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Complex role of individual digital skills and eHealth policies in shaping health policy

Lucia Leporatti [*], Marcello Montefiori

Department of Economics, University of Genoa, Italy

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A B S T R A C T

The COVID-19 pandemic has significantly impacted individuals' physical and mental health worldwide. Using data from the Survey of Health, Aging, and Retirement in Europe (SHARE) and a comparative approach across European countries, this study investigates the potential protective effect of individual digital skills and eHealth policies in mitigating the pandemic health effects.

Our analysis exploits a within-between random effects approach and shows that individuals with null or poor digital skills have a 2.4 % higher likelihood of experiencing a worsening health status and a 4 % higher probability of experiencing mental health issues. At the same time, living in countries characterized by high levels of digitalization minimizes the probability of worsening health status in a range between 1 % and 2.7 %. The protective effect of eHealth policies on mental health status is much stronger.

The impact of having poor digital skills is more substantial if one lives in a country where eHealth is widespread. These results show that the rapid advancement of healthcare digitalization could exacerbate healthcare inequality unless accompanied by the development of digital skills among the population.

1. Introduction

In most Western countries, the last decade has been pivotal for starting a digital transformation process across many economic sectors. The sudden onset of the COVID-19 pandemic has further expedited this process, witnessing particularly notable increases in the level of digitization within the production sector, public sector, and society.

Indeed, the restrictions imposed by the pandemic have made the adoption of new digital technologies not only possible but also necessary [1,2]. This need has been particularly strong in the healthcare sector, where problems related to infection, personnel, equipment, and supply shortages risked further increasing unmet health needs [3–5]. Studies have shown that COVID-19 has disproportionately affected the health of vulnerable populations, including older adults, people with underlying medical issues, and racial and ethnic minorities [6–8]. Poor health outcomes in these individuals are often the result of delayed diagnosis, inadequate treatment, and reduced access to care [9]. Digital health polices may be the answer; however, many conditions on the demand and supply sides must exist for eHealth policies to be effective.

Regarding demand, digital competencies are essential for patients, and caregivers to use digital tools and technologies effectively [10] and represent a crucial factor in mitigating the impact of COVID-19 [11–14], as well as addressing unmet health needs. Regarding supply, the infrastructures to guarantee a fast and widespread Internet connection throughout the territory are crucial.

According to data from the European Union, the average percentage of households with a fixed broadband download of at least 30 Mbps has risen from 72 % in 2017 to more than 90 % in 2022 [15]. However, the percentage of households subscribing to fixed broadband increased at a slower rate (from 72 % in 2017 to 78 % in 2022). Additionally, only 26 % of individuals reported having above-average digital skills by 2022, with some countries (e.g., Slovenia and Germany) having shares lower than 20 % [15].

This preliminary information highlights a substantial imbalance between the supply of online services by public administrations and their effective accessibility.

This study examined the role of digital competencies and eHealth policies in mitigating the impact of COVID-19 on physical and mental health in European countries. We determine whether and under what conditions digital health can alleviate barriers and contribute to improved physical and mental health outcomes, especially during the COVID-19 pandemic period.

* Corresponding author. Department of Economics (DIEC), APHEC Study & Research Centre, University of Genoa, Via Vivaldi, 5, 16126, Genova (GE), Italy.
E-mail addresses: lucia.leporatti@unige.it (L. Leporatti), montefiori@unige.it (M. Montefiori).

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Although there is a growing body of literature on digital healthcare and its impact on health, many studies have been primarily qualitative or focused on single telemedicine experiences [16]. There is a substantial lack of empirical studies on the impact of digital skills and digitalization on health status from an international perspective. We fill this gap, by proposing an analysis for all the European countries and disentangling the digitalization supply and demand factors. Specifically, using the Survey of Health, Aging, and Retirement in Europe (SHARE), we intended to investigate the role of personal digital skills, the country's level of digitalization, and interaction between the two in preserving health status among older individuals in Europe.

2. The digital transformation of public administration and healthcare sector

2.1. Measuring the level of digitalization of a country's public administration and the spread of eHealth policies

Measuring the level of digitalization of a country's public administration is challenging. According to OECD definitions [17], digital government is understood as "the use of digital technologies as an integrated part of the government's modernization strategies to create public value." Indicators connected to the level of digitalization of the public sector depict governments' use of available technology and information to provide better services to citizens and businesses and improve the opportunities for citizens to participate in democratic institutions and political processes [18].

The most comprehensive experience in measuring the level of digitalization of countries at the European Level is the Digital Economy and Society Index (DESI) [15].[1]

The DESI, available since 2014, is produced yearly by the European Commission [15] and all indicators are rated on a scale ranging from 0 (indicating the minimum level of digitalization) to 100 (representing the maximum level of digitalization). The level of digitalization of a country is assessed on the supply and demand sides using more than 30 single indicators belonging to four dimensions: human capital, connectivity, integration of digital technology, and digital public services.[2] The indicators connected to digital public services are particularly interesting because they describe the demand and supply of e-government services in terms of e-government users, pre-filled forms, digital public services available to citizens and businesses, and open data.

Although the data on DESI and sub-indicators of DESI can be good proxies for measuring the level of digitalization of public administration, focusing on the analysis of the healthcare sector may require the use of indicators specifically tailored to the concept of eHealth. According to the WHO (2019), eHealth (or digital health) is defined as the use of information and communication technologies (ICT) to support health and health-related fields. It is recognized as one of the most rapidly growing areas of health worldwide.[3] Among digital health services, telemedicine represents a crucial tool to overcome distance barriers in the delivery of health services.[4] However, internationally comparable indicators of digital health are rare. To the best of our knowledge, the two country-level indicators most representative of the digitalization of the healthcare systems [14] are the spread of telemedicine (i.e., the share of adults who received services from a doctor via telemedicine since the start of the pandemic) and spread of Electronic Medical Records (EMRs) (i.e., the proportion of primary care physician offices using electronic medical records).

In our analysis, we use the following four distinct indicators (ranging from broader to more specific) to assess the degree of country-level digitalization: the overall DESI score, Digital Public Services score, spread of telemedicine, and spread of EMRs.

2.2. Trends in digitalization before and after the COVID-19 pandemic

In recent years, the European DESI has undergone significant improvements. Between 2019 and 2020, there was an average increase of 8 % in the level of digitalization across European countries, indicating a substantial push toward digital transformation. This trend continued until 2021, with a further increase of 10 %. In general, during the period 2017–2021, most of the countries experienced growth in the DESI index higher than 30 %. These growth rates underscore the rapid advancement of digitalization in various sectors, including healthcare, education, and public administration.

Additionally, broadband coverage, a critical component of the digital infrastructure, has seen notable improvements. Within the EU, the percentage of households covered by fixed broadband with download speeds of at least 30 Mbps has increased from 72 % in 2017 to over 90 % in 2022. However, the adoption rate of fixed broadband services has increased increase at a slower pace, reaching 78 % in 2022. The DESI dimension connected to the digital public services dimension also showed a favorable trend over the period 2017–2022 (see Table 1).

A crucial aspect of our analysis is the relationship between individual-level digital skills and a country's digitalization level. A lack of digital skills can limit citizens' ability to interact with government digital platforms or retrieve data and information. We assume that the most digitized countries are those in which it is easier to deal with administrative problems during the COVID-19 pandemic. Nevertheless, as highlighted by Mihai, Liviu, and Maria [18], there is no clear relationship between the level of digitization in the country and the level of digital skills of the individual. Highly digitized government systems are unfair if digital skills are not equally distributed among the population. From a health perspective, this remains a relevant problem for the elderly, who represent the most needy and vulnerable component of the population [19]. According to the DESI, the digital skills of the population showed room for improvement. In 2022, only 26 % of individuals reported above-average digital skills, highlighting the need for more extensive digital literacy initiatives. Some countries, such as Slovenia and Germany, had even lower percentages, falling below 20 %. Furthermore, the percentage of individuals who have used the Internet in the last 12 months to interact with public authorities through websites or mobile applications increased from 58 % in 2017 to 64 % in 2022. This suggests that whereas Internet access for government-related activities has improved, there is room for broader digital engagement.

Regarding the share of adults who have received services from doctors via telemedicine since the start of the pandemic (Table 1), it is evident that this percentage has increased in most countries. Among OECD countries, before the pandemic, Denmark had the highest share of

[1] Also, OECD proposes an interesting indicator, the Digital Government Index (DGI). The DGI measures e-government according to six dimensions (proactiveness, digital-by-design, data-driven, government as a platform, open by default, and user-driven). Nevertheless, the indicator is available only for 2019 and, therefore, for the pre-pandemic period.

[2] The human capital dimension assesses the Internet user skills of citizens and the advanced skills of specialists. Conversely, the connectivity dimension analyzes fixed and mobile broadband in terms of coverage (supply side) and usage (demand side). The integration of the digital technology dimension comprises three subdimensions: digital intensity, uptake of selected technologies by enterprises, and e-commerce. DESI is a simple weighted arithmetic average of the four dimensions.

[3] The term eHealth can be thought of as a broader umbrella that also includes mHealth (i.e., "the use of mobile wireless technologies for health") and emerging areas, such as the use of advanced computing sciences in "big data," genomics, and artificial intelligence.

[4] Telemedicine is defined as "the delivery of healthcare services where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries, all in the interests of advancing the health of individuals and their communities."[54].

Table 1
Value for the indicator for 2021 and percentual change for selected periods.

Country	DESI		Digital Public Services		Telemedicine		Electronic medical records	
	Year 2021	% change 2020–2021	Year 2021	% change 2020–2021	Year 2021	% change 2020–2021	Year 2021	% change 2012–2021[a]
Austria	50.5	15.8 %	68.1	7.9 %	34.6 %	22.7 %	80 %	0.00 %
Belgium	46.7	5.6 %	60.0	7.3 %	32.2 %	5.6 %	80 %	14.29 %
Bulgaria	32.6	9.5 %	48.5	9.2 %	NA	NA	NA	NA
Croatia	43.1	16.4 %	49.4	12.8 %	NA	NA	NA	NA
Cyprus	40.0	13.1 %	52.9	9.2 %	NA	NA	NA	NA
Czechia	43.4	9.7 %	58.8	8.3 %	46.9 %	34.8 %	80 %	NA
Denmark	65.3	16.6 %	78.3	6.3 %	46.2 %	25.5 %	100 %	96.08 %
Estonia	53.2	8.4 %	86.3	6.7 %	45.7 %	32.5 %	100 %	2.04 %
Finland	63.2	8.1 %	82.5	6.3 %	48.6 %	65.3 %	100 %	0 %
France	45.9	8.0 %	62.8	8.7 %	23.2 %	5.5 %	80 %	NA
Germany	47.1	11.9 %	61.4	9.7 %	23.3 %	40.4 %	100 %	25.00 %
Greece	32.5	17.9 %	35.9	10.4 %	38.3 %	29.0 %	100 %	NA
Hungary	38.7	8.0 %	52.4	9.3 %	45.0 %	50.5 %	100 %	NA
Ireland	57.1	12.4 %	75.2	7.2 %	60.3 %	56.6 %	95 %	NA
Italy	40.9	11.2 %	53.8	11.2 %	29.9 %	32.3 %	90 %	NA
Latvia	46.1	4.7 %	74.7	7.6 %	49.9 %	54.5 %	70 %	NA
Lithuania	47.0	5.3 %	77.0	7.4 %	56.3 %	35.3 %	100 %	NA
Luxembourg	55.0	7.5 %	76.9	6.6 %	43.5 %	30.2 %	95 %	NA
Malta	54.5	5.7 %	80.3	6.8 %	NA	NA	NA	NA
Netherlands	62.4	14.1 %	79.4	8.0 %	41.7 %	36.7 %	100 %	0.00 %
Poland	36.5	10.0 %	51.1	9.4 %	61.9 %	35.4 %	30 %	100.00 %
Portugal	45.9	5.8 %	63.7	7.7 %	44.0 %	30.2 %	100 %	11.10 %
Romania	27.4	11.0 %	18.2	22.0 %	NA	NA	NA	NA
Slovakia	39.9	10.4 %	49.6	6.8 %	40.3 %	36.6 %	89 %	NA
Slovenia	48.0	11.7 %	65.2	11.2 %	65.4 %	47.0 %	100 %	11.10 %
Spain	54.8	10.2 %	78.0	7.9 %	71.6 %	48.5 %	99 %	10.00 %
Sweden	60.5	8.5 %	77.2	6.6 %	46.7 %	46.9 %	100 %	0.00 %

Note: NA = Not Available.
[a] Variations for EMRs indicators have been computed on the time available for the indicator (2012–2021).

remote consultations via phone or video (45 %), whereas most countries (e.g., Australia, Finland, Lithuania, Norway, and Slovenia) had percentages lower than 10 %. Since the start of the pandemic, these percentages have increased dramatically; by mid-2020, almost one in three adults had utilized remote consultation, and by early 2021, this ratio accounted for nearly one in two [20]. Nonetheless, significant differences exist between countries, ranging from Spain (with a share of 72 % in 2021) to France and Germany (with a share of 23 %) (Fig. 1).

An analysis of the adoption of electronic medical records, reveals relatively less variability among countries (Table 1). Approximately half of the countries under investigation claimed to have achieved 100 % electronic record coverage. However, a few countries, notably Poland and Latvia, report a notably lower prevalence of this tool at 30 % and 70 %, respectively.

2.3. *The impact of eHealth policies on health status: a focus on the COVID-19 pandemic*

eHealth policies have been found to be crucial to mitigate the increase of unmet health needs during the COVID-19 pandemic [21]. In 2020, several digital tools and technologies were introduced and expanded, including telemedicine, remote monitoring, mobile health apps, wearable devices, and electronic health records [20]. Growing evidence supports the effectiveness of digital interventions in mitigating the impact of COVID-19 on physical and mental health [6,8]. A systematic review of telemedicine interventions during COVID-19 found that telemedicine was associated with reduced hospitalizations, emergency department visits, and outpatient visits [22]. Remote monitoring has also effectively managed COVID-19 symptoms, enabling healthcare professionals to monitor and intervene remotely in respiratory distress, fever, and other symptoms [23]. According to Zeltzer et al. [24], increased access to telemedicine tends to increase primary care visits but decrease spending slightly. According to Eze et al. [25], more than 80 % of clinical effectiveness reviews on telemedicine have found it to be at least as effective as face-to-face care, with patients generally reporting high satisfaction. Telemedicine has been found particularly useful in the management of chronically ill patients, such as diabetes [26,27] and cardiovascular disease [28].

Despite these encouraging results, a vast literature exists on the inequality in the accessibility of eHealth policies. According to Cantor et al. [12], in the USA, the county poverty rate and level of urbanicity of the place of living were highly predictive of the use of telemedicine during the COVID-19 pandemic. In addition, as showed by Le et al. [29], disparities in telehealth use are exacerbated by individual differences in digital competence. The authors suggested that a one-point increase in the digital competence scale is associated with roughly 86 % greater odds of telehealth use. Similarly [30], found out that digital literacy is positively associated with having a video visit.

3. Data and methods

3.1. *Dataset*

In this study, we utilized data from the SHARE. The SHARE dataset is a comprehensive panel survey that focuses on respondents aged 50 years or older and gathers data from 28 European countries and Israel. In the SHARE project, the target population encompassed households with at least one member meeting the specific age criteria. For our analysis, we leveraged SHARE Corona Surveys 1 and 2. These SHARE Corona datasets comprise data collected through Computer-Assisted Telephone Interviews (CATI) during the two phases of the pandemic. Specifically, data were collected between June and August 2020 (SHARE Corona Survey 1) and one year later, between June and August 2021 (SHARE Corona Survey 2) [31–34].

The questionnaires in the SHARE Corona Surveys exhibited slight variations from generic questionnaires. They encompass the most critical domains of the target population and include questions on specific aspects of life during the pandemic, such as health and health behaviors, mental health, infections, healthcare, changes in work and economic situations, and social networks. As some socioeconomic variables were

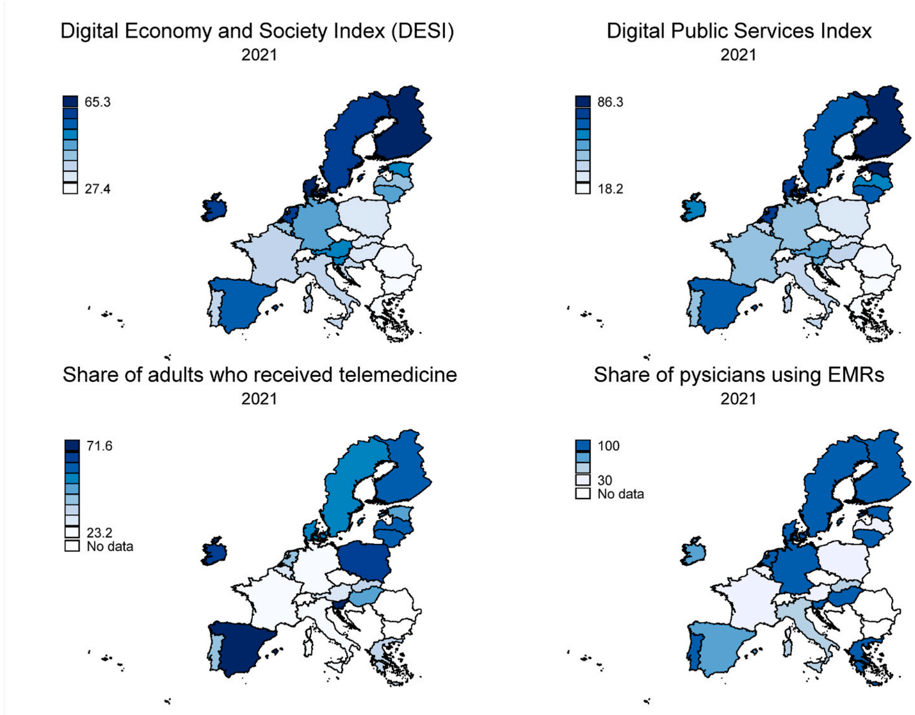

Fig. 1. Value of the digitalization indices for 2021. Source: EU, OECD.

not included in the Corona Survey (i.e. Educational level), this study draws on the SHARE database to supplement the pre-pandemic characteristics of the population, which are available from Wave 7 [32].

3.2. Outcome variables

Our study examines two aspects of health:

- General health status since the COVID-19 outbreak
- Mental health status since the COVID-19 outbreak.

Changes in general health status were assessed using a specific question on the eventual change (improved, worsened, or approximately the same) in health status since the outbreak.[5] A dummy variable was built that assumed a value of one if the person declared to have a deterioration in health since the last interview, and zero otherwise. Mental health status was assessed using a dummy variable that assumed a value of one if the person felt sad or depressed in the previous month, and zero otherwise.

Detecting the role of individual digital skills and country-level digitalization (and the possible interaction between the two dimensions) in influencing these two aspects (general health status and mental health status) during the pandemic was the focus of our analysis.

3.3. Individual and country-level control variables

Individual digitalization levels are gauged through self-declared computer skills in the SHARE dataset (ranging from "Excellent" to "I never used a computer"). To simplify this variable, we dichotomized it to create a binary variable equal to one for those with poor or no computer skills and 0 for those having Good, Very Good or Excellent computer skills.

In addition, as sensitivity analysis, different definitions of the country level of digitalization and individual digital skills have been used. The personal level of digital skills has been assessed using a dummy variable that assumes value 1 for those individuals who use (or have used in their previous job) a computer for working.

We also included a selection of demographic (age and gender) and socioeconomic (educational level, health status, number of children) individual characteristics as controls.

To investigate whether and to what extent country-specific contexts are relevant in explaining inequalities in health during the COVID-19 outbreak, we combined individual-level SHARE data with country-specific characteristics. The country level of digitalization is assessed using the following indices[6]:

- The DESI
- The Digital Public Services for Citizens index
- The index of telemedicine development
- The index connected to the spread of EMRs

These indicators have been dichotomized in dummy variables that assume value 1 for countries with a level of digitalization higher than the median level and 0 for those countries with a lower level of digitalization than the median level. As sensitivity analysis (see Appendix 2), countries characterized by a high level of digitalization are also classified as those having a digitalization level higher than the 25th percentile.

In addition, other country control variables have been included to control for the impact of COVID-19 spread in terms of mortality (i.e. the total number of deaths per 100,000 population) and the GDP per capita (i.e. level of the country). Tables 2 and 3 present the variables used in the analyses.

[5] As additional measures of health status change, we use the diagnosis of a major health condition since the last interview. Results are consistent with those presented.

[6] Moving from a more general measure (DESI) to a more specific measure for the healthcare sector, there is a loss of information in terms of available observations. In particular, data on telemedicine and electronic records were missing for Bulgaria, Croatia, Cyprus, Malta, and Romania.

Table 2
Description of the individual variables.

Level	Variable name	Description	Percentage	Source
individual	Health deterioration	Dummy = 1 if health deteriorated after COVID	12.65 %	SHARE Corona Survey 1-2
individual	Sad or depressed the previous month	Dummy = 1 if the person felt sad or depressed the previous month	31.01 %	SHARE Corona Survey 1-2
individual	Age Class	Categorical variable for age classes		SHARE Corona Survey 1-2
	<64		30.94 %	
	65–74		34.29 %	
	75–84		24.37 %	
	85+		10.40 %	
individual	Male	Dummy = 1 if the person is male	36.78 %	SHARE Corona Survey 1-2
individual	Poor or Fair Health before COVID	Dummy = 1 if the person had a poor or fair health status before the pandemic	37.78 %	SHARE Corona Survey 1-2
individual	Educational level	Categorical variable for educational level		SHARE Wave 7
	Primary or lower secondary		33.54 %	
	Upper secondary		44.85 %	
	Degree		24.61 %	
individual	Children	Having children	90.99 %	SHARE Wave 7

Table 3
Description of the country-level variables.

Level	Variable name	Description	Mean	Std. dev.	Min	Max	Source
country	COVID-19 mortality	COVID-19 mortality (the total number of deaths per 100,000 population)	1311.9	742.89	106.84	4501.945	WHO COVID-19
country	GDP per capita, PPP	Gross domestic product at market prices - euro per capita	28,426.6	16,195.8	8880	102,350	OECD
country	DESI index	Country DESI index	43.41	8.06	24.72	65.25	European Commission
country	Digital Public Services Index	Country Digital Public Services Index	57.77	13.34	14.89	86.26	European Commission
country	Telemedicine Share	Share of adults who received services from a doctor via telemedicine since the start of the pandemic	33.45	15.01	16.6	71.6	OECD
country	Electronic medical records	Proportion of primary care physician offices using electronic medical records	87.6	19.20	30	100	OECD
country	IV1	Percentage of households covered by FTTH and FTTB in 2018	29.83	22.09	0	85.69	European Commission
country	IV2	Percentage of doctors aged more than 55	40.48	9.61	20.4	55.2	OECD

3.4. Empirical strategy

3.4.1. Base specification

The dataset used was a longitudinal panel survey, where micro-level units (i.e., individuals) were nested within macro-level units (i.e. countries). Therefore, an empirical strategy was required to cope with the simultaneous presence of micro and macro (i.e., country) survey data. Imbens and Lancaster [35] showed that general macro data are helpful in micro–nonlinear models. However, country effects induce correlations across observations, which must be addressed to avoid estimating biased standard errors. Fixed-effects models are highly recommended in these contexts; however, they do not allow the estimation of time-invariant variables' effects. Among the available approaches,[7] we opted for using a hierarchical or multilevel approach to pool data. Multilevel models are extensions of regression in which data are structured into groups (countries in our study), and coefficients can vary by group. This approach allows for the estimation of the intraclass correlation that measures the extent to which individuals share unobserved factors within each country. This approach enables the inclusion of individual- and country-level predictors in the analysis [36]. By contrast, any other unobserved country effect is treated as being generated by a common mechanism between countries. Additionally, the dataset provided the possibility of analyzing the within and between effects of time-varying country-level covariates. This is possible by applying within-between random effects models (REWB) [37–39] that are particularly effective in these contexts [40,41].

The REWB model can be described as:

$$y_{itc} = \beta_0 + \beta_1 x_{itc} + \beta_2 x_{tcM} + \beta_3 \overline{x}_c + \beta_4 Time + v_c + u_{tc} + e_{itc}$$

where x_{itc} captures the individual level variables (e.g., digital skills), the time-varying country level variables (e.g., level of digitalization) (x_{tc}) are instead decomposed into two components: the between component ($\overline{x}_c$) that represents the country mean of x_{tc} over time, and within (longitudinal) component (x_{tcM}) that is obtained by a group-mean centering. The within component is derived by the difference between the time-varying variable (x_{tc}) and country mean ($\overline{x}_c$). The between component measures the persistent effect derived by differences between the countries' level of digitalization. Conversely, the within component captures the variation around the mean for each country and in each year.

We ran our models on two alternative dependent variables (i.e., worsening general and mental health). Given the binary nature of our dependent variables, all the models have been developed by using a probit specification. For each dependent variable, we propose a set of models in which the level of digitalization of the countries is assessed using the following indices: DESI; Digital Public Services index; index of telemedicine development; and index connected to the spread of EMRs.

We propose three model specifications: the first considers only individual variables (Base Model 1), the second considers country level variables (Model 2) in a basic random effect context, whereas the last specification (Model 3) uses the REWB specification by splitting the country level of digitalization in the between and within component. It

[7] In the presence of multilevel country datasets, four regression modeling approaches are commonly applied to consider this issue [55]. The simplest solution (approach 1) is to correct the regression estimations by including country-cluster-robust standard errors; this approach controls for country effects but does not model them. Other approaches control for country effects by representing country-specific differences using country-specific intercept terms. This can be obtained by running separate regression models for each country (Approach 2) or by using a country-fixed effects approach on pooled data (Approach 3).

is important to note that data on electronic records are available only for 2021. Therefore, for this specific model, it was not possible to compute the within country component of the REWB specification.

A heterogeneity analysis was performed by running the model separately for different groups. We split countries according to their level of digitalization and the spread of the COVID-19 pandemic. Additionally, we provided models splitting individuals according to their age to explore the impact of digital skills and eHealth on different subgroups (Table 6).

3.4.2. Endogeneity of digitalization variables

The potential endogeneity of the digitalization variables on the demand (i.e., digital skills) and supply sides (i.e., digitalization of the country system) were challenging. To partially mitigate this issue, we develop an alternative model specification as a further robustness analysis. For the year2020,[8] we propose an extended probit model capable of accommodating any combination of endogenous covariates, non-random treatment assignment, and endogenous sample selection [42].

The model includes a basic equation (run alternatively on or two dependent variables) and two additional modelling for the endogenous variables (i.e. individual level of digitalization; country level spread of eHealth policies). We dedicated much attention to searching for possible instrumental variables useful in instrumenting the two endogenous variables. After a careful research on available data, the proposed models use the percentage of households covered by Fiber To The House (FTTH) and Fiber to the Building (FTTB) in 2018 in each country as an instrumental variable for individual digital skills. Indeed, this "supply" variable (appropriately lagged for the period considered) may impact the possibility and the likelihood of individuals developing their digital skills.

Regarding the instrumental variable to be included to model the second endogenous variable (i.e., country level spread of eHealth policies), after a careful investigation, we used the percentage of physicians aged over 55 in the country. Again, the age of medical personnel could be strongly correlated with the practical possibility of implementing eHealth policies. The traditional tests (Under-identification test, Cragg Donald statistic, Sargan test statistic) run on instruments confirm the explanatory power of the instruments selected.

4. Results

4.1. Descriptive statistics

After correcting for non-missing values, we obtained information for 36,363 individuals[9] observed over two years (2020–2021)[10].

Given an average value of 28 % among all the analyzed countries, the average percentage of people who declared having mental health issues ranged from 39 % in Poland to 14 % in Denmark (see Figure A1 in Appendix 1 for more detail). Additionally, the percentage of respondents declaring worsening health varied significantly across countries, ranging from 16 % in Lithuania to 4.2 % in Denmark.

Fig. 2 reports the percentage of individuals experiencing physical or mental health issues during the COVID-19 pandemic depending on their digital skills (Poor skills or never using PC; Fair or higher computer skills) and year (2020–2021). As evident from the graphs, the second year of the COVID-19 pandemic (year 2021) seems to have a more relevant impact on health status. This is despite the reduction in movement restrictions. This result may be explained by the natural temporal lag between the onset of those conditions that lead to a deterioration in physical and mental health and the manifestation (or awareness) of the disease itself. A typical and debated case is the reluctance of many individuals to undergo tests and visits during the pandemic wave and lockdown period. This behavior has sometimes led to delays in the diagnosis and treatment of the disease, compromising (at least in part) the future health status of many individuals. Additionally, people with poor or null computer skills are more likely to have worsening physical health or poor mental health. In 2021, the percentage of individuals experiencing a worsening in health status was 10 % among those having good digital skills. However, it rises to approximately 19 % among individuals with low or null digital skills.

Table 4 reports the descriptive statistics on the outcome variables split by individual and country levels of digitalization. Regardless of a country's digitization measures, people with high computer skills tend to be protected from physical and mental health conditions. The percentage of individuals declaring a worsening health status during the pandemic was six percentage points lower for those with good digital skills (from 9.36 % to 15.34 %). The percentage of individuals who reported depressive symptoms was approximately 9 % lower among those with at least fair digital skills. The results on the impact of country digitalization on health status are less straightforward. Overall, the digitalization of public administration, identified by the components "DESI Index", "Digital Public Services," "Telemedicine," and "Electronic Medical Records," seems to have a limited role in containing the impact of COVID-19 in terms of health deterioration if this component is not accompanied by adequate computer and/or technological literacy among the population.

However, Table 4 also shows how, if we consider digitization measures specific to the healthcare system (telemedicine sharing and electronic medical records), the role of digital skills is more influential in countries with a high level of digitization. For example, when examining the difference in depression rates between individuals with at least good computer literacy compared to others (i.e., null or poor digital skills), this difference is 8.03 % in countries with EMRs below the median, and it rises to 11.99 % in countries with EMRs above the median. In countries with increased rates of telemedicine, the likelihood of having a deterioration in physical health is 7.83 points higher for those with low digital skills (but only 4.63 points for individuals living in countries characterized by a low level of telemedicine spread). Nonetheless, this

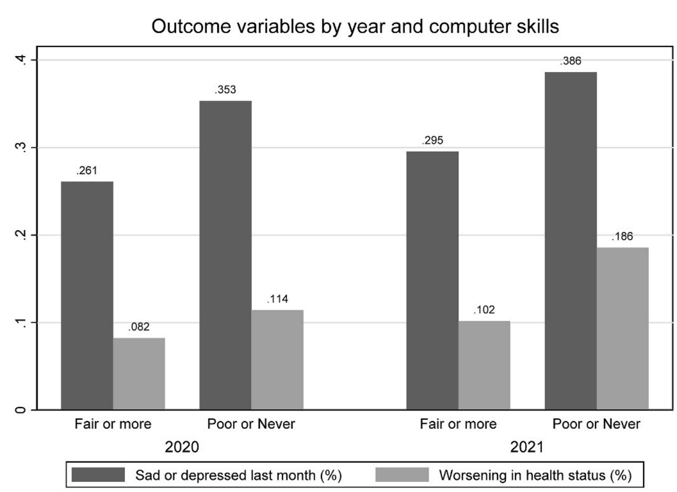

Fig. 2. Percentage of individuals who experienced a worsening in health status by year (2020; 2021) and level of digital skills (Fair or more; Poor or Never). Data are weighted by using calibrated sampling weights.

[8] To avoid the inclusion of a further element of complexity in the model (i.e. the panel nature of the dataset) the analysis has been performed only for 2020. The results are robust if we consider year 2021.

[9] Due to the presence of some countries particularly affected by missing values, the final analysis is focused on 17 countries, namely: Austria, Germany, Sweden, Spain, Italy, France, Denmark, Greece, Belgium, Poland, Luxemburg, Slovenia, Estonia, Lithuania, Finland, Latvia, Slovakia.

[10] All the analyses proposed weighted observations according to the calibrated longitudinal individual weight observations.

Table 4
Descriptive statistics on dependent variables.

Country digitalization level		Worsened Health (%)					Sad or depressed last month (%)				
		Individual digital skills					Individual digital skills				
		Total	Fair or higher	Poor or null	Δ	Sig	Total	Fair or higher	Poor or null	Δ	Sig
DESI Index	Lower than median	11.36 %	8.14 %	13.90 %	−5.76 %	[a]	30.74 %	25.83 %	35.05 %	−9.22 %	[a]
	Higher than median	11.74 %	10.44 %	17.44 %	−7.00 %	[a]	29.12 %	27.58 %	36.20 %	−8.62 %	[a]
Digital Public Services	Lower than median	10.93 %	8.28 %	13.80 %	−5.52 %	[a]	31.39 %	26.71 %	36.45 %	−9.74 %	[a]
	Higher than median	12.61 %	10.46 %	16.32 %	−5.86 %	[a]	31.24 %	27.87 %	37.07 %	−9.20 %	[a]
Tele medicine	Lower than median	11.21 %	9.96 %	14.59 %	−4.63 %	[a]	29.03 %	26.02 %	35.54 %	−9.52 %	[a]
	Higher than median	11.91 %	8.21 %	16.04 %	−7.83 %	[a]	30.89 %	28.96 %	35.85 %	−6.89 %	[a]
Electronic medical records	Lower than median	11.74 %	8.91 %	15.20 %	−6.29 %	[a]	31.13 %	28.27 %	36.30 %	−8.03 %	[a]
	Higher than median	11.09 %	10.08 %	16.49 %	−6.41 %	[a]	27.82 %	24.41 %	36.40 %	−11.99 %	[a]
Total		11.81 %	9.36 %	15.34 %	−5,98 %	[a]	30.15 %	26.39 %	35.58 %	−9,19 %	[a]

Note.
[a] = p-value <0.001.

does not apply to mental health, as it is largely affected by individual digital skills rather than the country level digitalization.

4.2. Regression results

Table 5 and Table 6 present the marginal effects of the regression models for physical and mental health statuses, respectively.

Beginning with the Base RE Model (i.e., the model including only covariates at the individual level) related to the decline in physical health status (Table 5), it is evident that, as expected, the likelihood of experiencing health deterioration increases significantly with age; older individuals (85+) have an 8 % higher probability of having a decline in health status compared to younger individuals (50–65). Notably pre-COVID health status: individuals with compromised health are more prone to further health decline. Lower educational attainment and absence of children are additional risk factors associated with an

Table 5
Marginal effects of RE and REWB probit models on worsening in self-declared health status during the COVID-19 pandemic.

	Base Model	Telemedicine		EMRs		Digital public services		Desi	
	Model 1 RE	Model 2 RE	Model 3 REWB	Model 2 RE	Model 3 REWB	Model 2 RE	Model 3 REWB	Model 2 RE	Model 3 REWB
Age class (reference: 50–65)									
65-74	0.005***	0.006***	0.006***	0.006***	0.004***	0.006***	0.006***	0.006***	0.006***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
75-84	0.043***	0.044***	0.043***	0.044***	0.044***	0.044***	0.045***	0.044***	0.045***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
85+	0.077***	0.077***	0.077***	0.077***	0.077***	0.078***	0.078***	0.078***	0.078***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	0	(0.000)
Male	−0.028***	−0.028***	−0.028***	−0.028***	−0.027***	−0.027***	−0.027***	−0.027***	−0.027***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bad health before the pandemic	0.076***	0.076***	0.076***	0.076***	0.075***	0.078***	0.078***	0.078***	0.078***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Educational level (reference: primary or lower secondary)									
Upper Secondary	−0.005***	−0.004***	−0.004***	−0.003***	−0.009***	−0.009***	−0.008***	−0.011***	−0.009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tertiary	−0.010***	−0.012***	−0.012***	−0.012***	−0.016***	−0.016***	−0.015***	−0.016***	−0.016***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of children	−0.000***	−0.000***	−0.000***	−0.001***	−0.001***	−0.000***	−0.001***	−0.000***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Poor or null digital skills	0.024***	0.024***	0.024***	0.024***	0.022***	0.023***	0.023***	0.023***	0.022***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year 2021	0.041***	0.024***	0.007***	0.023***	0.023***	0.039***	0.120***	0.034***	0.051***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
COVID-19 deaths higher than the median		0.017***	0.010***	0.017***	0.017***	0.014***	0.026***	0.022***	0.018***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GPD higher than the median		−0.001***	−0.003***	0.007***	0.009***	0.011***	0.010***	0.015***	0.011***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Digitalization higher than the median		−0.008***		−0.010***		−0.020***		−0.027***	
		(0.000)		(0.000)		(0.000)		(0.000)	
Digitalization_between			−0.001***		−0.001***		−0.001***		−0.001***
			(0.000)		(0.000)		(0.000)		(0.000)
Digitalization_within			0.003***				−0.020***		−0.006***
			(0.000)				(0.000)		(0.000)
Number of observations	61341	50842	50842	50842	50842	56504	56504	56504	56504

Note:. $p < 0.10$; *$p < 0.005$, *$p < 0.01$, ***$p < 0.001$.

Table 6
Marginal effects of RE and REWB probit models on mental health status (i.e., feeling sad or depressed since the outbreak) during the COVID-19 pandemic.

	Base Model	Telemedicine		EMRs		Digital public services		Desi	
	Model 1 RE	Model 2 RE	Model 3 REWB	Model 2 RE	Model 3 REWB	Model 2 RE	Model 3 REWB	Model 2 RE	Model 3 REWB
Age class (reference: 50–65)									
65-74	−0.021***	−0.021***	−0.021***	−0.022***	−0.025***	−0.021***	−0.022***	−0.021***	−0.023***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
75-84	0.028***	0.028***	0.027***	0.029***	0.029***	0.031***	0.031***	0.031***	0.031***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
85+	0.027***	0.030***	0.030***	0.030***	0.030***	0.032***	0.033***	0.032***	0.033***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	−0.149***	−0.153***	−0.153***	−0.153***	−0.152***	−0.150***	−0.149***	−0.150***	−0.149***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bad health before the pandemic	0.123***	0.126***	0.127***	0.123***	0.120***	0.123***	0.125***	0.123***	0.125***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Educational level (reference: primary or lower secondary)									
Upper Secondary	−0.031***	−0.022***	−0.026***	−0.024***	−0.035***	−0.029***	−0.033***	−0.029***	−0.038***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tertiary	−0.052***	−0.042***	−0.045***	−0.045***	−0.054***	−0.050***	−0.052***	−0.049***	−0.055***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of children	−0.003***	−0.001***	−0.001***	−0.002***	−0.003***	−0.002***	−0.002***	−0.002***	−0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Poor or null digital skills	0.040***	0.038***	0.037***	0.037***	0.033***	0.035***	0.032***	0.035***	0.029***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year 2021	0.028***	0.032***	0.060***	0.025***	0.025***	0.027***	0.148***	0.025***	0.075***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
COVID-19 deaths higher than the median		0.005***	0.015***	0.007***	0.007***	0.007***	0.016***	0.008***	0.004***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GPD higher than the median		−0.039***	−0.052***	−0.002***	−0.001***	−0.004***	0.008***	−0.004***	0.016***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Digitalization higher than the median		−0.052***		−0.023***		−0.003***		−0.002***	
		(0.000)		(0.000)		(0.000)		(0.000)	
Digitalization_between			−0.002***		−0.001***		−0.001***		−0.003***
			(0.000)		(0.000)		(0.000)		(0.000)
Digitalization_within			−0.005***				−0.027***		−0.011***
			(0.000)				(0.000)		(0.000)
Number of observations	61166	50697	50697	50697	50697	56352	56352	56352	56352

Note:. p < 0.10; *p < 0.005, *p < 0.01, ***.

increased likelihood of deteriorating health. Furthermore, individual digital skills are crucial in reducing the probability of health decline. People with poor digital skills have a 2.4 % higher likelihood of experiencing a worsening health status. The estimated marginal effect is stable across all model specifications.

Within Model 2, irrespective of the chosen measure of digitalization, residing in a country with a higher level of digitalization (i.e., a higher share of telemedicine and a higher percentage of physicians using EMRs; higher DESI Index or subindices) had a protective effect on health during the COVID-19 pandemic, reducing the likelihood of health deterioration. Living in countries characterized by high levels of digitalization minimized the probability of worsening health status in a range between 2.7 % (when the DESI measure is considered) and 1 % (when the spread of telemedicine or EMRs is included as a regressor).

Models 3 are the REWB models and decompose the overall effects of the country-level variables into their cross-sectional (between) and longitudinal (between) components. In all these models, the impact of the individual-level variables is consistent with previous specifications. The longitudinal component of the country level of digitalization is negative and significant in all models, suggesting that the persistent relation between digitalization and worsening in health status is negative. The within component is instead less stable across the specifications;, a sudden increase in telemedicine level risk in the same country deteriorates health status. Conversely, an increase in the level of digitalization of the country assessed through DESI components reduces the likelihood of experiencing health issues.

The findings on mental health (Table 6) echo those on physical health concerning individual digital skills, indicating the critical role of digital skills in preserving mental health. The effect is even higher than that observed for general health: people with null or poor digital skills have a 4 % higher probability of experiencing mental issues. There is robust evidence supporting a significant part of the country's level of digitization. Countries with a higher prevalence of telemedicine, widespread use of electronic records, and overall high digitalization of governments appear to shield individuals from mental disorders associated with depression. Living in a country with a higher spread of telemedicine is associated with a 5 % lower likelihood of having mental health issues. the between and within components go in the same direction in the REWB results, showing a negative and significant effect on the likelihood of having mental issues. This suggests that digitalization's advantages are persistent between and within countries. From a sociodemographic perspective, the critical risk factors include older age, female sex, and previous health problems. Nevertheless, having a tertiary education is a decisive protective factor for mental health.

As an additional exercise, we also run Model 2, including the interaction between the individual digital skills variable (i.e., Poor or null digital skills) and the country's digitalization level (i.e., Digitalization higher than the median). Table 7 reports the estimated marginal effects derived from that model and stratifying individuals based on the two main variables of interest. In most cases, the individuals at higher risk of bad health outcomes are those with poor digital skills and living in countries with low levels of digitalization. For example, if we look at the model run on DESI, the probability of a worsening in general health is 8 % for those living in highly digitalized countries and having at least fair digital skills. The same likelihood rises to 13 % for those with null or poor digital skills living in low-digitalized countries. We have an interesting exception when looking at telemedicine. Estimations suggest that those reporting the highest estimated likelihood of health worsening are

Table 7
Estimated probability of having physical and mental health issues split by individual and country level of digitalization and interactions between the two.

Country digitalization level		Worsened Health			Sad or depressed last month		
		Individual digital skills			Individual digital skills		
		Fair or higher	Poor or null	Total	Fair or higher	Poor or null	Total
DESI	Lower than median	11.80 %***	13.39 %***	12.55 %***	29.05 %***	33.74 %***	31.14 %***
	Higher than median	8.37 %***	11.38 %***	9.81 %***	29.99 %***	31.91 %***	30.85 %***
	Total	10.16 %***	12.44 %***		29.46 %***	32.96 %***	
Digital Public Services	Lower than median	11.43 %***	13.14 %***	12.24 %***	29.22 %***	33.69 %***	31.21 %***
	Higher than median	8.82 %***	11.64 %***	10.17 %***	29.78 %***	32.12 %***	30.83 %***
	Total	10.14 %***	12.41 %***		29.47 %***	32.99 %***	
Tele medicine	Lower than median	10.53 %***	12.26 %***	11.32 %***	30.45 %***	34.50 %***	32.16 %***
	Higher than median	8.39 %***	12.59 %***	10.31 %***	26.01 %***	31.24 %***	28.25 %***
	Total	9.85 %***	12.37 %***		29.09 %***	33.51 %***	
Electronic medical records	Lower than median	10.39 %***	12.71 %***	11.45 %***	31.09 %***	33.38 %***	32.07 %***
	Higher than median	9.41 %***	11.87 %***	10.54 %***	27.31 %***	33.72 %***	30.07 %***
	Total	10.02 %***	12.40 %***		29.70 %***	33.51 %***	

Note:. $p < 0.10$; *$p < 0.005$, *$p < 0.01$, ***.

individuals with poor digital skills and living in countries with a high share of telemedicine (12.59 %). In countries with a high spread of telemedicine, the gap in the probability of experiencing a health deterioration between highly and poorly digitalized individuals is very high (8.39 % vs 12.59 %). This suggests that low digital skills risk exacerbates health inequalities to a greater extent in countries where telemedicine is widespread. Therefore, even if telemedicine is effective globally in reducing the negative impact of COVID-19 on health status, this effect is lowered for those with low digital skills.

Regarding mental health, the negative impact of having poor digital skills is more substantial if one lives in a country where eHealth is widespread. Looking at the model that includes the spread of EMRs, it is interesting to notice that individuals with poor digital skills do not benefit from the widespread availability of EMRs (their likelihood of reporting depression is substantially stable at 33 % regardless of the spread of EMRs). In contrast, people with at least fair digital skills experience a 4 % lower risk of having mental issues if they live in highly digitalized countries (from 31.09 % to 27.31 %). This suggests that people living in countries where EMRs are well developed are at risk of experiencing a higher probability of mental health issues if they do not have enough personal digital skills. The same effect does not apply to telemedicine services. Regardless of the individual level of digital skills, living in countries where telemedicine is highly available reduces the probability of having mental health issues.

4.3. Heterogeneity across groups of countries and patients

Table 8 presents the results of the heterogeneity analysis. The first robustness check shows that the impact of having low or null digital skills on worsening general and mental health status outcomes was stronger in countries more hit by the pandemic. Contrary to our expectations, the benefits of the wider spread of digital health (i.e., telemedicine and EMRs) have affected more countries characterized by lower levels of COVID-19 spread. This may be because the health systems of countries heavily impacted by the COVID-19 crisis have been less able to fully exploit the benefits derived from a sudden turn to telemedicine as they are involved in greater urgency and contingency.

Additionally, we compared the impact of digital skills and digitalization of healthcare systems in 2020 (the year the pandemic began and placed the greatest pressure on healthcare systems) with the year 2021 (characterized by generally more aware management of the pandemic all inside healthcare facilities). The results show that in 2021, the protective effect of digital skills on people's health will be most relevant. The large availability of electronic medical records is particularly effective in preventing depressive symptoms during the first waves of the pandemic.

Moving to the submodels run for age classes (<75; 75+), the results show that not being confident about digital instruments primarily affects relatively younger individuals' general health. The contrary is true for mental health; poor digital skills seem to affect the probability of mental health issues for people aged more than 75 years. Regarding the impact of different eHealth instruments on different age classes, the results are not so clear. The impact of widespread access to EMRs is more effective in preventing the worsening of the health status of older individuals whereas no clear evidence has been found for telemedicine services. It is interesting to note how different healthcare system digitalization tools (telemedicine vs. electronic medical records) can, therefore, be effective for different sociodemographic groups.

4.4. Sensitivity analysis and endogeneity issues

Tables 9 and 10 report the odds ratio of the extended probit models where individual digital skills and country level of digitalization are treated as endogenous. The first specification (Base Model) reports the results of the main model (i.e., where the two potential endogenous variables are included), whereas columns 2 and 3 report the models run on the endogenous variables and include, respectively, the Percentage of households covered by FTTH and FTTB and the Percentage of doctors aged more than 55 as instrumental variables. The correlation estimate between the errors of our different equations is significantly different from zero, so we have endogeneity. Looking at the Base model, poor digital skills still positively impact bad health (and mental health) outcomes. Simultaneously, a high level of digitalization (in terms of the availability of telemedicine or EMRs) is still associated with better health outcomes (i.e., reduced risk of experiencing bad health issues). In terms of marginal effects, having poor digital skills increases the likelihood of experiencing a worsening in health status by 1.8%–3.5 % and of having issues connected to depression by 12–17 %. The high share of telemedicine or EMR use is confirmed to reduce bad health (3.8%–9.6 %) and mental health (8.6%–22.6 %) outcomes.

We also propose a sensitivity analysis, slightly changing the definition of our crucial variables. In particular, the indicators of country digitalization have also been assessed by splitting countries into those having a digitalization level (in terms of telemedicine share and electronic medical records spread) higher than the 25th percentile. In addition, the individual level of digital skills has been assessed using an additional dummy variable that assumes value 1 for those individuals who use (or have used in their previous job) a computer for work. The results of these two specifications (fully reported in Appendix 2) align with the base model results.

Table 8
Results of the heterogeneity analysis in terms of marginal effects.

		COVID Deaths		Age class		Year		Digitalization	
		Under Median	Above median	<75	75+	2020	2021	Low	High
Worsening in health status	Poor digital skills	0.000 (0.000)	0.048*** (0.000)	0.030*** (0.000)	0.016*** (0.000)	−0.000*** (0.000)	0.049*** (0.000)	0.018*** (0.000)	0.039*** (0.000)
	Telemedicine above median	−0.032*** (0.000)	0.012*** (0.000)	−0.008*** (0.000)	−0.009*** (0.000)	−0.028*** (0.000)	0.005*** (0.000)	–	–
	Poor digital skills	−0.000 (0.000)	0.048*** (0.000)	0.030*** (0.000)	0.017*** (0.000)	−0.000*** (0.000)	0.049*** (0.000)	0.020*** (0.000)	0.032*** (0.000)
	Electronic records above the median	−0.013*** (0.000)	−0.005*** (0.000)	−0.005*** (0.000)	−0.020*** (0.000)	−0.010*** (0.000)	−0.008*** (0.000)	–	–
Depression or sad last month	Poor digital skills	0.036*** (0.000)	0.049 *** (0.0001)	0.035*** (0.000)	0.042*** (0.000)	0.036*** (0.000)	0.039*** (0.000)	0.039*** (0.000)	0.032*** (0.000)
	Telemedicine above median	−0.053*** (0.000)	−0.008*** (0.0001)	−0.052*** (0.000)	−0.053*** (0.000)	−0.053*** (0.000)	−0.061*** (0.000)	–	–
	Poor digital skills	0.036*** (0.000)	0.037*** (0.000)	0.034*** (0.000)	0.044*** (0.000)	0.036*** (0.000)	0.038*** (0.000)	0.022*** (0.000)	0.067*** (0.000)
	Electronic records above the median	−0.040*** (0.000)	−0.002*** (0.000)	−0.018*** (0.000)	−0.036*** (0.000)	−0.039*** (0.000)	−0.010*** (0.000)	–	–

Note:.standard error in brackets. $p < 0.10$; $^{*}p < 0.005$, $^{*}p < 0.01$, $^{**}p < 0.001$.

5. Discussion

5.1. Healthcare challenges in Europe

As pointed out by the European Commission [15], the three most relevant challenges that European countries will face in the coming years are the aging population and chronic conditions putting pressure on health budgets, unequal quality and access to healthcare services, and shortage of health professionals. The COVID-19 emergency has made the urgency of strengthening territorial health services even more evident, and the responses of NextGenerationEU have gone in this direction to a large extent. To adapt to these trends, health-care systems need a fundamental rethinking and innovative solutions. The potential of digital health is well evident as it may help in creating efficient and integrated healthcare systems, guaranteeing time savings for patients and professionals and keeping patients at their homes as long as possible [43].

5.2. Operational challenges and equity concerns of Digital Health

However, as the use of digital health and telemedicine services spread, new challenges emerged from the operational and equity perspective.

Countries face new normative and operational challenges related to the financing, reimbursement, and legal issues associated with these new technologies [44]. As pointed out by the OECD [14], after the start of the pandemic, a considerable number of OECD countries lifted restrictions on teleconsultations and allowed reimbursement for telemedicine. Nevertheless, legal problems and limitations persist in some countries.

Much literature has explored the great disparities in digital competencies across different socio-economic groups. Significant demographic and socioeconomic differences exist in digital skills [45]. Some socio-demographic categories, particularly older adults, individuals with lower education levels, and those with lower incomes, are less likely to search for online health information and benefit from digital health [46–48]. The integration of technology into the lives of older adults is akin to a process of familiarization occurring within their daily routines [49].

The problem of guaranteeing health equity during the digital transformation of healthcare systems was pointed out before the pandemic [50]; nonetheless, the rapid expansion of digitalization caused by the pandemic risks exacerbating the issue. Therefore, digital disparities are likely to increase the exposure of vulnerable individuals to the health and non-health consequences of the virus [51]. In this sense, a problem of accessibility and health equity emerges [19,52,53]. Another important consideration is to ensure that digital health interventions are culturally sensitive and tailored to meet the diverse needs and preferences of various population groups. This requires engaging diverse communities in designing and implementing digital health interventions and promoting cultural competence among healthcare providers. Valokivi et al. [43] proposed a comparative study on eHealth in Italy, Finland, and Sweden, pointing out that despite "techno-enthusiasm" about digital health, less attention has been paid to the complexity of caring for older adults via eHealth.

5.3. Policy implications and future directions

Our findings showed that individual digital literacy plays a crucial role in mitigating negative outcomes in terms of health and depression. Additionally, the results show that eHealth may be an effective instrument for preventing health problems. Countries with lower levels of digitalization may require additional investments in digital infrastructure and services to realize the potential protective effects of digital skills.

The accelerated development of digitization in the entire public

Table 9
Results of the extended probit models analysis (odds ratio) for worsening in health status.

	Telemedicine			EMRs		
	Base Model	Poor or null digital skills	Digitalization higher than the median	Base Model	Poor or null digital skills	Digitalization higher than the median
Age class (reference: 50–65)						
65-74	1.036***	1.403***	0.996***	1.026***	1.394***	1.071***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
75-84	1.270***	2.489***	0.872***	1.241***	2.519***	1.174***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
85+	1.316***	4.795***	0.911***	1.219***	4.773***	1.076***
	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)	(0.001)
Male	0.867***	0.934***	0.981***	0.874***	0.940***	0.983***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bad health before the pandemic	1.543***	1.189***	1.515***	1.565***	1.215***	1.310***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Educational level (reference: primary or lower secondary)						
Upper Secondary	0.973***	0.524***	1.105***	1.096***	0.526***	1.722***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
Tertiary	0.955***	0.267***	1.062***	1.113***	0.268***	1.699***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
Number of children	0.987***	1.033***	1.093***	0.969***	1.023***	0.926***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Poor or null digital skills	1.132***			1.341***		
	(0.004)			(0.003)		
COVID-19 deaths higher than the median	1.160***	0.856***	1.134***	0.919***	1.114***	0.347***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)
GPD higher than the median	0.977***	0.656***	0.077***	1.505***	0.912***	5.338***
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.002)
Digitalization higher than the median	0.772***			0.535***		
	(0.001)			(0.001)		
IV1 (Percentage of households covered by FTTH and FTTB)		0.998***			0.965***	
		(0.000)			(0.000)	
IV2 (Percentage of doctors aged more than 55)			0.883***			0.925***
			(0.000)			(0.000)
Corr (Worsening in health status; Poor or null digital skills)	−0.176***			−0.142***		
Corr (Digitalization higher than median; Worsening in health status)	0.090***			0.064***		
Corr (Digitalization higher than median; Poor or null digital skills)	0.145***			−0.173***		

Note:.standard error in brackets. $p < 0.10$; $^*p < 0.005$, $^*p < 0.01$, $^{***}p < 0.001$.

administration sector (and to an even greater extent in the health sector) risks widening health inequalities in elderly countries characterized by a low level of digitization. Intervention policies in the healthcare digitization process must always be accompanied by policies aimed at vulnerable and elderly individuals. A mere "digital investment" from the supply side is insufficient, as it fails to yield adequate results if this policy is not accompanied by an adequate level of digital literacy from the demand side, i.e., among users. In this sense, a large part of the NextGenerationEU will be devoted to improving proximity and home healthcare by exploiting the possibilities offered by new technologies (telemedicine, home automation, and digitalization). Indeed, the positive effects of telemedicine are predominantly experienced by those with higher digital literacy. As the vast empirical literature has convincingly demonstrated, digital literacy is correlated with the level of education, which, in turn, is correlated with individual wealth. Here, the equity issue is: The digitization of health services is the "conditio sine qua" propaedeutic to the development of digital healthcare, but itself alone is not enough. This opportunity can only be captured if the government chooses to invest in education. Venturing a bit boldly beyond this conclusion, it could even be argued that effective widespread implementation of digital healthcare requires two conditions: a higher level of (digital) education and higher general wealth.

6. Conclusions

In most Western countries, healthcare systems are experiencing increasing budget pressure because of ageing, innovation, and the new challenges imposed by the management of chronic conditions. In this scenario, the opportunities offered by the digitalization of the healthcare system and, more generally, of public administration have been looked at with great enthusiasm.

This article highlights the potentiality of eHealth policies but also the critical role of digital competencies in maximizing the benefits of digital health.

Our research findings indicate several promising areas for future exploration, mostly focused on the equity ground. First, it is crucial to delve into the effectiveness of policies aimed at promoting digital equity in healthcare with reference to healthcare access. By understanding how these policies impact health outcomes, especially among individuals with lower education and income levels, we can gain valuable insights into bridging existing healthcare disparities. Pursuing these research topics will allow us to deepen our comprehension of the complex interplay between digital health, education, and socioeconomic factors.

While our study provides valuable insights into the complex interplay between individual digital skills and the role of eHealth in mitigating the health impact of COVID-19, it is important to acknowledge certain limitations. Despite the extensive nature of the SHARE dataset, certain variables pertinent to digital health may not be fully represented

Table 10
Results of the extended probit models analysis (odds ratio) for mental health issues.

	Telemedicine			EMRs		
	Base Model	Poor or null digital skills	Base Model	Poor or null digital skills	Base Model	Poor or null digital skills
Age class (reference: 50–65)						
65-74	0.879***	1.392***	1.000	0.914***	1.391***	1.067***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
75-84	0.892***	2.501***	0.876***	1.008***	2.511***	1.167***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
85+	0.855***	4.795***	0.912***	0.993***	4.775***	1.078***
	(0.001)	(0.003)	(0.001)	(0.001)	(0.003)	(0.001)
Male	0.657***	0.936***	0.980***	0.656***	0.939***	0.981***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Bad health before the pandemic	1.440***	1.207***	1.515***	1.504***	1.219***	1.305***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Educational level (reference: primary or lower secondary)						
Upper Secondary	1.033***	0.528***	1.102***	1.049***	0.527***	1.713***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
Tertiary	1.098***	0.267***	1.063***	1.065***	0.268***	1.682***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
Number of children	1.010***	1.026***	1.096***	0.993***	1.023***	0.923***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Poor or null digital skills	1.888***			1.407***		
	(0.003)			(0.003)		
COVID-19 deaths higher than the median	0.998***	0.998**	1.133***	0.755***	1.106***	0.348***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)
GPD higher than the median	0.858***	0.810***	0.078***	1.297***	0.905***	5.320***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.002)
Digitalization higher than the median	0.765***			0.497***		
	(0.000)			(0.001)		
IV1 (Percentage of households covered by FTTH and FTTB)		0.978***			0.966***	
		(0.000)			(0.000)	
IV2 (Percentage of doctors aged more than 55)			0.883***			0.925***
			(0.000)			(0.000)
Corr (Worsening in health status; Poor or null digital skills)	−0.299***			−0.273***		
Corr (Digitalization higher than median; Worsening in health status)	0.149***			0.028***		
Corr (Digitalization higher than median; Poor or null digital skills)	0.152***			−0.174***		

Note:.standard error in brackets. p < 0.10; *p < 0.005, *p < 0.01, ***p < 0.001.

since they are not available at the individual level. Moreover, the country level indicator of digital health is still limited in terms of time series (i.e., most indicators are not available in the pre-covid period) and this prevents the possibility of fully exploiting the panel nature of our dataset. Future research will be addressed towards the development of more detailed analysis on the use of eHealth policies at the individual level.

CRediT authorship contribution statement

Lucia Leporatti: Writing – original draft, Methodology, Formal analysis, Data curation. **Marcello Montefiori:** Writing – original draft, Supervision, Investigation, Conceptualization.

Data availability

The authors do not have permission to share data.

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Appendix 1

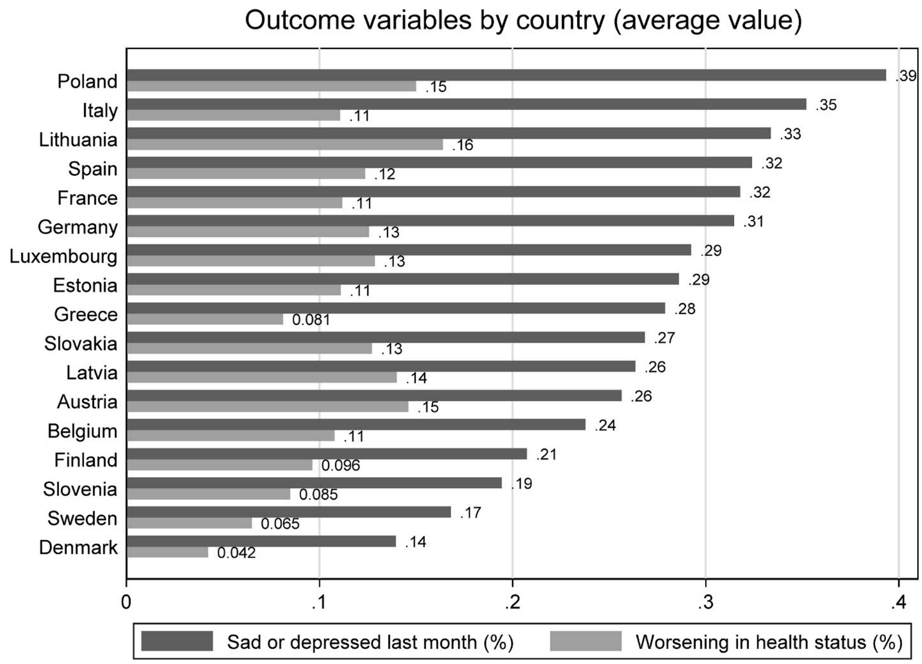

Fig. A1. Outcome variables by country. Data are weighted by using calibrated sampling weights.

Appendix 2

Table A2
Sensitivity analysis: Random effects model on worsening in self-declared health status and mental health during the covid-19 pandemic. Digitalization skills of individuals assessed by a dummy = 1 if the respondent use or has used PC at work; country level of digitalization is a dummy = 1 if the level of digitalization (telemedicine or EMRs share) higher than 25 percentile.

	Worsening in self-declared health status		Sad or depressed since the last interview	
	Telemedicine	EMRs	Telemedicine	EMRs
Age class (reference: 50–65)				
65-74	0.009***	0.009***	−0.011***	−0.011***
	(0.000)	(0.000)	(0.000)	(0.000)
75-84	0.052***	0.053***	0.048***	0.051***
	(0.000)	(0.000)	(0.000)	(0.000)
85+	0.085***	0.085***	0.058***	0.059***
	(0.000)	(0.000)	(0.000)	(0.000)
Male	−0.025***	−0.025***	−0.152***	−0.151***
	(0.000)	(0.000)	(0.000)	(0.000)
Bad health before the pandemic	0.075***	0.075***	0.114***	0.114***
	(0.000)	(0.000)	(0.000)	(0.000)
Educational level (reference: primary or lower secondary)				
Upper Secondary	−0.003***	−0.001***	−0.018***	−0.014***
	(0.000)	(0.000)	(0.000)	(0.000)
Tertiary	−0.012***	−0.011***	−0.035***	−0.032***
	(0.000)	(0.000)	(0.000)	(0.000)
Number of children	−0.000***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Using PC at work	−0.009***	−0.010***	−0.027***	−0.027***
	(0.000)	(0.000)	(0.000)	(0.000)
Year 2021	0.019***	0.016***	0.032***	0.025***
	(0.000)	(0.000)	(0.000)	(0.000)
COVID-19 deaths higher than the median	0.016***	0.017***	0.009***	0.014***
	(0.000)	(0.000)	(0.000)	(0.000)
GPD higher than the median	−0.003***	0.007***	−0.020***	0.012***
	(0.000)	(0.000)	(0.000)	(0.000)
Digitalization higher than 25th percentile	−0.012***	−0.014***	−0.038***	−0.042***
	(0.000)	(0.000)	(0.000)	(0.000)
Number of observations	43146	43146	43027	43027

Note: . p < 0.10; *p < 0.005, *p < 0.01, ***p < 0.001.

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Lucia Leporatti is Associate Professor in Public Economics at the Department of Economics of the University of Genoa. She is a member of the Scientific Committee of the APHEC Study and Research Center and Director (since 2021) of the Advanced Course in Health Economics, Pharmacoeconomics and Healthcare Technologies (APHEC). Her research interests include health economics, applied economics, public economics, and the redistributive impact of public policies.

Marcello Montefiori holds the position of professor of public economics at the Department of Economics, University of Genova, Italy. His research areas are in the fields of health economics, applied economics, public economics, and economics of information. He received a Ph.D. in Economics from the University of Pavia, Italy, and a Master of Science in Economics from the University of Glasgow, UK.

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