

# A Two-Stage Analysis of Internet Access and E-Health Adoption among Italian Older Adults

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## Abstract

Population ageing and the digital transformation of healthcare place older adults at the centre of telemedicine policy, yet e-Health services can only benefit those who are first able to access and then willing to use digital tools. This study identifies the determinants of the potential use of online health services among people aged 65 years and over in Italy, disentangling digital access from e-Health adoption. We analysed cross-sectional data from the 2024 wave of the ISTAT “Aspetti della Vita Quotidiana” (AVQ) survey, restricted to 11,705 respondents aged  $\geq 65$  years. A two-stage design was adopted to avoid circularity: Stage 1 modelled Internet access in the whole elderly sample, while Stage 2 modelled the use of at least one online health service among the 5841 elderly Internet users. Weighted binomial generalized linear models (logit link) with HC1 robust standard errors were fitted; discrimination, calibration and fit were assessed through the area under the ROC curve (AUC), the Brier score and the Cox-Snell pseudo- $R^2$ . Overall, 33.1% of people aged  $\geq 65$  years and 65.3% of elderly Internet users had used at least one online health service in the previous three months. Educational attainment was the strongest determinant in both stages (Stage 2 adjusted OR for a university degree versus primary education = 5.50, 95% CI: 4.48 - 6.76). A marked North-South geographic gradient (Stage 2 OR = 1.54, 95% CI: 1.37 - 1.72), advancing age (OR = 0.77 for  $\geq 75$  years) and health-care need proxied by specialist visits (OR = 1.58, 95% CI: 1.41 - 1.78) were consistently associated with e-Health adoption. Female sex was a barrier to digital access (Stage 1 OR = 0.81) but not to e-Health adoption (Stage 2 OR = 1.03, ns). The Stage 1 model showed excellent discrimination (AUC = 0.884), whereas the Stage 2 model was more modest (AUC = 0.691). The potential use of telemedicine among Italian older adults is structured by a two-layered social gradient: education, geography and age shape both physical access to the Internet and the subsequent adoption of

health services online. Policies implementing the digital-health objectives of the Italian National Recovery and Resilience Plan (Mission 6) should couple infrastructure investment with targeted digital-literacy interventions for the least-educated, oldest and southern older adults to prevent telemedicine from widening existing health inequalities.

## Keywords

Telemedicine, E-Health, Digital Divide, Ageing, Italy

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## 1. Introduction

Population aging is one of the defining demographic transformations of the twenty-first century. According to the World Health Organization, the share of the world's population aged 60 years and over will nearly double between 2015 and 2050, rising from 12% to 22%, while the absolute number of people in this age band is projected to reach 2.1 billion [1]. This transition is accompanied by a rising burden of chronic and non-communicable diseases, which now account for roughly three-quarters of all deaths globally and are especially concentrated in later life [2]. Older adults frequently live with multiple coexisting conditions, generating sustained demand for continuity of care, medication management, and regular contact with health services [3].

Italy is one of the oldest countries in the world. At the beginning of 2024, people aged 65 years and over represented approximately 25% of the resident population, and the old-age dependency ratio continues to rise as fertility remains low and life expectancy high [4]. This demographic structure translates into a heavy and growing burden of chronic non-communicable diseases, multimorbidity and functional limitation, increasing the need for continuous and integrated care [5]. Concurrently, the Italian National Health Service continues to exhibit marked regional disparities in healthcare resources, infrastructure, service organization and access to care, reflecting the longstanding socioeconomic divide between northern and southern Italy [6] [7].

Against this background, telemedicine and, more broadly, digital health services have been promoted as a strategic response to the sustainability challenge posed by an ageing population [8]. Remote consultation, online booking of medical appointments, access to the Electronic Health Record and the online retrieval of health information can support the shift from episodic, hospital-centred care towards continuous, community-based and preventive models. For older adults living with chronic conditions, such tools have been associated with better disease control, improved self-management, reduced avoidable hospitalizations and support for ageing in place. The COVID-19 pandemic acted as a powerful catalyst, forcing a rapid, large-scale adoption of remote care and exposing both the potential and the fragility of digital health delivery for older citizens [9] [10].

The Italian policy framework has responded decisively. Mission 6 (Health) of the National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza, PNRR) earmarks substantial resources for the digitalization of the health system, the strengthening of territorial care through Community Houses (Case della Comunità) and the national roll-out of telemedicine platforms [11]. However, the effectiveness and equity of these investments hinge on a simple but frequently overlooked precondition: telemedicine can only benefit those older adults who are first able to reach digital services and then willing and competent to use them.

This precondition is far from universally met. A well-documented “grey digital divide” separates older from younger citizens and, within the older population, separates the more advantaged from the more vulnerable [12] [13]. The divide is conventionally described across three levels: access to devices and connectivity (first level), digital skills and confidence (second level), and the concrete use of the Internet for meaningful activities such as e-Health (third level) [14] [15]. Empirical work across Europe and beyond has repeatedly shown that educational attainment, income, age, sex, place of residence and health status jointly shape whether older people cross each of these thresholds [16]. If digital health is deployed without attention to this stratification, it risks reproducing—or even amplifying—the very health inequalities it is meant to reduce, generating a digital inverse-care effect whereby those with the greatest health need have the least digital access.

Despite a rich international literature on e-Health adoption and the digital divide, three gaps motivate the present study. First, many studies conflate digital access with digital-service use, estimating the determinants of e-Health adoption on the whole population and thereby confounding the drivers of getting online with the drivers of doing health online. This creates a circularity problem: Internet use is simultaneously the strongest predictor and a constitutive component of e-Health behaviour. Second, nationally representative, recent and specifically Italian evidence on the elderly population remains comparatively scarce, even though Italy’s demographic profile and marked territorial heterogeneity make it a critical case. Third, few studies quantify the relative contribution and predictive performance of sociodemographic and health-need determinants using formal model-evaluation metrics.

The present study addresses these gaps using the 2024 wave of the Italian “Aspetti della Vita Quotidiana” (AVQ) survey conducted by the National Institute of Statistics (ISTAT) [17]. We adopt an explicit two-stage analytical strategy that separates the determinants of Internet access (Stage 1, estimated on all people aged  $\geq 65$  years) from the determinants of online health-service use among those who are already online (Stage 2, estimated on elderly Internet users). The specific objectives are: i) to describe the prevalence of the potential use of online health services in the Italian elderly population and among elderly Internet users; ii) to identify and quantify the sociodemographic and health-related determinants of digital

access and of e-Health adoption; iii) to evaluate the discrimination, calibration and fit of the two models; and iv) to explore heterogeneity across sex, age and geographic macro-area, with the aim of informing equitable telemedicine policy in Italy.

## 2. Materials and Methods

### 2.1. Data Source and Study Population

We analysed cross-sectional microdata from the 2024 wave of the multipurpose sample survey “Aspetti della Vita Quotidiana” (Aspects of Daily Life, AVQ), conducted annually by ISTAT as part of the Italian integrated system of social surveys. The AVQ survey targets the resident population living in private households and collects information on a broad range of domains, including socioeconomic conditions, health status and chronic conditions, lifestyle, satisfaction with public services and the use of information and communication technologies. Since 2018, data have been collected through a sequential mixed-mode technique combining computer-assisted web interviewing (CAWI) and paper-and-pencil interviewing (PAPI). The 2024 wave comprised 45,005 respondents of all ages.

For the present analysis, the sample was restricted to respondents aged 65 years and over, yielding an analytical population of 11,705 individuals. Of these, 5841 (50.7%) reported having used the Internet in the previous twelve months and constituted the population at risk for the second-stage analysis. All estimates were computed using the sampling weights provided by ISTAT to restore representativeness of the resident population aged  $\geq 65$  years.

### 2.2. Outcome Definition

The primary outcome was the potential use of telemedicine, operationalized as the use of at least one online health service in the three months preceding the interview. The composite outcome combined four self-reported activities: i) seeking health information online; ii) booking a medical appointment online; iii) accessing the Electronic Health Record; and iv) using other online health services. Respondents performing any of these activities were classified as e-Health users. This behavioural, service-oriented definition captures the concrete realization of telemedicine’s potential rather than mere attitudes or intentions.

### 2.3. Predictor Variables

The set of predictors was selected a priori on the basis of established digital-divide and technology-acceptance frameworks and grouped into three domains. Socio-demographic predictors comprised age class (65 - 74 versus  $\geq 75$  years), sex, marital status (married as reference; single, separated/divorced, widowed) and educational attainment (primary education or none as reference; lower secondary, upper secondary diploma, university degree). A contextual predictor captured the geographic macro-area, dichotomized as North versus Centre-South to summa-

size the well-known territorial gradient. Health-related predictors—intended as proxies of health-care need—comprised self-rated health (bad or very bad versus better), multimorbidity (two or more chronic conditions) and having had at least one specialist visit in the previous twelve months. Chronic-disease burden was derived from 17 specific AVQ items covering 19 distinct pathological conditions rather than from a single self-declared indicator. For the Stage 1 model, availability of a home Internet connection was additionally included as a strong structural determinant of individual Internet use.

## 2.4. Two-Stage Study Design

To avoid the methodological circularity that arises when Internet use is used to explain a behaviour that presupposes Internet use, we adopted a sequential two-stage design. In Stage 1, the determinants of Internet access were modelled in the full elderly sample ( $n = 11,705$ ), with a binary indicator of Internet use in the previous twelve months as the dependent variable. In Stage 2, the determinants of e-Health adoption were modelled exclusively among elderly Internet users<sup>1</sup> ( $n = 5841$ ), with the composite online-health-service indicator as the dependent variable. This design cleanly separates the drivers of crossing the first-level (access) threshold from the drivers of crossing the third-level (meaningful use) threshold, and prevents the overwhelming effect of Internet access from masking the more subtle determinants of health-specific behaviour.

## 3. Statistical Models

Both stages were estimated as weighted binomial generalized linear models (GLM) with a logit link function, using the survey sampling weights normalized to the analytical sample size. Because the public-use microdata do not include the primary sampling units and strata required for full design-based variance estimation, inference relied on Huber-White HC1 heteroskedasticity-robust standard errors, which provide conservative and consistent variance estimates under weighted quasi-likelihood estimation. Results are reported as odds ratios (OR) with 95% confidence intervals (CI) and two-sided p-values; associations were considered statistically significant at the 0.05 level.

The reliance on HC1 heteroskedasticity-robust (Huber-White sandwich) standard errors warrants further methodological justification. In the absence of the primary sampling units and strata required for full design-based variance estimation,

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<sup>1</sup>Internet use was operationalized from the variable “Have you ever used the internet?” (Domain 10 of the AVQ questionnaire), which records the most recent period in which the respondent used the Internet. In the subsample aged 65 and over, the distribution was as follows: used in the past three months ( $n = 5688$ ); used between three and twelve months ago ( $n = 153$ ); used more than one year ago ( $n = 464$ ); never used ( $n = 5106$ ); and blank, no response ( $n = 294$ ). An individual was classified as an Internet user if the Internet had been used at least once in the past twelve months. Respondents who had last used the Internet more than one year previously and those who had never used it were classified as non-users; blank responses were treated conservatively as non-use. This yielded 5841 Internet users and 5864 non-users.

robust sandwich estimators represent a well-established and conservative alternative [18]. Under moderate clustering, sandwich standard errors are, if anything, slightly larger—and therefore more conservative—than naïve model-based standard errors, so they do not artificially narrow confidence intervals or inflate statistical significance. Moreover, because the ISTAT AVQ sampling design involves stratification and multistage clustering, both of which generally increase rather than decrease sampling variance, the omission of design information is far more likely to understate than to overstate the true uncertainty of our estimates; the direction of any resulting bias is thus conservative with respect to Type I error.

Prior to multivariable modelling, bivariate associations between each predictor and the outcome were assessed using design-adjusted Rao-Scott chi-square tests, computed both in the full elderly sample and in the Internet-user subsample. Multicollinearity was screened through variance inflation factors, and no problematic collinearity was detected among the retained predictors.

Model performance was evaluated along three complementary dimensions. Discrimination—the ability to distinguish users from non-users—was quantified by the area under the receiver operating characteristic curve (AUC). Overall predictive accuracy and calibration were summarized by the Brier score, the mean squared difference between predicted probabilities and observed outcomes, for which lower values indicate better performance. The proportion of explained variation was reported through the Cox-Snell pseudo- $R^2$ . Calibration was additionally inspected with the Hosmer-Lemeshow rationale by comparing predicted and observed frequencies across risk deciles. This multi-metric evaluation allows a transparent appraisal of both the explanatory and the predictive value of each stage.

## 4. Results

### 4.1. Sample Characteristics

The analytical sample comprised 11,705 individuals aged 65 years and over. Half of the sample (50.9%) was aged 75 years or more, and 55.7% were women, reflecting the well-known feminization of the oldest age groups. Educational attainment was low overall: 36.9% of respondents held at most a primary-school certificate and only 10.1% held a university degree. The sample was distributed across all geographic macro-areas, with 47.2% residing in the North (North-West 27.5%, North-East 19.7%), 20.4% in the Centre and 32.3% in the South and the Islands. The burden of ill health was substantial: 79.7% reported at least one chronic condition, 58.1% met the criterion for multimorbidity (two or more chronic conditions) and 46.3% reported functional limitations. Just over half of the sample (50.7%) had used the Internet in the previous twelve months, while 72.6% lived in a household with a home Internet connection, signalling a marked gap between infrastructural availability and individual use. **Table 1** reports the full sociodemographic and health profile of the sample.

**Table 1.** Sociodemographic and health characteristics of the study sample (persons aged  $\geq 65$  years;  $n = 11,705$ ). Percentages are weighted.

| Characteristic                               | n    | % (weighted) | 95% CI      |
|----------------------------------------------|------|--------------|-------------|
| <b>Age class</b>                             |      |              |             |
| 65 - 74                                      | 5797 | 49.1         | 48.0 - 50.1 |
| $\geq 75$                                    | 5908 | 50.9         | 49.9 - 52.0 |
| <b>Sex</b>                                   |      |              |             |
| Male                                         | 5268 | 44.3         | 43.3 - 45.3 |
| Female                                       | 6437 | 55.7         | 54.7 - 56.7 |
| <b>Marital status</b>                        |      |              |             |
| Married                                      | 6761 | 53.7         | 52.7 - 54.7 |
| Single                                       | 768  | 7.0          | 6.5 - 7.6   |
| Separated/divorced                           | 929  | 9.1          | 8.5 - 9.7   |
| Widowed                                      | 3208 | 30.1         | 29.2 - 31.1 |
| <b>Educational attainment</b>                |      |              |             |
| Primary or none                              | 4328 | 36.9         | 35.9 - 37.8 |
| Lower secondary                              | 3288 | 28.2         | 27.3 - 29.1 |
| Upper secondary diploma                      | 2928 | 24.9         | 24.0 - 25.8 |
| University degree                            | 1116 | 10.1         | 9.5 - 10.7  |
| <b>Geographic macro-area</b>                 |      |              |             |
| North-West                                   | 2690 | 27.5         | 26.5 - 28.4 |
| North-East                                   | 2363 | 19.7         | 18.9 - 20.5 |
| Centre                                       | 2347 | 20.4         | 19.6 - 21.3 |
| South                                        | 3086 | 21.6         | 20.8 - 22.5 |
| Islands                                      | 1218 | 10.7         | 10.1 - 11.4 |
| <b>Self-rated health</b>                     |      |              |             |
| Very good                                    | 388  | 3.3          | 2.9 - 3.6   |
| Good                                         | 3959 | 33.7         | 32.7 - 34.6 |
| Neither good nor bad                         | 5623 | 48.2         | 47.2 - 49.2 |
| Bad                                          | 1438 | 12.3         | 11.7 - 13.0 |
| Very bad                                     | 297  | 2.5          | 2.2 - 2.8   |
| <b>Chronic disease (<math>\geq 1</math>)</b> |      |              |             |
| Yes                                          | 9300 | 79.7         | 78.9 - 80.6 |
| No                                           | 2405 | 20.3         | 19.4 - 21.1 |

**Continued**

| <b>Multimorbidity (<math>\geq 2</math>)</b> |      |      |             |
|---------------------------------------------|------|------|-------------|
| Yes                                         | 6753 | 58.1 | 57.1 - 59.1 |
| No                                          | 4952 | 41.9 | 40.9 - 42.9 |
| <b>Functional limitations</b>               |      |      |             |
| Yes                                         | 5398 | 46.3 | 45.3 - 47.4 |
| No                                          | 6307 | 53.7 | 52.6 - 54.7 |
| <b>Internet use (last 12 months)</b>        |      |      |             |
| Yes                                         | 5841 | 50.7 | 49.6 - 51.7 |
| No                                          | 5864 | 49.3 | 48.3 - 50.4 |
| <b>Home Internet access</b>                 |      |      |             |
| Yes                                         | 8557 | 72.6 | 71.6 - 73.5 |
| No                                          | 3148 | 27.4 | 26.5 - 28.4 |

**4.2. Chronic Disease Prevalence**

**Table 2** reports the weighted prevalence of each of the 17 chronic conditions considered. Hypertension was by far the most common (49.3%), followed by arthrosis or arthritis (41.6%) and osteoporosis (24.9%). Diabetes affected 17.4% of the sample, and the composite category of nervous disorders, Alzheimer's disease and Parkinsonism affected 12.5%. Conditions with lower but clinically important prevalence included allergic diseases (10.2%), depression (9.5%), chronic bronchitis or emphysema (9.2%), other heart diseases (8.6%), cancer (7.2%) and myocardial infarction (5.7%). Liver cirrhosis was the rarest condition (1.0%).

**Table 2.** Weighted prevalence of the 17 chronic conditions (adults aged  $\geq 65$ ).

| <b>Condition</b>                         | <b>% (weighted)</b> |
|------------------------------------------|---------------------|
| Hypertension                             | 49.3                |
| Arthrosis/Arthritis                      | 41.6                |
| Osteoporosis                             | 24.9                |
| Diabetes                                 | 17.4                |
| Nervous disorders/Alzheimer/Parkinsonism | 12.5                |
| Allergic diseases                        | 10.2                |
| Depression                               | 9.5                 |
| Chronic bronchitis/emphysema             | 9.2                 |
| Other heart diseases                     | 8.6                 |
| Cancer                                   | 7.2                 |

**Continued**

|                        |     |
|------------------------|-----|
| Bronchial asthma       | 6.4 |
| Myocardial infarction  | 5.7 |
| Kidney stones          | 5.2 |
| Gastric/duodenal ulcer | 4.5 |
| Gallstones             | 4.3 |
| Stroke                 | 3.5 |
| Liver cirrhosis        | 1.0 |

**4.3. Prevalence of Online Health-Service Use**

Overall, 33.1% of the population aged 65 years and over had used at least one online health service in the previous three months. This proportion more than doubled, to 65.3%, when restricted to elderly Internet users, confirming that digital access is the dominant gateway to telemedicine. Among the individual components, seeking health information online was the most common activity (29.2% of all older adults and 57.7% of Internet users), followed by the use of other online health services (15.2% and 30.1%), online booking of medical appointments (14.6% and 28.8%) and access to the Electronic Health Record (13.0% and 25.6%).

**Figure 1** contrasts the distribution of the outcome in the full elderly population and among Internet users.

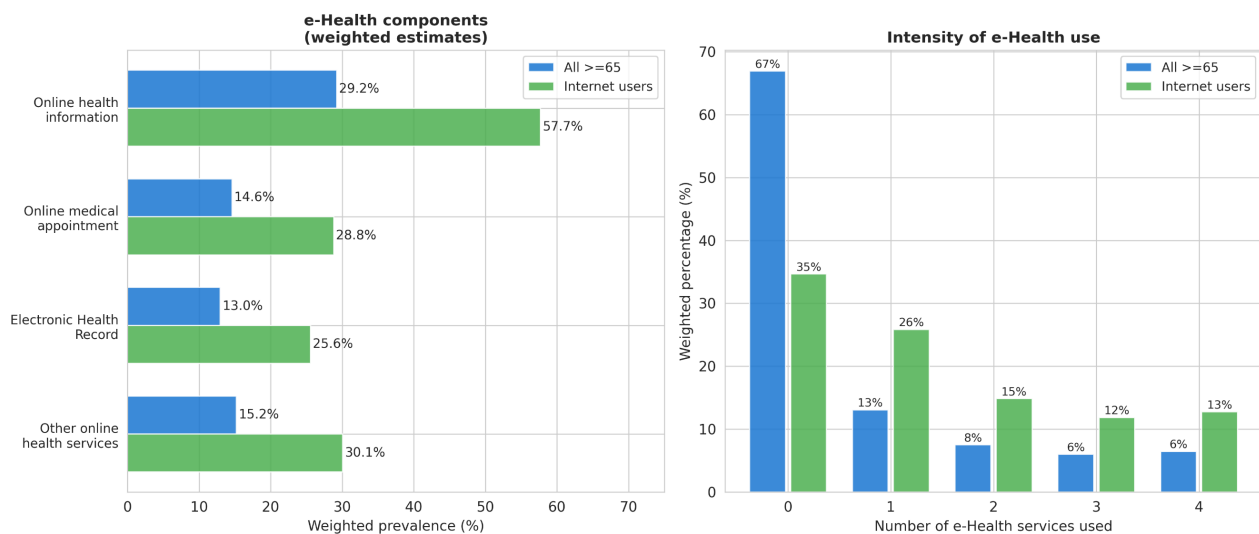


**Figure 1.** Prevalence of online health-service use and of its individual components among the population aged  $\geq 65$  years (light bars) and among elderly Internet users (dark bars).

**4.4. Bivariate Analysis**

In the full elderly sample, all sociodemographic and health-related predictors were strongly associated with online health-service use (design-adjusted  $p < 0.0001$ ), with the weakest bivariate association observed for chronic disease considered as

a simple binary indicator ( $p = 0.023$ ). Internet use displayed by far the strongest bivariate association with the outcome, followed by educational attainment. When the analysis was restricted to Internet users, several associations attenuated markedly: self-rated health and functional limitations were no longer significant, and sex lost significance ( $p = 0.107$ ), whereas education, geographic area, age and health-care need (specialist visits) remained robustly associated with e-Health adoption. This attenuation pattern is itself informative, indicating that some variables act primarily as barriers to getting online rather than as barriers to using health services once online. **Table 3** summarizes the bivariate results.

**Table 3.** Bivariate associations (design-adjusted Rao-Scott  $\chi^2$ ) between predictors and online health-service use, in the full sample aged  $\geq 65$  years ( $n = 11,705$ ) and in the Internet-user subsample ( $n = 5841$ ).

| Predictor              | $\chi^2$ ( $\geq 65$ , full) | p       | $\chi^2$ (Internet users) | p       |
|------------------------|------------------------------|---------|---------------------------|---------|
| Age class              | 817.5                        | <0.0001 | 35.1                      | <0.0001 |
| Sex                    | 87.8                         | <0.0001 | 2.6                       | 0.1070  |
| Marital status         | 353.9                        | <0.0001 | 42.5                      | <0.0001 |
| Education              | 1937.0                       | <0.0001 | 361.9                     | <0.0001 |
| Geographic area        | 145.8                        | <0.0001 | 53.4                      | <0.0001 |
| Self-rated health      | 155.4                        | <0.0001 | 5.7                       | 0.2272  |
| Chronic disease        | 5.1                          | 0.0230  | 14.0                      | 0.0002  |
| Functional limitations | 66.8                         | <0.0001 | 1.4                       | 0.2456  |
| Multimorbidity         | 39.4                         | <0.0001 | 9.3                       | 0.0023  |
| Internet use           | 4,446.2                      | <0.0001 | —                         | —       |
| Specialist visit       | 164.2                        | <0.0001 | 78.2                      | <0.0001 |

#### 4.5. Stage 1 Model: Determinants of Internet Access

The Stage 1 multivariable model explained a substantial share of the variation in Internet access (Cox-Snell pseudo- $R^2 = 0.4034$ ) and showed excellent discrimination (AUC = 0.884) and good calibration (Brier score = 0.1342). As expected, the availability of a home Internet connection was overwhelmingly the strongest determinant of individual Internet use (OR = 38.40, 95% CI: 31.33 - 47.05). Beyond infrastructure, a steep educational gradient emerged: relative to older adults with at most primary education, the odds of using the Internet were more than eight times higher for university graduates (OR = 9.04, 95% CI: 7.31 - 11.16), almost five times higher for diploma holders (OR = 4.81, 95% CI: 4.20 - 5.50) and roughly twice as high for those with lower secondary education (OR = 2.12, 95% CI: 1.87 - 2.39).

Advancing age was a powerful barrier: respondents aged 75 years and over had less than half the odds of Internet use compared with those aged 65 - 74 years (OR

= 0.39, 95% CI: 0.35 - 0.43). Women were significantly less likely to be online than men (OR = 0.81, 95% CI: 0.73 - 0.90), and residents of the North were more likely to be online than those of the Centre-South (OR = 1.41, 95% CI: 1.28 - 1.56). Health status showed a negative-selection pattern for access: poorer self-rated health (OR = 0.65) and multimorbidity (OR = 0.83) were associated with lower odds of Internet use, whereas having had a specialist visit—a marker of active engagement with the health system—was associated with higher odds (OR = 1.47, 95% CI: 1.33 - 1.64). **Table 4** reports the full Stage 1 estimates.

**Table 4.** Multivariable weighted logistic regression—Stage 1: determinants of Internet access in the population aged  $\geq 65$  years ( $n = 11,705$ ); pseudo- $R^2 = 0.4034$ , AUC = 0.884, Brier = 0.1342.

| Predictor                              | OR    | 95% CI        | p      |
|----------------------------------------|-------|---------------|--------|
| Age $\geq 75$ (ref. 65 - 74)           | 0.39  | 0.35 - 0.43   | <0.001 |
| Female (ref. male)                     | 0.81  | 0.73 - 0.90   | <0.001 |
| North (ref. Centre-South)              | 1.41  | 1.28 - 1.56   | <0.001 |
| Multimorbidity ( $\geq 2$ )            | 0.83  | 0.75 - 0.93   | <0.001 |
| Bad/very bad self-rated health         | 0.65  | 0.57 - 0.76   | <0.001 |
| Specialist visit (last 12 months)      | 1.47  | 1.33 - 1.64   | <0.001 |
| Home Internet access                   | 38.40 | 31.33 - 47.05 | <0.001 |
| Upper secondary diploma (ref. primary) | 4.81  | 4.20 - 5.50   | <0.001 |
| University degree (ref. primary)       | 9.04  | 7.31 - 11.16  | <0.001 |
| Lower secondary (ref. primary)         | 2.12  | 1.87 - 2.39   | <0.001 |
| Single (ref. married)                  | 1.21  | 0.98 - 1.48   | 0.073  |
| Separated/divorced (ref. married)      | 1.48  | 1.23 - 1.80   | <0.001 |
| Widowed (ref. married)                 | 1.02  | 0.90 - 1.15   | 0.772  |

#### 4.6. Stage 2 Model: Determinants of E-Health Adoption

Among elderly Internet users, the Stage 2 model explained a considerably smaller share of variation (pseudo- $R^2 = 0.0824$ ) and showed modest discrimination (AUC = 0.691, Brier score = 0.2027), indicating that, once older adults are online, their use of health services is driven by a more diffuse and less deterministic set of factors. Education nonetheless remained the dominant determinant: compared with primary-educated users, the odds of using online health services were more than five times higher for university graduates (OR = 5.50, 95% CI: 4.48 - 6.76), over four times higher for diploma holders (OR = 4.23, 95% CI: 3.58 - 5.00) and more than double for those with lower secondary education (OR = 2.30, 95% CI: 1.95 - 2.72).

The North-South gradient persisted and, in relative terms, strengthened at this

stage (OR = 1.54, 95% CI: 1.37 - 1.72), indicating that territorial inequalities in e-Health are not merely a by-product of unequal access but also operate at the level of service use. Health-care need was a significant positive driver: users who had had a specialist visit were 60% more likely to use online health services (OR = 1.58, 95% CI: 1.41 - 1.78), and multimorbid users were also more likely to do so (OR = 1.25, 95% CI: 1.10 - 1.40), a reversal of the negative health selection observed for access. Age remained a barrier, though weaker than for access (OR = 0.77, 95% CI: 0.68 - 0.87 for  $\geq 75$  years). Notably, the female disadvantage disappeared entirely at this stage (OR = 1.03, 95% CI: 0.91 - 1.15,  $p = 0.68$ ): once online, older women were as likely as men to use health services digitally. Widowhood was associated with lower adoption (OR = 0.76, 95% CI: 0.65 - 0.88).

**Table 5** reports the exact subgroup sample sizes underlying the Stage 2 regression estimates (**Table 6**) and the corresponding forest plot (**Figure 2**).

**Table 5.** Exact subgroup sample sizes (n = 5841).

| Predictor              | Category                   | n (total) | n (e-Health users) | Weighted % e-Health |
|------------------------|----------------------------|-----------|--------------------|---------------------|
| Age                    | 65 - 74 (ref.)             | 3965      | 2664               | 68.2                |
| Age                    | $\geq 75$                  | 1876      | 1076               | 59.4                |
| Sex                    | Male (ref.)                | 2951      | 1923               | 66.5                |
| Sex                    | Female                     | 2890      | 1817               | 64.2                |
| Geographic area        | North                      | 2794      | 1888               | 69.4                |
| Geographic area        | Centre-South (ref.)        | 3046      | 1851               | 61.0                |
| Multimorbidity         | Yes ( $\geq 2$ conditions) | 3007      | 1985               | 67.4                |
| Multimorbidity         | No (ref.)                  | 2834      | 1755               | 63.1                |
| Self-rated health      | Bad/very bad               | 581       | 369                | 66.6                |
| Self-rated health      | Better (ref.)              | 5260      | 3371               | 65.2                |
| Specialist visit       | Yes                        | 3638      | 2502               | 70.0                |
| Specialist visit       | No (ref.)                  | 2203      | 1238               | 57.2                |
| Educational attainment | Primary or none (ref.)     | 954       | 370                | 39.3                |
| Educational attainment | Lower secondary            | 1729      | 1028               | 61.0                |
| Educational attainment | Upper secondary diploma    | 2173      | 1580               | 74.3                |
| Educational attainment | University degree          | 961       | 751                | 78.6                |
| Marital status         | Married (ref.)             | 3746      | 2472               | 67.5                |
| Marital status         | Single                     | 375       | 245                | 67.1                |
| Marital status         | Separated/divorced         | 622       | 427                | 69.8                |
| Marital status         | Widowed                    | 1078      | 590                | 56.8                |
| Functional limitations | With limitations           | 2289      | 1502               | 66.3                |
| Functional limitations | Without limitations        | 3552      | 2238               | 64.7                |

**Table 6.** Multivariable weighted logistic regression—Stage 2: determinants of online health-service adoption among elderly Internet users (n = 5841).

| Predictor                                                                              | OR   | 95% CI      | p      |
|----------------------------------------------------------------------------------------|------|-------------|--------|
| Age $\geq 75$ (ref. 65 - 74)                                                           | 0.77 | 0.68 - 0.87 | <0.001 |
| Female (ref. male)                                                                     | 1.03 | 0.91 - 1.15 | 0.676  |
| North (ref. Centre-South)                                                              | 1.54 | 1.37 - 1.72 | <0.001 |
| Multimorbidity ( $\geq 2$ )(ref. no multimorbidity)                                    | 1.25 | 1.10 - 1.40 | 0.003  |
| Bad/very bad self-rated health (ref. good/fair self-rated health)                      | 1.08 | 0.89 - 1.31 | 0.442  |
| Specialist visit (last 12 months) (ref. no specialist visit in the previous 12 months) | 1.58 | 1.41 - 1.78 | <0.001 |
| Upper secondary diploma (ref. primary)                                                 | 4.23 | 3.58 - 5.00 | <0.001 |
| University degree (ref. primary)                                                       | 5.50 | 4.48 - 6.76 | <0.001 |
| Lower secondary (ref. primary)                                                         | 2.30 | 1.95 - 2.72 | <0.001 |
| Single (ref. married)                                                                  | 0.83 | 0.66 - 1.04 | 0.111  |
| Separated/divorced (ref. married)                                                      | 0.94 | 0.79 - 1.13 | 0.536  |
| Widowed (ref. married)                                                                 | 0.76 | 0.65 - 0.88 | <0.001 |

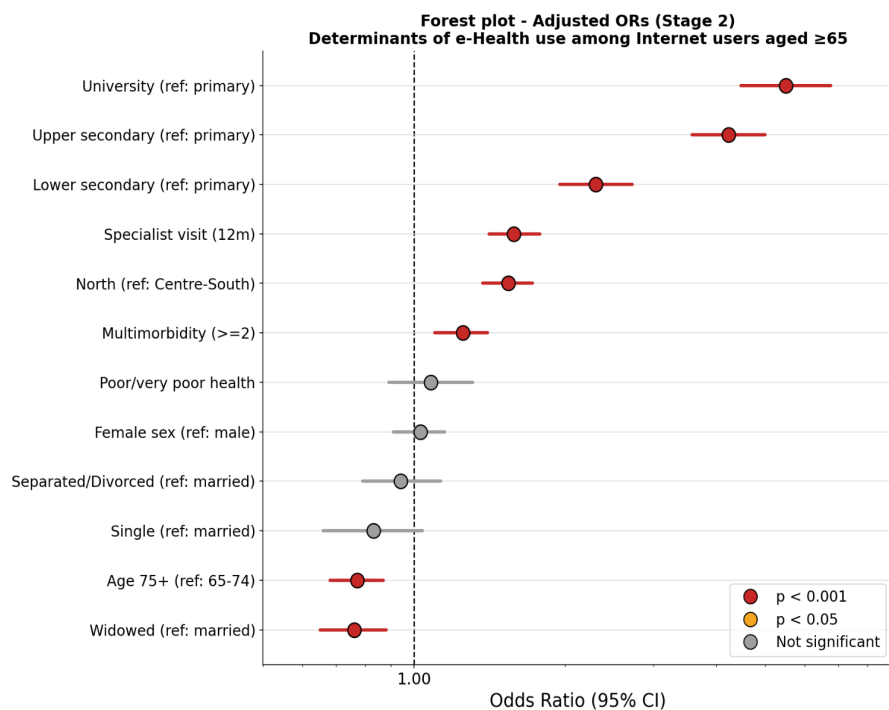
**Figure 2.** Forest plot of adjusted odds ratios (with 95% confidence intervals, log scale) for the determinants of online health-service adoption among elderly Internet users (Stage 2 model). The vertical line marks the null value (OR = 1).

**Figure 3** compares the ROC curves of the two stages, visually confirming the excellent discrimination of the access model and the more modest performance of the adoption model. The contrast reinforces the analytical value of the two-

stage design: the first threshold of the digital divide is highly structured and predictable, whereas the third threshold—meaningful health use—is comparatively open and therefore more amenable to behavioural and policy intervention.

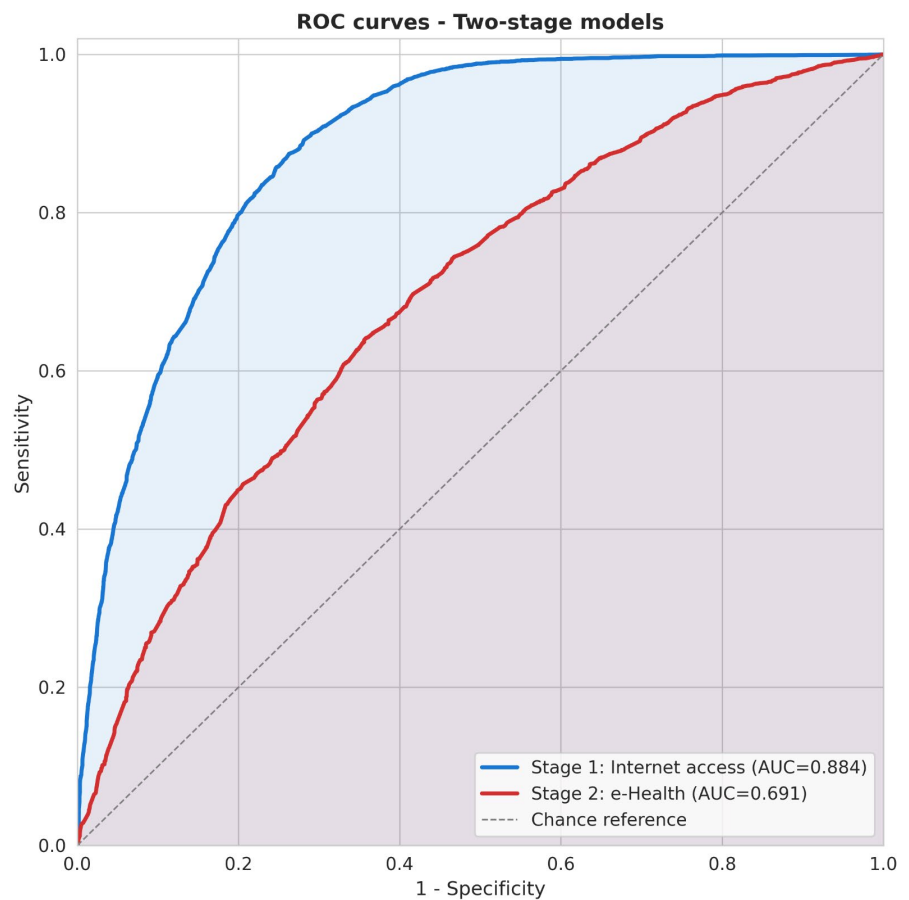


**Figure 3.** Receiver operating characteristic (ROC) curves for the Stage 1 Internet-access model (AUC = 0.884) and the Stage 2 e-Health adoption model (AUC = 0.691).

#### 4.7. Subgroup Analysis

Stratified models by sex and by geographic macro-area confirmed the stability of the main determinants while revealing informative heterogeneity. The educational gradient was steep and highly significant in every subgroup, with the university-degree odds ratio ranging from 4.95 in the North to 5.93 in the Centre-South, indicating that education is, if anything, a more powerful lever where infrastructure and services are scarcer. The effect of health-care need (specialist visits) was somewhat stronger among men (OR = 1.72) than among women (OR = 1.47). Widowhood was associated with lower adoption specifically among women (OR = 0.72) and in the North (OR = 0.67), plausibly reflecting the loss of a digitally active partner. **Figure 4** displays the subgroup odds ratios.

The joint distribution of prevalence across subgroups illustrates the cumulative nature of the divide. Among elderly Internet users, the weighted prevalence of online health-service use rose monotonically with education, from 8.7% among

those with at most primary education to 68.1% among university graduates, and was higher in the North (38.1%) than in the Centre-South (28.6%) when computed over the whole elderly population. The combination of young-old age and tertiary education produced the highest prevalence (about 83% among 65 - 74-year-old graduates), whereas the oldest and least-educated group showed the lowest (about 35%). **Figure 5** summarizes the weighted prevalence across key socio-demographic subgroups.

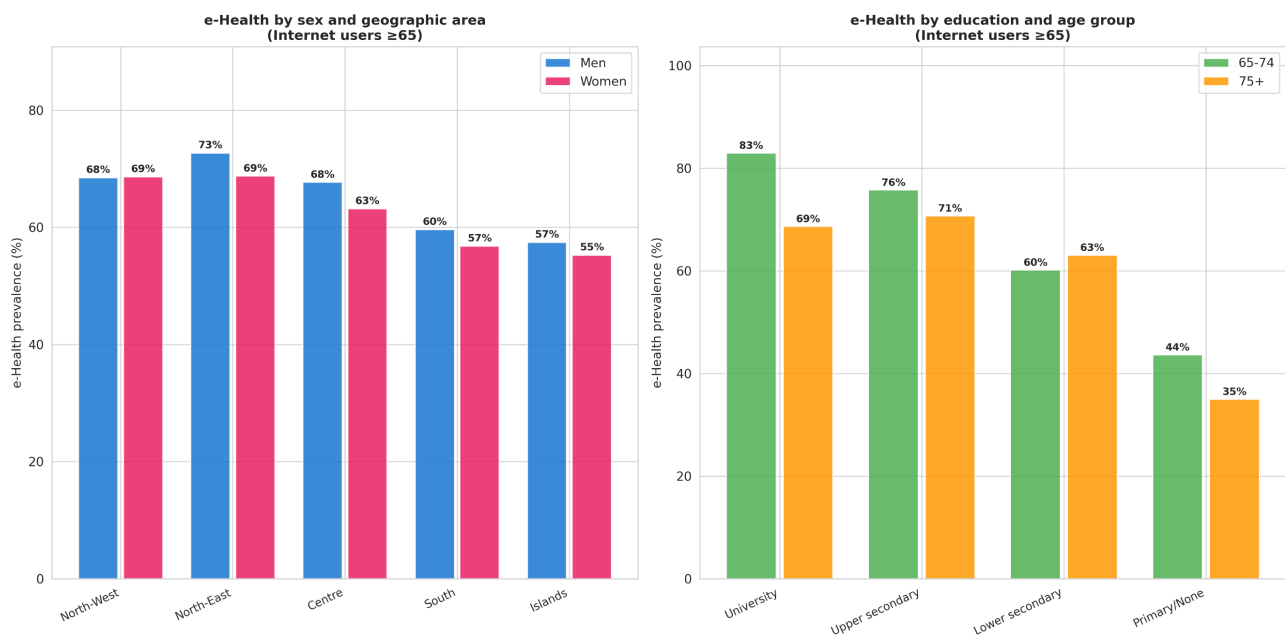


**Figure 4.** Subgroup analysis of adjusted odds ratios for online health-service adoption, stratified by sex (men, women) and by geographic macro-area (North, Centre-South).

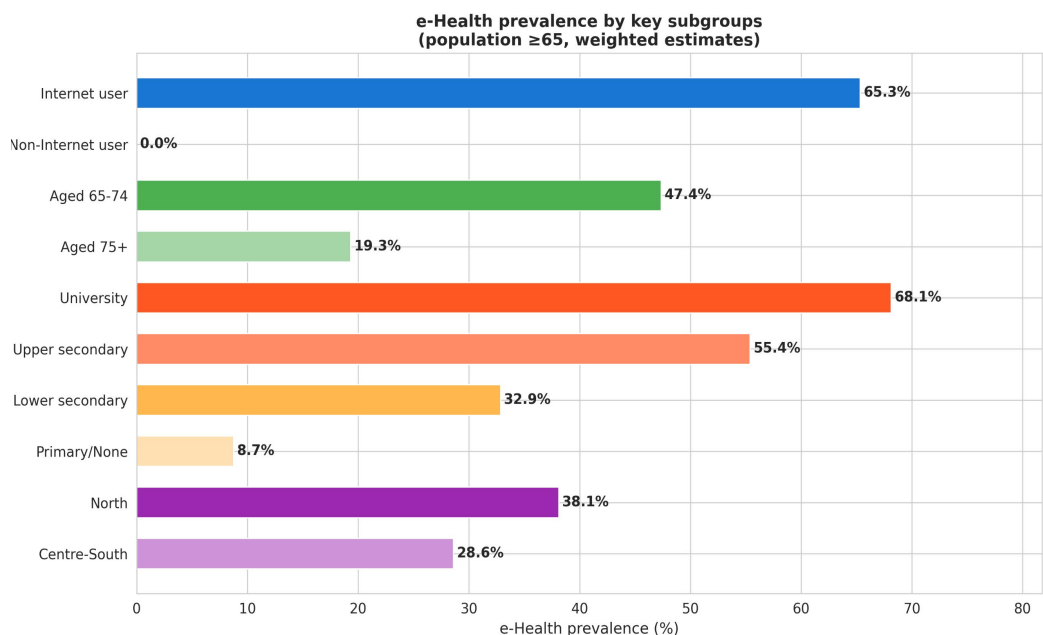


**Figure 5.** Weighted prevalence of online health-service use across key sociodemographic subgroups.

## 5. Discussion

This nationally representative study of Italian older adults shows that the potential use of telemedicine is governed by a two-layered social gradient. The determinants of getting online (Stage 1) and of using health services once online (Stage 2) partly overlap but differ in important respects, and only a design that separates the two thresholds can reveal this structure. The finding that 65.3% of elderly Internet users—but only 33.1% of all older adults—used at least one online health service quantifies the extent to which telemedicine’s reach is bounded by the first-level digital divide.

Educational attainment emerged as the single most powerful and consistent determinant across both stages and every subgroup, with adjusted odds ratios exceeding five for university graduates in the adoption model. This result aligns with a large body of international evidence identifying education among the strongest engines of e-Health literacy and digital participation among older adults. Education operates through several mechanisms: greater cognitive and literacy resources, higher self-efficacy and lower technophobia, richer social networks that model digital behaviour, and a stronger capacity to appraise online health information critically. The persistence of the educational gradient even among users who are already online indicates that it reflects a second level (skills and literacy) rather than a purely first-level (access) divide, consistent with frameworks such as the e-Health Literacy model [19] and the Unified Theory of Acceptance and Use of Technology [20].

The marked and persistent North-South gradient is a distinctively Italian feature with clear policy relevance. Its strengthening in the adoption stage suggests that territorial inequality in digital health is not merely infrastructural but is embedded in differences in service availability, institutional digitalization and local digital culture. Because the southern regions and islands combine lower ageing infrastructure with higher relative health-care need, the geographic gradient in e-Health risks compounding pre-existing inequalities in access to care, in line with concerns about an inverse-care dynamic in digital health.

Age was a barrier at both stages, but its effect was far stronger for access than for adoption, implying that once the oldest-old cross the connectivity threshold their health-related use of the Internet is comparatively close to that of the young-old. This is an encouraging message for interventions that focus on bringing the oldest adults online. The role of sex was strikingly stage-specific: women were significantly less likely to be online than men, yet among Internet users they were exactly as likely to use online health services. The digital gender gap among Italian older adults is therefore essentially an access gap; policies that succeed in connecting older women can expect their e-Health behaviour to converge with that of men.

Health-care need, proxied by specialist visits, was a robust positive driver of e-Health adoption, and multimorbidity shifted from a negative association with access to a positive association with adoption. This pattern indicates a partially self-

correcting mechanism: older adults with greater clinical need who manage to get online are more, not less, likely to translate connectivity into health-service use. It also underscores the clinical relevance of telemedicine for the chronically ill elderly, for whom remote monitoring, online appointment booking and access to the Electronic Health Record can reduce the burden of repeated travel and support continuity of care. This is consistent with evidence that telehealth improves chronic-disease control, self-management and appropriate health-care utilization in older populations, while acknowledging that the strength of that evidence is tempered by methodological heterogeneity.

A central point raised in the appraisal of the Stage 2 model concerns its low proportion of explained variation (pseudo- $R^2 = 0.0824$ ). We interpret this value not as a deficiency but as a substantively informative feature of the two-stage design. First, by construction, the two-stage architecture removes from Stage 2 the overwhelming share of variance that is explained by Internet access itself; the residual variation modelled among the already-connected therefore reflects a fundamentally different and more diffuse set of behavioural and attitudinal drivers, which are intrinsically harder to capture with standard sociodemographic predictors. Second, in large-sample, survey-based epidemiological research, pseudo- $R^2$  values in the range of 0.05 - 0.15 are common for behavioural-adoption outcomes and do not invalidate a model: the analytic goal is the identification of robust, policy-relevant associations at the population level rather than accurate individual-level prediction. Comparable or lower explanatory power has been reported for e-Health-adoption and digital-divide models elsewhere in the literature [14] [16]. Third, the modest pseudo- $R^2$  is consistent with the presence of unmeasured constructs known to drive meaningful health use—technology anxiety and technophobia, trust in digital-health platforms, perceived usefulness and perceived ease of use (the core Technology Acceptance Model constructs), caregiver or proxy use, household income, cognitive function, the strength of social-support networks, and the local supply of digitized health services—none of which is available in a multipurpose household survey.

Similar considerations apply to the modest discrimination of the Stage 2 model (AUC = 0.691). It is important to emphasise that Stage 2 is an explanatory (associational) model designed to identify population-level determinants, not a clinical prediction tool intended to classify individual patients; judged against that purpose, an AUC above 0.65 is generally considered acceptable for explanatory epidemiological models under conventional Hosmer-Lemeshow guidelines. Indeed, the contrast between the excellent discrimination of the access model (AUC = 0.884) and the more modest discrimination of the adoption model (AUC = 0.691) is itself a substantive finding rather than a shortcoming: it demonstrates that the first-level digital divide is highly structured and readily predictable from observable sociodemographic characteristics, whereas the third-level divide—meaningful health use among the already-connected—is governed by a more diffuse constellation of attitudinal, motivational and contextual factors that standard survey in-

struments do not capture. This carries a constructive policy corollary: precisely because e-Health adoption among the already-connected is not rigidly determined by fixed demographic attributes, it is more amenable to modifiable behavioural intervention—digital-literacy training, usability improvements and trust-building initiatives—than the more structurally entrenched first-level divide.

The comparatively low explanatory power of the Stage 2 model invites a more explicit, theory-grounded discussion of the psychological and behavioural determinants that a general-purpose household survey cannot measure. First, technology anxiety and technophobia are well-documented barriers: older adults' reluctance to engage with digital-health tools is frequently driven by anxiety about making errors, fear of privacy breaches, and low digital self-efficacy rather than by demographic characteristics *per se* [12] [13]. Second, trust operates as a critical but unmeasured mediator—trust in the security of personal health data, trust in the reliability of online health information, and trust in the institutional provider (for example, the National Health Service as opposed to private commercial platforms) all shape whether connectivity is translated into genuine health use. Third, caregiver or proxy use is largely invisible in individual-level survey data: many older adults, especially those with cognitive or functional limitations, access digital-health services through a family member or caregiver acting on their behalf, and such 'assisted use' may attenuate the observed associations with age and functional status. Fourth, within the Unified Theory of Acceptance and Use of Technology, perceived usefulness and perceived ease of use are the proximal determinants of adoption, yet they cannot be captured with the items available in the AVQ instrument.

A related concern is the absence of several key socioeconomic and behavioural variables that the literature identifies as established predictors of e-Health adoption—household income, validated digital-literacy scores, cognitive function, social support, and technology self-efficacy. These constructs are unavailable because the AVQ is a multipurpose household survey not specifically designed for e-Health research: it does not administer validated digital-literacy scales, cognitive-screening instruments, or individual-level income. This raises a legitimate omitted-variable concern. We note, however, that educational attainment is a strong proxy for several of these constructs—income, cognitive reserve and health literacy—so that the pronounced educational gradient observed here probably captures a substantial part of their joint effect, even though the underlying causal pathways are undoubtedly more nuanced and cannot be fully disentangled with these data. Despite these omissions, the associations reported here are robust, internally consistent, policy-relevant, and closely aligned with findings from the international literature.

These findings carry direct implications for Italian health policy. The digital-health investments of PNRR Mission 6—telemedicine platforms, the strengthening of the Electronic Health Record and territorial Community Houses—will deliver equitable benefits only if paired with demand-side measures. Three priorities

follow from our results. First, infrastructure and connectivity programmes should explicitly target the oldest-old, older women and residents of the South, who are least likely to cross the access threshold. Second, structured, age-appropriate digital-literacy interventions, potentially delivered through Community Houses, pharmacies, general practitioners and intergenerational or community mentorship, are essential to address the second-level divide driven by education. Third, telemedicine services should be designed with usability, simplicity and trust in mind, and integrated within blended care models that preserve in-person options, so as not to exclude those who cannot or prefer not to use digital channels.

The study has several strengths, including a large, nationally representative and recent sample, a behaviourally grounded outcome, an explicit two-stage design that resolves the circularity between access and use. Several limitations must nonetheless be acknowledged. First, the cross-sectional design precludes causal inference. Second, the outcome and predictors are self-reported and therefore subject to recall and social-desirability bias. Third, because the public-use microdata lack primary sampling units and strata, inference relied on weighted estimation with robust standard errors rather than full design-based variance estimation; this may modestly understate uncertainty. Fourth, the outcome captures the potential use of telemedicine—engagement with online health services—rather than clinical telemedicine encounters or their health outcomes. Finally, unmeasured factors such as digital skills, income, social support and the local supply of digital services could not be directly controlled and may partly underlie the observed educational and geographic gradients. In this respect, the modest pseudo- $R^2$  and AUC of the Stage 2 model should be read as a direct reflection of these unmeasured behavioural, attitudinal and socioeconomic constructs rather than as evidence of model misspecification. We further note that access to the restricted-use ISTAT microdata containing the full sampling-design variables would permit replication with proper design-based variance estimation, and that the incorporation of validated digital-literacy, income, cognitive and social-support measures would be expected to increase the explained variance of the adoption model.

## 6. Conclusions

In a nationally representative sample of Italian adults aged 65 years and over, the potential use of telemedicine was strongly and consistently structured by education, geography, age and health-care need, operating through two distinct thresholds: access to the Internet and the subsequent use of health services online. Education was the dominant lever at both stages, the North-South gradient persisted and strengthened at the adoption stage, the female disadvantage was confined to access, and older adults with greater clinical need who were online were more likely to use e-Health services.

For clinical practice and health policy, these results imply that telemedicine can genuinely support the management of chronic disease in the ageing Italian population, but only if its deployment is accompanied by deliberate equity safeguards.

Absent such safeguards, the digitalization of care envisaged by PNRR Mission 6 could widen rather than narrow existing health inequalities. Bridging the access threshold for the oldest, the least educated, women and southern residents, and simultaneously investing in digital-health literacy are the decisive conditions for translating telemedicine's potential into equitable benefit.

Future research should build on longitudinal and design-based data to establish causal pathways, incorporate direct measures of digital skills, income and social support, and link survey-based measures of potential use to administrative records of actual telemedicine encounters and health outcomes. Intervention studies evaluating the effectiveness of digital-literacy programmes for older adults, particularly in disadvantaged regions, are especially needed to inform the equitable implementation of Italy's digital-health agenda.

### Author Contributions

All authors contributed equally and jointly to all aspects of the research and the writing of the manuscript.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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