scholars have stressed that the adoption of technological innovation and the use of any technological system are affected by the potential users' level of acceptance (Hermans et al., 2008).

This large body of research refers to the technology acceptance model (TAM) theoretical framework, which is a key model describing teachers' intentions to use technology (Teo, 2009). The TAM hypothesises that teachers' choice of ICT adoption is the result of a system of interrelationships among attitudes towards technology (ATT), perceived usefulness (PU) and perceived ease of technology use (PEOU). Many scholars have explored these interrelations within the TAM framework by performing structural equation and path modelling (Marangunić and Granić, 2015) and evaluating model fit (Teo, 2015)[2]. Therefore, ICT integration into school teaching is not only a technological but also a cultural challenge. Institutions have the responsibility to provide computers for schools, as well as to foster a culture of acceptance amongst the end-users of these tools, whether they are teachers or students, and to

[2] An interesting meta-analysis of these studies is provided by Scherer and Teo (2019).

adopt policies and actions on several fronts to equip all learners with digital knowledge and skills (Gil-Flores et al., 2016). Many studies focus on the “catalyst” factors of ICT implementation; several authors have shown that teachers’ attitudes towards the potential of ICT are relevant factors for its implementation. Eickelmann and Vennemann (2017) analyse a selection of European educational systems and find that teachers’ attitudes are directly or indirectly related to the use of ICT in teaching. Hatlevik and Hatlevik (2018) address teachers’ ICT self-efficacy in a sample of Norwegian schools. They report that teachers’ self-efficacy and collegial collaboration among teachers have a positive association with the use of ICT in their teaching practice.

A different strand of research analyses the relationship between teachers’ ICT readiness and their level of technological competence. This aspect is particularly relevant because, as highlighted by Hanushek (2002), the teaching staff’s knowledge and skills are perhaps the most critical factors in explaining the learning level of students in schools. In these studies, the central question is as follows: do teachers have the required knowledge of ICT to integrate technology into their classrooms? The main findings of these research efforts highlight that the key factor in successful ICT integration in schools is improving the level of ICT knowledge among teachers. From this perspective, Albirini (2006) reports that teachers’ attitudes towards ICT are also related to teachers’ competence in using technology, while Rosnaini and Mohd Arif (2010) show that a minority group of teachers achieve a basic level of ICT competence and, at the same time, a vast proportion of teachers exhibit a very minimal knowledge of ICT. Røkenes and Krumsvik (2016) examine whether Norwegian preservice teachers are ready to teach with ICT. They indicate a high degree of variability in teacher preparedness to use ICT in education and highlight that, to integrate technology into teaching effectively, it is necessary to provide access to pedagogical support and time to experience how ICT can be used in their teaching. Kim and Kim (2017) investigate teachers’ ICT readiness in Korean schools, focusing on the use of tablets. Their results show a statistically significant relationship between teachers’ preparedness and tablet integration in the classroom. Saltan and Arslan (2017) analyse a sample of Turkish in-service and preservice teachers. They use the TPAK (technological pedagogical content knowledge) theoretical approach (Angeli and Valanides, 2005; Harris and Hofer, 2011; Koehler and Mishra, 2005) to assess teachers’ self-confidence in technology, pedagogy and content knowledge for technology integration in education. The results showed differences between the two main groups of teachers in relation to some of the constituent components (i.e., pedagogy, technology or content knowledge) of the TPACK model.

Although introducing ICT in education has been a priority of the Italian policy agenda, studies about this topic are relatively scarce at the national level. Gui and Gerosa (2019) exploit INVALSI data from 2014 to 2017 to analyse teachers' use of ICT. Their findings show that the teachers' use of ICT has grown slowly and in a way that is not proportional to the significant investments allocated to improve Italian schools' infrastructures and technological equipment. Similar results are reached by Calzone and Chellini (2016), who conducted empirical research on a sample of over 7,000 teachers to evaluate the use of ICT in the last two grades of upper-secondary schools in southern Italy. Their exploratory analysis highlights two results: first, that teachers in southern Italy use new technologies sporadically; and second, that ICT is mainly used as a tool to prepare lessons at home and not as a support to teaching activities in the classroom. The Italian Authority for Communications Guarantees (AGCOM; 2019) exploits the data collected by the Italian Ministry of Education (MIUR). It proposed a set of indicators to describe the teachers' use of ICT and the availability and quality of internet connections in the schools. Their findings draw attention to the need to improve teachers' digital skills to promote the efficient and conscious use of new technologies. More recently, Lucisano (2020) presented the results of a survey carried out by the Italian Society of Educational Research (SIRD) about the experience of Italian teachers during the COVID-19 health emergency. The survey reached more than 16,000 teachers from schools of all levels and grades from all Italian regions, and it highlighted that COVID-19 has probably accelerated the process of integrating ICT in Italian schools and, at the same time, pushed teachers to greater use and confidence in these tools. In summary, considering this literature, we propose that studying teachers' readiness to use ICT from a multidimensional perspective in Italy can contribute to producing new knowledge on this issue and help to implement more effective educational policies.

3. Data and Method

3.1. Data

The National Institute for the evaluation of education and training system (INVALSI) each year evaluates all Italian students at different school levels (primary and secondary education) through standardised tests related to students' achievement in reading, mathematics and English. The INVALSI assessment is a low-stakes test since the results do not affect students' academic progression or grades. At the same time, the INVALSI results help the central government assess the general performance of the school system and allow comparisons within and between schools across space (at the national, regional, and county levels) and over time (annual variations).

The INVALSI survey consists of two distinct surveys that differ in the method of administering the tests. The main survey is a census survey involving the administration of tests by teachers in each school and class. In addition, a probabilistic sample of schools and classes is considered to carry out the tests under the control of external observers. The sample survey provides more timely and qualitatively better data because external administrators' presence removes or minimises teachers' cheating (Longobardi et al., 2018). Additionally, the sample survey provides a wealth of information, as the INVALSI administers specific questionnaires to the principals and teachers included in the sample to broaden the set of available covariates and collect relevant data at multiple levels of analysis.

In particular, the teacher questionnaire is focused on teaching and evaluation methods. In contrast, the principal questionnaire collects important information related to various aspects of school life, such as management practices, availability of infrastructure, resources and school climate. Among the several aspects of school life investigated by the INVALSI, considerable attention is given to the teachers' use of new technologies as a support to teaching and evaluation activities. From this perspective, in our research, we use data from the 2018–2019 Teachers Questionnaire of the Grade 10 sample classes to assess the degree of teachers' ICT readiness before the COVID-19 pandemic. The choice to analyse the level 10 data is due to the more significant number of covariates on the use and the propensity of teachers towards ICT collected at this school level. The information is self-reported and collected at the regional level (NUTS 2) on a sample of 2,356 teachers (1,183 math teachers and 1,173 Italian teachers). As explained in the previous sections, "readiness to use ICT" is a complex phenomenon that includes different dimensions that are usually not directly measured. Its multidimensional nature implies that teachers experience a certain number of observed indicators that can be summarised into a reduced set of latent dimensions. Accordingly, we consider a broad set of items (*indicators*) of the Teachers Questionnaire related to the integration of new ICTs in teaching practice. Table 1 lists and describes these items.

We assume that these variables represent the potential set of indicators that are single observable manifestations of the multidimensional concept of "readiness to use ICT". All the considered indicators move in the same direction: the higher the indicator's value, the greater the likelihood that the teachers have a good level of readiness to use ICT.[3]

[3]The values of the items from D10a to D10g have been reversed in such a way that higher values suggest higher teachers' readiness toward ICT, then the reversed 4-point Likert scale of these variables becomes the following: 1="Not present at school"; 2="Not use"; 3="Occasional use"; 4="Regular use".
The answer "I don't know" of the items from D1a to D1d has been recoded by assigning them the median value, consequently the new scale of these variables is the following: 1=Strongly Disagree; 2=Little agree; 3=Fairly agree; 4=Strongly agree; 5=I do not know.

Table 1. List of items selected from the INVALSI Teacher Questionnaire.

ITEM	Survey questions	Type of variable (answers)
D1a	To what extent does the teacher believe that the transition from the paper test to the computer test helped in the understanding of the questions?	Categorical variable (1=Strongly Disagree; 2=Little agree; 3=Fairly agree; 4=Strongly agree; 5=I do not know)
D1b	To what extent does the teacher believe that the compensative instruments involved in the computer test adapt themselves to the single student's needs?	Categorical variable (1=Strongly Disagree; 2=Little agree; 3=Fairly agree; 4=Strongly agree; 5=I do not know)
D1c	To what extent does the teacher believe that the computer test increases the assessment objectivity?	Categorical variable (1=Strongly Disagree; 2=Little agree; 3=Fairly agree; 4=Strongly agree; 5=I do not know)
D1d	To what extent does the teacher believe that the computer test allows placing the student's competence level with respect to National Educational goals?	Categorical variable (1=Strongly Disagree; 2=Little agree; 3=Fairly agree; 4=Strongly agree; 5=I do not know)
D2a	Frequency of use of computer tests made available on the INVALSI site	Categorical variable (1=Never or almost never; 2=Sometimes; 3=Often Always, 4= Nearly always)
D2b	Frequency of use of computer tests on other platforms	Categorical variable (1=Never or almost never; 2=Sometimes; 3=Often Always, 4= Nearly always)
D2c	Frequency of use of computer tests prepared by the teacher	Categorical variable (1=Never or almost never; 2=Sometimes; 3=Often Always, 4= Nearly always)
D2d	Frequency of use of the computer lab	Categorical variable (1=Never or almost never; 2=Sometimes; 3=Often Always, 4= Nearly always)
D2f	Frequency of use of materials in digital format (links, video, website, etc.)	Categorical variable (1=Never or almost never; 2=Sometimes; 3=Often Always, 4= Nearly always)
D10a* D6a**	Frequency of use of ICT supports for teaching (computer)	Categorical variable (1=Regular use; 2=Occasional use; 3=Not use; 4=Not present at school)
D10b* D6b**	Frequency of use of ICT supports for teaching (Multimedia Interactive Whiteboard)	Categorical variable (1=Regular use; 2=Occasional use; 3=Not use; 4=Not present at school)
D10e* D6e	Frequency of use of ICTs supports for teaching (smartphone)	Categorical variable (1=Regular use; 2=Occasional use; 3=Not use; 4=Not present at school)
D10f* D6f**	Frequency of use of ICT supports for teaching (e-learning platforms)	Categorical variable (1=Regular use; 2=Occasional use; 3=Not use; 4=Not present at school)
D10g* D6g**	Frequency of use of ICT supports for teaching (educational software)	Categorical variable (1=Regular use; 2=Occasional use; 3=Not use; 4=Not present at school)
D11f* D7f**	Assessment method: Frequency of use of assessment platforms	Categorical variable (1=Never or almost never; 2=Sometimes; 3=Often Always, 4= Nearly always)

Note: *Item of the questionnaire for math teachers; **Item of the questionnaire for Italian teachers.

3.2. Method

We treat teachers' readiness to use ICT as a multidimensional phenomenon. Multidimensional approaches, in different frameworks, are generally based on several items that represent a potential set of indicators that are single observable manifestations of a multidimensional concept whose complexity is related to the different dimensions that define it. Different techniques and statistical procedures for measuring these dimensions have been developed, and obviously, they also vary widely among different frameworks (see, among others, Facchinetti et al., 2021; Alkire and Santos, 2013; Kern et al., 2015; Edo et al., 2021; Wu et al., 2022; Betti et al., 2006). Specifically, we address this issue by adopting a fuzzy approach (Zadeh, 1965), namely, we consider teachers' ICT readiness as a matter of degree (fuzzy concept) by the specification of a membership function to the set of teachers who are ready for ICT use. In particular, in this context we adopt the fuzzy set approach proposed by Betti et al. (2016) to study the quality of life because the set of available information and the general frameworks are very similar. The same approach has also been applied by Pi-Alperin (2016) for computing a multidimensional measure of individual health.

In the theory of conventional sets, the readiness to use ICT by a teacher would be represented by a dichotomous function that can take the values 0 and 1, following the idea that a teacher is ready or not to use ICT. Fuzzy set theory allows us to consider a more general membership function for each teacher according to each item presented in Table 1.

Let us assume that for a set of *n*-teachers, the *i-th* teacher possesses the *k*-vector $(x_{i1},\ldots,x_{ij},\ldots,x_{iK})$ of the indicators (*k=1,…, K*) displayed in Table 1, where x_{ij} specifies the level of indicator j possessed by teacher i, with categories c_j $(j = 1,\ldots,C_j)$ ordered from the lowest value of readiness to use ICT to the highest.

The membership function for the *i-th* teacher and the *j-th* indicator to the set of the teacher that have substantial confidence with ICT can be defined as follows:

$$\mu_j(x_{ij}) = \frac{F(c_{j,i})-F(1)}{F(C_j)-F(1)}, j = 1,\ldots,K;\ i = 1,\ldots,n, \qquad (1)$$

where $c_{j,i}$ is the category of the *j-th* indicator, corresponding to the *i-th* teacher, and $F(c_{j,i})$ is its corresponding cumulative function. When the indicator assumes a value equal to one (lowest level of the readiness to use ICT), then $F(c_{j,i}) = F(1)$, and therefore, $\mu_j(x_{ij})$ is equal to zero. Instead, when the item assumes the highest level of readiness to use ICT (e.g., C_j), then the numerator of Eq. (1) is equal to the denominator, and therefore, $\mu_j(x_{ij})$ is equal to one. Membership function values between 0 and 1 indicate intermediate degrees of readiness to ICT, e.g., the *i-th* teacher for the *j-th* item belongs to the set of "teachers ready to ICT".

Let also be *d* (*d=1..,D*), one of the possible dimensions that characterise a particular aspect of teachers' readiness to use ICT. In other words, each dimension *d* is an aggregation of different items presented in Table 1 that reflects a particular aspect of teachers' readiness to use ICT. As indicated by Betti et al. (2006), in the first step of the empirical analysis, a standard exploratory factor analysis (EFA) was performed. We used EFA just to discover if the multidimensional concept should be broken down into more than one dimension, but a formative perspective characterises our approach (Maggino and Zumbo, 2012). Therefore, we assume that the causality is from the elementary indicators to each dimension, and a change in each dimension does not necessarily imply variations in all its measures.

Accordingly, the multidimensional fuzzy index for the *i-th* observational unit in the *d-th* dimension is then derived by computing the weighted average across the $\mu_j(x_{ij})$ holding to dimension *d*, i.e.,

$$\mu_d(i) = \sum_k w_{(d)k}\mu_j(x_{ij}) \,/\, \sum_k w_{(d)k}, \qquad (2)$$

where $w_{(d)k}$ is the weight of the *k-th* single indicator in the *d-th* dimension, computed as $w_{(d)k} = w^a_{(d)k} * w^b_{(d)k}$. The first factor is the coefficient of variation of Betti and Verma (2008), while to control for redundancy, the second factor is a measure based on correlations among items within each given dimension. In particular, $\mu_d(i) = 0$ if the *i-th* teacher is completely deficient in using ICT, $\mu_d(i) = 1$ if the *i-th* teacher has total competence in ICT with respect to all the *K* items of dimension *d*, and $0<\mu_d(i) < 1$ if the *i-th* teacher's readiness in using ICT is partially, or totally, affected by some competences in using ICT but not fully affected by all of them.

Finally, it is also possible to construct a fuzzy multidimensional readiness index μ_d (henceforth called the overall fuzzy readiness index for dimension *d*). It measures the degree of readiness of the entire population of teachers with respect to the *d-th* dimension and is defined as the average value of individual values $\mu_d(i)$ defined by Eq. (2), across the population, as follows:

$$\mu_d = \frac{1}{n}\sum_{i=1}^{n} \mu_d(i). \qquad (3)$$

One way of exploring whether different groups of the teacher population have different degrees of readiness to use ICT is by dividing the whole population into different groups, computing the fuzzy multidimensional index μ_d for each group and finally testing for statistically significant differences between groups. In this context, a nonparametric bootstrapping approach that makes no assumptions about the nature of the underlying population is more appropriate (Chernick, 1999). Indeed, bootstrapping is a popular method of producing confidence intervals because of its generality (see, among others, Benedetti et al., 2020; D'Agostino et al., 2022; Rousselet et al., 2021). Accordingly, for comparing two groups, we create the distribution of bootstrap differences in the means (i.e., we generate M bootstrap samples from each group and compute the statistic of interest ($\mu_{d,group1} - \mu_{d,group2}$) for each bootstrap sample), and then we use the 25th value and the 975th value of the ranked differences as boundaries of the 95% confidence interval. If the confidence interval does not include zero, we conclude that the difference is statistically significant at 5% (Wood, 2005). For comparing regions, we use the 95% bootstrap confidence intervals for the sake of simplicity even if we used the Kruskall-Wallis (KW) nonparametric test (Kruskal and Wallis, 1952; Hollander et al., 2014) to detect differences between regions in fuzzy indices. Dunn's test with Holm-Sidák adjustment (Holm, 1979) was performed for multiple pairwise comparisons between regions.

4. Results

First, the items, presented in Table 1 and transformed using Eq. (1), are included as input variables[4] for EFA with a "varimax" rotation strategy (Bandalos, 1996). A three-factor structure is identified as mediating between the criterion of the number of factors to retain, based on the eigenvalue > 1 rule (EV > 1; Kaiser, 1960) and the scree plot that suggests a three-factor structure. We proceed to corroborate this structure composed of three dimensions by measuring the internal reliability (i.e., the degree to which the items in the scale represent each latent construct) estimated by Cronbach's alpha index. The three-factor structure is summarised in Table 2. We report the three dimensions identified with their description and Cronbach's alpha index. The reliability of each scale item is equal to 0.74 for the ICT dimension for TEACHING, 0.70 for the ICT dimension for ASSESSING and 0.72 for the EXPECTATIONS dimension for ICT. The alpha coefficients exceed or equalise the 0.70 cut-off recommended by Nunnally and Bernstein (1994). We, therefore, conclude that our three-dimensional structure is supported by the data.

Table 2. Dimensions description and Cronbach'a alpha values resulting from the analysis.

Dimension	Description	Cronbach's Alpha	Items
S2 ICT for TEACHING	Be able to support teaching process using ICT	0.74	D2f, D10a, D10b, D10e, D10f, D10g, D11f
S4 ICT for ASSESSING	Be able of making effective use of computer tests	0.70	D2a, D2b, D2c, D2d
S3 EXPECTATIONS for ICT	Have a positive attitude toward new educational tools	0.72	D1a, D1b, D1c, D1d

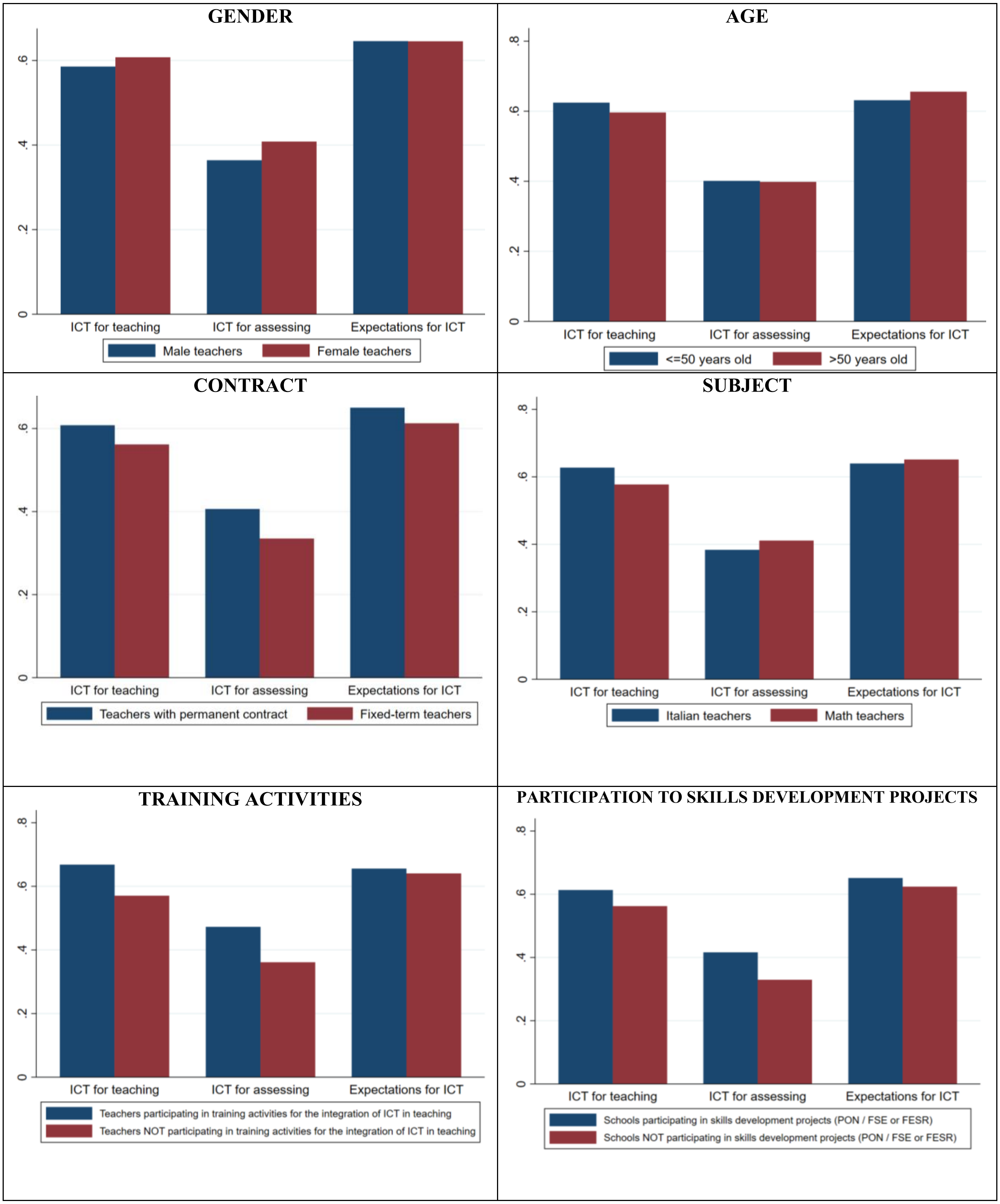
Note: Results are from authors' calculations based on INVALSI Data on Teachers Questionnaire.

[4] Preliminary analyses show a significant Bartlett's test of sphericity (p< .001) and a sufficiently high value of the Kaiser–Meyer–Olkin Measure of Sampling Adequacy (KMO=0.847) as suggested by Hair et al. (2018).

The multidimensional fuzzy readiness index μ_d for each of the three dimensions (ICT for TEACHING, ICT for ASSESSING and EXPECTATIONS for ICT**)** was then computed by averaging the overall membership function $\mu_d(i)$ defined in Equation (2) by teacher and school characteristics, and an analysis to test whether these dimensions differ by these variables was conducted. These variables have been defined as dummy variables so that two groups are identified for each of them (see Figure 1). For instance, the first graph in Figure 1 shows the value of the index μ_d for each dimension when we divide the sample according to gender. First, as expected, the teacher population has a certain level of competence in using ICT, as the multidimensional fuzzy index is never zero, but it is also evident that this level of competence varies by the subgroups under analysis. As explained in Section 3.2, empirical bootstrap 95% confidence intervals for the differences have been estimated (Efron and Tibshirani, 1994) to test whether there is a significant difference for each overall fuzzy readiness index μ_d between the two groups for each dimension. The intervals for the differences are reported in the Appendix (Table A1). When the interval includes zero, at a significance level of 0.05, we cannot reject the hypothesis of no difference between the two groups. The values reported in Table A1, in general, show that most of these differences are significantly different from zero, confirming the results highlighted by the graphs in Figure 1.

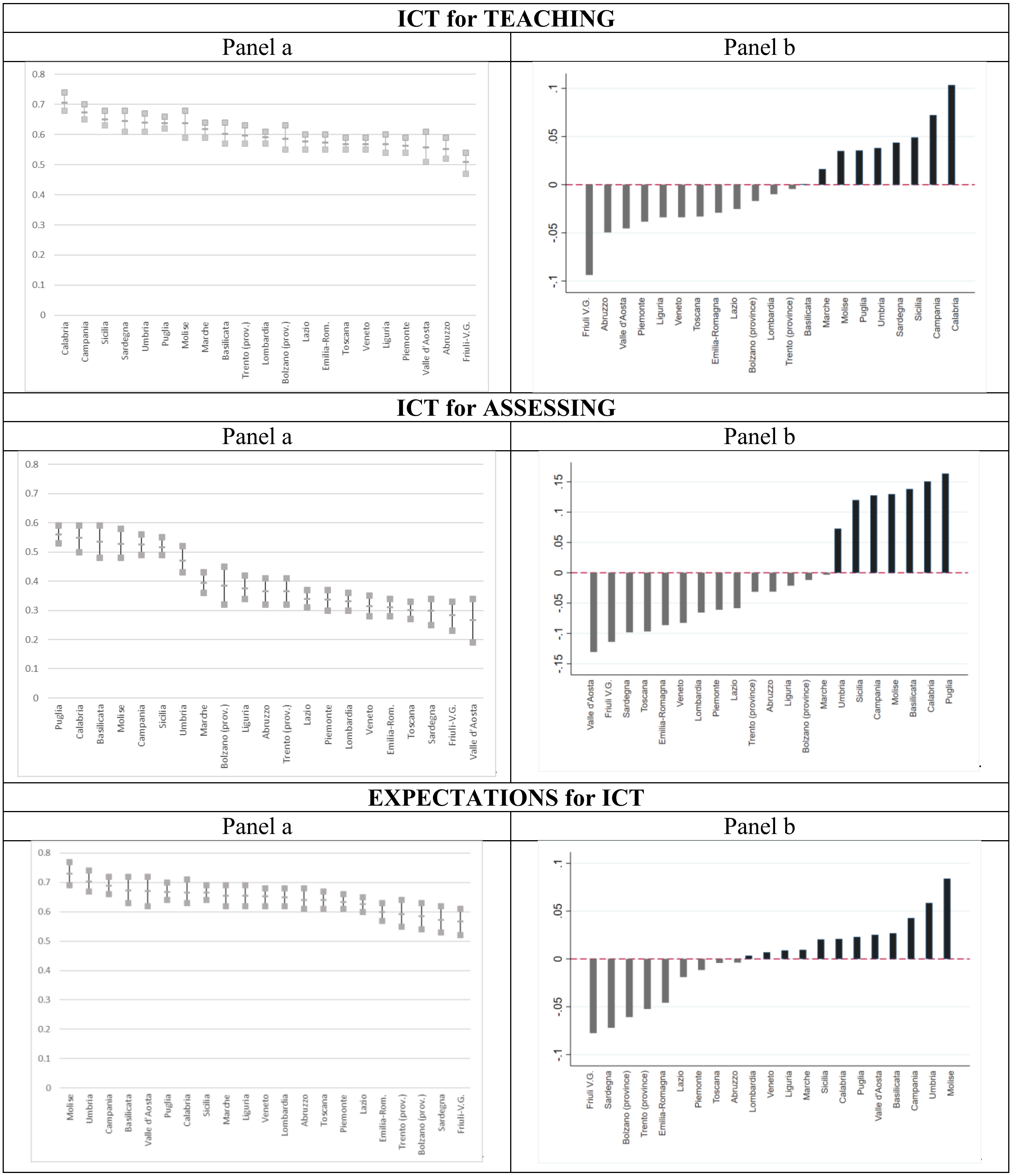
Finally, in Figure 2, we report both the empirical 95% confidence intervals of the three overall fuzzy readiness indices μ_d (EXPECTATIONS for ICT, ICT for TEACHING, and ICT for ASSESSING) by region (Panel A) and the regional differences from the country average (Panel B). Positive regional differences from the national average fuzzy indicator indicate that a given region is better positioned concerning teachers' readiness to use ICT. The p-values of Dunn's test are reported in Tables A2–A4 in the Appendix. They show that most of the differences between the southern and northern regions are significantly different from zero

Figure 1. Multidimensional fuzzy readiness index for each ICT readiness dimensions by teacher and school characteristics.



Note: Results are from authors' calculations based on INVALSI Data on Teachers Questionnaire.

Figure 2. Empirical confidence intervals (95%) at regional level (Panel A) and regional differences from national average (Panel B) by ICT readiness dimensions.



Note: Results are from authors' calculations based on INVALSI Data on Teachers Questionnaire.

5. Discussion

5.1. The dimensions that define teachers' readiness to use ICT

Our findings allow us to have a concise picture of different aspects of the overall ICT readiness ICT in the Italian case, showing that three underlying components explain the readiness of teachers to use ICT. Two components out of three measure the effective use of such ICT-based tools undertaken by teachers. The third component represents a specific dimension related to the teachers' perceived likelihood of success in using ICT for educational purposes.

Our first dimension summarises several aspects of the instructor's capacity to support teaching using ICT (hereafter, ICT for TEACHING). In fact, seven items (D2f, D10a, D10b, D10e, D10f, D10 g, D11f) of this dimension refer to the teachers' frequency of use of technology. Specifically, it includes the use of several tools, such as assessment platforms, smartphones, computers, Multimedia Interactive Whiteboards, e-learning platforms, educational software, and multimedia resources, such as links, videos, and websites. As a whole, ICT for TEACHING reflects the instructors' behaviour of incorporating ICT into their teaching practices and students' classroom activities to favour student-learning advancement.

The second dimension measures teachers' abilities to make effective use of computer testing and assessments (hereafter ICT for ASSESSING). The practice of computer-based testing has become extensive in recent years, and the literature has highlighted several benefits and challenges of introducing computer-based tests for students' assessment (Erstad, 2008; Thurlow et al., 2010; JRC - European Commission, 2009). The ICT for ASSESSING dimension involves three items (D2a, D2b, D2c) that refer to the frequency of use of computer tests prepared by teachers on the INVALSI site or other platforms. Additionally, it considers the extent to which teachers exploit the computer lab and its resources (D2d). Finally, the third dimension contributes to evaluating teacher capacity to have an overall positive attitude towards the use of new educational tools (EXPECTATIONS for ICT). Indeed, the four items included in this dimension (D1a, D1b, D1c, D1d) refer to the role played by computers in implementing the student learning outcomes assessments in an efficient and effective way. This dimension reflects issues such as whether computer-based testing meets the needs of all students equally, helps in the understanding of the questions, increases the objectivity of assessing student performance and allows correctly placing the student's competence level with respect to national educational standards. In this respect, it is worth noting that amongst the six International Society to Technology in Education Standards (ISTE, 2008), the *Assessment and Evaluation* phase suggests applying technology in assessing student learning by using a variety of appropriate evaluation approaches and appraisal techniques. Furthermore, several authors look at individual confidence as a factor associated with the "behavioural intention to use" a particular technology (Ajzen, 1991; Venkatesh et al., 2003). In fact, as described in the section devoted to the literature review (Section 2), some research shows that ICT-related educational beliefs are factors that may promote the teacher's capacity to incorporate technological innovation into the classroom. Consequently, EXPECTATIONS for ICT can be viewed both as a measure of teacher beliefs about adopting computer-based tests that may enhance classroom-teaching practices and as an intermediate input that may influence the overall level of ICT integration in teaching and learning contexts. It is worth noting that ICT for ASSESSING should be linked to the EXPECTATIONS for ICT dimension because the latter refers to the teachers' positive attitudes and perspectives in applying technology for students' assessment, which are considered central for encouraging the use of computer-based tests in teaching and learning contexts (van Braak et al., 2004).

5.2. ICT readiness by school and teacher characteristics

According to the literature in the field, we found that ICT readiness is also related to the specific characteristics of teachers. Female teachers are more likely to use ICT for both teaching and assessment, while the gender difference is not statistically significant in relation to ICT expectations. The relationship between the age factor and the three readiness dimensions seems heterogeneous; younger teachers (less than 50 years old) show a greater propensity to integrate ICT into teaching; on the other hand, older teachers, even those using fewer new technologies, have higher expectations about the usefulness of these tools. Teachers with permanent contracts are more likely to use ICT for assessment and teaching and have higher expectations of ICT integration. These findings are quite interesting, particularly for policy-makers, as they show the relevance of the type of contract on a teacher's propensity to use and believe in ICT tools. It can be assumed that teachers with fixed-term contracts are not fully incentivised to innovate and, therefore, are less likely to experiment and adopt new technologies in teaching practices due to the precariousness of their employment. Regarding the teaching discipline, there is a greater integration of technological tools for teaching by teachers of italian. Conversely, mathematics teachers are more likely to use ICT for assessment purposes, probably because it is easier to set up an evaluation test in mathematics using new technologies. Once again, we do not observe any statistically significant difference in the EXPECTATIONS for ICT dimension. The last two factors analysed in Figure 1 (training activities and participation to skills development projects are relevant for policy purposes, as they highlight differences in ICT readiness based on factors that policies and managerial choices can influence. Specifically, the first one shows that the overall fuzzy readiness index μ_d related to the first dimension (ICT for teaching), on average, is higher for teachers participating in specific training activities aimed at the integration of ICT in teaching. Similarly, teachers working in schools participating in skills development projects (PON/ESF or ERDF) are more likely to use ICT for teaching and for assessing compared with teachers who do not participate in these types of projects. Overall, these last findings confirm the importance of carrying out suitable ICT training in schools to promote and support the implementation of ICT devices in teaching and learning processes.

5.3. A regional comparative perspective

Our findings suggest a divide between the northern/central and southern regions along the dimensions considered. In particular, the southern regions, with some exceptions, are characterised by higher values, thus establishing a ranking for each dimension that substantially differs from the usual north-south gap in Italy.[5] The reasons for these particular rankings among the Italian regions across the three dimensions are complex to detect, as they may be due to cultural and political differences as well as to the availability of ITC facilities. Several mutually interrelated factors concerning teacher and school characteristics, as well as the Italian educational system, may explain the level of integration of ICTs in the classroom (Lai and Bower, 2019). The factors affecting individual perception involve social acceptance; and outcomes, in turn, derive from acting based on one's deeply held principles and values. From this perspective, the greater the outcomes obtained by using ICT are highly valued by the teacher, the greater the teacher believes in ICT tools. That is, the actual use of ICT may reinforce beliefs and confidence towards ICT tools and vice versa (Bower, 2019). As already mentioned in the introduction, the interest of policy-makers in this topic is the expectation that ICTs better support teaching and learning practices, and since the early 2000s, several major policy actions for fostering innovative teaching methods and technological infrastructure development have been adopted in Italy (Gui and Gerosa, 2019; Calzone and Chellini, 2016). The National Operational Programme 2007–2013 (*Competenze per lo sviluppo* and *Ambienti per l'apprendimento*) was often used to pilot the actions of the National Plan for Digital Education (PNSD), launched in 2007 with one large-scale intervention (*Piano LIM*) and three projects (*Class@2.0, Scuole@2.0, Editoria digitale*). This plan has been seen "*as a catalyser for innovation in education and*

[5] Our results are in line with findings reported by the Italian Society for Educational Research (SIRD, 2020, p. 6).

specifically for the renewal of teaching practices […]. By creating a technology shock in the school system, the government expects to change the teaching culture, […] promoting more active learning" with the purposes "*to modify the learning environment and adapt it to the needs of the information and communication society [...]; to promote the use of digital contents in teaching and learning; to foster a transformation of the organisational and pedagogical* model" (Avvisati et al., 2013).[6]

On the other hand, Italy's investment in education is low; the public expenditure on education, as a percentage of GDP, was only 4% in 2018, below the EU average of 4.6%. Moreover, we have observed a cut in Italian public spending in recent years. For example, in real terms, the variation in the annual public expenditure in education was -0.3 in 2015 and -1.2 in 2016 (European Commission, 2020). However, as shown in Figure 3, EU structural funding disproportionately favoured the southern regions in the last few years.[7] In a period of restrictions on national public spending, the EU regional funding policy has virtually become, especially for the southern regions, the first source of funding for investment spending (MEF, 2015; Römisch and Jestl, 2017).

We suppose that the interaction between two aspects, i.e., the "*technology shock* to *change the teaching culture*" and both the internal and external financial resources in education (i.e., national and EU funds) might play a role in understanding the characterisation of Italian regions defined by the set of fuzzy estimates. A large majority of investment spending in education in the southern region has been on ICTs (Giusti et al., 2015), and this may have pushed teachers in southern Italy to invest time and effort in ICT. In a situation of diminishing investment spending in education, teaching staff and school principals may have tried to make the best use of their limited resources. In short, money matters when money is scarce. This line of reasoning is reflected by our regional fuzzy estimates of teachers' ICT readiness and may at least partially help to understand the variation in our indicators among Italian regions.[8]

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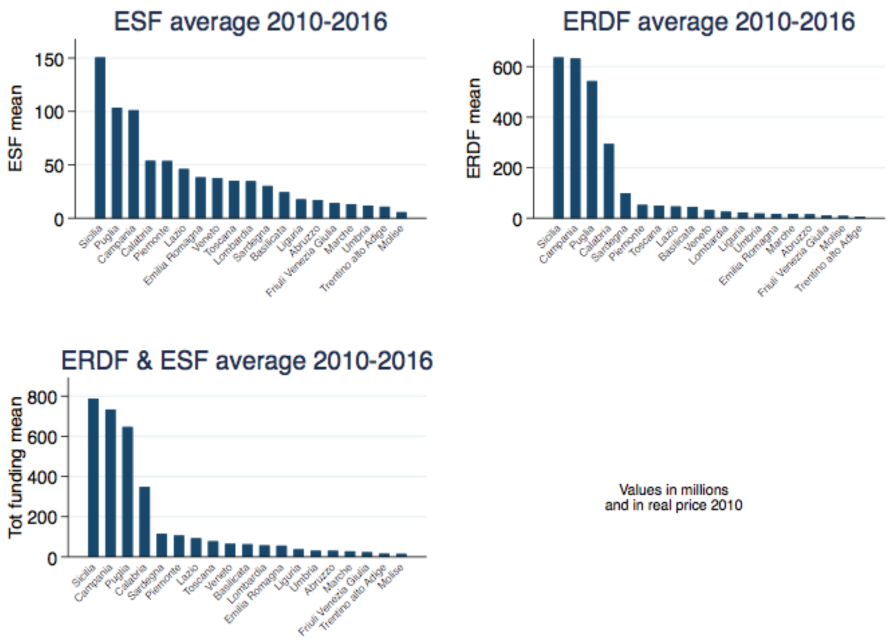
[6]The new PNSD, one of the pillars of "La Buona Scuola" school reform (Law 107/2015), still focused on sustaining professional development of teachers and their digital skills for innovative teaching methods, whereas the National Operational Programme 2014-20 (*Per la Scuola: competenze e ambienti per l'apprendimento*) aimed particularly at improving school technological infrastructure enhancing connectivity and the ICTs.

[7]Italy is one the largest beneficiary of the European Union's Cohesion Policy. EU regional funding policy allocates the funds among European regions according to a variety of targets. One of them, the Convergence Objective, focuses on the less developed regions (i.e. characterized by low levels of GDP and employment). The Southern Italy's regions (i.e. Campania, Puglia, Calabria, Sicily) are 'Convergence regions', that is the main beneficiaries of funds allocated by Cohesion Policy in 2007-2013 and 2014-2020 programming periods. In Italian education system, the implementation programme for teachers' professional development and school improvement projects funding has been administered by National Operational Programmes (PON).

[8]We computed the Pearson correlation coefficients between EU funds and our regional fuzzy readiness indexes: main findings, available upon request, indicate a positive correlation between the three fuzzy estimates and ERDF and ESF funds, particularly for the dimensions ICT for TEACHING and ICT for ASSESSING.

Figure 3. Distribution of ESF and ERDF funding in Italian regions.



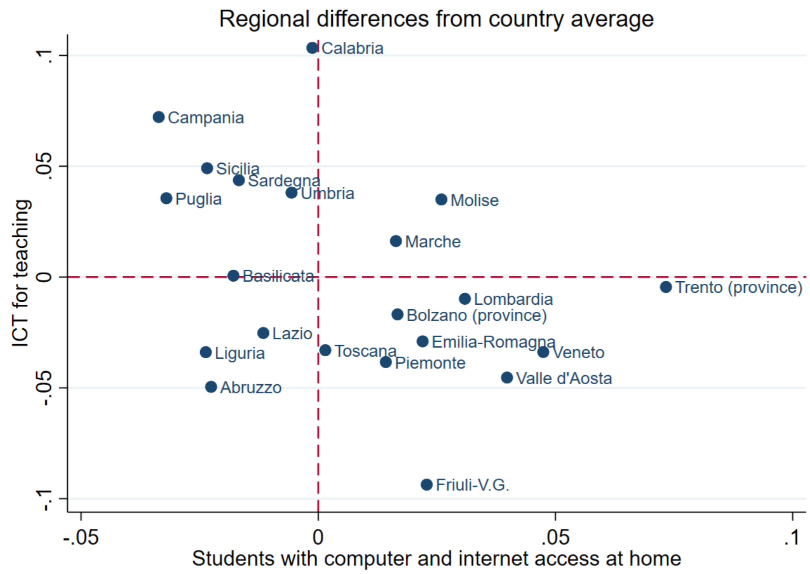
Note: Results are from authors' calculations based on Historic EU Payments - Regionalised and Modelled Data (https://cohesiondata.ec.europa.eu/Other/Historic-EU-payments-regionalised-and-modelled/tc55-7ysv). EU Funds Data are not available for Valle D'Aosta.

The greater ICT readiness that distinguishes teachers in the regions of southern Italy seems to be offset by the lower level of technological equipment of the families of southern students.[9] At the regional level, Figure 4 compares the averages of the fuzzy dimension ICT for TEACHING with the percentage of students who have both computer and internet access at home.[10] The graph highlights a territorial connotation of the inverse relationship between teachers' propensity to use ICT and the technological equipment of families. Most of the southern regions are located in the fourth quadrant (higher value of ICT for TEACHING and lower proportion of students with computer and internet access), while, in contrast, the cluster of regions located in the second quadrant (low value of ICT for TEACHING and higher proportion of students with computer and internet access) is mainly composed of the regions of northern Italy. Although the graph has a purely descriptive nature, it can help interpret the greater difficulty that schools in southern Italy have encountered in dealing with the COVID-19 pandemic.

[9] In 2018–2019, approximately 12% of all children in Italy between 6 and 17 did not have a computer or tablet at home, while in southern Italy almost 20% of children are affected by this issue (ISTAT, 2020).

[10] This information is carried out from the INVALSI background Student Questionnaire, and it refers to the percentage of students who answered affirmatively to both the question Q07_ITAb (Do you have a computer at home that you can use to study?) and the question Q07_ITAe (Do you have an internet connection at home?).

Figure 4. ICT for TEACHING and students ICT availability.



Note: Results are from authors' calculations based on INVALSI Data on Teachers Questionnaire and background Student Questionnaire.

Teachers in southern Italy, in addition to several remote teaching hours, also had to deal with the lower level of technological equipment of students at home. Naturally, the availability of computing devices is a clear requirement for access to education during the school closure phase (Lucisano, 2020). This negative correlation leads to the hypothesis that the skills gap of southern students (Bratti et al., 2007; Argentin et al., 2017) has been deepened by the pandemic (INVALSI, 2021; see also Di Pietro et al., 2020) due to socioeconomic reasons that undermined the starting advantage that teachers in these regions had accumulated in terms of ICT readiness.

6. Conclusions

Although several studies on teachers' readiness to use ICT have been conducted, the results presented in this paper introduce some elements of novelty into the argument. First, to the best of our knowledge, our analysis introduces a new perspective in studying this relevant issue because we define teachers' readiness to use ICT as a multidimensional and fuzzy concept. There are no similar approaches adopted in the literature. Second, this paper sheds new light on the degree of readiness of Italian teachers to integrate information and communication technologies into educational practice in secondary schools. Indeed, for our empirical analysis, we use a statistically representative sample at the national level, whereas most previous studies were mainly based on nonrepresentative samples.

Our findings clearly show that the readiness to use ICT can be explained by a three-dimensional structure. The first two dimensions measure teachers' effective use of ICT-based tools. ICT for TEACHING reflects the frequency of ICT utilisation to favour student-learning advancements, such as the use of computers, Multimedia Interactive Whiteboards, e-learning platforms and educational software. The second dimension, ICT for ASSESSING, is more related to the frequency of teachers' use of computer tests, on the INVALSI or other platforms, to evaluate their students' performance. The third dimension, defined as EXPECTATIONS for ICT, is related to the teachers' perceived likelihood of success in using ICT for educational purposes. It may be helpful to correctly assess the student's knowledge and competences with respect to the national educational standards.

Our empirical analyses attempt to identify the most relevant teacher characteristics that might support the design of effective policies to integrate and consciously leverage ICT in teaching practices. We have found that female teachers and teachers with permanent contracts are more likely to use ICT for teaching and assessment; and younger teachers and math teachers are more prone to incorporate ICT into teaching. Moreover, teachers participating in specific training activities aimed at integrating ICT in teaching and working in schools involved in development projects (PON/EFS or EFDR) are more inclined to use ICT. These results align with the recent findings in Gómez-Fernández and Mediavilla (2022), which use census data from individualised evaluations carried out in the Autonomous Community of Madrid in Spain.

Results in a policy perspective

The regional comparative evaluation of the teachers' readiness to use ICT stressed additional interesting conclusions. Looking at the regional deviations from the national average, we notice that the southern regions all have positive values, which contrasts with the traditional north-south gap in Italy. This result may reflect the fact that, in the context of persistent digital inequalities, such as that of southern Italy, teachers have a compensatory role in trying to offset the digital imbalance. The situation has been further exacerbated by the COVID-19 crisis; indeed, teachers in southern Italy have reported many cases of students from poor areas who were unable to regularly attend virtual classes. At the same time, the effort of schools and teachers to deal with digital exclusion has been demonstrated by different initiatives, such as the provision of laptops and internet connections to less-privileged pupils (The Guardian, 2020).

Furthermore, Lai and Bower (2019) point out several factors concerning teacher and school characteristics that affect individual perceptions and social acceptance and could explain the level of integration of ICTs in the classroom. In this regard, policy programs in Italy, such as the National Plan for Digital Education, aim at creating a technology shock in the school system to promote the use of digital content in teaching and learning. A related explanation, as highlighted in this paper, looks at the cut in Italian public spending on education in recent years, which could have been partially offset in the south by the provision of EU structural funding. The latter has become the first source for investment spending (MEF, 2015), and a large majority of that funding is specifically devoted to ICTs. The presence of the increasing availability of ICT resources, and despite diminishing spending on education, may have led teachers in southern Italy to devote more time and effort to ICTs. Unfortunately, the lower technological equipment at the family level counterbalanced the higher ICT readiness by teachers in the south. This may also explain the recent difficulties faced by the southern schools in dealing with the COVID-19 pandemic.

Policy direction

This study increases awareness by the public and policy-makers of a more structured knowledge of teachers' readiness to use ICT. We measure their readiness as a matter of degree by offering a multidimensional perspective that preserves the richness of the data and goes beyond the narrow view that teachers are ready or not to use ICT.

Recommendation for future study

Our findings call for future research that could enhance our understanding of teacher ICT readiness in Italy and the role played by public spending in education in recent years. Finally, our theoretical and empirical framework can be considered a starting point for evaluating the effect of the COVID-19 pandemic on the digitalisation process of Italian schools. From this perspective, future research should exploit the most recent INVALSI data (available in 2023) to compare ICT teachers' readiness before and after the pandemic.

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Appendix

Table A1. Empirical 95% confidence intervals of the differences between the two groups by dimension and school and teacher characteristics.

Variable	Confidence interval for the difference	
Gender (Females vs Males)	**Lower limit**	**Upper limit**
ICT for TEACHING	0.01	0.04
ICT for ASSESSING	0.02	0.07
EXPECTATIONS for ICT	-0.02	0.02
Age (Over 50 vs Younger 50)	**Lower limit**	**Upper limit**
ICT for TEACHING	-0.05	-0.03
ICT for ASSESSING	-0.02	0.01
EXPECTATIONS for ICT	0.01	0.04
Type of contract (Permanent contract vs Fixed contract)	**Lower limit**	**Upper limit**
ICT for TEACHING	0.03	0.06
ICT for ASSESSING	0.05	0.10
EXPECTATIONS for ICT	0.02	0.06
Subject (Italian vs mathematics)	**Lower limit**	**Upper limit**
ICT for TEACHING	0.04	0.06
ICT for ASSESSING	-0.04	-0.01
EXPECTATIONS for ICT	-0.03	0.00
Training activities (Training vs NO training)	**Lower limit**	**Upper limit**
ICT for TEACHING	0.04	0.06
ICT for ASSESSING	-0.04	-0.01
EXPECTATIONS for ICT	-0.03	0.00
Partecipation to skills development projects (No participation vs participation)	**Lower limit**	**Upper limit**
ICT for TEACHING	-0.11	-0.09
ICT for ASSESSING	-0.13	-0.09
EXPECTATIONS for ICT	-0.03	0.00

Note: Results are from authors' calculations based on INVALSI Data on Teachers Questionnaire.

Table A.2 P-values of pairwise comparisons test (*ICT for TEACHING*)

	Abruzzo	Basilicata	Calabria	Campania	Emilia Rom.	Friuli V.G:	Lazio	Liguria	Lombardia	Marche	Molise	Piemonte	Prov. Bolz	Prov Trento	Puglia	Sardegna	Sicilia	Toscana	Umbria	Valle d'Aosta
Basilicata	0.995																			
Calabria	0.000	0.164																		
Campania	0.000	0.675	1.000																	
Emilia Rom.	1.000	1.000	0.000	0.000																
Friuli V.G.	0.999	0.194	0.000	0.000	0.785															
Lazio	1.000	1.000	0.000	0.000	1.000	0.558														
Liguria	1.000	1.000	0.000	0.001	0.747	0.896	1.000													
Lombardia	1.000	1.000	0.000	0.002	1.000	0.299	1.000	1.000												
Marche	0.914	0.999	0.105	0.556	0.983	0.039	0.999	0.997	1.000											
Molise	0.577	1.000	0.964	1.000	0.767	0.015	0.913	0.869	0.977	1.000										
Piemonte	1.000	0.999	0.000	0.000	0.999	0.905	1.000	0.995	1.000	0.965	0.701									
Prov.Bolz	1.000	1.000	0.029	0.194	1.000	0.873	0.997	1.000	0.976	1.000	0.998	1.000								
Prov.Trento	1.000	1.000	0.048	0.301	1.000	0.557	1.000	1.000	1.000	1.000	1.000	1.000	1.000							
Puglia	0.255	1.000	0.427	0.963	0.300	0.001	0.578	0.570	0.848	1.000	1.000	0.263	0.997	1.000						
Sardegna	0.448	1.000	0.913	1.000	0.611	0.007	0.836	0.774	0.951	1.000	0.931	0.558	0.997	1.000	0.999					
Sicilia	0.037	0.999	0.904	1.000	0.029	0.000	0.093	0.117	0.231	0.999	1.000	0.027	0.881	0.962	1.000	1.000				
Toscana	1.000	0.998	0.000	0.000	1.000	0.943	1.000	1.000	1.000	0.930	0.601	0.991	1.000	1.000	0.176	0.444	0.015			
Umbria	0.355	1.000	0.904	1.000	0.497	0.004	0.740	0.679	0.912	1.000	0.499	0.435	0.995	0.999	1.000	0.965	1.000	0.331		
Valle d'Aosta	0.985	1.000	0.066	0.289	1.000	1.000	1.000	1.000	1.000	0.999	0.968	1.000	1.000	1.000	0.964	0.963	0.800	1.000	0.950	
Veneto	1.000	0.998	0.000	0.000	1.000	0.946	1.000	1.000	1.000	0.915	0.578	0.998	1.000	1.000	0.155	0.421	0.012	0.868	0.306	1.000

Table A3. P-values of pairwise comparisons test (ICT for ASSESSING)

	Abruzzo	Basilicata	Calabria	Campania	Emilia Rom.	Friuli V.G.	Lazio	Liguria	Lombardia	Marche	Molise	Piemonte	Prov. Bolz	Prov Trento	Puglia	Sardegna	Sicilia	Toscana	Umbria	Valle d'Aosta
Basilicata	0.014																			
Calabria	0.002	1.000																		
Campania	0.003	1.000	1.000																	
Emilia Rom.	0.997	0.000	0.000	0.000																
Friuli V.G.	0.992	0.000	0.000	0.000	1.000															
Lazio	1.000	0.000	0.000	0.000	1.000	1.000														
Liguria	1.000	0.029	0.003	0.005	0.831	0.851	1.000													
Lombardia	1.000	0.000	0.000	0.000	1.000	1.000	0.998	0.999												
Marche	1.000	0.089	0.012	0.022	0.458	0.578	0.991	1.000	0.961											
Molise	0.044	0.854	1.000	0.998	0.000	0.000	0.001	0.087	0.000	0.217										
Piemonte	1.000	0.000	0.000	0.000	1.000	1.000	0.974	1.000	0.920	0.988	0.001									
Prov.Bolz	1.000	0.250	0.068	0.162	0.952	0.924	1.000	0.996	0.999	0.985	0.418	1.000								
Prov.Trento	0.498	0.032	0.005	0.010	0.999	0.996	1.000	1.000	1.000	1.000	0.080	1.000	1.000							
Puglia	0.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.009	0.000						
Sardegna	0.998	0.000	0.000	0.000	0.999	0.993	1.000	0.929	1.000	0.713	0.000	1.000	0.963	0.999	0.000					
Sicilia	0.004	1.000	1.000	0.745	0.000	0.000	0.000	0.007	0.000	0.031	0.999	0.000	0.186	0.013	1.000	0.000				
Toscana	0.992	0.000	0.000	0.000	0.999	1.000	1.000	0.730	1.000	0.362	0.000	1.000	0.909	0.997	0.000	0.956	0.000			
Umbria	0.693	0.998	0.955	0.999	0.003	0.012	0.061	0.895	0.031	0.988	1.000	0.063	0.996	0.817	0.628	0.019	0.999	0.002		
Valle d'Aosta	0.996	0.005	0.001	0.003	1.000	1.000	1.000	0.956	1.000	0.863	0.009	1.000	0.960	0.997	0.000	1.000	0.003	1.000	0.127	
Veneto	0.999	0.000	0.000	0.000	0.990	1.000	1.000	0.933	1.000	0.659	0.000	1.000	0.981	1.000	0.000	1.000	0.000	1.000	0.007	1.000

Table A4. P-values of pairwise comparisons test (EXPECTATIONS for ICT).

	Abruzzo	Basilicata	Calabria	Campania	Emilia Rom.	Friuli V.G.	Lazio	Liguria	Lombardia	Marche	Molise	Piemonte	Prov. Bolz	Prov Trento	Puglia	Sardegna	Sicilia	Toscana	Umbria	Valle d'Aosta
Basilicata	1.000																			
Calabria	1.000	0.999																		
Campania	0.997	1.000	1.000																	
Emilia Romagna	1.000	0.838	0.821	0.023																
Friuli V.G:	0.997	0.593	0.579	0.038	1.000															
Lazio	1.000	1.000	1.000	0.633	1.000	0.998														
Liguria	1.000	1.000	1.000	1.000	0.984	0.858	1.000													
Lombardia	1.000	1.000	1.000	1.000	0.800	0.617	1.000	0.999												
Marche	1.000	1.000	1.000	1.000	0.854	0.634	1.000	1.000	1.000											
Molise	0.764	1.000	1.000	1.000	0.017	0.013	0.256	0.940	0.901	0.992										
Piemonte	1.000	1.000	1.000	0.826	1.000	0.997	1.000	1.000	1.000	1.000	0.374									
Prov.Bolz	1.000	0.916	0.918	0.242	1.000	1.000	1.000	0.994	0.959	0.952	0.066	1.000								
Prov.Trento	1.000	0.984	0.986	0.418	0.864	1.000	1.000	1.000	0.996	0.995	0.124	1.000	1.000							
Puglia	1.000	1.000	0.962	1.000	0.481	0.357	1.000	1.000	1.000	1.000	0.995	1.000	0.823	0.953						
Sardegna	1.000	0.758	0.751	0.069	1.000	1.000	1.000	0.952	0.801	0.803	0.022	1.000	0.998	1.000	0.530					
Sicilia	1.000	1.000	0.980	1.000	0.482	0.356	1.000	1.000	1.000	1.000	0.995	1.000	0.822	0.953	0.498	0.529				
Toscana	0.994	1.000	1.000	0.973	1.000	0.972	1.000	1.000	1.000	1.000	0.598	1.000	1.000	1.000	1.000	0.995	1.000			
Umbria	0.995	1.000	1.000	1.000	0.104	0.074	0.802	1.000	1.000	1.000	1.000	0.902	0.308	0.500	1.000	0.125	1.000	0.983		
Valle d'Aosta	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.748	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Veneto	1.000	1.000	1.000	1.000	0.856	0.661	1.000	1.000	0.928	1.000	0.942	1.000	0.966	0.997	1.000	0.826	1.000	1.000	1.000	0.997