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Telecare and elderly mortality: Evidence from Italian municipalities

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ABSTRACT

The growing ageing of the population in developed economies has necessitated the progressive use of advanced information and communication technologies for the home care of elderly individuals. The effect of these technologies on elderly health outcomes remains an open issue. This study analyzes the impact of telecare on the mortality rate of elderly people in Italy using data at the municipal level and a doubly robust difference-in-differences design. Our results show that telecare services significantly reduced the mortality rate of the elderly aged 65 and over by 1.7 individuals per 1000 inhabitants. This effect is sizeable, since it is a 4 % decrease in the elderly mortality rate relatively to the average elderly mortality rate in the treated municipalities. The effect was greater in municipalities with a large proportion of childless elderly people, suggesting that telecare may be particularly useful for the elderly who find it more difficult to rely on strong family ties. Moreover, it was larger in small municipalities, indicating that telecare may be more effective in areas where there is a greater need to compensate for a lower provision of traditional social and health care services.

1. Introduction

European countries have been experiencing a growth in the older population due to a declining fertility rate and an increase in longevity caused by advances in medical care technologies and living conditions, among other factors (Eurostat, 2020). The growing longevity of the population puts health facilities and budget resources under strong pressure (European Commission, 2021). This may entail expensive long-term home care treatments requiring labour-intensive services (Bujnowska-Fedak and Grata-Borkowska, 2015). Home technologies for remote care have been a response to these threats. They provide medical consultations, diagnosis, treatment, and daily monitoring to the elderly in their homes through remote assistance from medical personnel and social workers (Liu et al., 2006; Botsis et al., 2008; Barrett et al., 2014; Bujnowska-Fedak and Grata-Borkowska, 2015). Adoption of these technologies among older people may significantly curb public health costs through a decrease in hospitalization rates (Turner and McGee-Lennon, 2013).

Telecare is one of the forms of remote home care. It involves the use of information and communication technologies (ICTs) to sustain a safe and autonomous daily life at home for frail social categories that require long-term assistance, such as the elderly or persons with mental or physical disabilities (Barlow et al., 2006; Stowe and Harding, 2010; Turner and McGee-Lennon, 2013; Barrett et al., 2014). Telecare provides immediate remote assistance 24 h a day, 365 days a year, to vulnerable people.[5] Telecare is frequently conflated with telehealth and telemedicine, which use similar technologies and target older adults but focus on clinical rather than social or domestic support, and are

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[5] See also practitioners' and market reports such as Technopolis (2018), Benedetti et al. (2022), and Berg Insight (2024).

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generally delivered by healthcare professionals (Barlow et al., 2007; Stowe and Harding, 2010; Solli et al., 2012; Watson et al., 2021; Fothergill et al., 2025).

The importance of studying telecare resides in the fact that it is complementary to both telemedicine and telehealth (Stowe and Harding, 2010), by offering psychological support and continuous monitoring to elderly and fragile individuals, especially those living alone, and therefore by potentially having significant effects on their quality of life and risk of hospitalization and death. If well designed, telecare can improve health outcomes (e.g., hospitalization rate, mortality, public health costs) and the quality of life for older adults by encouraging them to manage their health and well-being safely while staying at home without requiring hospital care (Turner and McGee-Lennon, 2013; Bujnowska-Fedak and Grata-Borkowska, 2015).

The analysis of the impact of telecare on health outcomes appears relevant to support policymakers' decisions on whether to introduce this remote assistance service for frail people. Few studies have examined this impact using a diverse range of endpoints. Earlier reviews conducted on developed countries, including those by Barlow et al. (2007) and Martin et al. (2008), sought to identify clinical and economic outcomes influenced by telecare; however, their findings were either inconclusive or based on an absence of eligible studies. Van Grootven and van Achterberg (2019) reviewed 152 projects funded by a European Union programme and found that the majority lacked appropriate personal-level endpoints to assess the impact of telecare on health or well-being. In the UK, a limited number of studies have investigated the impact of telecare across multiple domains. Specifically, research has examined its effects on health care utilization and quality of life (Bower et al., 2011), the use of conventional health and social care services (Steventon et al., 2013), as well as on users' psychological well-being and overall quality of life (Hirani et al., 2014; Watson et al., 2021). Recent reviews have examined the impact of telecare in international contexts, focusing on the latter endpoints (Korkmaz Yaylagul et al., 2022; Eslami Jahromi and Ayatollahi, 2023; Fothergill et al., 2025). So far, no study has explored the telecare potential effects on longevity or mortality.

To the best of our knowledge, our study is the first to assess the effect of telecare empirically, understood as remote home care through daily calls and emergency intervention via technological devices, on the elderly mortality rate. Our empirical analysis is based on a sample of Italian municipalities observed in 2018 and 2019, years for which information about elderly users of telecare services is available.

More specifically, our contribution to the literature is twofold. First, our study focuses exclusively on telecare, a subset of remote elderly support services distinct from the clinically oriented telehealth and telemedicine interventions widely studied in the literature. By isolating the effect of telecare services provided by municipalities in Italy, we assess the extent to which non-medical, ICT-enabled interventions can impact elderly survival. This represents a novel contribution, as most empirical studies in this field fail to distinguish between types of remote services and often conflate telecare, telehealth, and telemedicine.[6] Disentangling the telecare effect from the telehealth and telemedicine effects is important because they serve different functions and they are likely to operate through distinct mechanisms. In fact, telecare is more likely to affect mortality by reducing response time in emergencies, improving safety in daily living and mitigating social isolation, mechanisms which are not captured in the clinical telehealth and telemedicine framework.

Second, this study contributes to the literature by providing the first causal evidence on the effectiveness of telecare services in a country that combines both a rapidly ageing population and a mature institutional framework for telecare provision. Italy not only has the highest share of individuals aged 65 and over in Europe (Spandonaro et al., 2023), 24.3 % of its total population in 2024 according to Eurostat, but also one of the longest-standing traditions in delivering telecare services, dating back to the 1980s (Tomaselli, 1992; Avallone et al., 2011) and significantly expanded through Law 328/2000. Despite the widespread adoption of telecare across Europe, with an estimated 9 million users and a market value of around €3.5 billion in 2023 (Berg Insight, 2024), the empirical evidence on whether such services improve hard outcomes like mortality remains scarce. By exploiting the institutional variation in Italy's decentralized system, our study offers policy-relevant insights into the real-world impact of telecare on elderly survival, with implications for aging societies both within and beyond Italy.

The impact of telecare on the elderly mortality rate is estimated using a doubly robust difference-in-differences (DR-DID) estimator proposed by Sant'Anna and Zhao (2020). The control group consists of 5101 Italian municipalities that did not have remote social assistance in either 2018 or 2019, while the treatment group consists of 160 municipalities that did not have it in 2018, but introduced it in 2019. We find that those municipalities that offered telecare services significantly reduced the mortality rate of elderly people aged 65 and over on average by 1.7 individuals per 1000 inhabitants. This effect is sizeable; relatively to the average elderly mortality rate in the treated municipalities, it is a 4 % decrease. Finally, we find that telecare had the strongest impact in municipalities with a large fraction of elderly people without children (−3.1 individuals per 1000 inhabitants), in smaller municipalities (−2.9) and in the North (−2.6).

The rest of the article is organised as follows. 2 describes the evolution of telecare services over time. 3 provides a theoretical framework on the impact of telecare on mortality. 4 describes the institutional context. 5 illustrates data and the econometric method. 6 presents the results and comments on them. 7 concludes.

2. Telecare definition and its evolution over time

Telecare services are typically implemented by public authorities and private providers and involves the systematic monitoring of both the individual's health and well-being and their home environment, with the aim of identifying and mitigating potential risk factors. This service is designed to prevent adverse events that may compromise the health of vulnerable individuals and threaten their ability to live independently (Barlow et al., 2006; 2007; Stowe and Harding, 2010; Barrett et al., 2014; Watson et al., 2021; Fothergill et al., 2025). Telecare comprises three distinct types of services: teleassistance, telerescue, and remote technical control.

Teleassistance typically involves regular scheduled telephone contact between professional staff and vulnerable individuals to monitor changes in their health or social care status (Barlow et al., 2006), as well as in their living environment. Users can also reach out to the professional staff to request various types of support. Each request is promptly evaluated, and the appropriate service is activated to address the user's needs. Teleassistance is especially important for elderly people living alone, because it provides social interaction and helps prevent feelings of isolation.

Telerescue involves responding to acute emergencies affecting vulnerable individuals, triggered by the activation of an automatic alarm system. Rapid interventions can be provided to elderly people in an emergency through portable alarm technologies, such as alert bracelets, pendants or smart devices, which enable them to send an aid request to professional personnel when needed. Moreover, telecare solutions often include ambient sensors designed to monitor users' daily routines and detect unexpected deviations, such as those caused by

[6] Only a few countries, including Italy and the UK, provide data that explicitly distinguish telecare from telemedicine and telehealth. In contrast, in many Northern European countries, the boundaries between these terms are more blurred and often overlap. The Italian National Institute of Statistics (ISTAT) conducts a nationwide survey that tracks the diffusion and use of various social policy instruments, including telecare, as distinct from other forms of remote healthcare.

smoke, gas leaks, or falls. In such cases, once an alarm signal is triggered, professional staff promptly notify the vulnerable person's family members, neighbours, and emergency services to ensure that assistance requests are addressed without delay.

Remote technical control involves the regular monitoring of alarm systems by professional staff to ensure they are functioning properly for users (Lattanzio et al., 2014; Coda Strategies, 2017; Benedetti et al., 2022).

The term telecare has some overlaps with terms such as telehealth and telemedicine, which can use similar technologies, and address the same age classes (the elderly) but provide care services that are not focused on social and domestic assistance, as telecare is (Barlow et al., 2007; Stowe and Harding, 2010; Solli et al., 2012; Watson et al., 2021; Fothergill et al., 2025). For example, also telehealth mostly concerns older people living at home, but it focuses on vital signs monitoring (Stowe and Harding, 2010). It facilitates the transmission of patients' health data on vital signs to healthcare providers via digital telecommunications technologies. Moreover, telehealth enables patients to schedule medical appointments, request prescription refills, and access a broader range of healthcare services remotely. Similarly, also telemedicine increasingly concerns the medical care of elderly patients living at home (Van den Berg et al., 2012), but it has the distinctive feature of being a medical act managed by a healthcare provider (Wootton, 2001). Telemedicine enables patients to receive clinical care remotely from healthcare professionals through online consultations and diagnostic services. Like telehealth, it also supports the monitoring of patients' vital signs, with patient's data transmitted to healthcare providers via digital technologies.

Differently, telecare services pertain to social policies and employ professionals "trained on purpose" and social workers, instead of medical personnel. It is oriented toward monitoring the daily life routines of frail individuals, rather than the clinical management of their health conditions. Information transmitted by home sensors are primarily intended to signal an emergency event involving vulnerable individuals, such as domestic accidents (injuries from smoke or gas leaks) and sudden illnesses (falls resulting from cerebrovascular strokes or equilibrium disturbances). Conversely, the information collected through telemedicine and telehealth is centred on patients' vital signs (e.g., glycaemic levels, arterial blood pressure, or cardiac activity), enabling continuous monitoring of their clinical condition and prompt intervention through televisit in response to significant changes in these parameters.

Telecare has evolved through three successive generations (Doughty et al., 1996; Turner and McGee-Lennon, 2013). The first generation featured a "reactive" model of service provision, and the wearable part of the domestic equipment typically consisted of a portable device (e.g., a pendant), which was used by the elderly person to send the initial alarm or the contact request to the call centre. Upgrades of these simple telecare services are still marketed and used today, being appreciated for their technological reliability, ease of use, and non-invasiveness of the patient's privacy (Technopolis group, 2018; Benedetti et al., 2022).

The second generation of telecare has been "proactive" (Turner and McGee-Lennon, 2013), with more complex and automatic domestic equipment. Both domestic devices and the call centre rely on the information transmitted by domestic sensors, which can also operate without the user's intervention to decrease the risk of incapacitation. In between the two generations lies the version of the service featuring a programmable schedule of preventive calls made by the call centre to monitor the user' conditions and offer social companionship.

The third generation is much more "high-tech" since it is based on robotics, home automation (domotics), artificial intelligence and broadband-based ICTs. Nevertheless, it is much less widespread and empirically appreciable than mainstream services, as noticed by Bentley et al. (2018) for the UK, which remains the largest European market for telecare.

3. A theoretical framework for telecare impact on mortality

No study has yet explored the telecare potential effects on longevity or mortality, contrary to telehealth and telemedicine, which have been studied in many countries. Snoswell et al. (2023) conducted a systematic review of meta-analyses covering the period from 2010 to 2019, finding that telehealth did not lead to increased mortality rates. Similarly, Chen and Dills (2024), in their analysis of the US legislation promoting telemedicine parity with standard care, reported that such laws were associated with reduced mortality rates between 1999 and 2016. More broadly, Eze et al. (2020) reviewed the effects of telemedicine across a range of clinical and non-clinical dimensions (e.g., its cost-effectiveness). It found that telemedicine can reduce mortality and hospitalization rates, as well as enhance mental health.

The impact of telecare on mortality might be mediated by psychological and physical well-being, according to the theoretical framework depicted in Fig. 1, where a second causal link unfolds between well-being and health status (including morbidity, longevity and mortality). Well-being constructs differ from direct and indirect measures of health status, although the two are correlated and can be linked through factors such as lifestyle and biological processes (Karimi and Brazier, 2016; Pressman et al., 2019; Steptoe, 2019). Similarly, other studies have examined constructs of negative feeling — such as loneliness, sadness, and stress — reporting consistent findings: negative feeling is inversely correlated with health status and longevity (e.g., Holt-Lunstad et al., 2015; Brandts et al., 2021).

Regarding the impact of telecare availability on psychological and physical well-being, as illustrated by the first logical link in Fig. 1, empirical research has shown that telecare has beneficial effects on well-being (Hirani et al., 2014; Korkmaz Yaylagül et al., 2022; Eslami Jahromi and Ayatollahi, 2023; Fothergill et al., 2025), which may result both from the relational benefits embedded in its core components and from its technological capacity to enable prompt rescue and medical assistance in domestic emergencies. Specifically, the regularly scheduled telephone contacts integral to the teleassistance aspect of telecare facilitate autonomous living at home and contribute to a higher quality of life, particularly by providing reassurance to elderly individuals living alone. By employing analogical inductive reasoning, we propose that telecare, through its inherent social interactions, generates what the "happiness and economics" literature (Frey, 2018) calls "relational goods". These goods, which arise from positive interpersonal relationships, are known to exert a beneficial influence on subjective well-being (Gui and Sugden, 2005; Becchetti et al., 2008). By enhancing psychological well-being, telecare may ultimately contribute to improved health outcomes (e.g., life expectancy and mortality), an effect that can be attributed to its function as a provider of relational goods. Additionally, the continuous availability (24 h a day, 365 days a year) of a remote operator accessible via an emergency device (e.g., a portable pendant or fall sensor), facilitates prompt intervention (telerescue) in emergency situations such as falls, fainting, strokes, acute illness, or even depressive episodes. In such circumstances, the prompt activation of an emergency response may conserve critical time and attenuate the progression of adverse health outcomes associated with bone fractures, cerebrovascular and cardiac accidents, or haemorrhagic events. The remote operator can assess the situation in real time and determine whether professional emergency services (e.g., ambulance) are required or whether the issue can be addressed by involving the frail individual's caregiver or the family.

Regarding the second logical link in Fig. 1, an extensive body of literature has empirically examined the relationship between well-being, defined in either psychological or physical terms, and health status. This body of literature draws on contributions from economics,

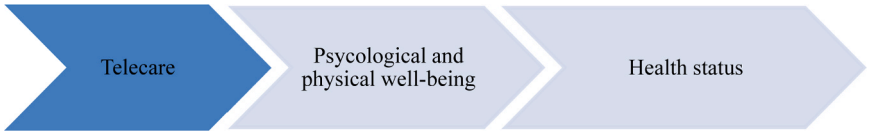

Fig. 1. Dissecting the impact of telecare on health status. Source: Authors' conceptualisation.

sociology, psychology, biology, and biomedical disciplines such as gerontology, and investigates well-being through a range of endpoints. According to the literature on the impact of well-being on health,[7] positive psychological states such as happiness are associated not only with enhanced emotional well-being but also with improved physical health outcomes, including reduced mortality and increased survival. This research varies in statistical rigor, such as the use of controls, causal identification strategies, effect size assessment, and the types of health outcomes considered, and in the generalizability of its findings (Diener and Chan, 2011). Although earlier studies faced challenges in fully addressing issues of causality, the field has progressively evolved, leading to more robust evidence on the link between subjective well-being and mortality (e.g., Martín-María et al., 2017; Steptoe, 2019; Andersen et al., 2021). A noteworthy insight is that happiness appears to be a stronger predictor of longevity in healthy populations than in those already experiencing illness, a pattern initially suggested by Veenhoven (2008). Moreover, the causal relationship between psychological well-being and physical health has been supported by biomedical research. For example, Steptoe (2019) and Pressman et al. (2019) detailed the psychological and physiological mechanisms that allow positive feelings to influence health status and mortality, including the mediating role of lifestyle factors and biological processes.

Telecare may not always achieve its intended goals or deliver the anticipated benefits, as its effectiveness can vary depending on both the technological design of the service and individual user characteristics (Fothergill, 2025). First, inadequate ergonomic design or insufficient user training in the use of telecare solutions may hinder their effective utilization, especially during emergency situations when rapid and correct operation is critical. Second, the "relational good" impact of telecare on well-being can be either positive or negative, depending on the interplay between its relational content and technological features. On the one hand, if telecare deployment is characterised by a strong element of sociability (effectively serving as a substitute for in-person care relationships), it may contribute to an enhancement of the health status. On the other hand, when remote care is delivered in a highly standardised and impersonal manner, without significant customization and with poor human interaction, it may fail to produce genuine relational goods akin to those generated through physical encounters. In such cases, telecare may operate analogously to other forms of digital communication that have been demonstrated to displace, rather than promote, meaningful social interactions (e.g., Bruni and Stanca, 2008; Rotondi et al., 2017). Accordingly, we expect a decline in individual's health status and an increase in the mortality rate.

Given the ambiguous theoretical impact of telecare on mortality, our empirical analysis seeks to identify the predominant underlying mechanism. To the best of our knowledge, this study is the first to rigorously test the entire causal chain depicted in Fig. 1 by examining, in the Italian context, the impact of telecare services on a tangible measure of health status such as mortality.

4. Institutional setting

Italy has a long-standing tradition in the diffusion of telecare services for older and vulnerable individuals, dating back to the 1980s (Tomaselli, 1992; Avallone et al., 2011). During that period, the country held an internationally recognized leadership position in ICTs, supported by the award-winning research and development laboratories of the STET–Telecom Italia group (Pisanelli et al., 1995; Cantoni et al., 2011). This technological specialization fostered an innovative industrial supply chain that enabled pilot projects and advanced applications in telephony and telematics, including early telecare and telemedicine solutions.

Such an early national specialization was accompanied by a marked awareness among Italian public institutions of the potential of telecare, which developed in a bottom-up manner through initiatives of subnational governments at the regional and municipal levels (Tomaselli, 1992; Avallone et al., 2011). According to the Italian Constitution, these local authorities are responsible for social policy. Subsequently, Law 328/2000 further accelerated the diffusion of telecare nationwide by promoting the integration of social and healthcare services at the local government level to support vulnerable populations. From a comparative perspective, the Italian model of telecare, while similar to that of the UK in terms of the nature, technologies and timing of the underlying social policies, differs in the institutional level of implementation. In the UK, particularly in England, telecare initiatives have been primarily managed at the national government level (Wright, 2020), whereas in Italy they have largely been implemented by regional and municipal governments, and are more heterogeneous.

Because of the long technical lifespan of early-generation telecare technologies, their use remains relatively widespread in Italy. Although comprehensive cross-country data are lacking, Italy is presumed to be close to the European leader and pioneer, the UK, which reports an installed base of approximately 1.7 million users. In comparison, estimates for France and Germany range between 500,000 and 585,000 users (Coda Strategies, 2017; Benedetti et al., 2022). Systematic data on telecare adoption in Italy, disaggregated by type and model, are currently lacking. Market analyses and academic studies (e.g., Technopolis group, 2018; Benedetti et al., 2022, sect. 4; Berg Insight, 2024) indicate that, internationally, personal response and alarm services, along with smart sensors (including fall detectors), account for most of the installed base, corresponding to the first- and second-generation telecare technologies defined by Doughty et al. (1996). Given Italy's long-standing experience with telecare diffusion and its similarity to the UK's model, its installed base is likely to reflect both UK and broader international trends, consisting primarily of personal response and alarm systems and smart sensors. By contrast, the third generation described by Doughty et al. (1996) — based on advanced ICTs such as home automation, broadband communications, and artificial intelligence — remains largely experimental and commercially unsustainable. In Italy, its deployment has been mostly limited to pilot and publicly funded projects (Lattanzio et al., 2014; Danesin et al., 2025), with similar patterns observed abroad, including in the UK (Bentley et al., 2018; Wright, 2020).

The Italian welfare system allocates 1.6 % of its Gross Domestic Product (GDP) to formal long-term care (LTC), which is comparable to the EU average of 1.7 % in 2022 (European Commission, 2024). Specifically, 1.2 % of the Italian GDP was spent on LTC for individuals aged 65 and older in 2023 (MEF, 2024, p. 125). Italian LTC expenditures for older people can be divided into three macro-functional components: "home care" (0.24 % of GDP), "residential care" (or care provided "in institutions", 0.34 % of GDP) and "cash benefits" (0.62 % of GDP) (MEF, 2024, p.125). Home care services support a greater number of

[7] Typically, psychological well-being is measured through constructs such as happiness, quality of life, or subjective well-being.

non-self-sufficient people than residential care services, despite fewer resources available. As shown by Brugiavini et al. (2023), residential care costs amounted to 7 billion euros for 288,000 non-self-sufficient users in 2015, while home care costs were only 4.63 billion euros but assisted 1444,410 non-self-sufficient users. This evidence suggests that home care services are more cost-effective, which is crucial for the future sustainability of the LTC system. This perspective is echoed in the international debate, which has emphasised the home and the family as fundamental welfare institutions for social assistance (e.g., Casanova et al., 2017) and healthcare (e.g., Melchiorre et al., 2022). In addition, the Italian model of LTC importantly relies on national cash benefits and informal care (Brugiavini et al., 2023; Casanova et al., 2017), being based on informal family support or migrant care workers often with irregular contracts (Jessoula et al., 2018).

Fig. 2 presents the evolution of home care expenditure per user aged 65 and over in Italy from 2011 to 2019, disaggregated by type of service. The main expenditure component is social home care, which includes costs for personal assistance, help with daily life routines, and psychological and educational support. This category is fully funded by the local municipalities' social policy budgets. The second largest expenditure is vouchers, which are economic transfers provided to families for the purchase of home care services for elderly relatives. The third component is spending on integrated home care services, which involve healthcare-oriented interventions for non-self-sufficient and frail individuals. These services are funded by the National Health System (NHS) and require coordination between the local NHS branches and municipal social services. The category "other home care services" is a residual grouping that includes additional, minor services provided and financed by municipalities. As shown in Fig. 2, all categories of home care spending declined between 2011 and 2019. The steepest drop occurred in vouchers, decreasing by 446 euros per user aged 65 and over.

Italy's LTC system is characterized by fragmentation across different tiers of government (central, regional, and municipal) and local health authorities (e.g., *Aziende Sanitarie Locali*). Its current structure was shaped by Law n. 328/2000, according to which the central government defines the so-called "essential levels of care", while the regions develop their regional social plans based on their budget resources. These resources are primarily managed by provinces, municipalities, and local health authorities (Hohnerlein, 2018; Brugiavini et al., 2023). Worldwide, telecare services are typically organized by local authorities managing social policies, which in Italy are municipalities. This governance architecture generates territorially unequal distributions of resources, causing variations in per-capita levels of LTC for non-self-sufficient elderly people, depending on the region, province and even the municipality of residence (Marenzi et al., 2023).

5. Data, sample and method

5.1. Data and sample

Our analysis exploited data on mortality rates and telecare for people over 65 in Italian municipalities in 2018 and 2019. Telecare is mostly addressed to people aged 65 or older who are not self-sufficient. Our goal was to shed light on the impact of the introduction of such a remote service for the elderly on their mortality rates. Data on telecare came from the Survey on Social Interventions and Services of Single and Associated Municipalities conducted each year by ISTAT. This survey collects information annually on welfare policies managed at local level, thus ensuring the monitoring of the resources employed and the activities carried out within the integrated network of social services at municipality levels. Regarding telecare, in this survey respondents are asked whether teleassistance or telerescue services are available in their municipalities. For brevity, we will refer to teleassistance and telerescue services as telecare services. The survey does not provide information to distinguish different types of telecare services, nor does it indicate whether services are directed at specific pathologies or population subgroups for the elderly.

The data for the mortality of the elderly and socioeconomic and demographic characteristics at municipality level were retrieved from ISTAT. We used socioeconomic and demographic characteristics which may directly or indirectly correlate with the dynamics of the mortality of the elderly. If these covariates were unbalanced between treated and control municipalities, they would lead to the failure of the parallel trends assumption, which is a key identifying assumption in our evaluation analysis, as it will be discussed later. More in detail, we used: *i*) the number of hospital beds, the fraction of the elderly living alone, the fraction of elderly couples without children and the migrant rate, because they are likely to determine the elderly mortality rate through factors like social isolation, health monitoring, health assistance and mental well-being; *ii*) the fraction of low-income taxpayers, the square meters per occupant in occupied housing and the fraction of families in potential care distress, as they may be factors capturing financial challenges, housing and living conditions and lack of resources influencing the health outcomes of the elderly; *iii*) the fraction of 0–2 year old children in public childcare services, the population density and the fraction of the population commuting for work or education using private means of transport, because they may correlate with the availability of infrastructures and broader social policies aimed at supporting families, which may also extend to elderly care services.

We restricted our analysis to 2018–2019. We could not use data before 2018 because ISTAT started collecting information on telecare use in 2018. We did not use data after 2019 because of the COVID-19 outbreak. COVID-19 significantly affected the mortality rates, especially among the elderly, resulting in a marked uneven distribution of the excess mortality across Italy (Henry et al., 2022). Fig. 3 reports the provincial distribution of elderly mortality rates (65 +) for 2018–2021. While 2018 and 2019 exhibit relatively stable trends, 2020 and 2021 show a sharp upward shift, with several provinces lying above the upper whisker, indicating extreme values and thus an uneven impact of the pandemic across local areas. Fig. 4 further illustrates this structural break: while the black line shows a smooth median trend at the national level, provincial trajectories (grey lines) diverge dramatically after 2019. The sharpest increases occurred in Northern provinces. Indeed, the ten provinces with the largest 2019–2020 relative increases in elderly mortality rates — Bergamo, Biella, Brescia, Cremona, Lecco, Lodi, Milano, Pavia, Piacenza, and Vercelli — are all located in the North. This uneven distribution very likely violates the identifying assumption of comparability between telecare adopters and non-adopters, which is instead exploited in our evaluation analysis.

At the same time, the pandemic prompted changes in healthcare assistance, like telemedicine and home-based care, partly due to mobility restrictions and hospital congestion. In April 2020, the Italian National Institute of Health (Istituto Superiore di Sanità, ISS) issued operational guidance recommending the activation of remote care pathways during the emergency (ISS, 2020). In December 2020, the State-Regions Conference established national definitions of telemedicine and telecare services and set a common reference for regional implementation (Conferenza Stato-Regioni, 2020). Yet rollout remained heterogeneous: descriptive counts by ALTEMS (2020) show that Lombardy, Tuscany, Veneto, Lazio, and Piemonte launched more initiatives than other regions.

The health system was also unevenly affected by COVID-19, with regional differences in the pressures on the healthcare system, hospital crowding, resource shortages, and delayed or limited access to care to non-COVID care. These shocks were unrelated to telecare adoption but would confound any estimate of its effect on mortality. Estimating a clean impact of telecare during this period, in which it served both as a substitute and a complement to other forms of social and healthcare, is therefore not feasible within our empirical design.

Considering the confounding effects of the COVID-19 pandemic and the different role that telemedicine may have played during that period,

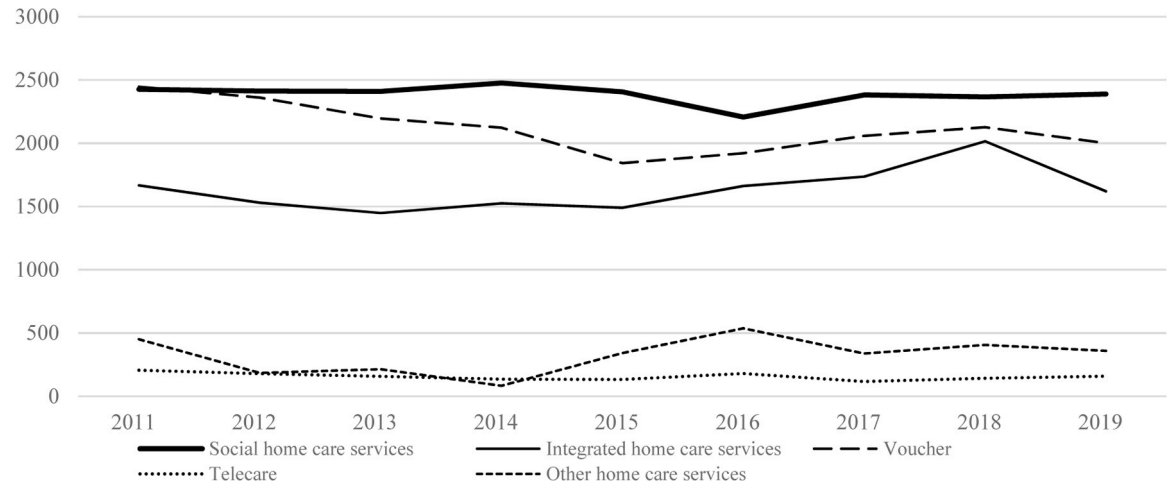

Fig. 2. Evolution of home care expenditure per user aged 65 and over in Italy, 2011–2019. Note: Authors' elaborations on data from the ISTAT survey "Social Interventions and Services of Single and Associated Municipalities". The vertical axis shows home care expenditure per user aged 65 and over, adjusted for inflation according to Eurostat's Harmonised Index of Consumer Prices (HICP, 2015 = 100).

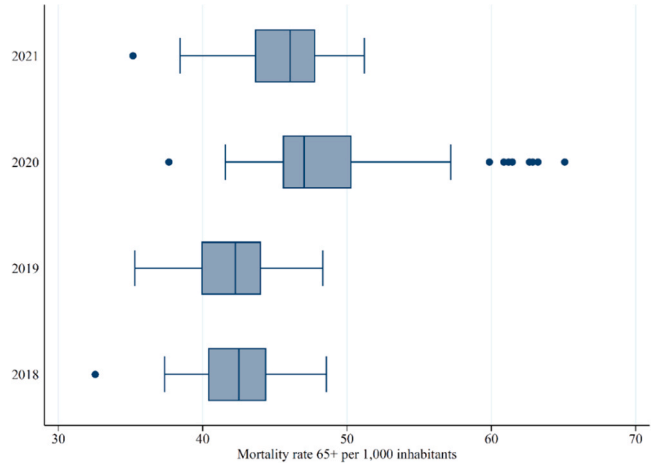

Fig. 3. Distribution of elderly (65 years and older) mortality rates across Italian provinces, 2018–2021 (per 1000 inhabitants). *Notes:* In the box plot, the central segment represents the median. The lower and upper segments of each box are the 25th and 75th percentiles. Their difference is the interquartile range. The left (right) "whisker" represents the 25th (75th) percentile minus (plus) 1.5 times the interquartile range. The dots are outlying provinces, falling outside the boundary of the whiskers.

both as a substitute for and a complement to other forms of social and healthcare, we exclude the pandemic years from our analysis and focus instead on identifying the effects of telecare under normal conditions. The pandemic constitutes a structural break, and assessing the effectiveness of telecare during such an extreme health shock is a distinct and important research question that we leave for future work.

Italy is divided into approximately 8000 municipalities (7954 in 2018), which represent the lowest level of local government. After deleting those municipalities which modified their size by merging with other municipalities between 2011 and 2019, we were left with 7785 municipalities. We further selected those municipalities that in 2018 had not yet implemented telecare for the elderly, reducing the sample to 5559 municipalities.[8] After discarding those observations with missing values for some of the variables used in the empirical analysis, our sample shrank further to 5261 municipalities. None of them had telecare in 2018; 160 municipalities had it by the time the 2019 survey was conducted.[9] These 160 municipalities constituted our treatment group. The remaining 5101 municipalities were the control units. Figure A.1 in appendix illustrates the geographical distribution of treated and control municipalities, indicating that they were predominantly located in the North.

5.2. Method

Table 1 reports the average of our outcome variable, the mortality rate for the elderly, by year and by telecare implementation. The mortality rate for the elderly is computed as the ratio between people who passed away when 65 or older each year and the resident population aged 65 and over per 1000 inhabitants. While those municipalities that did not introduce the telecare service in 2019 (the control group) saw the elderly mortality rate remain stable at about 44 deaths per 1000 inhabitants, those municipalities which started the service (the treated group) experienced a reduction of about 1.9 points. The difference between the before-after differences of the treated and untreated municipalities, i.e. the difference-in-differences estimator (DID) in its "canonical" setup with two periods and two groups (Roth et al., 2023), is equal to −2 and it is not significantly different from zero.

Fig. 5 displays the trends in elderly mortality rates for treated and untreated municipalities from 2014 to 2019. Up to 2018, both groups follow broadly similar time patterns, with treated municipalities consistently exhibiting lower mortality rates than untreated ones. After the treatment line, the gap widens, suggesting a deviation from the relative trends observed before 2018.

The interpretation of the finding in Table 1 as the causal effect of the telecare implementation relies on a strong assumption. The average

[8] Municipalities with teleassistance and/or telerescue services already in place in 2018 are excluded from the analysis, as they were treated prior to the start of our observation window and cannot be observed in a pre-treatment state. Therefore, the estimation sample consists only of municipalities without telecare in 2018, for which we observe both a pre-treatment year (2018) and a post-treatment year (2019).

[9] The treatment indicator is equal to 0 for all municipalities in 2018, and equal to 1 in 2019 for those municipalities that implemented telecare services.

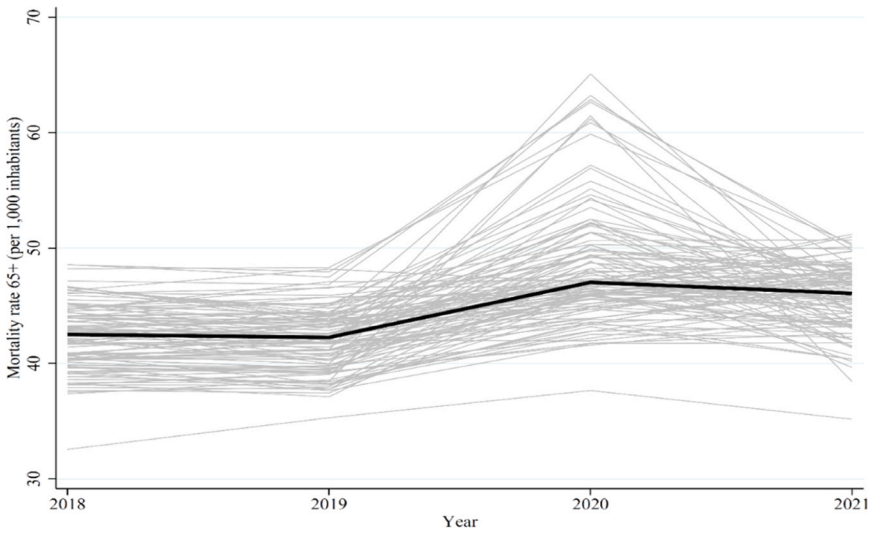

Fig. 4. Line plot of elderly (65 years and older) mortality rates across Italian provinces, 2018–2021 (per 1000 inhabitants). Notes: The bold black line is the median elderly mortality rate (per 1000 inhabitants) across Italian provinces. The grey lines are provincial trends.

Table 1
Summary statistics.

	Average mortality rate 65 or older		Before-after difference
	2018	2019	
Treated municipalities	42.364	40.510	-1.854
			(1.226)
Untreated municipalities	44.327	44.509	0.182
			(0.252)
Difference-in-Differences (DID)			-2.036
			(1.246)

Notes: The number of treated (untreated) municipalities is 160 (5101), corresponding to 3.04 % (96.96 %) of the sample. Standard errors robust to heteroskedasticity and within-municipality correlation are reported in parentheses.

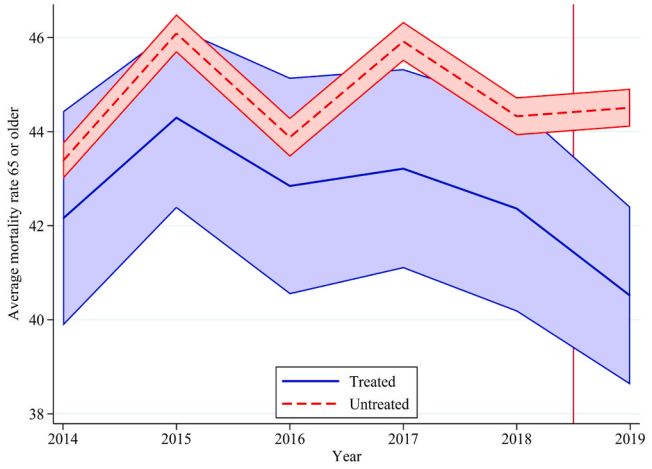

Fig. 5. Average elderly mortality rate (per 1000 inhabitants) for treated and untreated municipalities, 2014–2019. Notes: Shaded areas represent 95 % confidence intervals. The number of treated (untreated) municipalities is 160 (5101). The vertical red line separates the pre-treatment and the post-treatment periods.

outcomes for treated and control municipalities should have followed parallel paths over time in the absence of the treatment (Abadie, 2005). It is important to note that municipalities do not randomly decide whether to introduce telecare services. Their choice may depend on local factors, such as for example population size, budgetary constraints, the health profile of the residents, the quality of the local administrators, which could also influence elderly mortality rates. Although taking the first difference in the outcome variable removes bias from municipal fixed characteristics that affect mortality additively, the parallel trends assumption may still be questionable if pre-treatment characteristics of treated and untreated municipalities are unbalanced between the two groups and are associated with the dynamic of the outcome variable (Abadie, 2005).[10] Table 2 shows that treated and untreated municipalities differed in terms of averages of several demographic, social, economic, and employment features. Municipalities which implemented telecare were characterized by a greater use of childcare services, were richer, attracted more migrants, had a smaller fraction of the elderly living alone or without children, and had an employment structure more oriented towards high skilled jobs and artisan, manual, or agricultural occupations. Finally, treated municipalities were much more likely to be in the North-East (Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, and Emilia-Romagna) than in the rest of the Italian regions.

These differences in observed characteristics may create non-parallel outcome dynamics. We therefore deviated from a standard DID analysis and used the improved Doubly Robust DID (DR-DID) estimator proposed by Sant'Anna and Zhao (2020) to estimate the Average Treatment Effect on the Treated (ATT) of telecare implementation. The DR-DID exploits Inverse Probability Tilting (IPT) as proposed by Graham et al. (2012) in a DID design to balance the covariate distribution of the treated and untreated units (Abadie, 2005). Furthermore, it combines the IPT approach with an outcome regression (OR) procedure (e.g. Heckman et al., 1997). The first difference in the OR model eliminates the omitted variables bias generated by municipal fixed effects additively entering the conditional mean of the elderly mortality rate. The improved DR-DID estimator attains double robustness in terms of both consistency and inference. This means that it is consistent for the ATT, and it implies the exact form of the asymptotic variance of the estimator even if either, but not both, the propensity score model to compute probability weights or the OR model are misspecified.

Let us denote with X a set of predetermined characteristics at municipality level, with Y the outcome variable, i.e. the elderly mortality

[10] We formally test for the parallel trends assumption after controlling/balancing for observed municipality heterogeneity in Table 4, 6. The results of the test in Table 4 suggest that comparable municipalities according to observed heterogeneity moved in parallel in the pre-treatment period.

Table 2
Averages of pre-treatment covariates measured in 2018 by treatment indicator.

	Treated municipalities	Untreated municipalities	Difference
Elderly mortality rate (per 1000 inhabitants 65 +)	42.364	44.327	-1.963*
Children in childcare services (%)[a]	13.065	7.866	5.200***
Low income (%)[b]	27.626	33.385	-5.759***
Population density (pop/km^2)	327.877	282.884	44.994
Population (in 1000)	1.946	1.490	0.456
Migrant rates (%)	0.319	0.261	0.058***
Hospital beds over resident population	0.001	0.001	0.000
Elderly living alone (%)	27.718	30.141	-2.422***
Elderly with no children (%)	14.066	15.096	-1.030***
Surface per occupant in occupied housing (m^2)	44.399	43.346	1.053***
Commuting using public means of transport (%)[c]	11.181	11.649	-0.469
Families in potential care distress (%)[d]	3.061	3.341	-0.280***
Employment in artisan, manual or agricultural jobs (%)	29.076	26.281	2.795***
Employment in low-skilled jobs (%)	15.920	19.636	-3.716***
North-West	0.269	0.344	-0.075**
North-East	0.506	0.260	0.246***
Center	0.081	0.146	-0.065***
South	0.213	0.392	-0.180***
Observations	160	5101	

Notes: *** p-value$<$ 0.01; ** p-value$<$ 0.05; * p-value$<$ 0.1. Significance tests on the difference of the averages are based on an ordinary squared regression of the covariate on the indicator for the telecare introduction in 2019.

[a] This is the percentage ratio between the number of children aged 0–2 years who have benefited from childcare services offered by the municipality and the average annual number of resident children aged 0–2 years.

[b] This is the percentage ratio between the number of taxpayers with a total income of less than euro 10,000 and the total number of taxpayers.

[c] This is the percentage ratio between the resident population that daily commutes for work or study using collective means of transport (e.g. train, bus, metro) and the resident population that commutes daily for work or study.

[d] This is the percentage ratio between the number of families with at least two members, no cohabitants, with all members aged 65 and over and with the presence of at least one member aged 80 and over, and the total number of families.

rate, and with D the binary treatment indicator equal to 1 if treated and 0 otherwise. Sant'Anna and Zhao (2020) considered the estimand

$$\tau = E\left[\left(w_1(D) - w_0(D,X;\pi)\right)\left(\Delta Y - \mu_{0,\Delta}(X)\right)\right], \quad (1)$$

where:

- ΔY is the 2019–2018 difference of the elderly mortality rate;
- $\mu_{0,\Delta}(X) = \mu_{0,2019}(X) - \mu_{0,2018}(X)$ is the first difference in the absence of treatment of the true OR $m_{0,t}(x) \equiv E[Y_t|D=0, X=x] = X'\beta_{0,t}$, with $t = 2018, 2019$;
- $w_1(D) = D/E(D)$ and $w_0(D,X;\pi) = \frac{\pi(X)(1-D)}{1-\pi(X)} / E\left[\frac{\pi(X)(1-D)}{1-\pi(X)}\right]$, with π(X) an arbitrary model for the true, unknown propensity score.

The estimand in Eq. (1) is a weighted average of the regression-adjusted temporal differences in the outcome variable, with weights w_0 depending on the propensity score which, in our framework, is the probability that a municipality has implemented the telecare service.

Sant'Anna and Zhao's (2020) improved DR-DID estimator is a three-step estimator. In the first step, a logit model for the probability of telecare implementation is estimated using Graham et al.'s (2012) Inverse Probability Tilting (IPT) estimator with a set of covariates X_i. In the baseline specification, we plugged into X_i the value of the past elderly mortality rates, to control and balance the treated and untreated municipalities also for the pre-treatment values of the outcome variable. In the second step, the OR parameters for the control group are estimated by weighted least squares, with weights given by the propensity scores estimated in the first step. In the third step, the estimated propensity scores and the fitted values of the regression models are plugged into the sample analogue of τ specified in Eq. (1).

By conditioning the working models on predetermined municipal characteristics and on the pre-treatment value of the outcome variable, we allowed for time trends specific to each of these variables. This made satisfaction of the parallel trends assumption more likely. A further assumption that should be satisfied is the standard overlap condition (see for instance Assumption 3.2 in Abadie 2005 or Assumption 3 in Sant'Anna and Zhao 2020). We found that the support of the propensity score for the treated municipalities was a subset of the support of the propensity score for the untreated ones, which is evidence of the satisfaction of the overlap condition.

To assess if the estimated propensity scores adequately balanced the covariate distributions of treated and untreated municipalities, we recomputed the average of all the variables contained in X and listed in Table 2 by treatment status after weighting using IPT. We found that the weighted averages of the controls perfectly matched those of the treated: treated and control municipalities were exactly balanced, with Rubin's (2001) B, i.e. the standardized difference in the means of the propensity scores between the treated and the untreated units, decreasing from 102.8 to 0.0.

6. Results

6.1. Main findings

Table 3 presents the estimated ATT with three different combinations of covariates in X. In model (1) we used all the predetermined municipal characteristics displayed in Table 2, apart from the 2018 value of the elderly mortality rate. In model (2) we also included the 2018 elderly mortality rate. Finally, in model (3) we balanced treated and untreated municipalities also using 2013–2017 values of the elderly mortality rate. The estimated ATT is very stable across the three specifications, suggesting that on average the implementation of telecare reduced elderly mortality by about 1.7 deaths per 1000 individuals older than 65. If we standardize the dependent variable, this corresponds to a reduction of approximatively 12 % of a standard deviation. Relative to the average elderly mortality rate in the treated municipalities, the effect represents about a 4 % decrease. The main difference among the three specifications is in terms of precision: standard errors decrease with the inclusion in X of lagged elderly mortality rates.

Table 3
ATT of telecare service on elderly mortality rate estimated by DR-DID.

	(1)	(2)	(3)
ATT	-1.947	-1.647*	-1.698**
	(1.251)	(0.921)	(0.863)
ATT (standardized elderly mortality rate)	-0.132	-0.112*	-0.115**
	(0.085)	(0.062)	(0.059)
# of observations	10,522	10,522	10,338
# of treated municipalities	160	160	160
# of untreated municipalities	5101	5101	5009
Elderly mortality rate in 2018 in X	No	Yes	Yes
Elderly mortality rates from 2013 until 2017 in X	No	No	Yes

Notes: *** p-value$<$ 0.01; ** p-value$<$ 0.05; * p-value$<$ 0.1. Standard errors robust to heteroskedasticity and within-municipality correlation are in parenthesis. In model (3) the number of control units is smaller because the lagged values of the elderly mortality rate are observed for 92 untreated municipalities.

If the parallel trends assumption holds after balancing the treated and untreated municipalities, we should not detect significant ATT if we pretend that telecare was introduced in previous years. Table 4 reports the results of such a diagnostic check and shows that all the placebo effects are close to zero and not significantly different from zero.

To test if our results were sensitive to the DID estimator used, we replicated the analysis using three alternative DID estimators. Table 5 reports this robustness check. Column (1) displays the ATT from the outcome regression DID estimator based on ordinary least squares. Column (2) shows the ATT from Abadie's (2005) inverse probability weighting DID estimator. Column (3) reports the ATT from Sant'Anna and Zhao's (2020) DR-DID estimator based on stabilized inverse probability weighting and ordinary least squares. Column (4) displays the ATT from de Chaisemartin et al.'s (2022) DID estimator, which is doubly-robust (inverse probability weighting and outcome regression). In all the cases, the estimated effects are always very similar to those reported in Table 3.

6.2. Effect heterogeneity

There are valid reasons to suspect that the effect of the telecare implementation may vary depending on different demographic and socio-economic characteristics. Table 6 displays the estimated ATT for subgroups of the entire sample. Since the number of treated municipalities is small (160), for each heterogeneity dimension we split the sample into no more than two groups by using the median of the treated whenever possible.[11]

Telecare may be more effective and useful for the elderly who have fewer social ties and a smaller family network, so that, in the case of health problems, they are less likely to be assisted in time and properly. The top panel of Table 6 presents results after splitting the sample between municipalities below and municipalities above the treated median of the fraction of elderly people living alone (model (1)), the fraction of elderly with no children (model (2)) and the fraction of households in potential care distress (model (3)). The estimated ATTs in the top panel of Table 6 suggest that telecare assistance is especially effective in reducing elderly mortality in municipalities with a larger fraction of the elderly who find it more difficult to rely on family contacts because either they live alone or, even more importantly, they do not have children. Moreover, the top panel of Table 6 shows that the effect is absent in municipalities with a low share of elderly living alone or childless. This pattern suggests that where isolation is rare and family support is more readily available, the scope for telecare to reduce mortality is limited, and the program may not reach a sufficient share of the elderly to generate detectable aggregate effects.

Model (4) in Table 6 presents the telecare effects when we split the sample according to the pre-treatment level of the elderly mortality rate. We find that the effect was stronger in those municipalities which had a higher elderly mortality rate and, therefore, required the most intervention. However, the difference in the effects between municipalities with low and those with high elderly mortality rates is not significantly different from zero.

Furthermore, we checked whether the occupational structure may matter, because it may be correlated to the kind of employment history of the current elderly, which, in turn, may impact on their health status and, therefore, on their need for health services useful for coping with their health condition. The result of Model (6) suggests that the effect of telecare is stronger when the fraction of employment in artisan, manual, and agricultural jobs is larger. These kinds of jobs may be more physically demanding and therefore leave a larger fraction of the population in poor health later in life. The result of Model (5) goes in the opposite direction and suggests that the effect is strong in municipalities with fewer low-skilled workers, who are more likely to perform physically demanding jobs, and absent in municipalities with a larger share of low-skilled workers. This discrepancy may reflect the fact that high-skilled workers, because of their larger human capital, may better interact with and exploit the telecare service for themselves and for the elderly members of their family, leading to greater efficacy of this service in municipalities with a larger share of high-skilled workers. By contrast, in municipalities with more low-skilled workers, the elderly may face deeper socioeconomic and health disadvantages accumulated over the life course, which telecare alone cannot offset. In addition, lower awareness, uptake, or effective use of telecare in these areas may have limited its aggregate impact. Nevertheless, the differential effects of Models (5) and (6) are not statistically significantly.

In addition, we sought to determine whether telecare might exacerbate health inequalities among elderly populations who are more reluctant to use digital tools. To explore this, we speculated that a lower educational level among the elderly could be associated with a higher probability of reluctance to use telecare. We split the sample based on the fraction of elderly individuals with a maximum education level of primary school. The results from Model (7) in Table 6 indicate that telecare had the same effect regardless of the proportion of the elderly individuals with a low educational attainment.

Finally, we conducted two sensitivity analyses to explore whether the effect depends on municipality size and location. Firstly, we divided the sample into small and large municipalities based on population size. Smaller municipalities often face a higher risk of lacking nearby social and health care services due to a lower patient population, which may even result in lacking the presence of general practitioners (Federsanità, 2021). As a result, elderly individuals in these areas may derive the greatest benefit from telecare adoption. Moreover, previous research has shown that elderly residents in rural areas differ from their urban counterpart in terms of education, family structure, income, leisure activities and the use of technological devices (Marcellini et al., 2007), which may affect telecare efficacy. Results in Model (8) indicate that the efficacy of telecare is confined to smaller municipalities, suggesting that telecare was mostly effective in those areas where it needed most to compensate for the lower levels of traditional social and health care services. Secondly, we compared municipalities in the North with those in the Centre-South, finding that the baseline finding is primarily driven by municipalities in the North. This result suggests the existence of significant inequalities in the provision and effectiveness of social and health care services for the elderly in the northern regions. Such regions have a higher municipal per capita expenditure on social and health care services (ISTAT, 2021, 2024) that can turn out into a better performance in terms of elderly mortality for this part of the country. By contrast, in the Centre-South the estimated effect of telecare on elderly mortality is absent, and even slightly positive though statistically insignificant, indicating that the program did not translate into measurable mortality improvement in these areas. However, given the very small number of treated municipalities in the Centre-South and their concentration in very few clusters (see Figure A.1), this finding should be interpreted with caution

6.3. Treatment intensity

The ISTAT Survey on Social Interventions and Services of Single and Associated Municipalities also provides information on the number of telecare users at the municipal level since 2018. There is, however, a

[11] We examined nine heterogeneity dimensions and for each dimension we split the sample in two. We examined the correlations across the nine dummy variables used to split the sample, which are reported in appendix in Table A.1. Overall, the correlations are modest or weak suggesting that the nine dimensions are not redundant and should capture different aspects of municipalities' characteristics.

Table 4
Placebo effects estimated by DR-DID pretending that the telecare service started in previous years.

	(1)	(2)	(3)	(4)	(5)
Years:	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018
Pretending that telecare started in:	2014	2015	2016	2017	2018
ATT	-0.001	-0.724	0.962	-1.230	1.083
	(1.008)	(1.322)	(1.246)	(1.471)	(1.284)
# of observations	10,426	10,400	10,408	10,398	10,434
# of treated municipalities	160	160	160	160	160
# of untreated municipalities	5053	5040	5044	5039	5057

Notes: *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1. Standard errors robust to heteroskedasticity and within-municipality correlation are in parenthesis. We included in X the elderly mortality rate in the first of the two periods. The number of control units varies across placebo estimates because the 2013–2017 values of the elderly mortality rate are not always observed.

Table 5
ATT of telecare service on elderly mortality rate by different DID estimators.

	(1) DID (Traditional)	(2) IPW-DID (Abadie, 2005)	(3) IPW-DR-DID (Sant'Anna and Zhao, 2020)	(4) IPW-DR-DID (de de de Chaisemartin et al., 2022)
ATT	-1.765**	-1.706**	-1.698**	-1.698**
	(0.855)	(0.869)	(0.866)	(0.859)
# of observations	10,338	10,338	10,338	10,338
# of treated municipalities	160	160	160	160
# of untreated municipalities	5009	5009	5009	5009

Notes: *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1. Standard errors robust to heteroskedasticity and within-municipality correlation are in parenthesis. The model specification is the same as the one in model (3) of Table 3. Column (1) displays the ATT from the outcome regression DID estimator based on ordinary least squares (OLS). Column (2) shows the ATT from Abadie's (2005) IPW-DID estimator. Column (3) reports the ATT from Sant'Anna and Zhao's (2020) DR-DID estimator based on stabilized IPW and OLS. Column (4) displays the ATT from de de de Chaisemartin et al. (2022) which is doubly-robust (IPW and OR).

Table 6
Heterogeneity of ATT of telecare service on standardized elderly mortality rate.

(1) Fraction of elderly living alone (treated median: 25.74 %)			(2) Fraction of elderly with no children (treated median: 13.65 %)		(3) Fraction of households in potential care distress (treated median: 2.86 %)	
	Below median	Above median	Below median	Above median	Below median	Above median
ATT (standardized elderly mortality rate)	-0.056	-0.177*	-0.007	-0.192**	-0.123*	-0.120
	(0.061)	(0.103)	(0.075)	(0.092)	(0.074)	(0.093)
# of observations	3160	7178	4300	6038	4146	6192
# of treated units	80	80	80	80	80	80
# of untreated units	1500	3509	2070	2939	1993	3016
Significance test of the difference of ATT, p-value	0.082		0.077		0.977	
	(4) Elderly mortality rate in 2018 (treated median: 40.62)		(5) Fraction of employment in low-skilled jobs (treated median: 15.30 %)		(6) Fraction of employment in artisan, manual or agric. jobs (treated median: 29.70 %)	
	Below median	Above median	Below median	Above median	Below median	Above median
ATT (standardized elderly mortality rate)	-0.071	-0.130	-0.166**	-0.015	-0.073	-0.184*
	(0.069)	(0.091)	(0.081)	(0.091)	(0.076)	(0.098)
# of observations	4398	5940	3396	6942	6820	3518
# of treated units	80	80	80	80	80	80
# of untreated units	2119	2890	1618	3391	3330	1679
Significance test of the difference of ATT, p-value	0.516		0.354		0.339	
	(7) Fraction of 65 + with at maximum primary school diploma (treated median: 59.17 %)		(8) Population in 2018 (treated median: 3186)		(9) Geographical area	
	Below median	Above median	Below median	Above median	North	Centre-South
ATT (standardized elderly mortality rate)	-0.135*	-0.133	-0.199*	-0.016	-0.177**	0.060
	(0.074)	(0.095)	(0.108)	(0.043)	(0.051)	(0.114)
# of observations	5532	4806	6378	3960	2271	5570
# of treated units	80	80	80	80	113	47
# of untreated units	2686	2323	3109	1900	2208	2738
Significance test of the difference of ATT, p-value	0.986		0.066		0.032	

Notes: *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1. Standard errors robust to heteroskedasticity and within-municipality correlation are in parentheses. All the models are estimated including in X all the predetermined characteristics listed in Table 1 and the elderly mortality rates from 2013 until 2017. We tested the significance of the difference in ATT by bootstrapping the results 500 times.

caveat. For confidentiality reasons, this variable is left-censored: whenever the number of users is strictly positive but fewer than 3 (i.e., either 1 or 2), the number of telecare users is not reported. This censoring at 3 affects 87 of our 160 treated municipalities.[12] To use this measure as a treatment-intensity variable within the same DID framework as the main treatment indicator, we implemented a Monte Carlo imputation-style procedure. Specifically, we proceeded as follows: (i) for each treated municipality with telecare users censored from below, we assigned a value to the number of telecare users using a random draw from a binary distribution (1 or 2); (ii) we divided the imputed number of telecare users by the elderly population and multiplied by 100, thus obtaining the percentage of elderly residents with access to telecare services; (iii) we estimated the impact of this percentage on the elderly mortality rate and recorded the ATT and its standard error; (iv) we repeated steps (i)-(iii) 1000 times and the ATT of interest was then calculated as the average across the 1000 estimates, and its standard error was derived following Rubin's (1987) rule. The estimator used in point (iii) is the DID estimator proposed by de Chaisemartin et al.'s (2022). It is the Weighted Average of Slopes (WAS) estimator, which is doubly robust, combining IPW and OR, and can accommodate continuously distributed treatments.

Table 7 reports the estimated impact of the percentage of elderly using telecare services on the elderly mortality rate. In column (1), both the dependent variable and the treatment intensity are expressed in levels. The estimates indicate that a one-percentage-point increase in the share of elderly using telecare services reduces the elderly mortality rate by 1.7 deaths per 1000 individuals aged 65 or older. This is not negligible because a 1.7 drop is about 4 % reduction relative to the baseline for the treated municipalities. Columns (2) and (3) show that when the treatment intensity is expressed in standardized terms, the estimated effects are modest, due to the narrow distribution of the treatment intensity[13]: a one-standard-deviation increase in telecare coverage lowers the mortality rate by about 0.3 deaths per 1000 individuals aged 65 or older, or about 2.2 % of a standard deviation of the elderly mortality rate.

Table 7
ATT of percentage of telecare users among the elderly.

de Chaisemartin et al.'s (2022) WAS estimator	(1) Non-standardized percentage of telecare users	(2) Standardized percentage of telecare users	(3) Standardized percentage of telecare users & standardized elderly mortality rate
ATT	-1.705**	-0.332**	-0.023**
	(0.842)	(0.165)	(0.011)
# of observations	10,338	10,338	10,338
# of treated municipalities	160	160	160
# of untreated municipalities	5009	5009	5009

Notes: ** p-value < 0.05. The model specification is the same as the one in model (3) of Table 3. In column (1), neither the elderly mortality rate nor the percentage of elderly using telecare services are standardized. In column (2), only the percentage of elderly using telecare services is standardized. In column (3), both the dependent variable and the treatment intensity are standardized.

[12] The average of the number of telecare users is 18.17, with standard deviation of 78.33. The 75th percentile is 12, the 90th is 30, the 95th is 50 and the maximum is 785.

[13] The unconditional average of the percentage of the elderly using telecare services is 0.02 %, with standard deviation equal to 0.19 (2018 and 2019). For the treated municipalities in 2019, the average is 1 %, with standard deviation equal to 1.20 and maximum (minimum) equal to 12 % (0.05 %).

6.4. Limitations

Our analysis has three limitations. First, we were limited to the mortality rate as the sole outcome variable, whereas mental health outcomes could have provided a richer picture of the effectiveness of telecare services. Surveys containing information on mental health, loneliness, or perceived well-being are available, such as the Survey of Health, Ageing and Retirement in Europe (SHARE) or the European Social Survey (ESS). However, these surveys do not provide information on interviewees' municipality. To the best of our knowledge, no publicly available datasets contain mental health information along with detailed local-area identifiers.

Second, we could not explore further interesting dimensions of heterogeneity, such as the effects of different types of telecare services or the quality of the services. The ISTAT survey used in our analysis does not collect disaggregated information on the types or quality of telecare services, and we are not aware of any other dataset that provides such information.

Lastly, the number of treated municipalities is small and unevenly distributed across Italy, which somewhat limits the external validity and generalizability of our findings.

7. Conclusion

In modern society, technologies for remote home care play an increasingly important role in caring for the elderly and other fragile individuals, especially those who live alone and have no family to care for them. However, their effect on health outcomes remains an open question that warrants further investigation. Our study has sought to fill this gap by analysing the effects of telecare on the mortality rate of the elderly in Italy using data at the municipal level.

Our findings show that telecare reduces the elderly mortality rate, probably by allowing timely intervention in emergency cases and performing daily remote monitoring, thereby improving patients' quality of life and their subjective well-being. We found that those Italian municipalities that started the telecare service in 2019 experienced a reduction in the elderly mortality rate of about 1.7 per 1000 individuals aged 65 and over. Compared to the average mortality rate of the elderly in the treated municipalities, this is a 4 % decrease. This magnitude is substantial, especially considering that it might be seen as an intention-to-treat effect if one had data at individual level. Indeed, although the telecare service in 2019 in the treated municipalities, this does not imply that all the elderly persons who lived there eventually gained accessed to telecare. Hence, the effect that we estimated may be interpreted, in absolute terms, as a lower bound of the true ATT at patient's level. Our main finding is of crucial importance not only because it pinpoints this substantial magnitude. It is also important because the room for intervention is still large. Indeed, telecare is not yet adequately distributed in Italy: by 2019, about 70 % of the Italian municipalities had not yet activated it, according to our calculation using the ISTAT Survey on Social Interventions and Services of Single and Associated Municipalities. Therefore, our main policy recommendation is that local policymakers should launch telecare programmes for the elderly to assist them daily and reduce their risk of death.

Our analysis yielded other important results. First, the reduction of the mortality rate due to telecare services was greater in municipalities with a larger fraction of elderly people who could not rely on the support of their children or who were living alone. The absence of children and loneliness are additional fragilities for the elderly that can be partially remedied by furnishing home-care technologies. The fact that the effect of telecare on the elderly mortality rate depends on family characteristics is consistent with the findings of studies showing the important role of family members (spouses, partners, or children) in the provision of informal care services to the elderly aged 65 and over (Onor et al., 2008; Milligan et al., 2011; Parker and Hawley, 2013) and the significant impact of these services on their quality of life and longevity. In

developed countries, the family unit is becoming smaller, fewer children are born, and there are low fertility and low birth rates: trends which could raise the issue of the sustainability of health and social care systems for the elderly in the long run. In this case, telecare could be a useful tool with which to improve the quality of life and longevity of elderly people. Second, our findings indicate that the effectiveness of telecare is independent of the educational background of elderly individuals. This may suggest that the implementation of telecare was designed in a sufficiently accessible manner, enabling usage even among those who are hesitant to engage with digital services. Third, the telecare impact was significantly stronger in small municipalities, highlighting that telecare was particularly effective in those areas where there was a greater need to compensate for a lower level of traditional social and health care services. Finally, telecare adoption was effective only in the North. This is of particular interest for the formulation of future policy measures, as it suggests the potential for increased health inequalities between northern and southern Italy if telecare services are further expanded.

The sensitivity and importance of this issue is of utmost importance for policy and technical decision-makers interested in designing effective and customized policies, such as the creation of telecare services to counteract the decline in certain functions and quality of life of the elderly, support their autonomous life at home, and reduce the burden on their family caregivers. Policy measures that enable the elderly population to adapt to future technological changes to improve their quality of life and health, and to reduce their mortality risks and social isolation, will be among the most difficult challenges to face in the future, in which regard our study has sought to provide policymakers with useful supporting evidence.

Authors' declaration

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CRediT authorship contribution statement

Raffaella Santolini: Writing – review & editing, Writing – original draft, Validation, Supervision, Investigation, Formal analysis, Conceptualization. **Matteo Picchio:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Nicola Matteucci:** Writing – review & editing, Writing – original draft, Validation, Supervision, Investigation, Formal analysis, Conceptualization. **Rostand Arland Yebetchou Tchounkeu:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

None.

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Appendix

Table A.1
Correlation matric of the different dimensions of effect heterogeneity analysed in Table 6

	High fraction of elderly living alone	High fraction of elderly with no children	High fraction of households in potential care distress	High elderly mortality rate	High fraction of employment in low skilled jobs	High fraction of employment in artisan, manual or agric. jobs	High fraction of 65 + with at maximum primary school diploma	High population	North
High fraction of elderly living alone	1.000								
High fraction of elderly with no children	0.217	1.000							
High fraction of households in potential care distress	0.164	0.537	1.000						
High elderly mortality rate	0.169	0.154	0.201	1.000					
High fraction of employment in low skilled jobs	0.140	0.044	0.157	0.138	1.000				
High fraction of employment in artisan, manual or agric. jobs	-0.048	-0.021	-0.023	0.006	-0.056	1.000			
High fraction of 65 + with at maximumprimary school diploma	0.008	0.069	0.193	0.068	0.310	0.187	1.000		
High population	-0.327	-0.214	-0.129	-0.081	-0.053	-0.220	-0.119	1.000	
North	-0.018	-0.061	-0.256	-0.087	-0.410	0.375	-0.296	-0.135	1.000

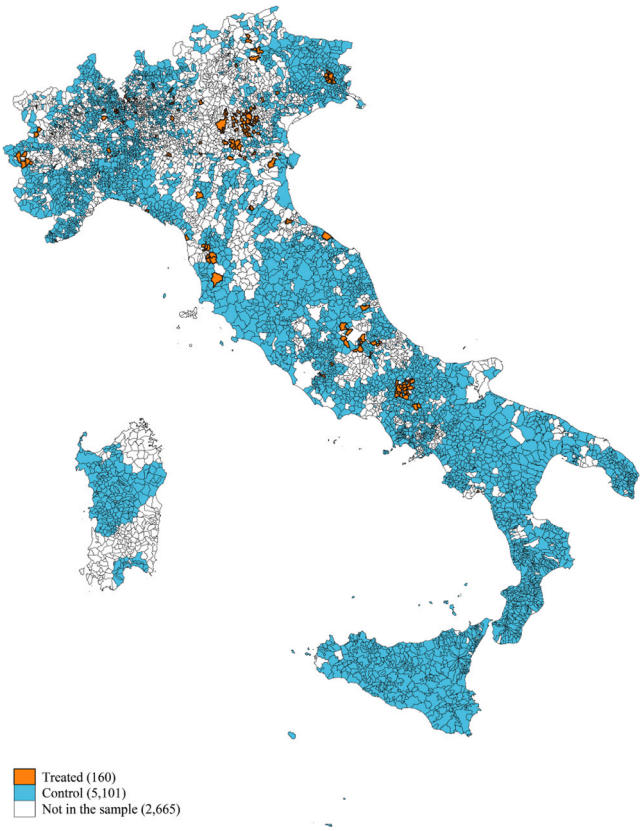

Fig. A.1. Map of treated and untreated municipalities. Notes: Treated municipalities are those without telecare services in 2018 but with telecare services in 2019. Control municipalities did not have telecare services in either 2018 or 2019

Data availability

Data will be made available on request.

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