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Working Paper

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GLO Discussion Paper, No. 1594

Provided in Cooperation with:
Global Labor Organization (GLO)

Suggested Citation: Matteucci, Nicola; Picchio, Matteo; Santolini, Raffaella; Yebetchou Tchounkeu, Rostand Arland (2025) : Telecare and Elderly Mortality: Evidence from Italian Municipalities, GLO Discussion Paper, No. 1594, Global Labor Organization (GLO), Essen

This Version is available at:
https://hdl.handle.net/10419/315052

Telecare and Elderly Mortality: Evidence from Italian Municipalities

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April 4, 2025

Abstract

The growing ageing of the population in developed economies has necessitated the progressive use of advanced information and communication technologies (ICTs) for the home care of elderly individuals. The effect of these technologies on elderly health outcomes remains an open issue. In this study, we analyze 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 1,000 inhabitants. This effect was sizeable, since it was a 4% decrease in the elderly mortality rate relatively to the average elderly mortality rate in the treated municipalities. The reduction in the elderly mortality rate 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 stronger in small municipalities, indicating that telecare may be more effective where there is a greater need to compensate for a lower level of traditional social and health care services.

Keywords: telecare, elderly, health, mortality rate, municipalities
JEL Classification: I10, I18

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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 has been defined as 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 (e.g., Bower et al., 2011; Turner and McGee-Lennon, 2013; Barrett et al., 2014).

Telecare services feature two main types of intervention: i) responding to an acute emergency suffered by fragile people signalled by an automatic alarm or a sudden variation in their health status; ii) gathering continuous (frequently monitored) evidence on a change in the patient's health or social care status (Barlow et al., 2006). Rapid interventions can be provided to elderly people in an emergency through portable alarm technologies, such as alert bracelets and pendants, which enable them to send an aid request to professional personnel when needed. Frequently, programmed calls from professional staff monitor the physical and mental health of the elderly every day: this service is especially important for the elderly living alone because it allows them to have daily social interactions and not feel abandoned. 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). This allows fragile people to maintain their independence in safety and to improve their quality of life (Bujnowska-Fedak and Grata-Borkowska, 2015).

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., 2006; Solli et al., 2012). For example, also telehealth mostly concerns older people living at home, but it focuses on vital signs monitoring (Stowe and Harding, 2010). 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. Differently, telecare services pertain to social policies and employ professionals 'trained on purpose' and social workers, instead of medical personnel.

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. 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 65 and over mortality rate. The health effects of telecare are little explored in the literature, which instead provides ample space for the study of telemedicine (Wootton, 2001) and, more recently, telehealth (Stowe and Harding, 2010), as forms of innovative medical remote assistance. However, the importance of studying telecare resides in the fact that it is complementary to both telemedicine and telehealth 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.

Our empirical analysis was based on a sample of Italian municipalities observed in 2018 and 2019, years for which information about elderly users of telecare services is available. Analysis of the Italian context is very suitable for two main reasons. Firstly, Italy is the country with the highest percentage of elderly people in Europe (Spandonaro et al., 2023). According to Eurostat data on the age structure of the population, in 2023 Italy has the highest percentage of individuals aged 65 and over within its total population (24%), exceeding the European Union countries (EU-20) average by 2.4 percentage points. Therefore, if telecare were effective, its use could have a large societal impact. Second, Italy has a long tradition of providing telecare services to the elderly, dating back to the 1980s (Tomaselli, 1992; Avallone et al., 2011), which demonstrates the strong sensitivity of Italian public institutions to this issue. In addition, law 328/2000 has accelerated the diffusion of telecare in Italy by promoting the introduction of integrated health and social care services at the local government level to support older individuals and families in difficulty.

The impact of telecare on the elderly mortality rate was estimated using a doubly robust difference-in-differences (DR-DID) estimator proposed by (Sant'Anna and Zhao, 2020). The control group consisted of 5,101 Italian municipalities that did not have remote social assistance in either 2018 or 2019, while the treatment group consisted of 160 municipalities that did not have it in 2018, but introduced it in 2019. We found 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 1,000 inhabitants. This effect was sizeable; relatively to the average elderly mortality rate in the treated municipalities, it was a 4% decrease. Finally, we found that telecare had the strongest impact in municipalities with a large fraction of elderly people without children (-3.1 individuals per 1,000 inhabitants), in smaller municipalities (-2.9) and in the North (-2.6).

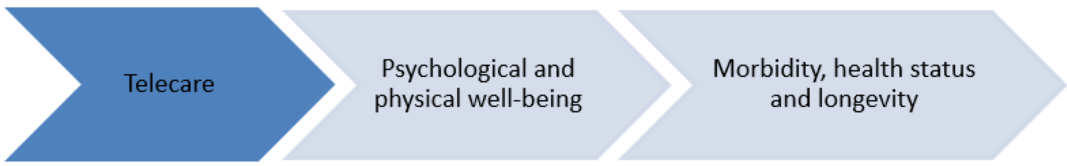
The rest of the article is organised as follows. Section 2 describes the evolution of telecare services over time. Section 3 provides a theoretical framework on the impact of telecare on mortality. Section 4 describes the institutional context. Section 5 illustrates data and the econometric method. Section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

2 Telecare services over time

Telecare moved through three distinct generations (Turner and McGee-Lennon, 2013). In the 1980s, broadband networks were not available, and the public telephone and cable networks were used to connect the home of the elderly person to the telecare provider managing the service (call centre), which could be either a private organization or a local authority (Doughty et al., 1996). 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. 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 domotics and broadband-based ICTs. Nevertheless, it is much less widespread and empirically appreciable than mainstream services.

An important theoretical and empirical issue is whether telecare mainly provides economic benefits, such as cost savings in social and health care policies, or whether it can also improve the user's subjective well-being. The latter could be understood as psychological and physical benefits that accrue to the remotely assisted patient, who would otherwise be left alone at home. Ideal experimental evidence should register subjective improvements in well-being not only with self-declared statements but also with established measures of health outcomes, such as morbidity, health status, and longevity. By this last term, the literature means improved survival and/or reduced mortality, the key endpoint targeted by our analysis. We represent this original and fundamental research issue with the logical chain between the three blocks of Figure 1. The chain assumes that there may be a causal relation between telecare and health conditions, mediated by the telecare impact on personal well-being.

Figure 1: Dissecting the impact of telecare on health outcomes



Source: Our conceptualisation.

3 A theoretical framework for telecare impact

The direct and indirect impacts of telemedicine or telehealth on health outcomes have been studied in many countries (Snoswell et al., 2023; Chen and Dills, 2024; Eze et al., 2020). Comparatively, they have been much less studied for telecare, whose literature is equally abundant but lacks analysis aimed at pinpointing the causal effects. Martin et al. (2008) conducted a Cochrane systematic review for a wide range of telecare services and searched for outcomes of both a clinical and an economic nature. In the period 1980-early 2007, they did not find any study that matched the inclusion criteria. The systematic review of Barlow et al. (2007) used different endpoints (both clinical and economic, such as the use of health care) and found that until 2006, some effectiveness was detectable for services that monitored vital signs and telephone follow-up by nurses (technically, telehealth), while the systems for home safety and security alert systems (properly, telecare) did not provide sufficient evidence of effectiveness. Van Grootven and van Achterberg (2019) surveyed the telecare projects run under the EU-sponsored Ambient Assisted Living Programme and noted that these projects failed to assess the impact on health and well-being outcomes (only 12 of 152 projects did so, but with poor methodological quality). The UK was an exception. It was a Western pioneer in telecare services and had set itself the ambitious goal of making telecare available for all homes in need by 2010 (Barlow et al., 2005). In England, the Whole System Demonstrator (WSD) project ran a cluster randomized trial and tested the impact of a variety of telecare instruments on health care usage and quality of life (Bower et al., 2011). Telecare was found to have no impact on the use of traditional health and social care services (Steventon et al., 2013) and contributed to improving the psychological well-being and quality of life of the user (Hirani et al., 2014).

No study has addressed the relation between telecare and more tangible measures of health such as longevity. Despite this knowledge gap, there are some streams of interdisciplinary literature which found interesting results by studying pairwise the single blocks composing Figure 1. The relationship between telecare and health outcomes can be studied by resorting to the literature that addresses the link between telecare and psychological and physical well-being, i.e. the 'first link', and the literature that investigates the relationship between the latter and health outcomes, i.e. the 'second link'.

Quantitatively, the second link has been studied by a much larger body of literature, featuring contributions from economics, sociology, psychology, biology, and other biomedical studies, such as gerontology. A common trait is the focus on positive affect constructs such as happiness, quality of life, or subjective well-being. Well-being constructs differ from direct and indirect measures of health status, but the two are correlated and can be explained with a series of elements such as lifestyle factors and biological processes (Karimi and Brazier, 2016; Pressman et al., 2019; Steptoe, 2019). Similarly, other studies have focused on constructs of negative affect such as loneliness, sadness or stress (e.g., Holt-Lunstad et al., 2015; Brandts et al., 2021). They report an analogous finding: the negative effect is negatively correlated with the health status and longevity.

According to this abundant literature, positive affect measures, such as happiness, are directly associated not only with health status but also with reduced mortality or improved survival. The empirical methods and results present in this literature differ for levels of statistical quality (e.g., use of statistical controls, causality, effect size and significance, or type of dependent variables) and generalization of results (Diener and Chan, 2011, p. 1). Although some studies could not resolve all potential causality biases, over time the methodological and statistical standard of this literature has improved, together with the generalizability of the relation between subjective well-being and mortality (e.g., Martín-María et al., 2017; Steptoe, 2019; Andersen et al., 2021). An interesting result is that happiness tends to predict longevity better in healthy populations compared to sick ones, a finding initially envisaged by Veenhoven (2008). Moreover, the causal interpretation of statistical relations has been backed by biomedical considerations. 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.

Regarding the relation between telecare and psychological or physical well-being ('first link' in Figure 1), there is no scientific evidence. To the best of our knowledge, no study has specifically conceptualized or tested the possible impact of remote care on subjective well-being, whereas many studies within the literature on 'happiness and economics' have examined its socio-demographic determinants (Frey, 2018). By using analogical inductive reasoning, we can infer that, because telecare concerns social relations, which are known to impact on subjective well-being through the production of 'relational goods' (Gui et al., 2005), also telecare can have an impact on subjective well-being (Becchetti et al., 2008). The expected impact on well-being of care offered through ICTs instruments may be either positive or negative, depending on what relational phenomena are considered to be prevalent. On the one hand, if we hypothesize that telecare has a prevalent sociability content, and therefore acts as a good substitute for physical care relations, we expect a reduction in mortality. On the other hand, remote care mediated by digital technology may not generate authentic relational goods like those produced by physical encounters, and it may act in the same way as other communication and digital media, which crowd out relational goods. If so, ICTs-mediated remote care may not improve, or it may even depress, subjective well-being (e.g., Bruni and Stanca, 2008; Rotondi et al., 2017). Accordingly, we expect an increase in mortality. Given that the theoretical impact of telecare on mortality is ambiguous, the empirical analysis now reported sheds light on the prevalent mechanism.

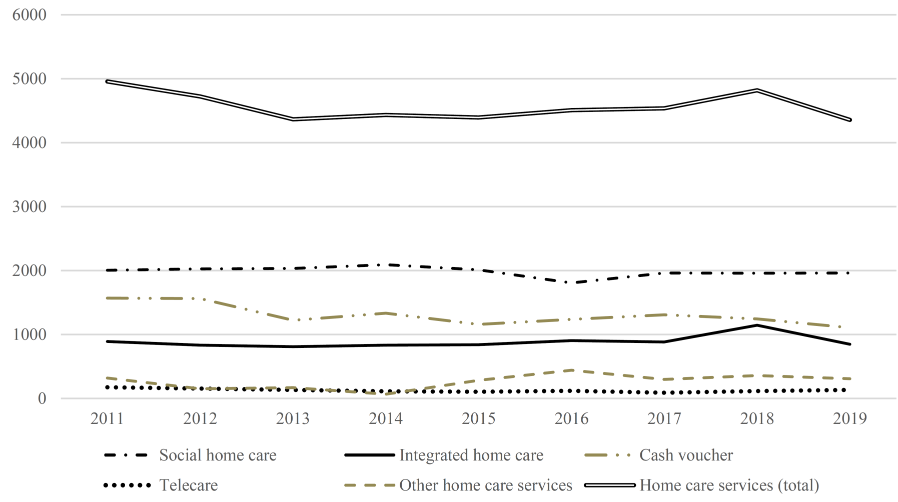
4 Institutional setting

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 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 1,444,410 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).

Figure 2 presents the evolution of the per-user home care expenditures of Italian municipalities for people aged 65 and over from 2011 to 2019 by type of services. As shown by the top line in Figure 2, the per-user total home care expenditure declined from €4,957 in 2011 to €4,357 in 2019. Spending on all categories of home care decreased during this period. The decline was most severe for cash vouchers, which fell by €462 per-user.

The LTC system in Italy is fragmented across different levels of government (central, regional, and local) and local authorities. 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

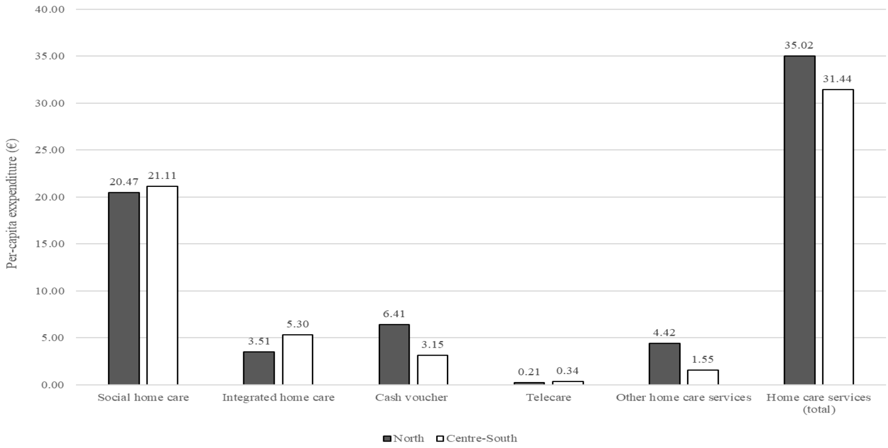
Figure 2: Evolution of per-user home care expenditure of Italian municipalities for people aged 65 and over from 2011 to 2019



Source: Authors' elaborations on data from the Istat survey "Social Interventions and Services of Single and Associated Municipalities". The vertical axis represents deflated euros (2010 prices).

resources. These resources are primarily managed by provinces, municipalities, and local health authorities (e.g., *Aziende Sanitarie Locali*) (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). Figure 3 illustrates the home care expenditure of Italian municipalities per-person aged 65 and over in 2019 by macro-areas and type of services. It shows that the North was the largest investor, particularly in cash vouchers. The municipal expenditure on elderly home care services per-person aged 65 and over amounted to €35.02 in the North, compared to €31.44 in the Centre-South. Per-capita municipal spending on cash vouchers for the elderly in the North was €6.41 in 2019, more than double that of the Center-South, which stood at €3.15. The per-capita municipal expenditure in telecare was low in both macro-areas: €0.21 in the North and €0.34 in the Centre-North.

Figure 3: Home care expenditure of Italian municipalities per person aged 65 and over by macro-area and expenditure type in the year 2019



Source: Authors' elaborations on data from the Istat survey "Social Interventions and Services of Single and Associated Municipalities". The indicator is computed as the share of municipal expenditure on home care services for people aged 65 and more on population aged 65 and more. The vertical axis represents deflated euros (2010 prices).

5 Data and method

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 the Italian National Institute of Statistics (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. 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 importantly affected the mortality rates, especially of the elderly, with a strong uneven distribution of the excess mortality across Italy (Henry et al., 2022). At the same time, it induced relevant pressures to the health system, with resource shortages and delayed or limited access to care. Moreover, it prompted changes in health assistance, like telemedicine and home-based care. Given the confounding effect that concomitant changes induced by the COVID-19 outbreak may have had and given the different role that telemedicine may have played in that period, both as a substitute and a complement to other forms of social and health care, we preferred to exclude the COVID-19 years from our analysis and focus on identifying the effect of telecare in normal times.

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 trend 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.

Italy is divided into about 8,000 municipalities (7,954 in 2018), which are the smallest local administrative units. After deleting those municipalities which modified their size by merging with other municipalities between 2011 and 2019, we were left with 7,785 municipalities. We further selected those municipalities that in 2018 had not yet implemented telecare for the elderly, leaving us with 5,559 municipalities. After discarding those observations with missing values for some of the variables used in the empirical analysis, our sample shrank further to 5,261 municipalities. None of them had telecare in 2018; 160 municipalities had it by the time the 2019 survey was conducted. These 160 municipalities constituted our treatment group. The remaining 5,101 municipalities were the control units.

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 in a given year and the resident population aged 65 and over per 1,000 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 1,000 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 is not significantly different from zero.

Table 1: Summary statistics

	Average mortality rate 65 or older		
	2018	2019	Before-after difference
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 (5,101). Standard errors robust to heteroskedasticity and within-municipality correlation are reported in parentheses.

The interpretation of the finding in Table 1 as the causal effect of the telecare implementation relies on a strong assumption. The average outcomes for treated and control units should have followed parallel paths over time in the absence of the treatment (Abadie, 2005). Although the first difference in the outcome variable eliminates the omitted variables bias generated by municipal fixed effects additively entering the conditional mean of the elderly mortality rate, the parallel trend assumption may be implausible 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). 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 located in the North-East (Trentino-Alto Adige, Veneto, Friuli-

Venezia Giulia, and Emilia-Romagna) than in the rest of the Italian regions.

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

	Treated municipalities	Untreated municipalities	Difference
Elderly mortality rate (per 1,000 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 1,000)	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	0.400	0.105	0.295***
Center	0.019	0.114	-0.095***
South	0.213	0.316	-0.104***
Observations	160	5,101	

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 €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.

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

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

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 $w_0(D, X; \pi) = \frac{\pi(X)(1-D)}{1-\pi(X)} \Big/ E\left[\frac{\pi(X)(1-D)}{1-\pi(X)}\right]$, with $\pi(X)$ an arbitrary model for the true, unknown propensity score.

The estimand in Equation (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. We plugged into X_i the value of the elderly mortality rate in 2018, in order to control and balance the treated and untreated municipalities also for the pre-treatment value 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 Equation (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 trend 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

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 the implementation of telecare reduced the elderly mortality rate on average by about 1.7 people out of 1,000 people older than 65. Relative to the average elderly mortality rate in the treated municipalities, this is a 4.1% 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.

If the parallel trend 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

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)
# of observations	10,522	10,522	10,338
# of treated municipalities	160	160	160
# of untreated municipalities	5,101	5,101	5,009
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.

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	5,053	5,040	5,044	5,039	5,057

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.

estimator based on stabilized inverse probability weighting and ordinary least squares. In all the cases, the estimated effects are always very similar to those reported in Table 3.

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)
ATT	-1.765** (0.855)	-1.706** (0.869)	-1.698** (0.866)
# of observations	10,338	10,338	10,338
# of treated municipalities	160	160	160
# of untreated municipalities	5,009	5,009	5,009

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. 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.

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.

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 ATT in the top panel of Table 6 suggest that telecare assistance is especially effective in reducing the elderly mortality rate 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.

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

Table 6: Heterogeneity of ATT of telecare service on elderly mortality

	(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	-0.824	-2.611*	-0.096	-2.284**	-1.811*	-1.775
	(0.902)	(1.517)	(1.099)	(1.354)	(1.090)	(1.379)
# of observations	3,160	7,178	4,300	6,038	4,146	6,192
# of treated units	80	80	80	80	80	80
# of untreated units	1,500	3,509	2,070	2,939	1,993	3,016
Significance test of the difference of ATT, p-value[(a)]	0.162		0.066		0.986	
	(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	-1.049	-1.923	-2.441**	-0.215	-1.074	-2.718*
	(1.020)	(1.347)	(1.194)	(1.335)	(1.124)	(1.453)
# of observations	4,398	5,940	3,396	6,942	6,820	3,518
# of treated units	80	80	80	80	80	80
# of untreated units	2,119	2,890	1,618	3,391	3,330	1,679
Significance test of the difference of ATT, p-value[(a)]	0.437		0.199		0.919	
	(7) Fraction of 65+ with at maximum primary school diploma (treated median: 59.17%)		(8) Population in 2018 (treated median: 3,186)		(9) Geographical area	
	Below median	Above median	Below median	Above median	North	Centre-South
ATT	-1.991*	-1.964	-2.939*	-0.229	-2.612**	-0.888
	(1.094)	(1.405)	(1.594)	(0.635)	(1.051)	(1.678)
# of observations	5,532	4,806	6,378	3,960	2,271	5,570
# of treated units	80	80	80	80	113	47
# of untreated units	2,686	2,323	3,109	1,900	2,208	2,378
Significance test of the difference of ATT, p-value[(a)]	0.986		0.032		0.038	

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.

[(a)] We tested the significance of the difference in ATT by bootstrapping the results 500 times.

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 stronger in municipalities with fewer low-skilled workers, who are the ones more likely to perform physically demanding jobs. This discrepancy may be explained by the fact that high-skilled workers, because of their larger amount of human capital, may better interact with and exploit the new telecare service for themselves and for the elderly members of their family, leading to the greater efficacy of this service in municipalities with a larger fraction of high-skilled workers. Nevertheless, the differential effects of Models (5) and (6) are not significantly different from each other from the statistical point of view.

In addition, we sought to determine whether telecare may exacerbate health inequalities among the elderly populations who are more reluctant to use digital tools. To explore this, we speculated that a lower educational level among the elderly may 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 the proportion of the elderly with a low educational attainment.

Finally, we conducted two sensitivity analyses to explore the spatial dimension of the data. First, 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. Second, 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.

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 1,000 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 is low fertility and a low birth rate: 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, indicating 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 must attract the attention of 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 (Hirani et al., 2014; Millán-Calenti et al., 2017), support their autonomous life at home (Steventon et al., 2013), and reduce the burden on their family caregivers (Millán-Calenti et al., 2017).

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 policy-makers with useful supporting evidence.

Authors' conflict of interest declaration

This study did not receive specific grants from funding agencies in the public, commercial, or non-profit sectors.

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