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The Role of Digital Health Under Taiwan's National Health Insurance System: Progress and Challenges

Jui-fen Rachel Lu, Sc.D., Takemi Fellow 2004-2005
rachel@mail.cgu.edu.tw

Li-Lin Liang, Ph.D. (corresponding author)
liang.lilin@nycu.edu.tw

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Abstract

With aims to improve access to health care, quality of care, and system efficiency, digital health covers a wide spectrum of applications of digital technologies in the healthcare field and has significantly transformed the landscape of modern medicine and health care. This paper examines the role of digital health under Taiwan NHI, considering the profound impacts of digital health during the COVID-19 pandemic. It focuses specifically on big data management and analytics (MediCloud) and innovative service provision models (telemedicine). We discuss two imminent challenges that any health system is likely to encounter: digital trust and digital divide. Our study shows that high income levels and the presence of chronic or severe illness were positively correlated with the use of telemedicine. This observation suggests that poor people who have poorer health status were most likely to suffer from unmet needs for telemedicine. Enhancing cybersecurity to safeguard confidentiality, and effective communications with the public are fundamental and essential steps to regaining public trust in the digital era. When calling for more investment in digital technology, policy-makers should be mindful of the potential digital divide across the demographic and socioeconomic strata, and specific policies should be devised to provide support to target the socially disadvantaged group.

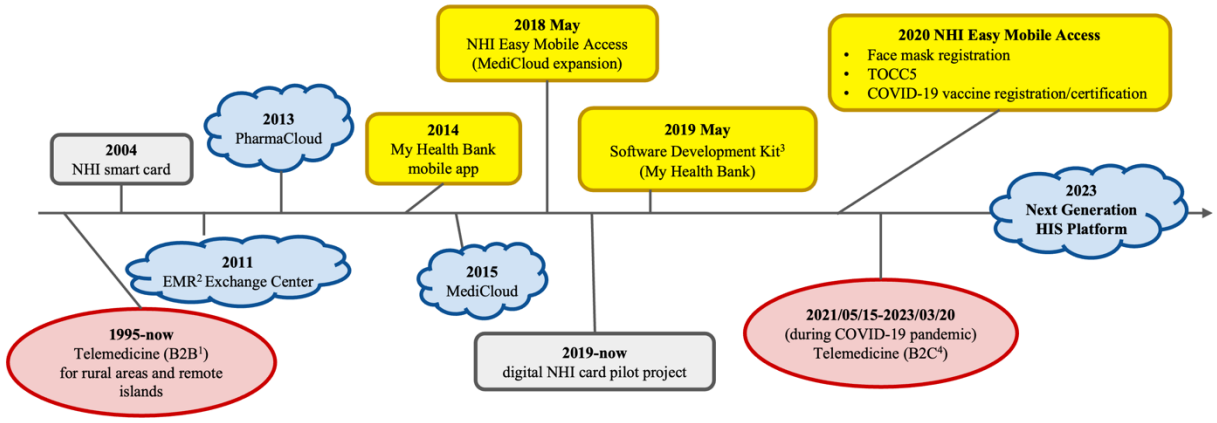
Keywords: digital health, digital trust, digital divide, Taiwan NHI

Introduction

Digital health covers a wide spectrum of applications of digital technologies in the healthcare field. As Ronquillo et al.[1] defined, "Digital health refers to the use of information and communications technologies in medicine and other health professions to manage illnesses and health risks and to promote wellness. Digital health has a broad scope and includes the use of wearable devices, mobile health, telehealth, health information technology, and telemedicine". With aims to improve access to health care, quality of care, and system efficiency, digital health has significantly transformed the landscape of modern medicine and health care.

The Taiwan National Health Insurance (NHI) has embraced the advantages of digital technology in service provision and data management over the last 28 years. To provide better access to care for residents in remote areas, the Taiwan NHI initiated a telemedicine program (B2B, medical institution to medical institution) in 1995. In 2004, Taiwan NHI was a global pioneer when it launched the use of the NHI smart IC card., The inception of the smart IC card can be attributed to the vision of Dr. Lai Mei-Shu, the second General Manager of the Bureau of National Health Insurance (BNHI, starting 2013, NHI Administration, NHIA), and the proactive implementation of her successor, Dr. Hong-Jen Chang. The timeline of the adoption of various digital health applications is delineated in Figure 1.

Figure 1. Development of digital health applications in Taiwan NHI



[1] medical institution to medical institution
[2] Electronic Medical Record, EMR
[3] allow third-party applications connecting with My Health Bank
[4] medical institution to patients
[5] Travel history, Occupation, Contact history and Cluster

*Color and shape notation: red oval for telemedicine; gray square for NHI card; blue cloud for cloud-based health data sharing platform; yellow square for mobile app

Source: NHIA, 2023

Further, NHIA used the payment system to incentivize providers to utilize the medical information system—for example, it would lower the withholding rate if medical claims were filed electronically, rather than on paper. Before the implementation of the NHI, reimbursements by previous health insurance authorities typically took six months or longer, leading to cash flow problems for the medical providers. To address this issue, Dr. Ching-Chuan Yeh, the founding General Manager of BNHI, adopted a carrot-and-stick policy. The "carrot" involved disbursing 90% of the claimed amount within 15 days, which successfully enticed large hospitals to submit their claims electronically. The "stick" was applied when, after two years of the pilot project, and with most hospitals already submitting claims electronically, BNHI began to penalize healthcare providers who were reluctant to modernize their systems. Consequently, healthcare providers at every level swiftly transitioned to electronic claim submissions.

In 2013, with an aim to reduce duplicate medication and enhance patient safety, NHIA introduced a centralized medication record-sharing platform called "PharmaCloud", which provides contracted healthcare providers nationwide with access to patient medication information.[2,3] PharmaCloud later was expanded into "MediCloud" in 2015, which is the cloud-based central clearinghouse for all clinical services rendered and testing results (in addition to medication) across all provider institutions.

To enhance patients' awareness of their service utilization, NHIA launched the national ID-based "My Health Bank" mobile app in 2014. With the data available in MediCloud, the app was quickly expanded to "NHI Easy Mobile Access" which provides the full range of information in addition to health care utilization, such as NHI enrollment (status and premiums paid), and medical query (one can search for self-pay items and the relevant price list), etc.

During the COVID-19 pandemic, the government made good use of the NHI Easy Mobile Access for public communications and as an ID-based distribution platform. Witnessing the power of digital technology applications and the flourishing development of Artificial Intelligence (AI), the Taiwan Ministry of Health and Welfare has recently announced its plan for the "Next Generation Health Information (HIS) Platform" to enhance interoperability as the key agenda in the next phase.

Considering the profound impacts of digital health on service delivery, especially during the COVID-19 pandemic in Taiwan, our paper examines the role of digital health under Taiwan NHI with a focus on the NHI's adoption of digital health in big data management and analytics (via MediCloud) and innovative service provision model (using telemedicine). We first provide an overview of the Taiwan NHI program. This is followed by a discussion of innovative applications of digital technology in health care under Taiwan NHI, in particular, how the digital health applications have combated COVID-19 pandemic. We also discuss challenges likely to be encountered by health systems exploiting digital technology in healthcare, namely,

digital trust and the digital divide, as assessed by the use of telemedicine and its determinants. Finally, we conclude the paper with a summary of findings and suggestions.

Taiwan NHI

Taiwan's journey to universal health coverage took 45 years (1950-1995) to complete . It provided the population of 23 million people with access to care without financial risk by implementing a single-payer social health insurance model in 1995. The NHI program provides the insured with comprehensive benefits coverage, including inpatient services, ambulatory visits to doctors, licensed traditional Chinese medicine practitioners, and dentists, home care, and hospice care for modest copayment/coinsurance. All NHI-contracted providers are subject to a uniform fee schedule (this is done mainly on a fee-for-service basis, despite various payment models having been experimented with and adopted). To control health care costs, the Taiwan NHI operates under a global budget, which is set through rounds of negotiation between the payers (representatives of employers and employees) and medical providers in the previous year. The global budget is composed of four service sectors: dental services(implemented in 1998); outpatient Chinese medicine services (introduced in 2000); primary care services provided at clinics (added in 2001); and inpatient and outpatient hospital services (introduced in 2002).[4]

When the NHI was inaugurated, revenue collected through premiums was assessed at 4.25% of the payroll, with government subsidies targeting the vulnerable and employees of specific occupation categories. To resolve a financial deficit and enhance equity in financing, the NHIA adopted a dual-track premium collection system in 2013, which included a 4.91% (now 5.17%) premium tax assessed on payroll and an additional 2% (now 2.11%) tax levy on six categories of nonpayroll income (such as rental income, stock dividend, etc.). In the 28 years of NHI history, the government has only successfully increased the premium contribution rate four times (in 2002, 2010, 2013, and 2021). Each time, the government had to fight fierce protests from the payer groups. As of 2021, current health expenditures took up 6.2% of the Gross Domestic Product (GDP) (which is far below the OECD average of 9.7%), and the NHI accounted for 51.36% of national health expenditures.[5]

The single-payer model makes NHI a monopoly in the health insurance market and a monopsony in the service delivery market, which is dominated by the private sector. In 2021, privately-owned hospitals accounted for 74% of all beds and 83% of hospitals. Nearly 64.1% of physicians work in the hospital sector and the rest in private local clinics.[6] Over the years, driven by the payment incentive, hospitals have developed large outpatient departments to maximize patient flows and compete with neighborhood private clinics for patients.[4]

Taiwan NHI has consistently enjoyed high public approval ratings (91.6% in 2021) due to improved access to health care, financial risk protection, and health outcomes.[7]

Progress

Digital health has impacted the healthcare industry in terms of effective and innovative management and service provision models–it has also stimulated an influx of investment in software and computer industries for information technology (IT)-based services needed due to the demand for digital technology in healthcare (e.g., wearables, telemedicine, and mobile apps through Software Development Kit (SDK)).

According to government statistics, the gross revenues of digital health-related products and services have been growing at 10% annually for the past few years, reaching 50 billion NTD (roughly 1.67 billion USD) in 2022. Since 2016, more than 360 biomedical start-ups have emerged in the marketplace (personal communication with Bio Taiwan Committee, June 27, 2023). Nonetheless, compared with the sizable and still speedily expanding IT industry, revenues contributed by digital health-related products and services account for less than 1% of the gross IT industry revenues. Over the years, the top IT companies in Taiwan have continuously allocated annual funding for the research and development of digital health—however, the investment seems rather modest when compared with other IT business sectors.

MediCloud

The NHI MediCloud, introduced in 2015, is a cloud-based data-sharing system that expanded on PharmaCloud, which was set up in 2013 for mainly medication records. MediCloud integrated medical information across all contracted medical doctors and pharmacists. These medical providers can access this health information exchange system for 12 types of patient medical records covering treatment and diagnostic tests, including medical imaging, which was added in 2018. These records cover services from Western and Chinese dental and medical doctors in both outpatient and inpatient settings, discharge summaries and vaccination records from the Centers of Disease Control.[8]

Lin and Cheng[3] exploited 2013 to 2015 NHI claim data for a difference-in-difference analysis to evaluate the impact of the PharmaCloud program, in terms of the effects of inquiry rate on the probability of receiving duplicate medications and on the number of days of overlapping medication prescriptions. The study found that after the introduction of PharmaCloud, the inquiry rate increased to 55.36%-69.16% and patients had a significantly lower likelihood of receiving duplicate medications in all seven medication groups included. However, a higher inquiry rate led to a lower likelihood of receiving duplicate medication, and shorter periods of overlapping medications were only found in some of the medication groups. The study concluded that the reduction might not be entirely associated with record inquiries. It is also plausible that, with PharmaCloud, NHIA incentivized hospitals to enhance their internal prescription control via a prescription alert system, which resulted in the reduction in duplicate medications (a positive unintended consequence of the intervention).

In 2022, the inquiry rates (percentage of patients whose medical records in MediCloud were ever accessed by medical providers) at medical centers, regional hospitals, district hospitals, and clinics were 82%, 79%, 76%, and 93%, respectively.[9] The inquiry rate has been increasing at a slow pace and is still below the target rate of 95%. One of the main reasons is probably due to the "too long/slow" time it takes to access MediCloud, as perceived by providers conducting often rather time-pressed outpatient visits.

According to the 2021 annual polls, 87.3% of respondents aged 18 and above agreed to allow medical providers access to their medical records on MediCloud, and 86.3% were satisfied with the travel history, occupation, contact history, and cluster query (TOCC) reminder system during the pandemic. It appears that the younger respondents are, the more positive their opinions about digital health applications.[7]

Though not designed with pandemic control in mind, the widespread adoption of cloud-based digital technology was instrumental in carrying out tasks arising in the battle against the COVID-19 pandemic. During the COVID-19 pandemic, the NHI MediCloud System was linked with the national immigration system and recorded individuals' occupations, travel and contact history, and medical records, allowing health professionals to identify high-risk patients. The system was essential to effective contact tracing. Coupled with early and timely border control, Taiwan was able to achieve the world record for the longest period without a local infection (253 days) and to avoid imposing lockdowns throughout 2020.

A digital fencing tracking system that utilized smartphones to locate individuals' positions was imposed on quarantined people. They were asked to upload daily body temperature on a LINE Bot system, and local civil affairs personnel could call up anytime to check on them. Those who left quarantine facilities without government permission were arrested and heavily fined. Similarly, the geofencing system was imposed on people who had close contact with confirmed cases.[10] They were required to self-isolate for 14 days and be monitored by the local health bureau. Because more than 85% of cases were detected during the 14-day post-entry quarantines, the burden of contact tracing was largely reduced.

For infections detected outside the geofencing system, detailed retrospective contact tracing was conducted. Data from the disease surveillance system, surveillance camera footage, electronic tolls, and personal phone records were synchronized to identify sources of infections and possible contacts.[11] These surveillance efforts were enhanced by the NHI database, which covers all populations and was accessible to all hospitals and 93% of clinics in Taiwan. The general public was so wary of the contagion of COVID-19 that the majority of the people were willing to temporarily sacrifice their freedom to comply with the quarantine requirements. The public reprimanded those who breached the government quarantine policy. Hence, the government did not release the identities of confirmed cases to avoid conflicts. In summary, Taiwan substituted mass testing with mass quarantine, contact tracing, and NHI records through the utilization of big data and digital technology.

My Health Bank/NHI Mobile Easy Access

My Health Bank, first launched in 2014, is an electronic medical records repository that aims to help patients manage their health. With My Health Bank, individuals can track their health care use, including visits to Western and Chinese doctors and dentists, hospitalization (including diagnoses, prescriptions, and results of tests, imaging, and pathological examinations), and NHI expenditures and copayments incurred in the three years before the login date. The Mobile Application version, NHI Mobile Easy Access, was introduced in 2018. Though the app aimed to increase insurees' awareness of their healthcare usage, it did not attract much attention until the COVID-19 pandemic.

During the COVID-19 pandemic, however, the NHI Mobile Easy Access mobile application facilitated ID-based distribution of face masks and rapid tests, when there were shortages of protective gear. The NHI Mobile Easy Access application could be used to register for COVID-19 vaccination appointments, and to obtain digital vaccination certificates when vaccinated and Polymerase Chain Reaction (PCR) test results. These functions successfully and quickly attracted millions of new users . As of July 2023, approximately 11.25 million users were signed up for NHI Mobile Easy Access and the use rate had reached 315 million times. (2023 June 27 personal communication with NHIA).

In the 2021 annual polls, 38.4% of the respondents said they were aware that they can access their medical utilization records through My Health Bank and 70.6% indicated their willingness to use it in the future. However, only 20.9% of the respondents had actual user experience. Among the experienced users, 86.4% expressed their satisfaction with the app. Not surprisingly, the elderly group had the lowest use rate of My Health Bank.[7]

Telemedicine

Two telemedicine service models are in use in Taiwan: 1) B2B (medical institution to medical institution), and 2) B2C (medical institution to patient).

1. **B2B (started in 1995).** B2B is mainly used for an online consultation session with a specialist. It requires having physicians (B) at both ends. It is specifically used with residents in remote mountainous areas and isolated islands. In addition to the regular payment for the physician on the patient's side, a consultation fee is also paid to the specialist who provided the online consultation.

2. **B2C (May 15, 2021 – March 20, 2023).** During the COVID-19 pandemic, people (C) who tested positive or were in close contact with a confirmed case were required to self-quarantine. Their cases would be "confirmed" by a physician (B) via a telemedicine session. The providers received the same payment rate for these visits as for a physical visit.

To enhance people's access to health services during the COVID-19 pandemic, NHIA expanded telemedicine coverage to patients with chronic diseases who could not come to a physical visit and to all residents in remote mountainous area and isolated islands. In addition, when there were surges in the number of confirmed COVID-19 cases (May 15-September 30, 2021 and April 27-July 31, 2022) NHIA briefly allowed telehealth sessions via telephone; however, it is difficult to monitor the quality of service provided during telephone sessions.

The 2021 thematic poll found that 73.2% of the respondents supported the government's efforts in providing telemedicine services. Among the 12.1% who disagreed, "don't know how to use digital services" and "distrust in service quality" were the two most commonly cited reasons for their response.[7] Another study was conducted to evaluate the time input and patient satisfaction of a double triage and telemedicine protocol in the emergency department (ED) at a medical center. That study found that the telemedicine protocol in the ED reduced physicians' time of exposure to suspected COVID-19 patients without compromising patient satisfaction.[12]

Challenges

Despite generally positive user feedback on the digital health applications adopted by Taiwan NHI, two potential challenges deserve scrutiny: digital trust, and the digital divide.

Digital trust

It is crucial to recognize that the digital evolution and productive use of new technologies rest on how well digital trust can be built.[13] In 2022, the World Economic Forum's report entitled "Earning Digital Trust: Decision-Making for Trustworthy Technologies" defines digital trust as "Individuals' expectation that digital technologies and services – and the organizations providing them – will protect all stakeholders' interests and uphold societal expectations and values."[14]

The report proposes a digital trust framework that includes "security and reliability", "accountability and oversight", and "inclusive, ethical and responsible use"[a] The framework also defines dimensions against which the trustworthiness of digital technologies can be operationalized and evaluated: cybersecurity, safety, transparency, interoperability, auditability, redressability, fairness, and privacy. Further, the report emphasizes that ensuring

[a] This framework echoes the four pillars delineated in Albinson et al., 2019[22]: ethics and responsibility, privacy and control, transparency and accessibility, and security and reliability. These authors also emphasize that the technologies used for digital transformation can be leveraged to enhance trust, that is, to enhance transparency, reinforce ethical practice, boost data privacy and harden security.

digital trust is a leadership responsibility that crosses domains and functions and should be shared by companies, governments, civil society, and all individuals.

The design of contact tracing applications during the COVID-19 pandemic is one illustrative example. To combat COVID-19, there was widespread use of contact-tracing applications in countries around the globe. Many companies and governments sprinted to deploy contact tracing applications that were not properly monitored for performance, privacy, or security issues; privacy and security remain primary concerns for app users.[15]

The Taiwan and South Korea governments both exploited cell phone base station positioning data (GPS and location-based tracking), which provides accurate timestamps and location information, to evaluate individuals' exposures and risk in order to prevent further COVID-19 spread. However, this data has a significant price: the substantial relinquishment of individual privacy. Fahey et al.[16] point out that a salient way to categorize different contact tracing approaches is to distinguish between "data-first" and "privacy-first". Data-first prioritizes the retention of tracking data and its availability to health authorities and researchers. Privacy-first emphasizes citizens' control over their data—namely, to what extent identifiable individuals' movements and interactions was accessible to authorities. During the COVID-19 pandemic, the Taiwan and South Korean governments adopted a data-first approach.

A recent study[15] noted that when the demands of public health and public welfare are at odds with privacy, the acceptability of the tradeoff between privacy and utility may vary depending on social stability. An illustrative example of this is the use of de-identified NHI claims data for academic research purposes, which has caused a heated debate in Taiwan. To safeguard patient privacy and confidentiality, the Taiwan government passed the Cyber Security Management Act in 2018 and in 2019 amended the Regulations on the Classification of Cyber Security Responsibility Levels. These acts laid the foundation for cyber security management policies. However, in the digital era, assuring the public that their privacy is protected, while making data available for academic research and commercial use, remains a daunting challenge.

In an opinion on a lawsuit filed by a human rights group against the use of NHI claim data in academic research, the Taiwan Supreme Court Justice Jau-Yuan Hwang wrote: "In a digital era, to gain public support and consent in the secondary use of the NHI databank, it is crucial to make every attempt to eliminate or ameliorate the public's distrust".[17] In August 2022, the Supreme Court handed down a ruling that the practice of using NHI claims data for academic research partially violated the people's constitutional rights. Consequently, the Ministry of Health and Welfare was ordered to amend the law (or enact a new law) within three years that enhances the protection of user privacy and adds an opt-out option.

In early 2023, news coverage about leaks of NHI user data further aroused public concern about the government's credibility and capability in data management and auditing systems. Three NHIA senior employees responsible for managing data under Taiwan's NHI system were

interrogated for alleged breaches of user data and intelligence leaks over 13 years.[18] As a result, the Director of NHIA stepped down as part of a cabinet reshuffle in February 2023. The user data leak served as a big blow to NHIA's efforts to digitalize its data through SDK for public use (including commercial enterprise). Cybersecurity is one fundamental and essential step to regaining public digital trust and should be high on the policy agenda.

Digital divide

In the process of making the most of digital technology in healthcare applications, the other major challenge is that inequality in access may exist due to "the digital divide". This was evident when socially-disadvantaged groups had limited access to appropriate health care amid the COVID-19 outbreak due to lack of access to internet services and digital devices.

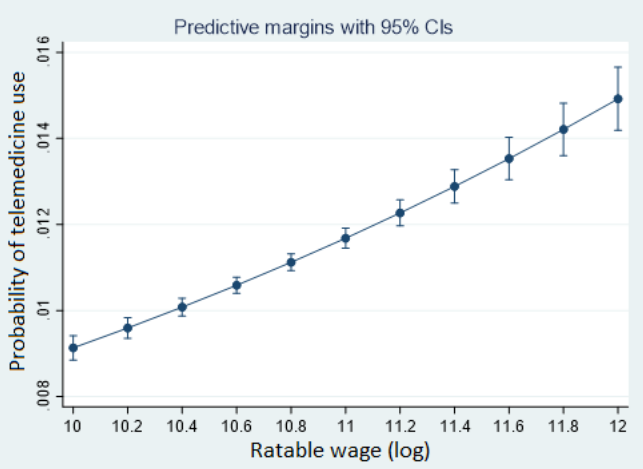
Older individuals in particular are predisposed to experiencing a specific form of the digital divide, commonly known as the "Grey Digital Divide".[19] This divide extends beyond issues of access. It also encompasses a range of other contributing factors, including diminished digital literacy, the impacts of visual impairments or cognitive decline, and age-associated learning obstacles. Scholars caution that the pandemic has expedited the imperative to bridge the digital divide for older adults.[20,21] The grey digital divide may also exist on the provider side. Senior medical providers who are less adept at digital technology are often found to be resistant to exploiting digital health applications.

We conducted a study to explore the issue of the digital divide among patients by examining the determinants of the use of telemedicine during the COVID-19 pandemic. We conducted a cross-sectional study employing individual-level logistic regression analysis. Detailed descriptions of methodology are provided in Appendix A. The determinants hypothesized to influence the use of telemedicine services included enrollees' demographic factors, health status, an income proxy, and characteristics of the township and city/county where enrollees resided (see Table A1, Appendix A). Information on an income proxy was only available for 60% of the NHI enrollees (1,164,611 people). Therefore, our regression analysis was limited to this subgroup.

The regression results (see Table A2, Appendix A) revealed that utilization of telemedicine was positively and significantly associated with female sex, age, the presence of catastrophic illness and chronic diseases, income proxy, the density of physicians, and COVID-19 cases. However, the marginal effects were small (<1) for most predictors, except for the presence of catastrophic illness or chronic disease. On average, the probability of using telemedicine was 1.24% and 1.49% higher for enrollees with catastrophic illness and chronic diseases, respectively. In addition, a 1% increase in wage bracket was associated with a 0.27% increase in telemedicine use.

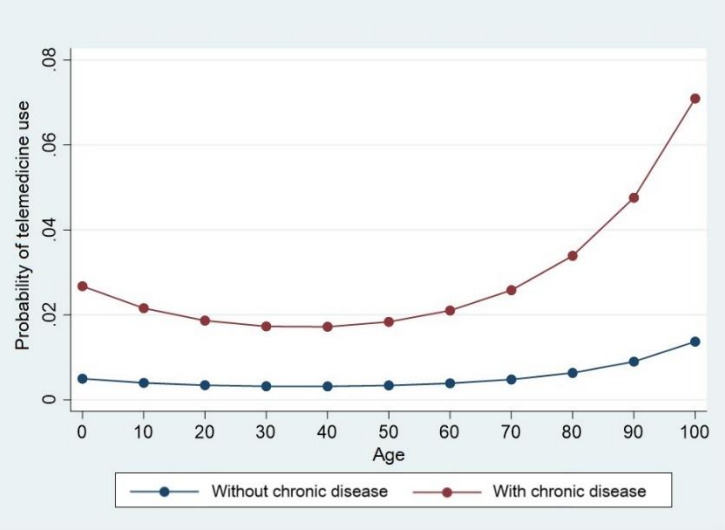
Figure 2 shows the predicted probability of using telemedicine for enrollees in different wage brackets. There was a positive association between income and utilization of telemedicine. From the lowest to the highest wage bracket, the probability of telemedicine utilization increased from 0.9% to 1.5%. We further examined whether the positive association was dose-dependent. This was done by categorizing the wage brackets into four categories: low (NTD 24,000 – 43,900), medium (NTD 43,901 – 63,800), high (NTD 63,801 – 101,100), and very high (>NTD 101,100). Detailed results are presented in Appendix A, Table A3. The estimated average marginal effect revealed a dose-dependent relationship: compared with the low-income group, the probability of using telemedicine was 0.17, 0.30, and 0.36 percentage points higher for the medium-, high- and very high-income groups, respectively.

Figure 2. Predicted probability of telemedicine use for different brackets of ratable wage (log)



Chronic disease was a key driver of telemedicine use and accounted for a large share of the population. Therefore, we compared the probability of using telemedicine between those with and without chronic diseases over the life course. As Figure 3 shows, for chronic disease patients (red line), telemedicine use is U-shaped: it reached the lowest point at age 40 and increased at an accelerated rate from age 60. In contrast, for patients without chronic diseases (blue line), the probability of using telemedicine remained relatively low and steady throughout their lifetime. According to our sample, the top three principal diagnoses of telemedicine were essential (primary) hypertension (4.2%), Type 2 diabetes without complications (2.7%), and hypertensive heart disease without heart failure (2.4%). For other diagnoses recorded via telemedicine visits see Appendix B.

Figure 3. Predicted probability of using telemedicine, by age groups and chronic disease status



Age was statistically associated with telemedicine utilization; however, its marginal effect was minimal. A one-year increase in age elevated the likelihood of telemedicine usage by a mere 0.01% (see Table A2, Appendix A). This suggests that, when accounting for other variables such as the presence of chronic conditions and catastrophic illnesses, age does not serve as a significant determinant for the use of telemedicine. This trend is corroborated by the blue line in Figure 3, which illustrates a relatively stable trend of telemedicine utilization across age groups for individuals without chronic diseases. A small increase in utilization was noted among individuals aged 80 and above, potentially attributable to their limited mobility and decreased propensity for in-person medical consultations, necessitating an increased dependence on telemedicine services. Additionally, in Taiwan, it is customary for children to co-reside with their elderly parents. This cultural emphasis on family support facilitates easier access to telemedicine for the older population and is an acknowledged strategy to bridge the digital divide among seniors[19]. Collectively, these factors—risk perception and family culture—may contribute to the small positive association between age and the likelihood of telemedicine utilization during the pandemic.

In summary, we discovered that, after controlling for enrollees' demographics and health status, as well as the density of COVID-19 cases and healthcare resources, those with higher incomes were more likely to use telemedicine. Moreover, the marginal effect analysis revealed that the use of telemedicine was especially high for patients with chronic diseases and catastrophic illnesses. Altogether, these results seemed to imply that poor people who have poorer health status were most likely to suffer from an unmet need for telemedicine. Future policies should target this most-vulnerable group to reduce inequality in access to health care during a pandemic. A limitation of our regression analysis was that it was restricted to only 60% of NHI enrollees who were employed in the formal sector. Future studies ought to investigate the determinants of telemedicine use specifically for the informal sector.

Conclusion

In its 28 years of operation, Taiwan NHI has introduced several innovative digital health applications. On the provider side, MediCloud is a cloud-based data-sharing system integrating patient medical information across all the contracted medical providers. It allows medical providers to access patient's treatment records during visits to avoid duplicate medications and assure patient safety. On the patient side, My Health Bank (now known as NHI Mobile Express Access) keeps insured individuals fully informed and aware of their medical utilization, and enabled ID-based distribution of protective gear and vaccination appointments during the COVID-19 pandemic. On service provision, the investment in telemedicine infrastructure paid off when access to in-person care was restricted during the pandemic.

However, speedily advancing digital technology applications inevitably lead to daunting challenges of digital trust and digital divide. The public's attitude toward privacy-utility tradeoffs is shaped by local cultural attitudes. Ensuring digital trust is a leadership responsibility that crosses domains and functions and should be shared by companies, governments, civil society, and all individuals.[14] Hence, all stakeholders should be held accountable to employ their best efforts to safeguard confidential information.

To gain public trust, digital industry enterprises should devote resources to enhancing cybersecurity by implementing infrastructure and systems to secure confidentiality when processing user data. The government can impose audit-based third-party certifications on the uses of digital technology and set up mechanisms to empower users to monitor how their information is used. Last but not least, timely and effective communications with the public through a transparent process will be a critical component of building digital trust.

When examining the use of telemedicine to assess the digital divide, our analysis showed that, despite high access to care under the Taiwan NHI, poor people who have poorer health status were more likely to suffer from unmet needs for telemedicine during the COVID-19 pandemic. Hence, in the future, specific policies should be devised to provide support to target socially disadvantaged groups. For example, in remote areas where internet access is limited, the government should incentivize telecommunication companies to install 5G base stations and provide mobile hotspots to facilitate the delivery of telemedicine services.

In addition, it is crucial to enhance digital literacy to improve the digital skills of potential telemedicine and app users, particularly the elderly, through public educational sessions. Advancements in digital technology have largely proved telemedicine services effective with satisfying outcomes. Yet as the COVID-19 pandemic was winding down, NHIA terminated the B2C telemedicine model in March 2023—this may hinder further development of an effective telemedicine service model.

In 2004, when BNHI launched the NHI smart IC card to replace the paper card, it was a pioneer. However, as an early adopter of digital technology in health, Taiwan NHIA might eventually become the victim of its own success. As NHI expenditures are constrained by the global budget, medical providers have limited resources they can devote to modernizing their IT infrastructures and keeping pace with the digital technologies adopted by advanced economies. NHIA, meanwhile, also faces the challenges of underinvestment: its operating costs (funded by a separate government budget) currently only account for less than 1% of total NHI expenditures.

Digital health is the trend of the future; thus a the call for more investment in digital health is in order. Taiwan's experience may be instructive to other countries as they develop the role of digital health in the future.

References

1. Ronquillo Y, Meyers A, Korvek SJ. Digital health. Treasure Island (FL): StatPearls; 2023.
2. Lin JH, Cheng SH. The impact of a medication record sharing program among diabetes patients under a single-payer system: the role of inquiry rate. International Journal of Medical Informatics. 2018;116:18-23. doi: 10.1016/j.ijmedinf.2018.05.004. PMID: 29887231.
3. Lin JH, Cheng SH. The impact of a national health information exchange program under a single-payer system. Medical Care. 2020;58(1): 90-97. doi: 10.1097/MLR.0000000000001227. PMID: 31688553.
4. Lu JR, Sheu JT, Lee TJ. A tale of two social insurance systems in South Korea and Taiwan: a financial risk protection perspective. Health Systems and Reform. 2022;8(1): 2114648. doi: 10.1080/23288604.2022.2114648.
5. Taiwan Ministry of Health and Welfare, Department of Statistics. National Health Accounts. Taipei: Taiwan Ministry of Health and Welfare; 2022 Mar 02 [accessed 2023 Aug 22]. https://www.mohw.gov.tw/lp-130-2.html.
6. Taiwan Ministry of Health and Welfare, Department of Statistics. Hospital and clinic statistics. Taipei: Taiwan Ministry of Health and Welfare; 2023 June 25 [accessed 2023 Aug 22]. https://www.mohw.gov.tw/cp-6614-75351-2.html.
7. Hsieh C, Chuang H, Wu Y, Wang T, Lee P. Major National Health Insurance policies in Taiwan and residents' satisfaction with them during the COVID-19 pandemic. Taiwan Journal of Public Health. 2022;41(6):666-677. doi: 10.6288/tjph.202212_41(6).111069.
8. National Health Insurance Administration. NHI MediCloud System. Taipei: National Health Insurance Administration; 2022 May 19 [accessed on July 1, 2023]. https://eng.nhi.gov.tw/en/cp-43-28d42-23-2.html.
9. National Health Insurance Administration. Tracking the indicator performance by global budget service sectors under National Health Insurance, 2022. National Health Insurance Commission. 2023; Taipei, Taiwan.
10. Summers J, Cheng HY, Lin HH, Barnard LT, Kvalsvig A, Wilson N, et al. Potential lessons from the Taiwan and New Zealand health responses to the COVID-19 pandemic. The Lancet Regional Health – Western Pacific. 2020;4: 100044. doi: 10.1016/j.lanwpc.2020.100044.
11. Taiwan Ministry of Health and Welfare. The Taiwan model for combating COVID-19. Taipei: Taiwan Ministry of Health and Welfare; 2023 Feb 10 [accessed 2023 Aug 22]. https://www.mohw.gov.tw/cp-5055-58017-2.html.
12. Lin C, Tseng W, Wu J, Tay J, Cheng M, Ong H, Lin H, Chen Y, Wu C, Chen J, Chen S, Chan C, Huang C, Chen S. A double triage and telemedicine protocol to optimize infection control in an emergency department in Taiwan during the COVID-19 pandemic: retrospective feasibility study. Journal of Medical Internet Research. 2020;22(6): e20586. doi: 10.2196/20586.

13. Chakravorti B, Bhalla A, Chaturvedi SR. The 4 dimensions of digital trust, charted across 42 countries. Harvard Business Review. 2018 Feb 19. [accessed 2023 April 19]. https://hbr.org/2018/02/the-4-dimensions-of-digital-trust-charted-across-42-countries.
14. World Economic Forum. Earning digital trust: decision-making for trustworthy technologies. Insight Report. 2022 Nov 15. [accessed 2023 Aug 22]. https://www.weforum.org/reports/earning-digital-trust-decision-making-for-trustworthy-technologies/?DAG=3&gclid=Cj0KCQjw3JanBhCPARIsAJpXTx4UUW8otuh2FmI4TMFGGC5wiulK8gNr-RJK6Wd1Cev3tWanux1NwgIaAgojEALw_wcB
15. Hogan K, Macedo B, Macha V, Barman A, Jiang X. Contact tracing apps: lessons learned on privacy, autonomy, and the need for detailed and thoughtful implementation. Journal of Medical Internet Research Medical Informatics. 2021;9(7):e27449. doi: 10.2196/27449.
16. Fahey AR, Hino A. COVID-19, digital privacy, and the social limits on data-focused public health responses. International Journal of Information Management. 2020;55: 102181. doi: 10.1016/j.ijinfomgt.2020.102181.
17. Liu HH. From Taiwan supreme court ruling on the use of NHI databank – how Taiwan can better govern the management of big data in health. Reader viewpoint, The Reporter. 2022 Aug 19. [accessed 2023 Feb 12]. https://www.twreporter.org/a/opinion-health-insurance-constitutional-debate-3.
18. Chang S. Taiwan's health officials investigated for leaking NHI user data. Taiwan News. 2023 Jan 10. [accessed 2023 Jan 31]. https://www.taiwannews.com.tw/en/news/4776093.
19. Mubarak F and Suomi R. Elderly forgotten? digital exclusion in the information age and the rising grey digital divide. INQUIRY: The Journal of Health Care Organization, Provision, and Financing. 2022; 59: 00469580221096272. doi: 10.2196/20586.
20. Nash S. The pandemic has accelerated the need to close the digital divide for older adults. Stanford Center on Longevity. 2023. [accessed 2023 Sept 4]. https://longevity.stanford.edu/the-pandemic-has-accelerated-the-need-to-close-the-digital-divide-for-older-adults/.
21. Yang E, Kim MJ, Lee KH. Digital divide and difficulties in acquiring health resources in disabled older adults during the pandemic. Innovation in Aging. 2022;6(Suppl 1):797. doi: 10.1093/geroni/igac059.2876.
22. Albinson N, Balaji S, Y Chu. Building digital trust: Technology can lead the way. Deloitte. 2019 Sept 22. [accessed 2023 April 19]. https://www2.deloitte.com/content/dam/insights/us/articles/6320_Building-digital-trust/DI_Building-digital-trust.pdf.

Appendix A: Determinants of the use of telemedicine services: logistic regression analysis

Data source and study population

Our study exploited the two million population sample randomly drawn from the NHI database based on national ID numbers. The sample was cross-validated for the distribution of age, gender, and city/county of household registration from the NHI enrollees as of December 2019. Those who died in 2021 and those who had a confirmed diagnosis of COVID-19 (730 enrollees) were excluded because they were special cases. According to the regulations, those who tested positive were required to be quarantined, and consequently had to utilize telemedicine services, hence they were excluded.

As the policy for telemedicine (B2C) was enacted in May 2021 when Taiwan entered the lockdown period (19 May – 26 July), we decided to focus on telemedicine use in the year 2021. The final analytical sample was composed of 1,963,676 NHI enrollees, with the observation period from 1 January – 31 December 2021.

Model variables

Table A1 presents a summary of the variables included in the logistic regression analysis for telemedicine utilization. The outcome variable, whether an individual used telemedicine services, is constructed as a dichotomous variable which takes the value of one if an individual ever used telemedicine services and zero otherwise. The explanatory variables are categorized into three categories: enrollee characteristics, township characteristics, and city/county characteristics. Enrollee characteristics include age, sex, presence of chronic diseases and catastrophic illness, and income. The presence of chronic diseases was defined by the following criteria: (a) prescription days exceeding 14 days, (b) with a continuous prescription for chronic diseases, or (c) with a diagnosis being one of the 101 chronic diseases defined by the NHI. We defined catastrophic illness as major diseases stipulated by the NHI that are expensive to treat, e.g., cancer and chronic renal failure.

Information on income was not available in the NHI database. Therefore, we used the bracket of ratable wage for monthly premium calculation as a proxy measure for income. In 2021, there were 47 brackets, with each bracket corresponding to a specific range of actual monthly wages. For example, 24,000 NT$ (bracket 1) referred to monthly wages no greater than 24,000 NT$, while 25,200 NT$ (bracket 2) referred to monthly wages between 24,001 and 25,200 NT$. The ratable wage system was applicable to approximately 60% of the NHI enrollees (1,164,611 people), including civil servants, public officials, volunteer military personnel, employees of public/private owned organizations, employers, self-employed individuals, and independent professionals. Consequently, our regression analysis was limited to this subgroup.

Township and city/county characteristics were treated as control variables. We hypothesized that a higher supply of physician services in the township where an enrollee resided would result in a higher quantity of telemedicine services. Additionally, we conjectured that a higher number of COVID-19 cases in the city/county where an enrollee lived might lead to fear of infection during visits to doctors, thus potentially increasing the demand for telemedicine. The regression analyses were conducted using Stata 17.

Table A1. Summary of variables

Variable ***N=1,164,611***	**Description**	**Median (IQR)**	**Number (%)**
Use of telemedicine	1=Yes		12,585 (1.1)
Enrollee Characteristics			
Age	From 2 to 100	39 (26 – 53)	
Sex	1=Male		577,875 (49.6)
Presence of catastrophic illness	1=Yes		6,398 (0.6)
Presence of chronic diseases	1=Yes		495,214 (42.5)
Ratable wage bracket (thousand NT$)	From 24 to 182	38.2 (26.4 – 55.4)	
Township characteristics			
Number of physicians (per 1,000 people)	From 0 to 22.39	2.14 (0.98 – 4.20)	
City/county characteristics			
Number of COVID-19 cases (per 10,000 people)	From 0 to 19.33	3.55 (0.74 – 19.33)	
No. of institutions providing telemedicine (per 1 million people)	From 2.42 to 7.78	3.62 (3.11 – 5.97)	

As Table A1 shows, during 2021, 1.1% of the enrollees used telemedicine, approximately 50% were male, 0.6% had a catastrophic illness, and 43% had at least one chronic disease. Relating to township and city/county variables, there was substantial variation in the number of physicians and COVID-19 cases across localities.

Regression results

The results from logistic regression are presented in Table A2. For a description of the key results please refer to the main text. Note that the density of medical institutions with telemedicine services was not associated with the probability of using telemedicine. This may be because telemedicine is not geographically restricted. As long as there is internet access, medical consultations can be obtained through telemedicine, regardless of the location. Therefore, the density of healthcare facilities offering telemedicine in the city/county where an enrollee resides is not a determining factor for telemedicine utilization.

Table A2. Logistic regression for utilization of telemedicine

Variable	Marginal effect [95% CI][a]	p-value
Enrollee Characteristics		
Age[b]	0.009 [0.008, 0.010]	<.001
Sex (1=male)	-0.156 [-0.194, -0.119]	<.001
Presence of catastrophic illness (0/1)	1.244 [0.976, 1.511]	<.001
Presence of chronic diseases (0/1)	1.493 [1.450, 1.536]	<.001
Ratable wage bracket (log)	0.266 [0.226, 0.305]	<.001
Township characteristics		
Number of physicians (per 1,000 people)	0.025 [0.020, 0.031]	<.001
City/county characteristics		
Number of COVID-19 cases (per 10,000 people)	0.014 [0.012, 0.017]	<.001
No. of institutions providing telemedicine (per 1 million people)	0.006 [-0.006, 0.019]	0.331

Note: N=1,164,611. The sample was 60% of the NHI enrollees in this study who had ratable wages.

[a.] The unit of marginal effect is percentage points.

[b.] The model included the squared term of age to capture the nonlinear relationship between age and the likelihood of telemedicine use.

Table A3 presents the results of an alternative specification of the logistic regression. We grouped the 47 wage brackets into four categories: low (24,000 – 43,900; brackets 1-15),

medium (43,901 – 63,800; brackets 16-23), high (63,801 – 101,100; brackets 24-33), and very high (>101,100; brackets 34-47). The marginal effect increased with income level, suggesting that the positive association between income and telemedicine use was more pronounced in higher wage groups.

Table A3. An alternative specification of logistic regression for utilization of telemedicine: grouping the wage bracket

Variable	Marginal Effect [95% CI][a]	P-value
Enrollee Characteristics		
Age[b]	0.009 [0.008, 0.010]	<.001
Sex (1=male)	-0.153 [-0.191, -0.115]	<.001
Presence of catastrophic illness (0/1)	1.242 [0.974, 1.509]	<.001
Presence of chronic diseases (0/1)	1.495 [1.451, 1.538]	<.001
Wage brackets (reference: 24,000 – 43,900)		
43,901 – 63,800	0.166 [0.119, 0.212]	<.001
63,801 – 101,100	0.295 [0.238, 0.353]	<.001
>101,100	0.355 [0.262, 0.448]	<.001
Township characteristics		
Number of physicians (per 1,000 people)	0.025 [0.020, 0.031]	<.001
City/county characteristics		
Number of COVID-19 cases (per 10,000 people)	0.014 [0.012, 0.017]	<.001
No. of institutions providing telemedicine	0.005 [-0.007, 0.018]	0.412
(per 1 million people)		

Note: N=1,164,611. The sample was confined to 60% of the NHI enrollees in this study who had ratable wages.

[a.] The unit of average marginal effect is percentage points.

[b.] The model included the squared term of age to capture the nonlinear relationship between age and the likelihood of telemedicine use.

Appendix B: Disease categories and primary diagnoses via telemedicine

Among the full sample of 1,963,676 NHI enrollees, 24,785 individuals (1.26%) utilized telemedicine during the year 2021. The total frequency of telemedicine use was 43,319, indicating an average of 1.75 telemedicine sessions per person. The relevant disease categories and principal diagnoses are summarized in Table B1 and B2, respectively.

Table B1. Major disease categories via telemedicine services (N=43,319)

ICD-10-CM	Disease Category	Frequency	%
I00-I99	Diseases of the circulatory system	6,680	15.8
E00-E90	Endocrine, nutritional and metabolic diseases	5,134	12.14
F00-F99	Mental and behavioral disorders	4,152	9.82
J00-J99	Diseases of the respiratory system	3,370	7.97
M00-M99	Diseases of the musculoskeletal system and connective tissue	2,810	6.65
R00-R99	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	2,802	6.63
K00-K93	Diseases of the digestive system	2,734	6.47
N00-N99	Diseases of the genitourinary system	2,695	6.38
Z00-Z99	Factors influencing health status and contact with health services	2,129	5.04
	Total	32,506	76.9

Note: The table presents only disease categories that accounted for more than 5% of total telemedicine.

Table B2. Principal diagnosis via telemedicine services (N=43,319)

ICD-10-CM	Description	Frequency	%
I10	Essential (primary) hypertension	1,784	4.22
E119	Type 2 diabetes mellitus without complications	1,132	2.68
I119	Hypertensive heart disease without heart failure	1,000	2.36
B20	Plain radiography	695	1.64
J309	Allergic rhinitis, unspecified	678	1.6
E1165	Type 2 diabetes mellitus with hyperglycemia	630	1.49
Z008	Encounter for other general examination	610	1.44
F0390	Unspecified dementia, unspecified severity, without behavioral disturbance, psychotic disturbance, mood disturbance, and anxiety	561	1.33
E1121	Type 2 diabetes mellitus with diabetic nephropathy	551	1.3
	Total	7,641	18.06

Note: The table presents only principal diagnoses that accounted for more than 1% of total telemedicine.