**Smart Healthcare solutions in China and Europe, an international business perspective**

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**Salutation**

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**Abstract of the Thesis**

The thesis is part of the Marie Curie Fellowship project addressing health related challenges with IoT solutions. The author tries to address the challenge for the implementation of telehealth solutions by finding out the demand of the telehealth solution in selected European economies and in China (chapter 1), analyzing the emerging business models for telehealth solution ecosystems in China (chapter 2), how to integrate telehealth solutions with institutional stakeholders (chapter 3) and why are elderly users willing to use telehealth solutions in China.

Chapter 1 and chapter 2 form the theoretical background for empirical work in chapter 3 and chapter 4. The thesis addressed four research questions, namely "Which societal and social-economics unmet needs that Internet of Healthcare Things can help to resolve?", "What are the business model innovation for tech companies in China for the smart health industry?", "What are the facilitators and hurdles for implementing telehealth solutions", "Are elderly users willing to use telehealth solutions in China?".

Both qualitative study and quantitative analysis has been made based on data collected by in depth interviews with stakeholders, focus group study work with urban and rural residents in China.

The digital platform framework was used in chapter 2 as the theoretical framework where as the stakeholder power mapping framework was used in chapter 3. The discretion choice experiment was used in chapter 4 to design questionnaire study while ordered logit regression was used to analyze the data.

Telehealth solutions have great potential to fill in the gap for lack of community healthcare and ensuring health continuity between home care setting, community healthcare and hospitals. There is strong demand for such solutions if they can prove the medical value in managing chronic disease by raising health awareness and lowering health risks by changing the patients' lifestyle. Analyzing how to realize the value for preventive healthcare by proving the health-economic value of digital health solutions (telehealth solutions) is the focus of research.

There remain hurdles to build trust for telehealth solutions and the use of AI in healthcare. Next step of research can also be extended to addressing such challenges by analyzing how to improve the transparency of algorithms by disclosing the data source, and how the algorithms were built. Further research can be done on data interoperability between the EHR systems and telehealth solutions. The medical value of telehealth solutions can improve if doctors could interpret data collected from telehealth solutions; furthermore, if doctors could make diagnosis and provide treatment, adjust healthcare management plans based on such data, telehealth solutions then can be included in insurance packages, making them more accessible.

## Introduction

Three years ago, when I started my PhD, telehealth solutions were emerging with remote consultation, remote diagnosis and treatment, online pharmacies started to get attention. Urbanization, aging and the resulted changes in family structure has made me often wonder about the prospects for caring for my parents when they get old as an only child who lived 10,000 miles away. I joint the program with that notion in mind and realized that the healthcare system is a complex structure which has its own norms. Technology has changed many procedures, pathways but realizing penetration of telehealth solutions will take a long time.

COVID-19 has accelerated the digitalization pace for the healthcare system given the nature of its transmission. Today sleep monitoring via mobile phone apps and devices, nutrition monitoring (via mobile phone scanning for RFID code or taking pictures), predicting the weight gain for pregnancy women, predicting the risk for Alzheimer' disease, monitoring heart rate and stress level with a mobile phone camera has all become possible. The data interoperability between telehealth solutions and hospitals have improved as well; in CES 2021, Omron has showcased its blood pressure monitoring system with EKG embedded from which data collected can be shared with doctors from Mount Sinai and Northwestern Medicine in Chicago. Both the usage rate for telehealth solutions and spending has grown exponentially since the quarantine started in March/April 2020.

The thesis is mainly about implementing telehealth solutions in Europe and in China for both institutional stakeholders and individual users. The thesis started by analyzing the support for telehealth solution development in Italy, Germany, Denmark and China by performing a dichotomy of the healthcare system in Europe (Italy, Germany, Denmark) and in China. Then the thesis moves to analyze the innovation ecosystem for telehealth solution providers such as Huawei and Xiaomi and the value chain for wearables. In chapter 3, the thesis uses the stakeholder power mapping framework to analyze the power and attitudes of each stakeholder (government, tech companies, healthcare service provider, users) for the integration of telehealth solutions with the healthcare system in China. In the final chapter, a multi-layer model was built to analyze the willingness of 50 + users in Shenzhen, Hangzhou, Wuhan and Yichang to use telehealth solutions.

The thesis reached the conclusion that there remain hurdles to implement telehealth solutions and to build trust for telehealth solutions among medical professionals and individual users. With COVID-19 becoming a global pandemic, the demand for digital health credentials such as vaccination passports, telehealth diagnosis and treatment tools are becoming stronger. The need for telehealth solution is not only felt by patients but by governments, healthcare providers and tech companies. Even though the pace for digitalization has been accelerated, there are still demand for population health management platforms to predict the pandemic such as COVID, and to manage healthcare resources accordingly. In order to promote a resilient economic response and to control the losses caused by the pandemic and preventing such crisis in the future, promoting the digitalization of healthcare system and the use of telehealth solutions has become essential.

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# *Chapter 1:*

# *Telehealth solution market demands in China and in Europe in the case of Germany, Denmark and Italy*


## Abstract

**Background:** Traditionally healthcare is a closed cycle process where information flows one way from physicians to patients; research universities serve as the center of innovation and progress in healthcare. Due to the digitalization of patient healthcare records, today data flow is becoming much freer. Patients are engaged in more complex data sharing with connected devices and wearables. This gives patients more power to be engaged in their healthcare process.

**Objective:** This chapter aims to analyze emerging opportunities and challenges from the development and implementation of tele-health solutions in Europe and in China and its impact in the respective healthcare systems.

**Methods:** The discussion focuses on the analysis of unmet challenges in the healthcare system in China and in selected countries in Europe, regarding the demand for telehealth solution and the supply of such solutions. The chapter describes general trends for telehealth solutions in Europe and in China, the features of healthcare systems in selected part of China and in some countries in Europe, the target market for telehealth in China and in Europe, and the policy incentives for developing tele-health solutions. Denmark, Germany and Italy are taken as a sample for the healthcare systems in the EU to make a contrast on the degree of digitalization of the healthcare system, and the market potential for Internet of Healthcare solutions.

**Results:** The paper reaches the conclusion that both Europe and China can benefit from the adoption of smart health solutions. China and Europe are still struggling to deal with providing care for the elderly at home. Different parts of the healthcare system in Europe and in China all collect data with their own electric healthcare system with service quality varies at various healthcare institutions. Fragmented data sources make it difficult for patients and healthcare institutions to access healthcare data. Unequal healthcare qualities resulted from lack of benchmarking of services in the healthcare system. This leaves space for tele Solutions to fill in the gap to provide care for elderly at home setting, improve data interoperability in the healthcare system and provide healthcare service providers with quality benchmarking.



**Key Words:** Aging Healthcare systems in Europe and in China Internet of Healthcare Things

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**List of Abbreviations**

| | |
|---|---|
| AF | Atrial Fibrillation |
| AI | Artificial Intelligence |
| API | Application programming interface |
| B2B | Business to Business |
| CD | Compact Disk |
| CD-ROM | Compact Disc Read-Only Memory |
| CHCs | Community health centers |
| COPD | Chronic Obstructive Pulmonary disease |
| ECG | Electrocardiography |
| EEA | European Economic Area |
| eHealth/ E-Health | The use of information and communication technologies (ICT) for health |
| EHRs | Electronic Health Records |
| EIU | Economist Intelligence Unit |
| e-journals | Patient records from hospitals |
| EU | European Union |
| Eurostat | The EU Open Data Portal |
| FDA | The US Food and Drug Administration |
| FHIR | Fast Healthcare Interoperability Resources |
| GDP | Gross domestic product |
| GKV | Gesetzliche Krankenversicherung |
| GP | General Practitioner |
| HALE | Healthy life expectancy |
| HEART | Health related Activity Recognition system based on IoT<br>an interdisciplinary training program for young researchers |
| HIS | Hospital Information System |
| Telehealth | Internet of Things in Healthcare |
| IOS | A mobile operating system created and developed by Apple Inc |
| IoT | Internet of Things |
| IoT | Internet of Things |
| IT | Information Technology |
| JAMA | The Journal of the American Medical Association |

| | |
|---|---|
| MRI | Magnetic resonance imaging |
| NRCMS<br>NHC | New Rural Cooperative Medical System<br>National Health Commission |
| O2O | Online to Offline |
| OECD | The Organisation for Economic Co-operation and Development |
| PPG | Photoplethymographic |
| Q1 | Quarter I |
| RMB | The official currency of the People's Republic of China |
| SHI | Social Health Insurance |
| EBMI | Employee Basic Medical Insurance |
| UI | User Interface |
| RBMI | Resident Basic Medical Insurance |
| US | The United States |
| VO2 | The maximum rate of oxygen consumption measured during incremental exercise |
| WHO | World Health Organization |

## 1. Introduction

Healthcare can be costly and inefficient on different stages, from diagnosis to treatment, from prevention to care at home. With the population aging in Europe and in China, rising healthcare costs and lack of efficient healthcare solutions are posing challenges for the society.

Indeed, technology is changing the landscape for healthcare. In the past, the healthcare industry was stuck in the paper and pen age where all health records were stored on paper-based dossiers; diagnosis was made based on experience. Artificial Intelligence (AI) allows automation of repetitive tasks in the healthcare industry, such as image processing, saving time and reducing working loads of healthcare service providers; AI also enables doctors to make diagnosis with the assistance of a vast amount of patient records databases, improving diagnosis efficiency and accuracy. Wearables, chatbots, smart home healthcare make it possible to raise health awareness of patients, thereby enable them to control their own healthcare conditions easily.

Nowadays it has become increasingly more important that the elderly people can live independently and comfortably in their home. Living at home improves healthcare qu reduce social expenses for healthcare including time, energy and resources (Fattah et al., 2017a, p. 2311). When primary level of healthcare failed to serve as gate keeper and coordinator for the healing, the telehealth solutions can potentially fill in the gap by providing solutions with telecommunication and telemedicine for patients with no severe conditions, or with chronical diseases, or even just in need of health monitoring. Telehealth solutions provide an alternative model for the aging society with potentiality of systematic data analysis, benchmarking best practices, and potentially optimizing health outcomes in relativity of costs.

For consumers, the internet of things (IoT) stands as an opportunity to make the healthcare system more equitable and efficient, particularly for preventative healthcare and chronic disease management. Smart healthcare solutions such as health coaching apps and wearables can potentially alter the traditional ways of treating chronical diseases such as diabetes by promoting patient self-management and homecare, thereby promoting the quality of life.

Direct-to-consumer telehealth devices offer people the chance to monitor heart rate, sleep quality, weight, blood glucose level, blood pressure, and other key health indicators (Apple, 2018; Philips, 2018; Huawei, 2018; Eversense, 2018). Telehealth solutions thus bears the possibility to remove barriers for keeping continuous and sufficient healthcare records for patients (Tang *et al.*, 2006). Health coaching apps now provide healthy lifestyle services such as workout coaching, medication sessions, instructions on maintaining oral health, nutritional advices, thereby promoting health self-management.

Telehealth solutions has promoted healthcare management efficiency by significantly lowering patient waiting time and empowering patients with more information. In China, for instance, Telehealth platforms such as Tencent Health, Ali Health, and Jing Dong Health, offer online consultation sessions with doctors via chat boxes, and online patient registration, internet hospital services including, online prescription and sale of medications, medication reminder and other chronic disease management functions etc (Tencent Doctor Work, 2018; Alihealth, 2018; Jing

Dong Online Healthcare, 2019).

For the supply side of healthcare services, Telehealth solutions can potentially optimize healthcare outcomes relative to costs by providing systematic data analysis. Patient data interoperability poses significant challenges for realizing the potential of telehealth solutions. One problem exists in patient record and medical image sharing between different levels of healthcare providers and patients. Telehealth networks make it possible for patients to retrieve data from different healthcare institutions and gather them together on a single platform (Dameff et al., 2019, p. 339). Healthcare data communication standards have been developed, rendering it possible for patients to connect their mobile devices to healthcare organizations with User Interfaces (UIs). Retrieving health records from patient portals at healthcare institutions to their smart phones and sending clinical related information such as glucose level connected from wearables to healthcare organizations have been automated. For chronical ill patients, it would great benefit them with patient controlled portable records. Patients with electronic healthcare records compatible with different healthcare information systems can easily receive treatment at different institutions and doctors.

Smart healthcare solutions bear the potential to transform medical research, medical practices, and the role patients play in their own healthcare by equipping patients with data, technology and access to expertise. Telehealth now has the potentiality to democratize healthcare for the first time in history (Standford Medicine, 2018). The transformation happens on two levels, namely the distribution of data and the ability to generate and apply insights at scale. It equips patients with data, technology and access to expertise, thereby empowering them to manage their own health. On the institutional level, the transformation brought by telehealth solutions essentially means less focus on routine tasks and more energy on the areas creating the most value and satisfaction (Standford Medicine, 2018).

To sum up, the ubiquitous use of mobile telehealth devices, the maturation of health information transfer standards and accessible healthcare related software have been contributing to personalizing healthcare records. Despite all the great potentials posed by connected devices, the potentiality of telehealth solutions to improve patient outcome, reduce cost and improve healthcare efficiency remains debatable (Dameff et al., 2019, p. 339). In the stage of adoption of electronic patient health records systems have showed great enthusiasm. Direct patient facing technology continuously developed by mature technology companies and well-established research institutions suggest that the digital healthcare landscape may be sufficient to trigger wide adoption of smart health solutions (Dameff et al., 2019, p. 339). Examples of such solutions include the algorithms detecting early signals of kidney failure developed by Deep Mind and Google Health (FT, 2019), the breast cancer early detection algorithms developed by MIT (MIT, 2019), and the Neuralink brain implant designed for people with brain and spinal injuries or congenital defects such as Parkinson's disease (The Guardian, 2019) all have triggered significant scientific and business interest. Meanwhile, the wide adoption of smartphones, the upgrade of communication standards, the availability of software, hardware and sensors also lays foundation for such technology leaps with AI application in healthcare to happen (Dameff et al., 2019, p. 339). It takes time to observe the long-term benefits of AI in healthcare on quality improvement, cost reduction

and patient outcomes. yet the enthusiasm of early adopters has suggested the potential benefits of the adoption of smart health solutions.

Despite heavy investment made by the government and private sector in telehealth solutions in the U.S., in Europe and in China, embedding IoT in different stages of healthcare is an ongoing process. It is challenging for the medical community to take use of the large amount of data generated by IoT devices (*Deloitte*, 2018). Most physicians find it difficult to interpret the data presented by wearables and generate valuable insights (Schnall et al., 2016, p. 248).

Algorithms may be powerful, yet utilizing AI to identify useful information from redundant data and to improve accuracy in identification and prediction with limited amount of training data (Minor, 2018, p. 10). Realizing population health management can be challenging with ethics and legal concerns regarding sharing data over third party app providers(Terry, 2016). Consumers maybe enthusiastic to try out innovative telehealth solutions in the early stage; the stakeholders in the healthcare system is yet to take upon the cost for implementation of smart healthcare solutions in the long term; whether telehealth platforms can be useful, sustainable, scalable, can actually improve health outcomes and lower cost still demand further testing (Dameff et al, 2019). The research question for this part of the chapter therefore derives from the previous discussions as:

- Which societal and social-economics unmet needs Internet of Healthcare Things can help to resolve?

In this chapter, the first part is devoted to describing the research purpose and the research questions. The second part covers the research methodology by describing briefly the reasons for selecting countries and regions in the EU and in China. The paper compares the healthcare systems in rural and urban areas in China, and compare the healthcare systems in Germany, Denmark and in Italy. The third part discusses the current trends and emerging technology in smart healthcare. In the fourth part, a summary of the target for telehealth solutions observed in Europe and in China is provided. The paper continues to discuss policy initiatives for developing solutions for healthcare services with big data, Artificial Intelligence (AI) and Internet of Things (IoT). The aim is to find out similarities in the emerging trends, challenges and the features for the European and Chinese healthcare system. The concluding part of the chapter discusses the added value of IoT solutions for different phases in healthcare following the order of healthy living, prevention, diagnosis, treatment, homecare in different healthcare systems.

## 2. Research Methodology

Qualitative study was mainly used in the paper for part three, four and five. Quantitative analysis is used to describe the market features and consumer preferences in Europe and in China over healthcare and lifestyle choices. Secondary data is used in this case for the study. To compare the healthcare quality in China and Europe, key indicators such as insurance coverage, leading causes of death, life expectancy in Denmark, Germany, Italy rural and urban China are used.

China is a diverse country with different public health situation in rural and urban areas. Urban residents in Tier-1 cities enjoy better medical resources including a concentration of high-quality hospitals, doctors, and reliable pharmacies (WHO, 2016, pp. 3, China Development Research Foundation, 2017). As for insurance coverage, most employees in urban enterprises, with the exception of migrant workers, are covered by mandatory Employee Basic Medical Insurance (EBMI). EBMI covers basic medical cost and varies by city on coverage ratio. In addition to EBMI, the Resident Basic Medical Insurance (RBMI) scheme cover the rest of other residents such as students, elderly, etc. (State Council, 2016).

In comparison with urban residents, the rural population have less reliable medical resources to refer to. With the fall of commune system in the reform era, no effective public health system has emerged in rural area in replacement for the bare foot doctors. There are less good hospitals (tier-3 hospitals), well-educated doctors and reliable pharmacies providing authentic medication available in the rural area. Rural residents are only covered by the voluntary New Rural Cooperative Medical System (NRCMS) before 2018, limiting their choices in seeking medical resources. The NRCMS has merged with URBMI since, raising the coverage ratio and category for rural residents (Pan et al., 2016, p. 1274).

With the ongoing urbanization and population mobilization trends intensifying in China, by now 57.96 percent of all population live in urban areas, resorting to medical resources in urban areas (World Bank, 2019). 92 percent of all patients in China go to public hospitals because the hospitals, particularly the large ones in big cities are supposed to provide the best care. China has no effective primary care system, making hospitals over-stretched (Mckinsey, 2010). Therefore, in order to identify the unmet needs for the healthcare system in China, it is essential to differentiate between urban and rural areas.

The European healthcare system is generally more equitable. The general health care system in Europe, despite all differences concerning their extent and quality, presents various competences and values (Leichsenring, 2004). It is no news that the health care expenditures are decreasing from Northern to Southern European countries. In terms of social care, it can be observed different traditions and states of systemic development with a general North-South-gap. Nordic countries started to develop specific social services in the 1950s, and have developed different types of services and institutions regarding social care, and professional concepts and approaches. On the other hand, in Southern European countries, most social care services are scarce with lack of funding and staff. When it comes to aging and care for elderly in terms of social services, Northern and South European countries mark a large difference (Leichsenring, 2004). Because of differences of healthcare quality and services observed in past literatures, we chose to focus on three significant national cases: Denmark, Germany and Italy.

The reason for choosing Denmark is because it leads in Europe for the digitalization of the healthcare system (Kierkegaard P, 2013). Denmark has established a national electronic m-health (eHealth) portal which provides access to personal health data from hospitals, general practitioners' offices and municipalities (Ministry of Health and Healthcare Danmark, 2017). The Danish eHealth portal aims to provide a more coherent patient experience and to facilitate treatment locally, regionally and nationally (WHO, 2018).

Germany has been chosen as an example because it represents a Northern European country which has important economic and political role to play in the European Union. Germany is on the way towards the digitalization for its healthcare system (Lovell, 2019). Berlin has also become one of the most exciting start-up incubating cities in Europe; therefore Germany is an interesting example to study over the potential implementation over smart healthcare solutions.

Italy is an example of Southern European country, the healthcare system of which currently ranks 4$^{th}$ place in the World for its efficiency (Bloomberg, 2018).

## 3. The current trends and emerging technology in smart healthcar

### *3.1 Wearables, monitoring of patients and preventive healthcare*

Traditionally healthcare is a closed cycle process where information flows one way from physicians to patients; research universities serve as the center of innovation and progress in healthcare (Stanford Medicine, 2018). Due to the digitalization of patient healthcare records, today data flow is becoming much freer. Patients are engaged in more complex data sharing with connected devices and wearables. This gives patients more power to be engaged in their healthcare process.

Wearables today offer patients the opportunity to monitor key parameters such as heart rate, enabling early detection and self-diagnosis for cardiovascular diseases. For instance, Apple Watch, Fitbit, Xiaomi Watch and other smart watches and bands have embedded photoplethysmography (PPG) sensor to monitor heart rate via transmission and absorption of light against the skin (Allen, 2007).

Table 1.1 describes the world's top 5 wearable brand and their health monitoring and coaching related function. Most variables today have basic heart rate monitoring, sleep monitoring, and work out tracking or coaching, and have integrated VO2 monitors and virtual assistants. Only Apple watch have integrated fall detection, ECG diagram generator, nutrition tracking, stress management function, etc. Sadly among all World's top five wearable brands, all belong to American and Chinese companies. Apple and Fitbit are San Francisco based tech companies, Garmin originates from Texas while Huawei and Xiaomi are based in mainland China. No European brands appear in the list.

Table 1.1: World's Top Five Wearable Brands (by shipment) and their health/wellbeing related functions; Source: Apple, 2019; Xiaomi, 2019; Fitbit, 2019; Huawei, 2019;Garmin, 2019.

| Manufacturer/Function | Apple | Xiaomi | Fitbit | Huawei | Garmin |
|---|---|---|---|---|---|
| Fall Detection | X | | | | |
| ECG Diagram Generation | X | | | | |
| Heart Rate Monitor | X | X | X | X | X |
| Emergency SOS Call | X | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Meditation Coaching/Stress Management | X | | X | | X |
| Period Tracking | X | | X | | |
| Glucose Tracking | X | | | | |
| Nutrition Tracking | X | | | | |
| Water Intake Tracking | X | | | | |
| Workout Tracking and Coaching | X | X | X | X | X |
| Sleep Monitoring | X | X | X | X | X |
| Call & Text | X | X (Reminders) | X (Reminders) | X | X |
| GPS Tracking | X | X | X | X | X |
| VO2 Max Tracking | X | X | X | X | X |
| Wireless Music Play | X | X | X | X | X |
| Virtual Assistant | X | X | X | X | |

Monitoring diets, activities, medication intake, sleep quality, heart rates are important for doctors to make precise diagnosis and monitoring for the early recovery of patients. Image recognition algorithms can make it faster for doctors to process test images, therefore reducing mistakes. Patients with chronical conditions may find it much easier to adjust their treatments and easier to communicate with healthcare professionals and perform self-care. For healthy living, smart health solutions already provide a wide range of solutions for controlling of stress level, monitoring and enhancing sleep quality, workout coaching, pregnancy related functions such as portable ultrasound, dietary logging.

Smart healthcare solutions have the potential to improve healthcare quality by promoting healthcare efficiency. For hospitals, taking use of IoT solutions can help doctors to reduce repetitive workloads and management to better control costs. Automating repetitive tasks such as inputting for Electronic Health Records (EHRs) and managing medical resources and in/out-flow of patients can greatly reduce costs for hospitals (Stanford Medicine, 2018). Smart health solutions can also deliver faster and more precise diagnosis, reduce burn out risks for physicians with AI assistants providing image reading advice, diagnosis advice and prescription advices.

Health AI market is projected to reach $ 6.6 billion by 2021, with AI could help to reduce the cost for healthcare in the United States by $ 150 billion by 2026; (Accenture, 2018; Stanford Medicine, 2018). The most valuable new developments are predicted to be robotic assisted surgeries, with projected economic value of $ 40 billion. The next most valuable development is virtual nursing assistance, with projected economic value of $ 20 billion; the third most valuable developments is administrative work-flow assistance, with projected economic value of 18 billion (Accenture, 2018; Stanford Medicine, 2018).

Telehealth solutions provide potentiality to establish a systematic data processing system to cover each stage of care to perform preventive healthcare tasks. Telehealth devices can perform real-time and synchronized monitoring of biometric and environmental indicators, including temperature, humidity, luminosity, acoustic noises. With systematic monitoring of human body and interaction with environment, it is possible to analyze the correlations between the environment and the bio-signals (Rinbeat, 2018). The systematic monitoring can also generate significant trends and patterns related to human health and to develop algorithms. These algorithms can potentially predict users' stress and wellbeing, emotions, cardiopathies, discomfort level, quality of sleep, sports performance and recovery time, attention capacities and concentration level, etc. (Rinbeat, 2018).

Wide application in health, fitness, military, automotive industry, transportation, and insurance may emerge. For instance, in military use, fitness tracker and environmental sensor combined can help soldiers to predict attention capacities, and adjust stress level, therefore adapt to war situations. In sports activities, the system will be able to enhance sports performances, calculate recovery time, and evaluate the level of discomfort for users. In healthcare, the system has the capacity to perform real-time monitoring for the heart and the central autonomic system (Rinbeat, 2018).

With healthcare cost on the rise, Internet of Healthcare Things can help curbing the trend by preventing diseases and promoting healthy lifestyle. Spending on preventive healthcare has long been a small part for entire healthcare system. Most spending is focused on acute and extreme conditions. Internet of Healthcare Things can potentially detect early symptoms of complex conditions such as breast cancer (MIT, 2019; Ehteshami Bejnordi et al., 2017, p. 2199). Wearables through monitoring vital signs can warn patients important changes of their biometric signals, thereby urging them to utilize early intervention methods. Population health management can predict the breakout of epidemics, and therefore making control efficient. The China National Disease Control Center has implemented real-time monitoring systems for communicable diseases such AIDS, hepatitis A/B to perform early intervention.

The use of telehealth solutions is vital for establishing a value-based healthcare system, by establishing a system wide monitoring of treatment, outcomes and costs. Using systematic data processing and benchmarking of best practices, Telehealth provides a potential solution for combating the rising healthcare cost and lack of access for basic healthcare services.

### *3.2 New business models for Internet of Healthcare Things developed in China*

It is argued that the Internet of Things is more about business play rather than about technology (Subramania, 2019). The way business organized for the Internet of Things should start from finding the market needs, and how technology can feed the needs better than the current methodology (Subramania, 2019). The more important thing is to align innovation with market needs and organize products and services with IoT and extend the market into new areas (Subramania, 2019).

Currently in China, big tech companies are marching into the healthcare market, trying to offer products and services targeting at the full cycle of care. Table 1.2 and 1.3 summarize their services and business models. These companies can be categorized into software and hardware companies.

The leading actors in software are Alihealth, Tencent Doctorwork, and Ping An Good Doctor while the leading hardware producers are Xiaomi and Huawei. Among the successful companies, their business models vary. Some chose to establish their own app and network, like Alihealth and Ping An. Tencent, has both invested in its own app, and invested in smart health startups, like We Doctor Platform, Ding Xiangyuan, etc.

Table 1.2: Leading Smart Health Service and Product Providers, filtered by the amount of users, Source: Technode, 2018; Financial Times, 2018; Alihealth, 2018; Tencent Doctorswork, 2018; Bloomberg, 2018;

| Competitor | Service | | | | | | |
|---|---|---|---|---|---|---|---|
| | Wearables | App | Mobile Payment for hospitals | Medicine O2O Sale | Self-Cloud Computing Platform for Developers | AI appliances in Diagnosis | Smart Home Appliances - Hardware |
| We Doctors Limited Holdings | | X | X | X | | X | |
| Tencent | | X | X | | X | X | |
| Ping' An Healthcare and Technology Ltd | | X | | X | | | |
| Huawei | X | X | | | X | | X |
| Xiaomi | X | X | | | | | X |
| Alihealth (Alibaba) | | X | X | X | X | X | |
| Microsoft | X | X | | | X | X | |
| Samsung | X | X | | | | | X |

Table 1.3: Business Models and Profitability for leading smart health product and service providers, filtered by the number of users
Source: Technode, 2018; Financial Times, 2018; Alihealth, 2018; Tencent Doctorswork, 2018; Bloomberg, 2018; B2B: Business to Business, Q1: Quarter 1, O2O: Online to Offline

| Competitor | Business Model | Profitable Businesses | Overall Performance |
|---|---|---|---|

| | | | |
|---|---|---|---|
| We Doctors Limited Holdings | Wedoctor based medical treatment + medine management + insurance + cloud computing / data stroage | Payment Systems for hospitals + Medication Supply Chain + Insurance + PHM based on Cloud and AI | Turn profitable in Q1 2018; |
| Tencent Clinics | Online + Offline Treatment; Target High End Customers; Focus on generalized practioners and treatment | B2B Businesses | Not yet |
| Ping' An Healthcare and Technology Ltd | Provide each user with a family doctor, EHR and long-term health management plan | Consumer based healthcare service such as physical examination, | Loss |
| Huawei | Smart Phone + additional smart devices + 5G + Telecommunication Infrastructure | Smart Phone + Wearables + Cloud based Healthcare Solutions | Profitable |
| Xiaomi | Wearables, Homeappliances+ Smart Phones | Smart Phone | Profitable |
| Alihealth (Alibaba) | Doctor's Network + Payment System + AI in Diagnosis | O2O Medication sales system | Profitable |
| Microsoft | B2B Based Business | Software, hospital management system | Profitable |
| Samsung | IoT ecosystem | Smart Phones, watches, etc. | Profitable |

One of the challenges for Telehealth solutions lies in the interoperability of the electronic health record (EHR) systems. Until today, doctors in Europe typically put medical images on CD-ROM

and give the CDs to patients when most laptops no longer carry a CD reader. Hospitals still use fax to share patient records (Stanford, 2018). In China, usually patients pay $0.5 for a blue paper book where the doctors put notes on. Patients then get the X-Ray or MRI images printed out and taken away; most patient records are stored in separate electronic health record systems at different hospitals. EHR records are static and usually stay within the institutions who collect them (EHR data stored at different systems creates the interoperability problem. Hospitals generally have no exact standards on the type of data input in the EHR system, with each individual physician and department entering data with their own preferences. This brings disparity and differences in quality for EHR stored (Stanford Medicine, 2018).

For patients with chronic diseases, it is difficult to consult different levels of healthcare service providers with scattered medical records at different medical institutions. There is greater interest for patients to access information from hospital records and carry convenient, patient controlled portable records. Personal health records distinct from electronic patient records maintained by the health care system patient portals; Personal health records are deposits of clinical data managed by patients (Bates & Wells, 2012, p. 2034). They may contain the same types of data as hospital maintained medical records such as medical history, diagnostic test results and clinician documentation (Dameff et al., 2019, p. 339). Telehealth solutions offer a change to patients for such services.

Doctors on the other hand, find EHR input a large part of their daily routine. The study conducted by Stanford medical school confirmed that EHR inputs contributed to physicians burn out and has stood in the way of doctor-patient communication (Stanford Medicine, 2018). 44% of all physicians surveyed says primary purpose of EHR is for data storage, with 8 % of physicians cited medical factors related to EHR (Stanford Medicine, 2018). One third of all physicians surveyed expressed hopes for financial information to be integrated in the system so that patients can weigh their cost options; the primary concern is still the interoperability problem, where data can become available for all parts of healthcare systems.

Health Level Seven International (HL7.org)[1] has developed the Fast Healthcare Interoperability Resources (FHIR), offering a standard data formatting and an API for exchanging EHR (Stanford Medicine, 2018). The FHIR has become popular with the healthcare community. Apple, for instance, has taken use of it and made it possible for consumers with IOS 11.3 beta to have medical information from various organizations organized into one view (Apple, 2018). These medical information covers allergies, conditions, immunizations, lab results, medications, procedures and vitals; consumers also receive notifications when data gets updated. By January 2019, 163 hospitals and clinics in the US have connected their EHR portal with Apple (Apple, 2019).

In China, the Ministry of Public Health has drafted the "Health Profile of Basic Architecture and

[1] "Health Level Seven International (HL7) is a not-for-profit, ANSI-accredited standards developing organization dedicated to providing a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services.", available at: http://www.hl7.org/about/index.cfm?ref=nav, last access September 2nd 2019

Data Standards (for trial implementation)" (BLED 2010 Proceedings et al., 2010). The new regulation set standards for five types of EHRs, namely the basic personal health information record, disease control record, maternal and child health record, medical services and community health record (BLED 2010 Proceedings et al., 2010). However, there exists no standard "Community Health Service Information Management System'. Most hospitals build their EHR systems based on the hospital information system (HIS). By 2011 in China, 120 EHR systems were fully in place and being used daily. Another 40 systems were on their way to completion, and 100 more were in the planning stage out of approximately 20,000 hospitals. As of 2014, half of all tertiary hospitals in China use their own EHR system, as do 30% of urban health centers and 20% of rural hospitals. (Pacific Ventures, 2016).

In Europe, the heterogeneity of the EHR system also became one of the largest barriers for accessing healthcare data across the borders (European Commission, 2019). The European Commission has started the public consultation in 2017 to address the issue. Following the consultation, the EC has adopted a recommendation on the exchange of electronic health record format. Several projects and initiatives have been carried out since then to promote cross border data exchange. The e-Health digital infrastructure framework has been implemented (European Commission, 2019) to facilitate the exchange of two types of data: patient summaries and electronic prescriptions. In the beginning of 2019, Finland and Estonia managed the exchange of patient information. By 2021, 22 member states are expecting to exchange the types of information (European Commission, 2019). In general, the northern European countries were the first to launch digital health initiatives with the southern European economies only recently started to launch the digital health platform. The market acceptance of smart health solutions, both with institutional customers (government and private sector) and with individual users vary significantly.

In Denmark, 98 percent of all healthcare records are exchanged electronically (Ministry of Health and Healthcare Danmark, 2017). Patients can access eSundhed.dk for information about the quality of healthcare services and make an informed choice about hospitals. The other website, Sundhed.dk provides patients with a few personal services and data such as patient records from hospitals (e-journals), as well as general information on health, diseases, and patient rights. With mature IT support, it is relatively easier for doctors to perform tele-medicine treatment to manage chronically sick patients, offer adjustment for medication, and advice for diet and exercises. For instance, the recent program run in Denmark for chronic obstructive pulmonary disease (COPD) patients has successfully reduced hospital admission rate, with tele-medicine proves to be less time consuming than regular visits to hospitals. The other programs intend to assess the wounds for 70 percent of all patients in Denmark by tele-medicine. Trained nurses tend to the wounds at home or at local health clinics for patients, take a picture and upload the picture to the online patient records for doctors at the hospitals to assess. The program reduces hospital admission days, saves the time for healthcare professionals and transportation time for patients. From the Danish experiences and business model analysis for leading Telehealth product and service suppliers, the following can be summarized about developing a successful Telehealth system (Ministry of Health and Healthcare Danmark, 2017).

Germany is the biggest healthcare market in Europe (GTAI, 2017). There is a wide acceptance of fitness tracker for lifestyle improvement such as nutrition monitoring, calorie control, and sleep tracking, with 31 percent of all German population using wearables to track their bio-metric signals (GTAI, 2017). The integration of smart health solutions in the primary level of healthcare brings huge market potential. The main hurdle for implementing such solutions in Germany is the strict market regulation (GTAI, 2017). The insurance industry is cooperating with startups and managed to reimburse the use of several healthcare apps. One of the largest health insurance firms in Germany, Barmer, for instance, has co-developed the app "Hearing Test" with Mimi Hearing Technology to help youngsters to test their hearing ability at home with headsets. The German Federal Institute for Drugs and Medical Devices (BfArM) oversees differentiating medical apps and fitness and life style ones (BfArM, 2019). The German Medical Device Act and the European guidelines apply to the classification of the app (GTAI, 2019). Once considered as medical apps, the software and apps are subject to the same rule as regular medical devices. The medical apps will then need to follow CE marked and EU guidelines (GTAI, 2019). The German smart health market bears market value of 2.967 billion in 2017 (GTAI, 2019).

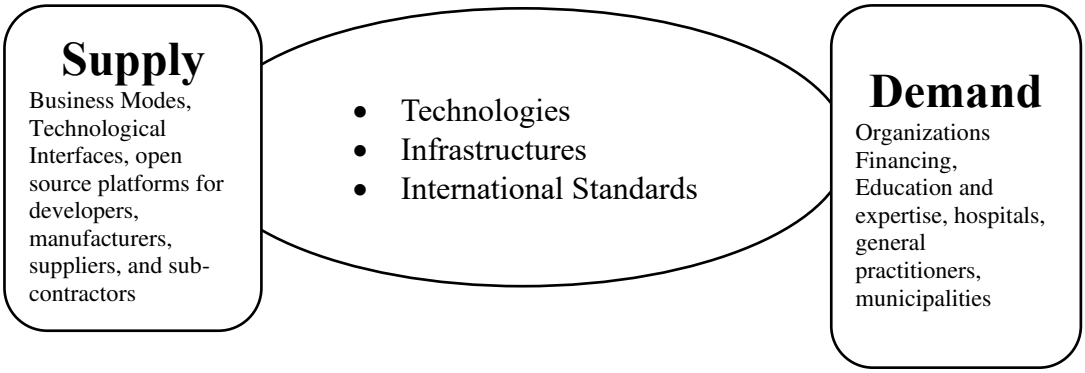


Figure 1.1: Smart Health Ecosystem, Source: Kyng et al, 2019, pp 1

In Italy, there has been attempts to launch the national digital heath strategy since the 2014. In 2017, the government launches the «three-year plan for digitalization of the public administration » (AgID, 2018). The policy initiative aims to improve healthcare service quality, take control of waste, improve healthcare cost efficiency, and lower health service inequality between different regions in Italy (AgID, 2018). There are three projects associated with the digital health initiative proposed by the «the three year plan». The plan aims to build a EHR system which serves as the infrastructure for digital health solutions, a central e-health hub which serves as the sole interaction platform between patients and the public health administration, and a telemedicine system (AgID, 2018). The projects also aim to facilitate cross border data transfers for patient summaries and the e-prescriptions following the EC recommendation (AgID, 2018).

In China, for instance, regional hospital networks embedded with larger IoT networks such as smart city networks, centralized data processing centers, and cloud platforms now allow doctors to check patient electronic healthcare records online. Internet hospitals also allow patients to start

online consultation for second time visits (Wuzhen Internet-based hospital, 2018). Cloud computing has also made it possible to perform pandemic disease management, to make prediction for epidemic outburst and to analyze contributing factors for chronical diseases (Ping An Technology, China News, 2018). Ping An Health Cloud Computing platform has also expanded from collecting and organizing clinical data to provide medical resources management and medical cost management services by incorporating data from private and public medical insurance systems (Ping An Technology, China News, 2018).

The advancement of technology in healthcare has been reducing costs for healthcare, provides easier access to healthcare, personalize healthcare services, more precise and immediate treatment, and in general a greater role in doctor-patient relationship (Stanford Medicine, 2018). One of the positive changes brought by smart healthcare is reduced patient waiting time. Patient waiting time has been identified as one of the key factors by the WHO as one of the key indicators for a responsive healthcare system (WHO, 2003).

For instance, in China the waiting time mainly occurs at the hospital reception and admissions window and between the appointment time and the time patients are attended by doctors (Sun J, Lin Q, Zhao P, et al., 2017). Usually, Chinese patients need to endure long waiting time in hospitals for registration, checkups, payment; the observable change with telehealth solutions is a significant reduction of waiting time for treatment. The mobile payment and patient registration system connected to Wechat, a popular Chinese social medial software available for smart phone and computers with more than 1 billion users (Forbes, 2018), has significantly lowered waiting time for patients and promoted accessible healthcare (Forbes, 2014).

The mobile payment system has integrated patient registration, payment, and prescriptions distribution services. With Wechat, more than 13,3000 hospitals now allow patients to pay with their mobile devices; more than 22,800 hospitals offer patients online appointment system, and more than 38,000 hospitals publish healthcare related information via Wechat public accounts. (Tech Nodes, 2018; Financial Times, 2018).

Wearables with heart rate monitoring functions make it possible for patients with potential cardiovascular diseases to get prompt treatment. Recently, a patient in his 70s with intermittent palpitations observed paroxysms of tachycardia at rest on his fitness tracker. The patient then purchased an AliveCor Kardia device approved by the US Food and Drug Administration (FDA) to get single-channel electrocardiographic images on his smart phone. He recorded the irregular heartbeats with retrograde P waves. The patient's self-diagnosis was confirmed by subsequent 12 lead electrocardiographic recordings and received corresponding treatment (lp, JAMA, 2019). The newest model of Apple Watch is able to generate electrocardiographic recordings with the back and the bezel of the watch serving as lead I electrocardiographic bi-poles (lp., JAMA, 2019). Apple Watch 4 is designed to detect occult atrial fibrillation (AF) (Apple, 2018). Wearables now bear the potential to improve the diagnosis for cardiovascular diseases such as sporadic or occult AF. However it remains challenging for the physicians to analyze and interpret the information provided by the smart devices of patients. The reason is that the devices may generate false alarms and result in unnecessary further testing for the patients; one recent study for 100 patients with

cardiovascular AF conditions show that the devices algorithm categorized 34 percent of all recordings as unclassified even under direct observations (Bumgarner et al., 2018b, p. 2386). Applying diagnosis based on recordings generated by smart devices bears the risks for misinterpretation and inappropriate results, which can be problematic if devices are used in population with low prevalence of diseases.

To summarize, telehealth solutions bears huge market values, and great potential to improve efficiency and save cost in each stages of healthcare. There are still challenges for implementing smart healthcare solutions, the biggest one lying in lack of interoperability. Further challenges for large scale implementation of telehealth solutions in the healthcare process stands in data management, cybersecurity, regulation and financing.

## 4. Unmet needs for healthcare systems in China and in Europe

### *4.1 The general European healthcare system overview and implications for Telehealth*

The European healthcare system has been identify to be consisting of three types of healthcare system clusters:

Type I: a health service provision-oriented system which provides a large amount of healthcare service providers and offers patients free access to doctors;

Type II: a universal coverage system whereby access to health care is taken as a citizenship right and therefore equal access has higher the status of a social citizenship right and equal access to healthcare is of higher priority than free access and freedom of choice;

Type III: a low budget restricted access system where patients have limited access to the healthcare system due to high percentage of out-of-pocket payments and the fact that patients have to sign up for a family doctor and endure long waiting time (Wendt, 2009).

Among the three countries for case studies, Germany belongs to the first cluster, where the healthcare system is characterized by a high level of health expenditures, and the system receives a substantial amount of public funding (OECD, 2017). The portion of out-of-patient funding is moderate. There are also high level of out-patient care and a moderate level of inpatient care. There exists a large amount of autonomous self-employed doctors, offering a high level of choice for patients. Denmark and Italy belong to the universal coverage group, whereby the healthcare system incurs a medium level of total health expenditure. The share of the public health spending is high while the out-of-pocket funding is moderate. Compare with the previous group, the inpatient healthcare providers are similar, but the outpatient provider level is low. Access to doctor is highly regulated, while doctor face high level of regulation for additional income opportunities (Wendt, 2009). Graph 1 describes the healthcare spending from 2012 to 2016 in Denmark, German and Italy from 2012 to 2016. This correlates with the population aging trends in the EU as shown in Graph 2. The European Union average life expectancy at birth is 80.62 years in 2016 with age dependency ratio reaching 54.39% in 2017 (World Bank, 2018).The following graph shows the

age dependency ratio comparison between the EU and China. Both economies are marching into the age of aging with aging at a more intensive pace in the EU.

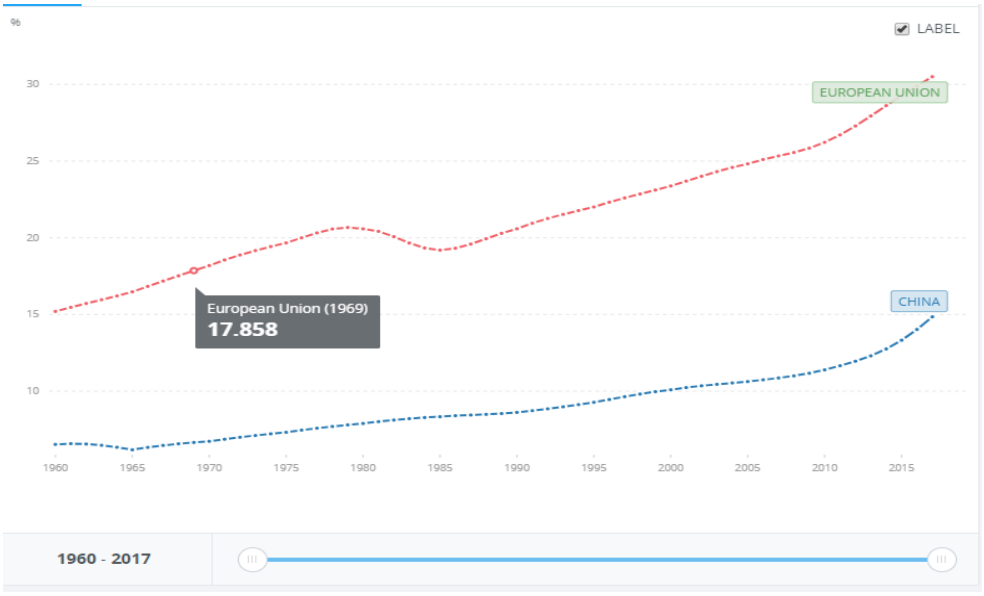


Figure 1.2 Age Dependency ratio (old) European Union and China, 1960-2017
Source: World Bank, 2018

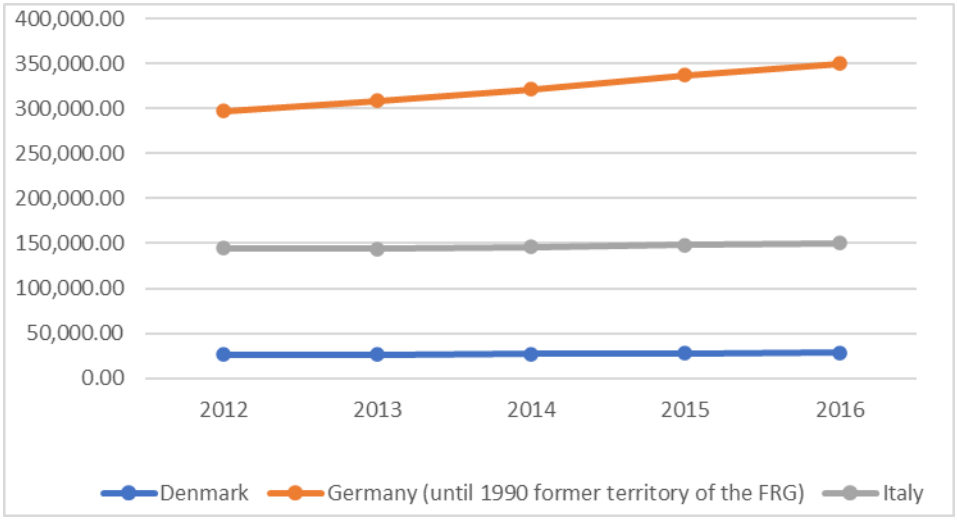


Figure 1.3 Healthcare expenditures in Germany, Italy and Denmark, 2012-2016
Source: Eurostat, 2019

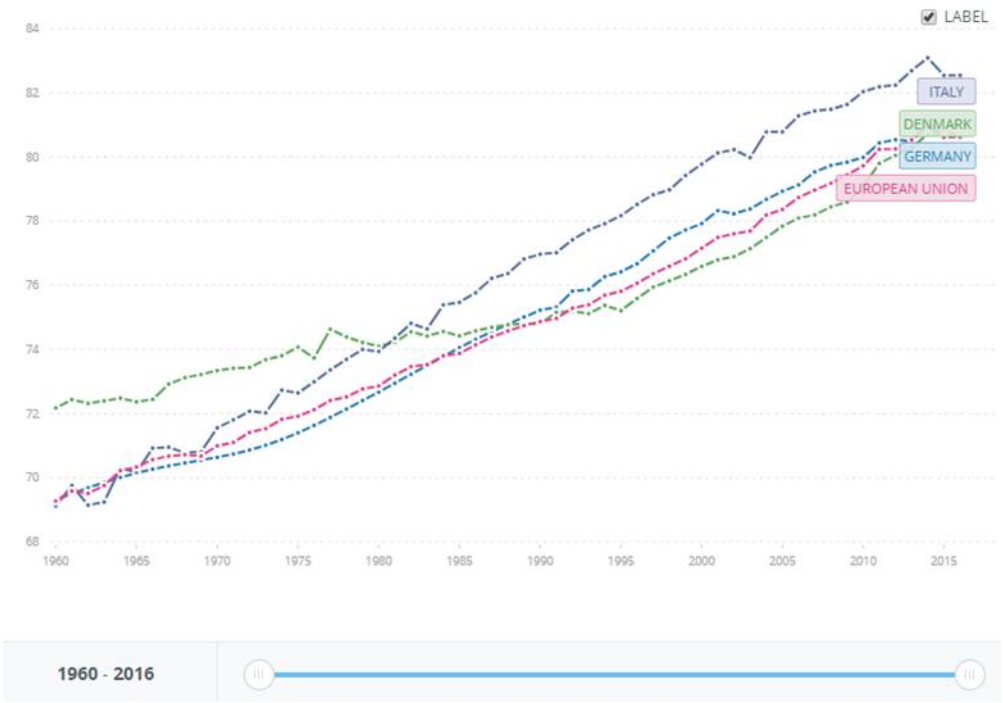


Figure 1.4: Life Expectancy in Germany, Denmark, Italy and the EU average, Source: World Bank, 2018

Strong primary care is supposed improve the capacity of a country to establish a responsive, high quality, and cost-effective healthcare system. The primary level of healthcare structure consists of the primary care governance, economic conditions for primary care, and primary care workers development (Kringos *et al.*, 2013).

The primary care process regards the primary healthcare accessibility, coverage scope for primary level of healthcare, continuity of primary level and coordination of primary care (Kringos *et al.*, 2013). In the EU 27 member countries, Belgium, Denmark, Estonia, Finland, Lithuania, the Netherlands, Portugal, Slovenia, Spain, and the UK are identified to be equipped with strong primary care system (Kringos *et al.*, 2013). Germany shows weak coordination role of primary level healthcare while Italy shows weak coverage scope on primary level of healthcare. GPs in western European countries generally earns more than eastern European countries.

Countries with strong primary level usually show the following characteristics,

First of all, the primary level of healthcare is the main point of entry for the rest of the healthcare system. The majority of the countries have enacted national policies to ensure access to primary care both geographically and financially. The first contact point of the healthcare system can also be nurses, where a supplementary policy can enhance the accessibility of the healthcare system.

Secondly, the primary care system takes a medical advocacy role for individual patients, which monitors prevention, diagnosis, treatment, and other follow up activities.

Thirdly, the primary level of healthcare takes up the coordination role within and outside primary level of care.

The fourth characteristic for countries with strong healthcare system has strong commitment for universal access to primary level healthcare; all countries have lowered co-payment ratio for primary level of healthcare as much as possible; policies ensuring accessibility for lowest income group, the elderly, patients with chronical conditions or disabilities, children and pregnant women have been designed. For access for medication, a co-payment system has been developed with insurance system offer deductibles.

The European healthcare policy making is heavily guided by the principle of subsidiary (Jakubowski & Busse, 2002). With the global financial crisis in 2008, the governments in Europe are struggling between austerity measures which cut government budgets and increasing healthcare costs due to increasing portion of the aging population with chronical diseases. With the healthcare budget tumbling and growing healthcare demand from the population, policy makers in Europe are trying to find a way to improve healthcare quality while taking control of healthcare budgets. Several European countries are trying to implement the value-based healthcare system, trying to taking a look at the healthcare system as a whole. There are several challenges however to implement the value-based healthcare model; firstly, there lacks detailed data on healthcare outcomes across the care cycle; secondly, there is growing pressure for new pricing models, especially in terms of medications and medical devices; fourthly, there needs to be mechanisms to ensure the most vulnerable group of the society have access to healthcare (Economist Intelligence Unit, 2016). So far in Europe, there are many pilot programs running at individual healthcare institutions for value-based healthcare model; there has also been greater focus on the impact on the spending on pharmaceutical and technology on general population. There is greater collaboration for developing the European Network for Assessing Health Technology Assessment, to better evaluate the cost effectiveness for policy makers to make precise decisions(Economist Intelligence Unit, 2016). There are also needs to improve government – industry collaboration to maximize the value of investment on health-technology. The remains the need to ensure accessibility of the healthcare system, a problem for countries with weak primary level of healthcare.

The Internet of Healthcare Things can potentially monitor patients closely over the whole care cycle, and therefore offers a good opportunity to identify best practice in the healthcare system to establish benchmarking for healthcare services, to ensure all team members follow the same protocol, to share data across different layers of healthcare so as to ensure the continuity of healthcare services, and to promote access to healthcare services by providing online consultation. By collecting large amount of data and use algorithms to detect patterns in the data, it is easier to detect early stages of chronical diseases before the symptoms even appear (Kaminsky, 2019); it is also easier to provide better treatment with the established protocol and follow ups on patients on whether they follow the clinical pathway. Therefore, integrating telehealth solutions with the value based healthcare system can potentially lower healthcare cost, improve healthcare quality and efficiency.

#### *4.1.1 Demark*

The Danish healthcare system operates with three administrative levels, the national level, the provincial level and the local level. The state is in charge of regulatory and supervisory function, the five regional administrative care systems are responsible for hospitals, GPs and psychic care. The municipalities take care of a number of general practitioner services and elderly care (Ministry of Health and Healthcare Danmark, 2017). Generally, all healthcare services are paid by general taxes, and are supported by the central government grant, reimbursement and equalization schemes. Public finance provides 84 percent of all healthcare expenditures while the rest of 16 percent of healthcare expenditures are funded through patient co-payment schemes in 2015. Healthcare costs accounts for 30 percent of total public expenditures and 10.6 percent of GDP in 2015, which is higher than average 9 percent of GDP in OECD countries (Ministry of Health and Healthcare Danmark, 2017).

All residents in Denmark have access to healthcare, with most of the services are offered for free. National legislation ensures diagnosis and treatment are offered within certain time limits with patients have the right to have a free choice for hospitals. Residents in Denmark may also seek treatment from abroad if treatment were not offered in Denmark upon approval; treatments received in other European Union (EU) / (European Economic Area) EEA countries are also entitled for reimbursement. Patients complaints and compensation for injuries incurred in the treatment procedures are guided by a specific set of rules (Ministry of Health and Healthcare Danmark, 2017). Every year, over 25,000 patients are invited to participate in patient empowerment programs whereby the differences in patient experiences are compared, input for quality improvement is collected, development for patient experiences is evaluated over time. There is also survey targeting at elderly who receive treatment at home or at elderly care facilities, the elderly is asked whether they feel self-sufficient after receiving the services and whether they know their right to choose their own service provider. There are two websites where Danish residents can get information about the healthcare qualities and make an informed choice about hospitals; patients can also access their personal services and patient health records online.

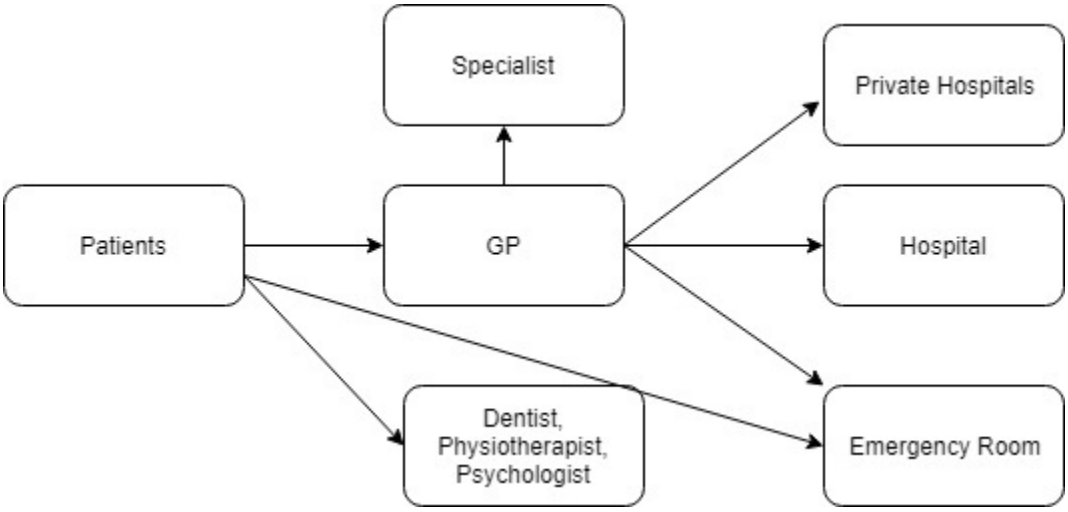


Figure 1.5. Danish Health Care System Structure, Source: Ministry of Health and Healthcare Danmark, 2017

99 percent of all residents in Denmark are registered with a GP under insurance scheme 1. In this case, they have the right to go to a private practice for specialist treatment with referral from the

GP. Patients registered in insurance scheme 2 can go to any GP or private practice as they want without a referral, however they may need to pay under the co-payment scheme. The Danish senior healthcare policy aims to promote and extend the independency of senior residents, and to ensure their self-sufficiency and wellbeing (Ministry of Health and Healthcare Danmark, 2017). The municipalities provide home care and nursing home services free of charge for seniors. The municipalities are also responsible for preventive healthcare measures for senior citizens, including organized social activities, physical training facilities, and other volunteer activities. Home visits are also offered for senior residents whenever they need; for seniors more than 80 years old, the visits are offered on an annual basis.

As life expectancy in Denmark has gone from 77.9 years in 2005 in Denmark to 80.7 years in 2016 (WHO, 2018), the number of patients suffering from dementia is an increasing problem in the aging Danish society. By estimation, around 80,000 people in Denmark suffers from dementia. There has been initiatives and efforts to promote the early detection and precise diagnosis for patients with dementia. The objectives are to make sure Denmark become a dementia patient friendly country where patients can live a dignified life, to treat patients with dementia according to their needs and values in a coherent way to ensure early detection and alignment with the latest technology and research. The other objective is to offer relatives enough support and make sure they are fully involved in the process (Ministry of Health and Healthcare Danmark, 2017). Other than dementia, patients suffering from chronical diseases such as diabetes, arthritis or lung disease have increased. By estimation, there are a million people in Denmark today suffering from chronical diseases (Ministry of Health and Healthcare Danmark, 2017). The two most common chronical diseases in Denmark are diabetes and compulsory obstructive pulmonary disease (COPD); the Danish government has developed an action plan aiming for early detection and treatment for the patients; it also aims to ensure all patients receive comprehensive high-quality treatment regardless of their geographical location. The action plan also aims to make sure patients are aware of what to expect after the diagnosis, thus promoting patient participation in the treatment, management of the disease and patient empowerment.

The Danish healthcare system is highly digitalized, with digital communication between healthcare providers, systematic data use and digitalized working procedures. Public hospitals and GPs in Denmark are able to keep contact with patients over a long period, which makes it possible to perform large scale data monitoring and analysis. The records stored in the national patient registration and medication databases make it possible to monitor patient compliance. The common data sharing standards make it possible for GPs, hospitals, labs, elderly care facilities to share data with one another (Ministry of Health and Healthcare Danmark, 2017). In Denmark, all GPs keep electronic health records, and 98 percent of all exchange records electronically. GPs also receive test results from labs electronically, with 99 percent of GPs send prescriptions to the pharmacies electronically. All 97 percent patients are referred to the hospital electronically and all patients are referred to specialists and psychologists electronically (Ministry of Health and Healthcare Danmark, 2017). There have been efforts to increase the interoperability for the current E-Health system. The vision is to support a cohesive system where exchange of information between different service providers can go on smoothly.

Regarding the value-based healthcare system, Denmark has been a forerunner in the field. The linkage between different levels of patient registration system, and biobanks allow rich data to be used on research and improvement of healthcare services. There has been a national level of reform measures calling on utilizing all the data and create better strategy for transparency and monitoring

for health outcomes and results. The vision aims to offer better healthcare services through through systematic monitoring and benchmarking of results and outcomes, and encouraging better services by setting higher standards; secondly, the results-oriented treatment will focus on provide precise diagnosis and early intervention based on risks predicted by the data for certain segments of population. Thirdly, the system aims to compare healthcare quality across the healthcare system by comparing key patient information regarding accessibility and quality of the healthcare services including waiting time and outcomes, waiting time and outcomes. The program also aims to promote management style based on systematic data analysis for health outcome benchmarking whereby the system is rated on outcomes and efficiency. As part of the program to establish a more efficient healthcare system, in 2014 a four-year program was launched to create better health through better use of data. To achieve this vision, the Health Data program focuses on establishing new data model and user interface to promote better data use for healthcare professionals, researchers, governments and citizens, on modernizing the IT structure for the national healthcare system, on enhancing data quality to improve data validity and reliability, on supporting cross-sectional data cooperation (Ministry of Health and Healthcare Danmark, 2017). For combating COPD, Denmark aims to implement the telemedicine solutions for chronical ill patients at municipalities and regions by 2019 by closely monitoring their key indicators such as oxygen level, heart rate, weight, and blood pressure for a couple of weeks; the results are then sent to the local hospitals for analysis, and to adjust medication if needed. The system aims to ease the patient's life by letting them know how exercise and diet can change heart rate and blood oxygen saturation level. The project reduces the number of hospital admission days and telemedicine is more efficient than ordinary treatment methods.

In summary, Denmark has led in the transformation to the value-based healthcare system with its deeply digitalized healthcare system; data is key for closely monitoring patients throughout the care cycle, establishing health outcome benchmarking, sharing the benchmarking for healthcare professionals across the system, and for efficiently adjusting treatment for patients. Establishing a high-quality data collecting and data sharing platform plays an important role for the value based healthcare system.

#### *4.1.2 Germany*

The German healthcare system is characterized by universal coverage of insurance for a wide range of services (Busse et Blümel. 2014). The system holds a strong solidarity principle whereby treatment is offered regardless of financial status of the patients or the premium paid and the morbidity risks ( Ridic et al., 2012, p. 112; GKV, 2019); the principle of benefits ensures the benefits without the up-front payments for the insured Residents are also free to choose the services and insurance plan service providers (GKV, 2019). The system offers a network of excellent service providers, private and public. The 'Bismark' model of social insurance system has extended sick benefits to all low wage workers since 1871. After the Germany reunification, all 16 provinces ("Laender") carry an independent healthcare policy on a large extent.

All citizens in Germany are now required by law to have health insurance, with more than 90 percent of the population are covered by the state statutory insurance system. The rest of the 10 percent are covered by private insurance or government schemes for students, police force or special assistance. Only those with annual income more than 576,000 Euros are entitled to choose private insurance. The state insurance funds are formed with contributions from both the employers and employees; the uniform contribution rate for all insured were introduced since 1st

of January of 2009. A tool to decide the supplementary premiums for individual insurance funds was also introduced in 2009. Private insurance, however function based on the equivalence principle, where the premiums are determined by the benefits and risk agreed upon; in this case, higher premium plans usually cover more services and offer a higher level of reimbursement for treatment such as dental treatment costs.

As funding administrators for the statutory health insurance funds have the right for self-governance by elected members of employers and the insured. The self-government via negotiations with healthcare providers shape a large part of the healthcare system in Germany. The National Association of Statutory Health Insurance Physicians, the National Association of Statutory Health Insurance Dentists, the German Hospital Federation, the National Association of Statutory Health Insurance Funds forms the Federal Joint Committee. The Committee decides on the benefits included in the statutory health insurance (GKV, 2019). The benefits include outpatient care provided by doctors working in private practices, inpatient care, home care, preventive services, and visits to spas, etc. The contracts between the statutory funds professional organizations and the regional statutory health insurance funds regulates the inpatient care (Obermann, 2013). The main actors in the German system is thus the physician professional organizations such as the National Association of Statutory Health Insurance Physicians, rather than the insurance companies, nor the individual physicians.

Despite the large scale of autonomy for patients and professional autonomies, the government intervention for the healthcare reform is extensive. The federal government in Germany passes legislation for healthcare policies and jurisdiction. The individual state is responsible for hospital planning, managing state hospitals, and supervising the statutory insurance funds, and the doctor associations. Local governments manage the local hospitals and public health programs (Ridic, Gleason and Ridic, 2012). When the utilization rate is higher and the fees are lowered proportionally. The government is deeply involved in the cost cutting reforms. There are several legislations and acts since the 1970s regarding cost control and healthcare quality control; high and rising costs and overcapacity and low reimbursement level leading to over utilization of services and costs with no improvement in healthcare outcomes. It is noticeable that among the three chosen countries, Germany has incurred the highest amount of healthcare costs in real terms and in relativity of GDP, as described in graph 3. For instance, in Germany, 300 hospitals cover the 18 million people in North-Westphalia while in the Netherlands only 70 hospitals cover the same population. The current reform, however, has been focusing on shutting down hospitals and reducing the number of doctors rather than optimizing the existing resources (EIU, 2015). In general, there exists large variation in inpatient and outpatient treatment. For outpatient treatment, primary level doctors do not have such a strong role as it is in Denmark. Patients can visit a specialist without referral from a family doctor; the primary level healthcare do not play a strong role in coordinating the care process as the healthcare system itself is quite fragmented. Different service providers vary greatly in the service qualities.

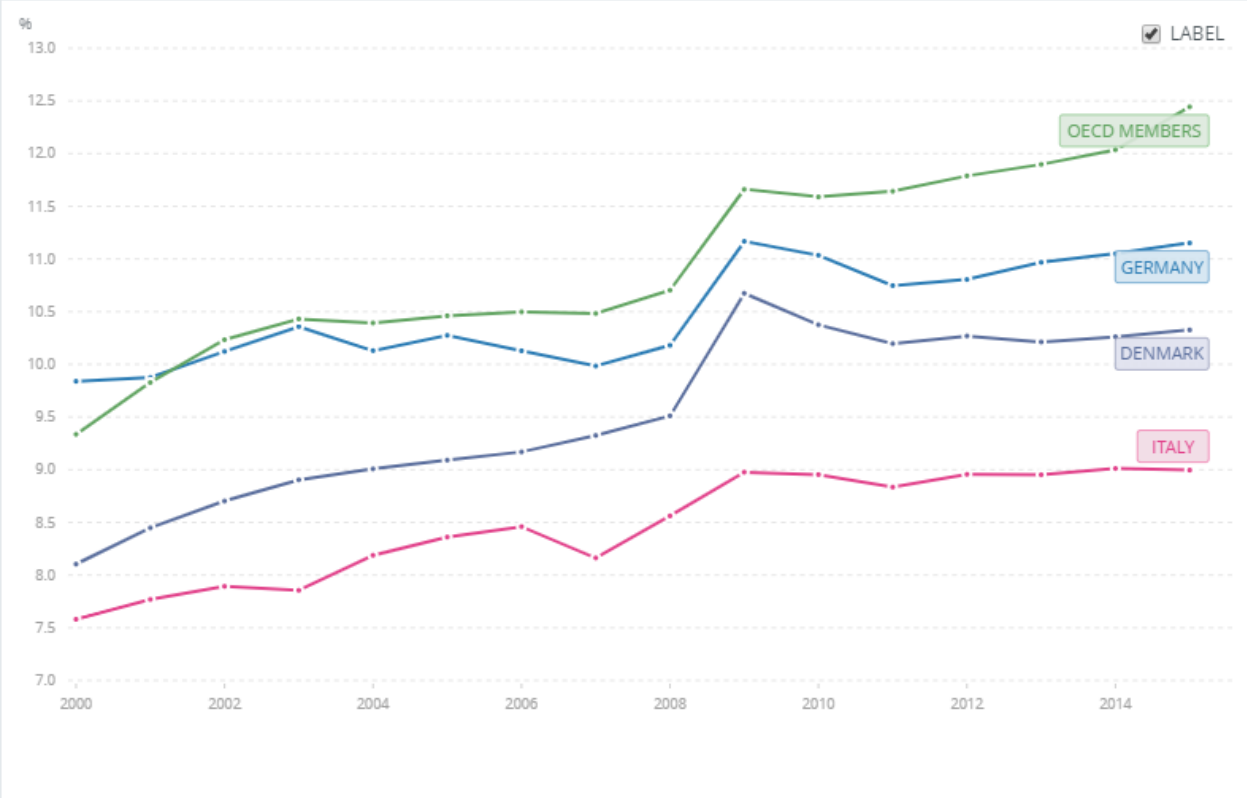


Figure 1.6 Healthcare expenditures as percentage of GDP in selected EU countries and OECD member states, Source: World Bank, 2018

Currently, the Statutory Health Insurance system encounters several challenges brought by the changing structure of population, the first major challenging the declining amount of contribution to the insurance system, with high-income groups migrating to the private insurance system and a drop in the population liable for compulsory insurance; secondly, the aging population is driving up healthcare costs; thirdly, the income portfolio of the households became less wage dependent. With the advancement of technology, the inefficient structure of the healthcare system, and the fast-rising cost for certain sectors are all driving up costs for the healthcare system. The following chart suggests that hospital incur the highest amount of cost in the German healthcare system. Data suggests that from 2003 – 2013, inpatient care accounts for around 32 percent of public health expenditures, while outpatient care costs around 23 percent of public health expenditures, with pharmaceuticals and other medical non-durables costs around 15 percent health expenditures (European Commission, 2016).

There are several reforms targeting rising healthcare costs in Germany and an initiative to develop e-health system. The reforms focus on changing the traditional holistic approach, whereby the health system focuses on collective goals which are to a large extent monetary. Quality evaluation are based on economical results, with individual patients are categorized into a specific group. The management is mainly based on a top-down approach. The new scheme intends to determine the appropriate resources depending on the individual patient-physician relationship. Healthcare expenditures are made based on the perceived responsibility for the individual patient which aimed at optimal result with appropriate cost(Obermann., 2013).

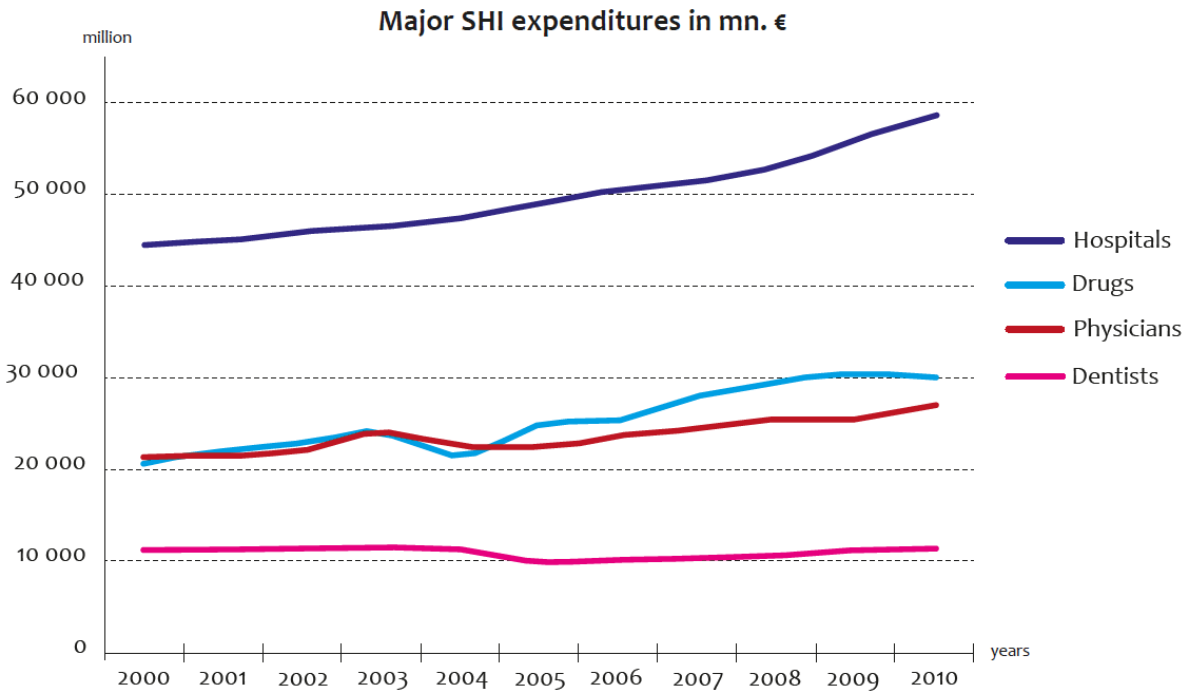


Figure 1.7 Major Statutory Insurance Spending in Germany, 2000-2010, Source: Obermann., 2013, p.85

The E-Health in Germany is supposed to contribute to better medical care provision, to improve communication among all parties involved and ensure great efficiency in the healthcare process (European Commission, 2016). Obermann et al has identified the following stakeholders for the implementation for the E-health solutions, which include all actors in the public healthcare system, including insurance companies, physicians, dentists, pharmacists, hospitals. An important project in Germany for expanding E-Health in Germany is the introduction of a E-Health card. Patients can choose from 2018 onwards to store their emergency medical information, electronic medication plan and electronic health records (Obermann et al., 2013; European Commission, 2016; AOK, 2018). Gematik, the system constructor ensures the electronic health records contain information regarding discharge letters, medication history, emergency medical data maintained, examination images by healthcare professionals. From 2019 onwards, patients have the option to log their own data such as heart rate or blood glucose level in the e-health folder on the card (European Commission, 2016; Obermann et al., 2013; AOK, 2017). 75 percent of the German population with 93 percent of the population with chronical disease conditions are willing to send data on their vital signs to the doctor (Bitkom,2016; Rinbeat, 2018). One third of the German population are already using wearables not just for monitoring sports activities, but also for vital signs monitoring. This suggests that there is a large demand side request for telehealth solutions to get implemented (Rinbeat, 2018).

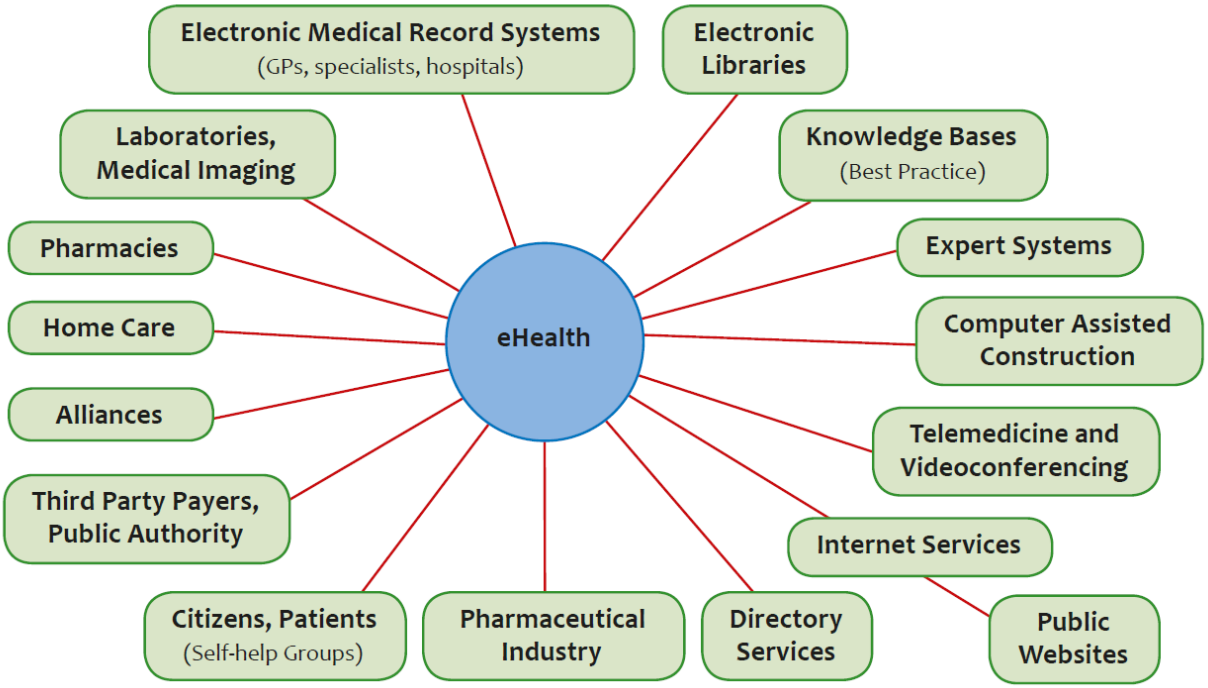


Figure 1.8 Stakeholders in the German Healthcare System for implementing E-Health solutions, Source: Obermann et al., 2013, p.121

To summarize, the smart healthcare solutions are closely linked to empowering the patients, and change the traditional top-down management approach to distribute healthcare resources in the German healthcare system. The top-down approach has led to over-utilization rate of medical resources. Telehealth solutions can potentially link doctors, hospitals, pharmacies and insurers, thus allow streamlining of administrative tasks and cost reduction. Access to patient's medical history, previous examinations can make diagnoses and treatment more precise and faster. Patients have the right to decide the data to share with the doctors on their health folders (Obermann et al., 2013). There are other challenges for the German health system, such as the enhancing the capacity and use of GPs in the healthcare system, promoting healthcare spending efficiency. Evidence shows that using wearables can reduce hospital costs by 16% over 5 years (Rapid Value Solutions, 2014). Given hospital costs consists the largest part of the German healthcare costs and are rising at a faster pace than physician costs and drug cost, it is worth to study how to implement smart health solutions to reduce hospital stay, promoting patient self-care, thereby reducing healthcare costs.

### *4.1.3 Italy*

Italy is an interesting case for study given the north-south differences on economic development level and thus diversification on health service quality. The Italian health system is decentralized to a large extent, with most regions manage the organization of healthcare; the national level only has limited amount of power (Cicchetti and Gasbarrini, 2016). The state has full control of the core benefit package, but evidence shows the service quality varies greatly by regions(Cicchetti and Gasbarrini, 2016). The Italian national health service (NHS) is organized at national, regional and local level (European Commission, 2017). The Ministry of Health takes a stewardship role in the

healthcare system, determining the core benefits packages, and allocating budgets to regions (Cicchetti and Gasbarrini, 2016). The regional healthcare authority is responsible for delivering community, primary care, specialist care with physicians or public hospitals or approved private practices(Cicchetti and Gasbarrini, 2016).

The decentralization is based on the idea that localization can be the best option to meet local healthcare needs (Cicchetti and Gasbarrini, 2016); Due to decentralization policies, different regions show large divergence on public resources available for healthcare because of the choice they made about . For instance, northern and central regions have higher healthcare capacity, more advanced technology and better perceived quality of care than southern regions. In the end, patients flow from the south to the north for better treatment. Almost 30,000 patients leave the area of Campania, Calabria and Sicily per year for better quality of care in the north (Ministry of Health, 2011). The healthcare spending in southern regions, such as Campania spent more than 40 percent less than national average spending on health in 2016 (Ministero dell'Economia e delle Finanze and Istat, 2017).After the financial crisis of 2008, there has been calls to recentralize the healthcare system. As a result, half of the regions report deficit in the health sector (European Commission, 2017).

In comparing the other European countries, the out-of-pocket spending ratio for Italian residents are high, even though the Italian healthcare system provides universal healthcare coverage to those with a residence permit (European Commisson, 2017). 23 percent of healthcare expenditures in Italy are paid out of pocket, compared to EU average 15 percent in 2015. Primary and inpatient care are free, while co-payment are applied for specialist visits with GP referral, on diagnostic procedures and on medications (European Commission, 2017). Because of austerity measures after the financial crisis, patient out of pocket payment ratio has been rising. The system has proved to be pro-rich for specialist visit, diagnostic procedures and basic medical tests while pro-poor in primary care. Possible reason are for those in higher social – economic class, health literacy level is high while free primary care, long waiting time and low quality services in southern regions are driving higher income population to private healthcare services (European Commission, 2017). Private healthcare expenditures in rich regions such as Bolzano, Lombardia, and Valle de Aosta is two times that of the poorer regions in Campania and Calabria (European Commission, 2017).

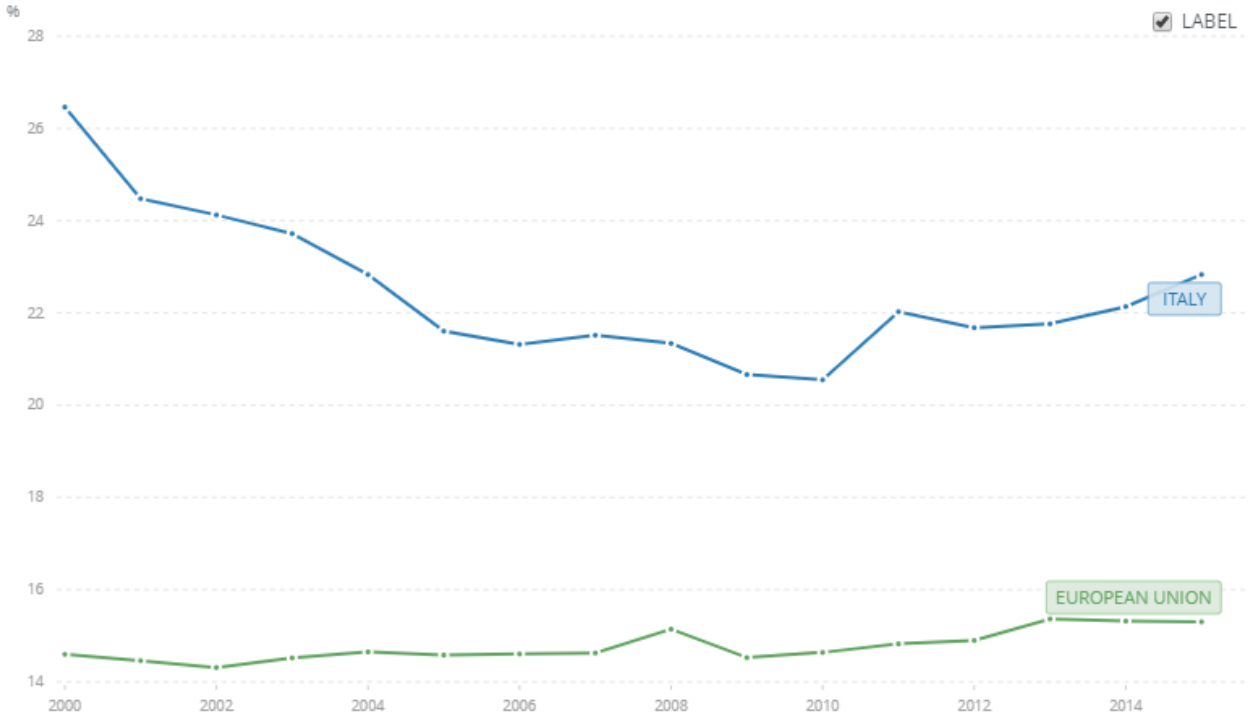


Figure 1.9 Out of Pocket Payment Expenditure in Current Health Expenditures, Source: World Bank, 2018

Aging has become an issue threatening the financial stability for the healthcare system. Italy has become one of the oldest population in Europe, with an age dependency ratio (old) of 37 percent in 2017 as shown in graph 9. In 2016, public health expenditures accounts for 75 percent of all healthcare costs (in equivalence of 6.7 percent of GDP), while total healthcare expenditures accounts for 8.9 percent of GDP (Istat, 2017). Hospitals costs consist of 45.5 percent on total healthcare expenditures, while outpatient care costs 22.4 percent of all healthcare expenditures (Istat, 2017). In the long term, as aging intensifies the population with one or multiple chronic condition will rise. This will bring a burden to the healthcare system.

For the electrification of the healthcare system, Italy lags behind on wide use of exchange of data via internet and offering e- prescriptions. Only 3 percent of GPs send administrative data to other care providers with internet, and only 1 percent of GPs use e-prescriptions (Ferré et al., 2014). In some regions, pilot programs have been running for implanting E-health solutions. The collection of administrative data and patient history on electronic patient records have been deployed in Lombardy and Emilia Romagna (European Commission, 2019b). In Emilia Romagna, the project 'SOLE – Online Healthcare' has aimed to develop an integrated network for hospitals and physicians, including the function for offering e-prescriptions for patients. The 'Renewing Health' European funded project in Veneto region supported by EU funding targeted the adoption of telemedicine services for chronical sick patients with COPD and diabetes (Renew Health, 2009).

However, it remains challenging for wide adaptation for telehealth solutions. The delivery of healthcare and decision making are on regional level with quality, financial resources, priorities

varied. There are two areas whereby Telehealth solutions can contribute; firstly, Telehealth can facilitate establishing a national level for evaluating healthcare quality, therefore providing a more efficient use for public spending on healthcare. Secondly, Telehealth solutions can help to promote access to healthcare, reduce waiting time, and improve healthcare quality on primary level of care. This requires long – term dedication to the Telehealth initiative, where Italy stands at a preliminary level. Currently, there are two national level policies targeting promoting smart health. The first initiative is the implementation of the New Health Care Information System (NSIS, Nuovo Sistema Informativo Sanitario), an information system to supervise all primary level of healthcare services. The second initiative is E-Government Plan 2012, which aims at developing online solutions, EHR systems, and offering e-prescription system for patients. The effects for the initiatives are yet to be evaluated(Ferré et al., 2014).

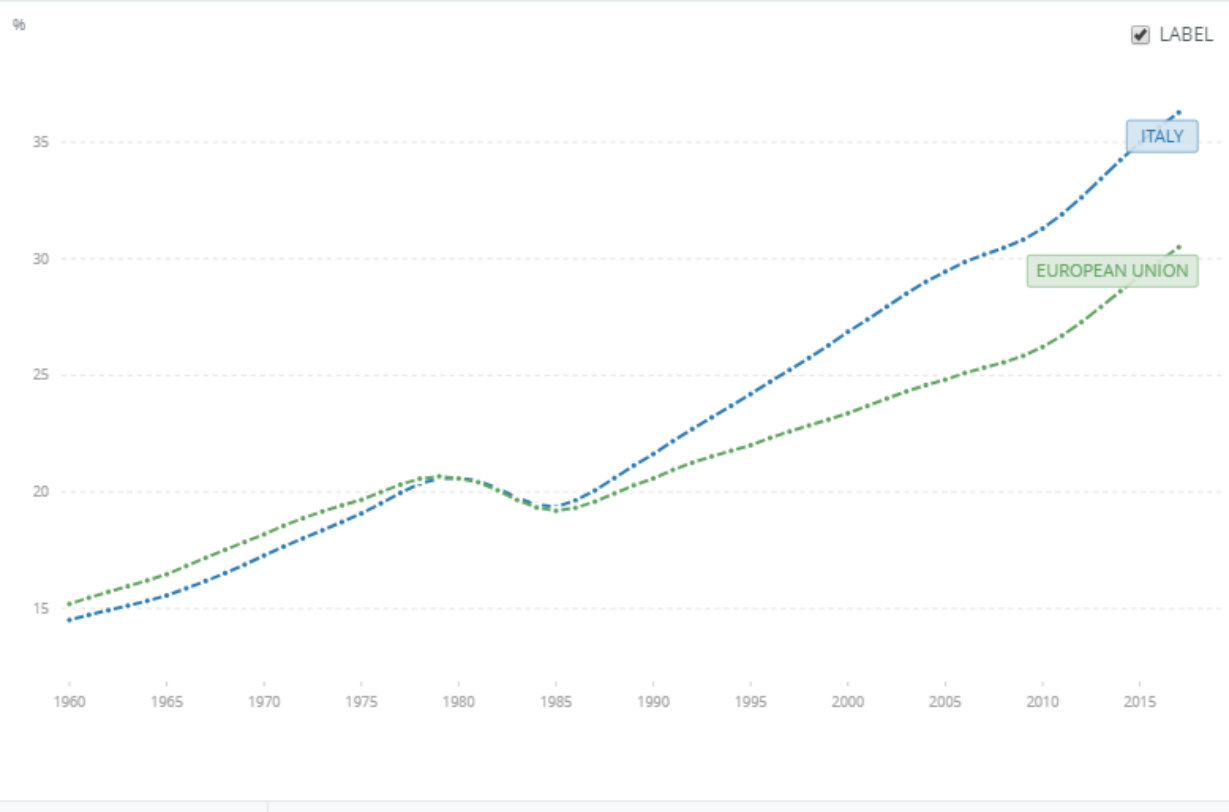


Figure 1.10: Age Dependency Ratio, Old in Italy and European Union, Source: World Bank, 2018

### *4.2 Challenges for the Chinese healthcare system and implications for Telehealth*

#### *4.2.1 Challenges for the healthcare systems in China*

The majority of inpatient and outpatient care in China are preformed by public hospitals, in which level III and II hospitals account for most patient visits (National Health Commission, 2018). The designated family doctor services, which fall into the jurisdiction of urban community care centers and rural village clinics play a limited role in the diagnosis and treatment process (SCMP, 2019).

For outpatient care in China, the key problem is long patient waiting time (Sun et al, 2017). Patients prefer public hospitals for better facilities, services, and qualification of doctors(Mckinsey, 2010). From living in China for 23 years, generally, in a hospital, patients wait in several queues for registration, paying for treatment and getting prescribed medicine separately. In the case whereby doctors find it necessary to perform diagnostic such as MRI scan, or X Ray, patients need to wait in the queue to pay for the diagnostic tests. After payment, patients can take the receipt to the nurse station and get a number for the test. Finishing waiting for the number to be called and tests are performed, patients can take the receipt back to the doctor for interpretation. If lucky, the process can take up to half a day or one day with patients go home with a large bag of medication prescribed by the doctors (SCMP, 2019). The public hospitals will only suffer from the aging population and intense patient-doctor relationships.

The growing demand from the aging population for high-quality medical services has prompted tech companies to work together with healthcare institutions to develop new healthcare models. For instance, Alihealth works hospitals to improve diagnosis accuracy (Alihealth, 2019); patients can now register for doctor appointments via the Alipay app. Tencent works to develop a family doctor service app and has acquired clinics, offering patient reliable primary care services; Tencent has also invested in Wedoctor platform, making it possible for patients to register for primary care services over Wechat (Reuters, 2018). Huawei has worked with hospitals to develop heart rate monitoring wearables (Huawei, 2019). Xiaomi developed Mi Band to monitor user sleep patterns (Xiaomi, 2019).

For inpatient care in China, hospitalization is expensive, particularly for patients with no insurance coverage in rural and urban areas who need to pay out of pockets. Most hospitals are crowded for both in and outpatient care for the same reason that most medical resources, such as qualified doctors, advanced medical devices, useful medication can only be found in 'Tertiary Level Hospitals'. Both rural and urban patients in China have the incentive to go to the level three hospitals for diseases ranging from flu to cancer. This resulted in over use and burdensome hospitals and insufficient use of primary care centers, and other primary care facilities. The chart 1.4 describes the utilization rate for all levels of hospitals in China.

Table 1.4 Hospital bed utilization rate in China 2017; Source: National Health Commission, 2018

| **Year 2017** | **Number** | **Beds** | **Bed Utilization (%)** | **Number of outpatients (Billions)** | **Number of Inpatients (Millions)** |
|---|---|---|---|---|---|
| **Level III Hospital** | 2340 | >500 | 98.6 | 1.73 | 84 |
| **Level II Hospitals** | 8422 | 100-499 | 84 | 1.27 | 80 |

| | | | | | |
|---|---|---|---|---|---|
| **Level I Hospitals** | 10050 | 20-99 | 57.5 | 0.22 | 11.7 |

It is noticeable that the number of Level III hospitals and the number of out-patients treatment are non-proportional. This justifies long waiting time at the hospitals and patient complaints of poor services received, including seeing doctors for 2 mins with waiting time of half an hour (Lim, 2014).

The Chinese government has taken measures to ensure universal healthcare coverage. The Employee Basic Medical Insurance (EBME) covers all state-owned and privately owned firm employees on a mandatory basis. The Resident Basic Medical Insurance (RBMI) covers the rest of residents such as children, elderly, students, unemployed population; it operates on a voluntary basis. By the end of 2018, roughly 95 percent of the population have been covered by health insurance. However, medical expenses still account for a major expense for Chinese. The reason lies in the scope and the extent by which the EBMI, and RBMI covers remain limited. The following form describes the coverage scope for EBME, RBMI and New Cooperative Basic Medical Insurance (NCBMI). The NCBMI has been integrated with URBMI in some provinces to form the RBMI with the ongoing medical reform.

Table 1.5 Public Health Insurance Coverage in China 2016; Source: National Health Commission, 2018;

| **Domain** | **Category** | **Eligibility** | **Covered Population (million) by 2018** | **Coverage Cap (RMB), Ratio** |
|---|---|---|---|---|
| Public Health Insurance in China | Urban Employee Basic Medical Insurance （UEBMI) | Mandatory Basic Insurance,covered by employers and employees, annual premium $ 100-250 | 316.81 | Varies by region, Outpatient coverage:10-500,000 , Co-payment: Average 60% ; |
| | Resident Basic Medical Insurance (RBMI) | Voluntary Basic Insurance, for urban residents not eligible for UEBMI, Funded by government and individual, annual | 897.36 | Varies by region, Outpatient coverage: 0-500, Co-payment: |

| | | | | |
|---|---|---|---|---|
| | | premium $20-100 | | Average 50% |
| | New Rural Cooperative Meical Insurance (NRCMS) | Voluntary Basic Insurance, for rural residents, Funded by government and individual, annual premium $20-50 | 130 | N/A, because of ongoing medical reform, NRCMS is going to be intergrated into RBMI. |

The scope and the extent of refund for insurance scheme coverage varies by the location of the insured subject; for instance, the percent of contribution paid by employers for EBME varies by city. Take Wuxi-Jiangsu Province, Shaoxing-Zhejiang Province, Nanchang-Jiangxi Province, Guiyang-Guizhou Province for example, the payment cap for outpatient treatment ranges from RMB 50 to RMB 900 for regular diseases, the payment cap for catastrophic diseases ranges from RMB 80,000 to RMB 110,000 with insurance coverage ratio between 30%-100%. The payment cap for inpatient treatment ranges from RMB 35,000 to RMB 100, 000, with insurance coverage ratio ranges from 30%-100% As hospital costs rose while the percentage for out of pocket payment also increased significantly; the healthcare system has become more pro-rich; rendering rural residents subject to lack of reliable health care resources (Mckinsey, 2010).

This has left room for the smart health platforms operating in the business of pharmaceutical e-commerce platform, pharmaceutical self-operated business, tracking for authentic business, consumer health business. For one of the largest smart health business in the Chinese market – Alihealth, the online-offline medication and service sale has shown a year-on-year growth for 2018/19 financial year of 296.8% and 275.5% respectively (Alihealth, 2019).

Table 1.6 Healthcare cost structure in China 2017; Source: National Health Commission, 2018

| | | |
|---|---|---|
| Healthcare Cost in China | Healthcare cost as percentage of GDP (2017) | 6.20% |
| | Government Public Expenditures | 30.10% |

| | | |
|---|---|---|
| | Social Healthcare Expenditures | 40.10% |
| | Personal Healthcare Expenditures | 28.80% |
| | Annual average medical cost per person | 474.73 Euro |

In China, patients usually pay for a small-government-capped fee for doctor visit, yet hospitals are free to charge for checkups, prescribed drugs, and special treatment (EIU, 2016). The government funds 10 percent of healthcare costs at public hospitals, leaving hospitals making profit from prescribing medication and diagnostic tests for making up for the rest of the 90 percent of the cost and profit (EIU, 2016). This leads to over-prescription of medication, overuse of image examinations and other services which profit hospitals and clinics. The financial model also leads to under use of primary level care resources.

Meanwhile with an aging population, the Chinese healthcare system is facing a different challenge than before. Life expectancy at birth in China has reached 76.3 years in total (World Bank, 2018). More healthcare issues arise from chronical conditions instead of acute conditions and injuries. At the same time, age dependency ratio/old (World Bank, 2018) is projected to reach 25 percent by 2030 and by 2050 to 44%.

Chart 1.7 describes the leading causes of death in China. Chronical diseases have become leading causes of deaths in China, with the deaths caused by chronical diseases reaching up to 86.6% by 2012 (National Health and Family Planning Commission, 2015). Cardiovascular diseases have become the primary causes of deaths in China, followed by cerebrovascular diseases, respiratory diseases, perinatal diseases, digestive diseases, and nutrition metabolic diseases (National Health Commission, 2018).

Among the factors leading to chronic diseases, environmental risks, behavior risks, dietary risks, sexual abuse and violence, unsafe sex, and metabolic risks are contributing to losses of life (Zhou et al, 2019). Behavior risks include dietary risks, under nutrition, tobacco, alcohol and drug use, unsafe sex, physical inactivity, unsafe sex, sexual abuse and violence. Environmental risks include air pollution, water, sanitation, handwashing, occupational risks, and other factors. Metabolic risks include high blood pressure, high body-mass index, high plasma glucose, high cholesterol level, low glomerular filtration, low bone mineral density (Zhou et al, 2019).

For the Chinese population, hypertension, obesity, over intake of sodium, physical inactivity, nutrition imbalance, high cholesterol level, high glucose level, diabetes, unsaturated fat, lack of intake for vegetables and fruits, use of tobacco and alcohol have been identified as key risk factors (National Disease Control Center of China, 2013). Among the risk factors, hypertension stands out, a survey from 2012 to 2015 among 451,755 residents from 31 provinces reveals that 23.2% ($\approx$ 244.5 million) of the Chinese adult population with hypertension and 41.3% ($\approx$ 435.5 million) had pre-HTN according to Chinese guidelines; Among individuals with hypertension, 40.7% were taking prescribed medications; 46.9% were aware of their conditions and 15.3% have conditions under controlled (Wang et al, 2018). Prevalence of hypertension according to the guidelines from

the American College of Cardiology/American Heart Association guideline was twice as high as that based on Chinese guideline, reaching 46.4% with control rate for the condition falling to 3.0% (Wang et al., 2018).

Table 1.7 : Health Status for the Chinese population; Source: National Health Commission, 2018

| **Indicators** | **China** | |
|---|---|---|
| | **Rural China (2016)** | **Urban China** |
| **Life Expectancy (Years)** | 75.6 (2015) | 77.9 (2015) |
| **Infant mortality (‰)** | 7.9 (2017) | 4.1 (2017) |
| **Under-five mortality (‰)** | 10.9 (2017) | 4.8(2017) |
| **Maternal mortality (1/100,000)** | 21.1 (2017) | 16.6 (2017) |
| **Leading cause of death (1st to 10th)(2014)** | Cardiovascular disease/17.9% | Cancer/20.7% |
| | Cerebrovascular disease/17.3% | Cardiovascular disease/19.5% |
| | Cancer/16.5% | Cerebrovascular disease/16.4% |
| | Respiratory disease/9.4% | Respiratory disease/9.6% |
| | Injury and poisoning/8.5% | Injury and poisoning/6% |
| | Perinatal disease/2.2% | Endocrine nutrition metabolic disease/2% |
| | Digestive system disease/1.6% | Digestive system disease/1.8% |
| | Endocrine nutrition metabolic disease/1.3% | Perinatal disease/1.4% |
| | Infectious and parasitic diseases/1.1% | Neural System Disease/1% |
| | Neural System | Infectious and parasitic |

| | | |
|---|---|---|
| | Disease/0.95% | diseases/0.95% |

With aging intensifying in China, more general practitioners are in need for performing care at home and deal with routine consultations (The Economist, 2017). The reforms in China to direct patients to the primary care level has focused on two targets; the first goal is to make healthcare cheaper for patients; the second goal is to revive primary healthcare by diverting patients from hospitals to local clinics. The government has pledged to establish 7,000 more of urban community health centers (CHCs) by 2011 and small hospitals with higher standards in rural areas.

However, the reform did not successfully divert patients to primary level of care for several reasons.

The first reason is there existing no official gate-keeper system in China on primary level of healthcare, which means there lacks professionally trained general practitioners in China. Currently, there are about 60,000 licensed general practitioners (GPs), accounting for just 3.5% of all doctors in China; this leaves 650 million Chinese without access to a GP (Wang et al, 2018). Most medical schools in China do not offer general practitioner training, with students choosing to become from specialists since year 3 of medical school. Even under the 5+3 training model, aiming at training general practitioners in China after students completing the bachelor's degree and three year of clinical practice, only a small portion of students choose to become a general practitioner rather than pursuing a higher degree. In the study of 2017, students who choose to become a GP are either female, or come from rural areas, or come from families with less monthly income of RMB 4,000, an equivalent of about 521 euros (Wang et al, 2018).

Secondly, there are less incentive for medical students to become general practitioners; compared with primary care institutions such as community healthcare centers and secondary hospitals, tertiary hospitals offer better payments, more career advancement opportunities, and higher social status for doctors. A doctor works at a hospital earns an annual income of RMB 80,000 on average (an equivalence of 10, 397 Euro), with well-trained specialists usually have a large opportunity to receive 'red envelopes' as a thank you note from desperate patients. A GP in China usually earns about RMB 50,000 (an equivalence of 6498 Euro) (The Economist, 2017). This make career opportunities at tertiary hospitals more attractive for highly educated and well-trained doctors. Thirdly, most doctors working at primary care facilities are not well qualified. According to the Guideline for Establishing the General Practitioner System promulgated by the Chinese government, less than 23 percent doctors at community healthcare centers in rural areas have a bachelor's degree. There are less than 4 percent of doctors in community health centers with a senior title; less than 56.7 percent of country side doctors are qualified to apply for the registered doctor license in China.

Lastly, most Chinese patients distain primary care, even with treatment from fully qualified GPs. The reason lies in that most GPs are not authorized to prescribe a wide range of drugs as hospital doctors can; besides this, most Chinese do not trust GPs, which remind people of bare foot doctors age (The Economist, 2017). Most Chinese patients feel comfortable seeing a university educated doctor at a hospital with modernized facilities (The Economist, 2017). People also have less incentives to consult a GP; the basic government insurance coverage leaves patients paying

between 30 percent and 40 percent of their outpatient treatment costs, wherever the treatment takes place. Seeing a GP risks being referred to a specialist later, inferring higher cost. Therefore, most Chinese prefers getting treated at the hospital and see a specialist directly (The Economist, 2017). Until now, it remains challenging to establish a hierarchical healthcare system.

Meanwhile, because of the decentralized healthcare system, healthcare quality varies greatly by geography (EIU, 2016). Differences in healthcare quality arises from the fact different provinces operate independently to provide healthcare, with healthcare quality higher in coastal areas and big cities, and lagging behind in inland regions (EIU, 2016). For example, the number of GP per 1000 people is twice as high in coastal areas as it is in western and central China.

The healthcare reform has been initiated by the State Council in China, merging the previously fragmented healthcare service regulators into one single entity: National Health Commission (NHC) in China (NHC. 2019). The NHC has promulgated the "Internet + Healthcare" initiative (State Council, 2018; NHC, 2019). This prompted tech companies to partner with hospitals for infrastructure development for cloud storage and processing of data, and to develop new business models in healthcare. This also gives insurance companies to work with tech companies to provide online medical insurance sale and compensation schemes. In some pilot cities, it is possible to use the basic medical insurance schemes to pay for services and medical products and reimburse online. The rural cooperative medical insurance scheme (NRCMI) has been integrated with URBMI in the medical reform to reduce the medical care cost for rural citizens and migrant workers (State Council, 2016). So far, the insurance scheme has been able to cover over 90 % of the population in China.

### *4.2.2 Implications for Telehealth*

Recently, there has been calls to promote the value-based healthcare system, whereby the outcome of treatment in relativity of the cost became the primary index, cate for evaluating healthcare qualities. The model aims to control rising healthcare cost, promote healthcare qualities, take care of patient complaints on excess use of medication and diagnostic tests and reduce opportunity cost on over utilization of existing resources to divert them on investment in new drugs, clinical pathways and technology.

In the pilot program promoted by the World Bank at the People's Hospital of Yiyang in Henan Province, the hospital introduces clinical pathways for certain medical conditions and try to move away from payment-for-service model to case based payment, thus diverting incentive for overcharge for drugs and tests. The evaluation criteria for payment is based on whether patient has successfully completed treatment following prescribed evidence based clinical pathways for the condition or disease (EIU, 2016). Doctor's income depends on the number of patients successfully treated under the clinical pathway. If the pathway were not followed due to errors or inaction, there will be financial penalty for the care team. If there were successful completion of pathways at the discharge, there might be a bonus for the team (EIU, 2016).

Data were collected on several indexes to make sure clinical pathways are followed, including the

number of patients enrolled in the clinical pathway protocols, readmission rates at 14 and 31 days, hospital acquired infections, drug outlays, health insurance reimbursement amount, out-of-pocket spending and patient satisfaction rates. The evaluation of whether the clinical pathways were followed were done through a sophisticated IT system to monitor patient condition and whether protocol are followed in real time (EIU, 2016). The People's Hospital in Yiyang has claimed to shorten the length of hospital stays by a full day and report a increase of revenue of 8.7 percent with a better reputation attracts more patients. Unnecessary treatment has dropped by 20 percent; Communication between patients and medical staff has improved as well (EIU, 2016).

Telehealth is able to monitor for key health indicators such as heart rate, sleep quality, weight, etc; for implementing the three foundational principles of value-based care delivery, for the systematic measurement of the health outcomes that matter to patients and the costs required to deliver those outcomes across the full cycle of care, for the identification of clearly defined population segments and the specific health outcomes and costs associated with those segments, and for the development of customized segment-specific interventions to improve value for each population segment (World Economic Forum and Boston Consulting Group, 2017). Telehealth provides a good opportunity to make sure the care team follow the same protocol to treat patients, and enable the routine collection for medical data, to share and analyze outcome data, analyze population segment medical costs for patients given the cloud platform can collect data from multiple systems including from healthcare institutions, from public and private insurance systems. By collecting data about detailed health outcomes, it is possible to identify the best practice treatment practice and reduce inefficiency (Philips, 2018).

For lack of utilization for primary level of healthcare, Telehealth service providers has developed some innovative solutions where internet-based hospitals in China are providing online patient consultation, online prescription, long distance patient treatment services (Wu Zhen Internet based hospital, 2019; Ping An Good Doctor, 2019). Ping An has developed a '1-minute clinical box' for patients can consult the doctor in the box, get online prescriptions with an automatic machine outside to get the prescribed medication. The Ping An '1-minute clinical box' service will be free, with patients only paying for medication fees. So far, the boxes have become available at High Way service stations in Nanjing (Sohu Finance, 2019). In the future, Ping An has planned to provide the service at airports, railway stations, shopping malls, and Ping An Good Doctor network clinics and hospitals (Sohu Finance, 2019).

## 5. Conclusions

The current discrepancies in the healthcare system and unsatisfactory patient experiences leave room for the smart healthcare industry to mend the gaps. For instance, to tackle the problem of inter-regional, international patient data transfer, there have been standards developed to facilitate such data transfer in the EU. Online appointment system and mobile phone apps have developed to help patients book appointments at hospitals and reduce waiting time. Chatbots apps are able to deal with stress. Wearables can monitor key bio-metric signals of patients and facilitate chronic disease management. Sensors at home can detect elderly living patterns such as sleep, eating and

falls. The new technology developments offer hopes for elderly to live independently at home. It also offers opportunities for governments to further digitalize the healthcare system, improve data transparency for patients, and improve health equity for patients in remote areas.

Current healthcare policies in Europe and in China focus on promoting access, universal healthcare, cost control and improving healthcare quality(Terry, 2016). These pillars reflect the impossible trinity of access versus cost versus quality(Terry, 2016). The value-based healthcare system proposes a solution where the healthcare service providers are rewarded on health outcomes rather than on the amount of services provided. To transform into such a system demands the healthcare system perform systematic evaluation for each stage of healthcare, which is only achievable via comprehensive data collection and analysis.

Europe like China varies on the digitalization for the healthcare system. In both healthcare systems, the public sector plays an important role in stewardship and guidance. Public spending also accounts for a large part for healthcare expenditures. Out-of-pocket payment ratios are higher in China with 28.8 percent compared to EU average of 15 percent. Aging and the management of chronical disease proved to be a common challenge for the healthcare system in China and in the EU. Establishing standards for benchmarking the best clinical pathways and practices are challenges in both China and EU. For this, the full digitalization of the healthcare system, establishing a national system with patient databases, a system whereby different levels of healthcare institutions and professionals can exchange data, patients can store vital health data and medical history and share with doctors, healthcare service providers, pharmacies, and insurance companies, public or private are necessary. To improve data quality, system interoperability, and promoting the use of eHealth solutions are common challenges in the EU and China to realize Telehealth solutions in dealing with challenges associated with the aging society.

China and Europe differ in many aspects, but shares the common challenge of aging and rising costs in healthcare sector brought by chronical diseases such as diabetes, COPD, obesity, hypertension. Using smart health solutions can potentially help to establish value-based healthcare system to maximize health outcome and minimize costs. The key for transformation into a value-based healthcare system is systematic evaluation for each stage of health care with through data collection, analysis and subsequent benchmarking of best practices. With such a system in place, it is possible to perform telemedicine, long-distance monitoring of patients, and empowering patients for self-care. It is also possible for telehealth solutions to fill in the gap where primary care and gatekeeper function are weak. To improve the use of internet for exchange data, reduce cost, and to improve system interoperability are challenges for such successes. In the next chapter, a detailed analysis on relevant stakeholders, their roles, powers, and attitudes towards taking use of smart healthcare solutions will be performed.

In the next three chapters, I will elaborate more on the potential of use of tele-health solutions, challenges for their implementations, and the role and power of each stakeholder.

**References**

Accenture. (2018). ARTIFICIAL INTELLIGENCE: Healthcare's New Nervous System. https://www.accenture.com/us-en/insight-artificial-intelligence-future-growth

Agency for Digital Italy. (2018, May). National Agenda for e-Health. https://www.himss.eu/sites/himsseu/files/Basile_Italian_Vision_Smart_Healthcare_National_Agenda_e-Health.pdf,

Alihealth. (n.d.). Online and Offline Integrated Healthcare solution. Retrieved November 28, 2018, from https://www.alihealth.cn/

Alihealth. (2019). Alihealth Annual Report 2018/19. http://doc.irasia.com/listco/hk/alihealth/annual/2019/ar2019.pdf

Allen, J. (2007). Photoplethysmography and its application in clinical physiological measurement. Physiological Measurement, 28(3), R1–R39. https://doi.org/10.1088/0967-3334/28/3/r01

AOK. (2018). Electronic Healthcare Card in Germany. https://www.gemalto.com/govt/customer-cases/germany-second-generation

Apple. (n.d.). Apple Watch Series 4 - Health; ECG – Apple. Retrieved January 14, 2019, from https://www.apple.com/watch/

Apple. (2018, January). Apple announces effortless solution bringing health records to iPhone. Apple Newsroom. https://www.apple.com/newsroom/2018/01/apple-announces-effortless-solution-bringing-health-records-to-iPhone/

Apple. (2021, March 8). Institutions that support health records on iPhone and iPod touch. Apple Support. https://support.apple.com/en-us/HT208647

Asia Insights. (2018a, March 19). One Billion Users And Counting -- What's Behind WeChat's Success? Forbes. https://www.forbes.com/sites/outofasia/2018/03/08/one-billion-users-and-counting-whats-behind-wechats-success/#1842eaee771f

Asia Insights. (2018b, March 19). One Billion Users And Counting -- What's Behind WeChat's Success? Forbes. https://www.forbes.com/sites/outofasia/2018/03/08/one-billion-users-and-counting-whats-behind-wechats-success/

Bao, L., Han, R., & Wang, Y. (2014). Analysis of human resources deployment and the policies in China. Chinese Journal of Hospital Administration, 3, 197–201. http://caod.oriprobe.com/articles/41213303/Analysis_of_human_resources_deployment_and_the_policies_in_China.htm

Bates, D. W., & Wells, S. (2012). Personal Health Records and Health Care Utilization. JAMA, 308(19), 2034. https://doi.org/10.1001/jama.2012.68169

Bitkom e.V. (2016). Telemedizin trifft auf großes Interesse. https://www.bitkom.org/Presse/Presseinformation/Telemedizin-trifft-auf-grosses-Interesse.html

BLED 2010 Proceedings, Yu, Y., Wilfred, H., Juergen, S., & Nilmini, W. (2010). Evaluation of e-Health in China. BLED 2010 Proceedings | BLED Proceedings | Association for Information Systems. https://aisel.aisnet.org/bled2010/

Bloomberg. (2018a, April 19). Advice for the Good Doctor: Stop Smoking Cash,. https://www.bloomberg.com/gadfly/articles/2018-04-19/advice-for-the-good-doctor-stop-smoking-cash

Bloomberg. (2018b, June 15). Ping An Technology Stock Price. https://www.bloomberg.com/quote/1833:HK

Bloomberg. (2018c, September 10). These are the economies with the most and least efficient health care. https://www.bloomberg.com/tosv2.html?vid=&uuid=b72af320-84e3-11eb-a334-d76e586ff4d2&url=L25ld3MvYXJ0aWNsZXMvMjAxOC0wOS0xOS91LXMtbmVhci1ib3R0b20tb2YtaGVhbHRoLWluZGV4LWhvbmcta29uZy1hbmQtc2luZ2Fwb3JlLWF0LXRvcA==

Boulding, K. E. (1966). The Concept of Need for Health Services. The Milbank Memorial Fund Quarterly, 44(4), 202. https://doi.org/10.2307/3349064

Bumgarner, J. M., Lambert, C. T., Hussein, A. A., Cantillon, D. J., Baranowski, B., Wolski, K., Lindsay, B. D., Wazni, O. M., & Tarakji, K. G. (2018). Smartwatch Algorithm for Automated Detection of Atrial Fibrillation. Journal of the American College of Cardiology, 71(21), 2381–2388. https://doi.org/10.1016/j.jacc.2018.03.003

Busse, R., Blümel, M., & WHO. (2014). Germany: health system review. Health Systems in Transition. https://apps.who.int/iris/bitstream/handle/10665/130246/HiT-16-2-2014-eng.pdf

China News. (2018, June 11). China News, Ping An Medical Insurance Cloud Computing Healthcare Platform Update and Expansion, in Chinese “平安医保科技“卫健云”全面升级上线. http://sh.chinanews.com/swzx/2018-06-11/40394.shtml

China Security Regulatory Commission. (2018, June 4). Pitch Book for Xiaomi CDR based Stock Offering. http://www.csrc.gov.cn/pub/zjhpublic/G00306202/201806/P020180611106685793601.pdf

Cicchetti, A., & Gasbarrini, A. (2016). The healthcare service in Italy: regional variability, European Review for Medical and Pharmacological Sciences. European Review. https://www.europeanreview.org/wp/wp-content/uploads/The-healthcare-service-in-Italy-regional-variability.pdf

Dameff, C., Clay, B., & Longhurst, C. A. (2019). Personal Health Records. JAMA, 321(4), 339. https://doi.org/10.1001/jama.2018.20434

Deloitte. (2018). Global health care outlook The evolution of smart health car. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-hc-outlook-2018.pdf

Digital Transformation. (2021, March 8). Huawei. https://www.huawei.eu/what-we-do/digital-transformation

Economist Intelligence Unit. (2016). Value-based healthcare in Europe: Laying the foundation', The Economist Intelligence Uni. EIU. https://eiuperspectives.economist.com/healthcare/value-based-healthcare-europe-laying-foundation

Ehteshami Bejnordi, B., Veta, M., Johannes van Diest, P., van Ginneken, B., Karssemeijer, N., Litjens, G., van der Laak, J. A. W. M., Hermsen, M., Manson, Q. F., Balkenhol, M., Geessink, O., Stathonikos, N., van Dijk, M. C. R. F., Bult, P., Beca, F., Beck, A. H., Wang, D., Khosla, A.,

Gargeya, R., … Venâncio, R. (2017). Diagnostic Assessment of Deep Learning Algorithms for Detection of Lymph Node Metastases in Women With Breast Cancer. JAMA, 318(22), 2199. https://doi.org/10.1001/jama.2017.14585

EIU. (2016). China's healthcare challenges: The People's Hospital of Yiyang County in Henan Province, A case study from the Economist Intelligence Unit. http://vbhcglobalassessment.eiu.com/wp-content/uploads/sites/27/2016/10/EIU_Medtronic_CaseStudy_Chinas_Healthcare_Challenges

Enthoven, A. C. (1978). Consumer-Choice Health Plan. New England Journal of Medicine, 298(13), 709–720. https://doi.org/10.1056/nejm197803302981304

European Commission. (2016, October). Health Care & Long-Term Care Systems, Germany, An excerpt from the Joint Report on Health Care and Long-Term Care Systems & Fiscal Sustainability. https://ec.europa.eu/info/publications/joint-report-health-care-and-long-term-care-systems-and-fiscal-sustainability-country-documents-2019-update_en

European Commission. (2017). State of Health in the EU Country Health Profile 2017 Italy. https://ec.europa.eu/health/state/country_profiles_en

European Commission. (2019a). Digital Single Market - Exchange of Electronic Health Records. https://ec.europa.eu/digital-single-market/en/exchange-electronic-health-records-across-eu

European Commission. (2019b, June). eHealth strategies. country brief: Italy. https://ec.europa.eu/health/sites/health/files/ehealth/docs/ev_20190611_co922_en.pdf

Eversense. (2019). Long-term CGM System | Eversense Continuous Glucose Monitoring. https://www.eversensediabetes.com/eversense-cgm-system

Fattah, S., Sung, N.-M., Ahn, I.-Y., Ryu, M., & Yun, J. (2017). Building IoT Services for Aging in Place Using Standard-Based IoT Platforms and Heterogeneous IoT Products. Sensors, 17(10), 2311. https://doi.org/10.3390/s17102311

Feldman, R., & Dowd, B. (1993). What does the demand curve for medical care measure? Journal of Health Economics, 12(2), 193–200. https://doi.org/10.1016/0167-6296(93)90028-d

Ferré, F., de Belvis, A. G., Valerio, L., Longhi, S., Lazzari, A., Fattore, G., Ricciardi, W., & Maresso, A. (2014). Health System Review. Health Systems in Transition: Vol. 16(4) [E-book]. WHO. https://www.euro.who.int/__data/assets/pdf_file/0003/263253/HiT-Italy.pdf?ua=1

Fitbit. (n.d.). Fitbit Comparison | Compare Fitness Trackers & Smartwatches. Retrieved April 10, 2019, from https://www.fitbit.com/global/us/compare

Foundation, China Development Research. (2019). Reforming China's Healthcare System (Routledge Studies on the Chinese Economy) (1st ed.). Routledge.

Garmin. (n.d.). Fitness Watches | Sport Watches | Smartwatches | Garmin. Retrieved April 10, 2019, from https://buy.garmin.com/en-US/US/wearabletech/wearables/c10001-c10002-p1.html

German Trade and Invest. (2017, February 15). The Mobile Health Market in Germany – Fact Sheets. GTAI. https://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/Life-sciences/digital-health.html

GKV. (2019, July). Responsibility for healthcare - The national association of the health and long-term care insurance funds. https://www.gkv-spitzenverband.de/media/dokumente/presse/publikationen/GKV-Spitzenverband_Imagebroschuere_englisch_07-2019_barrierefrei.pdf,

Huawei. (n.d.). Healthcare — Huawei solutions. Huawei Enterprise. Retrieved June 25, 2019, from https://e.huawei.com/uk/solutions/industries/healthcare

HUAWEI. (n.d.). Huawei Consumer Wearables. Retrieved June 25, 2018, from https://consumer.huawei.com/en/?type=wearables

HUAWEI Accessories - HUAWEI Global. (n.d.). Huawei. Retrieved January 17, 2019, from https://consumer.huawei.com/en/accessories/

Ip, J. E. (2019). Wearable Devices for Cardiac Rhythm Diagnosis and Management. JAMA, 321(4), 337. https://doi.org/10.1001/jama.2018.20437

Jakubowski, E., & Busse, R. (2002, May 31). Health care systems in the EU a comparative study : working paper. Publication Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/6125eac3-c1d3-4ea3-8f3d-9d9888d25e56

Jing Dong Online Healthcare. (n.d.). Jing Dong Internet based Hospital. JD. Retrieved January 20, 2019, from https://care.jd.com/nh_home

Jourdan, A. (2018, May 9). Tencent's WeDoctor raises $500 million, values firm at $5.5 billion pre-IPO. Reuters. https://www.reuters.com/article/us-china-tencent-wedoctor/tencents-wedoctor-raises-500-million-values-firm-at-5-5-billion-pre-ipo-idUSKBN1IA08G

Kaminsky, L. (2019, January 17). The invisible warning signs that predict your future health. BBC Future. https://www.bbc.com/future/article/20190116-the-invisible-warning-signs-that-predict-your-future-health

Kierkegaard, P. (2013). eHealth in Denmark: A Case Study. Journal of Medical Systems, 37(6), 1–10. https://doi.org/10.1007/s10916-013-9991-y

Kringos, D., Boerma, W., Bourgueil, Y., Cartier, T., Dedeu, T., Hasvold, T., Hutchinson, A., Lember, M., Oleszczyk, M., Pavlic, D. R., Svab, I., Tedeschi, P., Wilm, S., Wilson, A., Windak, A., Van der Zee, J., & Groenewegen, P. (2013). The strength of primary care in Europe: an international comparative study. British Journal of General Practice, 63(616), e742–e750. https://doi.org/10.3399/bjgp13x674422

Leichsenring, K. (2004). Providing integrated health and social care for older persons—A European overview. Providing integrated health and social care for older persons—A European overview of issues at stak. Aldershot: Ashgate Publishing Limited.

Leng, S. (2019, June 11). China's fragmented health care system under increasing pressure as nation rapidly ages. South China Morning Post. https://www.scmp.com/economy/china-economy/article/3013976/chinas-fragmented-health-care-system-under-increasing

Lew, L. (2020, June 7). How Tencent's medical ecosystem is shaping the future of China's healthcare. TechNode. https://technode.com/2018/02/11/tencent-medical-ecosystem/

Lim, J. (2014a, June 17). WeChat Is Being Trialled To Make Hospitals More Efficient In China. Forbes. https://www.forbes.com/sites/jlim/2014/06/16/wechat-is-being-trialed-to-make-hospitals-more-efficient-in-china/#1db5084255e2

Lim, J. (2014b, June 17). WeChat Is Being Trialled To Make Hospitals More Efficient In China. Forbes. https://www.forbes.com/sites/jlim/2014/06/16/wechat-is-being-trialed-to-make-hospitals-more-efficient-in-china/#59f5678755e2

Lo Scalzo, A., Donatin, A., Orzella, L., Cicchetti, A., Profili, S., & Maresso, A. (2009). Italy: Health system review. Health Systems in Transition: Vol. 11(6）. WHO. https://www.euro.who.int/__data/assets/pdf_file/0006/87225/E93666.pdf

Lovell, T. (2019a, February 27). German health minister sets digitalisation as a top priority for new. Healthcare IT News. https://www.healthcareitnews.com/news/emea/german-health-minister-sets-digitalisation-top-priority-new-initiative?fbclid=IwAR34AD4DbmMh-3V9Z_9N-O8dnVgkRSbRG6DayvEs-CFTx5_rTxJfKjoa_0Y

Lovell, T. (2019b, February 27). German health minister sets digitalisation as a top priority for new. Healthcare IT News. https://www.healthcareitnews.com/news/emea/german-health-minister-sets-digitalisation-top-priority-new-initiative

Mckinsey. (2010). China’s Healthcare Reform. https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/healthcare%20systems%20and%20services/health%20international/hi10_china_healthcare_reform.ashx

Ministry of Health Danmark. (2017). Healthcare in Denmark, AN Overview. https://www.healthcaredenmark.dk/media/1479380/Healthcare-english-V16-decashx-3.pdf

Ministry of Healthcare Italy. (2011). 7.10. Sistema di valutazione e monitoraggio della qualità dell'assistenza e delle performance dei sistemi sanitari - Relazione sullo Stato Sanitario del Paese. Ministry of Health Italy. http://www.rssp.salute.gov.it/rssp/paginaParagrafoRssp.jsp?sezione=risposte&capitolo=valutazione&id=2677

MIT. (2019, May 7). Using AI to predict breast cancer and personalize care. MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2019/using-ai-predict-breast-cancer-and-personalize-care-0507

Murgia, M. (2019, July 31). DeepMind creates algorithm to predict kidney damage in advance. Financial Times. https://www.ft.com/content/c7cbcfba-b2b2-11e9-8cb2-799a3a8cf37b

National Health and Family Planning Commission of the People's Republic of China. (2015, June). Report of National Nutrition and Chronic Disease Status in China. http://en.nhc.gov.cn/2015-06/15/c_45788.htm

National Health Commission. (2018, June). Health System Review 2017 (in Chinese). http://www.nhc.gov.cn/guihuaxxs/s10743/201806/44e3cdfe11fa4c7f928c879d435b6a18.shtml

National Health Commission. (2019, September 4). China starts mapping standards for 5G-based hospitals. http://www.gov.cn/guowuyuan/2019-09/04/content_5427271.htm

Obermann, K. (2013). Understanding the German Health Care System. Mannheim Institute of Public Health. http://www.goinginternational.eu/newsletter/2013/nl_03/SpecialDE_EN_Understanding_the_German.pdf.

OECD/European Observatory on Health Systems and Policies. (2017). Germany: Country Health Profile 2017. State of Health in the EU, 1–20. https://doi.org/10.1787/9789264283398-en

Pacific Ventures. (2016, January 11). Electronic Health Records in China Provide Opportunities for International Healthcare Ventures. http://www.pcg-group.com/

Pan, X.-F., Xu, J., & Meng, Q. (2016). Integrating social health insurance systems in China. The Lancet, 387(10025), 1274–1275. https://doi.org/10.1016/s0140-6736(16)30021-6

Philips. (2019, October 18). The four pillars of a value-based healthcare future. https://www.philips.com/a-w/about/news/archive/future-health-index/articles/20180126-pillars-value-based-healthcare.html

Ping An Good Doctor. (n.d.). Ping An Good Doctor. Retrieved September 16, 2019, from https://www.jk.cn/

Ram, A. (2018, April 5). Babylon signs Tencent deal to deploy health technology on WeChat. Financial Times. https://www.ft.com/content/40fae194-381d-11e8-8eee-e06bde01c544

Rapid Value Solutions. (2020, November 3). Is Wearable Technology the Future of Healthcare? RapidValue. https://www.rapidvaluesolutions.com/wearable-technology-the-future-of-healthcare/

Renew Health Project. (2009). Renew Health-Project Objective. https://www.consorzioarsenal.it/en/web/guest/progetti/renewing-health/gli-obiettivi

Ridic, G., Gleason, S., & Ridic, O. (2012). Comparisons of Health Care Systems in the United States, Germany and Canada. Materia Socio Medica, 24(2), 112. https://doi.org/10.5455/msm.2012.24.112-120

Rinbeat. (2018). Rinbeat – Intelligent Monitoring. http://rinbeat.it/

Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieguez, A., Carry, M., Gelaude, D., Mosley, J. P., & Travers, J. (2016). A user-centered model for designing consumer mobile health (mHealth) applications (apps). Journal of Biomedical Informatics, 60, 243–251. https://doi.org/10.1016/j.jbi.2016.02.002

Sohu Finance. (2019). Ping An Good Doctor service reaching high way service stations. https://www.sohu.com/a/292263887_115865?scm=1002.44003c.fd00fe.PC_ARTICLE_REC

Stanford Medicine. (2018). The Democratization of Health Care', Standford Medicine 2018 Health Trends Reports. https://med.stanford.edu/content/dam/sm/school/documents/Health-Trends-Report/Stanford-Medicine-Health-Trends-Report-2018.pdf

State Council. (2016, January). Opinions on Integrating medical insurance schemes for rural and urban residents, in Chinese 国务院关于整合城乡居民基本医疗保险制度的意见_政府信息公开专栏. http://www.gov.cn/zhengce/content/2016-01/12/content_10582.htm

State Council. (2018, April). Opinions on Promoting Internet + Healthcare Industry development, in Chinese 国务院办公厅关于促进"互联网+医疗健康"发展的意见（国办发

〔2018〕26 号）_政府信息公开专栏. http://www.gov.cn/zhengce/content/2018-04/28/content_5286645.htm

Subramania, J. (2019, March 25). Why IoT is not a technology solution—it's a business play. Microsoft Azure. https://azure.microsoft.com/en-us/blog/why-iot-is-not-a-technology-solution-it-s-a-business-play/

Sun, J., Lin, Q., Zhao, P., Zhang, Q., Xu, K., Chen, H., Hu, C. J., Stuntz, M., Li, H., & Liu, Y. (2017). Reducing waiting time and raising outpatient satisfaction in a Chinese public tertiary general hospital-an interrupted time series study. BMC Public Health, 17(1), 9–21. https://doi.org/10.1186/s12889-017-4667-z

Tang, P. C., Ash, J. S., Bates, D. W., Overhage, J. M., & Sands, D. Z. (2006). Personal Health Records: Definitions, Benefits, and Strategies for Overcoming Barriers to Adoption. Journal of the American Medical Informatics Association, 13(2), 121–126. https://doi.org/10.1197/jamia.m2025

Tencent Doctorwork. (2019). Tencent Doctorwork. https://www.doctorwork.com/index/pc/

Terry, N. (2016). Will the Internet of Health Things Disrupt Healthcare? SSRN Electronic Journal, 327–352. https://doi.org/10.2139/ssrn.2760447

The Economist. (2017, May 11). China needs many more primary-care doctors. https://www.economist.com/china/2017/05/11/china-needs-many-more-primary-care-doctors

The Economist Intelligence Unit. (2015). Value-based health assessment in Italy A decentralised model. EIU. https://eiuperspectives.economist.com/healthcare/value-based-health-assessment-italy-decentralised-model

The German Federal Institute for Drugs and Medical Devices. (n.d.). BfArM - About us. BfArM. Retrieved September 5, 2019, from https://www.bfarm.de/EN/BfArM/_node.html

The System of Health accounts in Italy. (2017, July 4). ISTAT. https://www.istat.it/en/archive/201949

Wang, S., Fu, X., Liu, Z., Wang, B., Tang, Y., Feng, H., & Wang, J. (2018). General Practitioner Education Reform in China: Most Undergraduate Medical Students do not Choose General Practitioner as a Career Under the 5+3 Model. Health Professions Education, 4(2), 127–132. https://doi.org/10.1016/j.hpe.2017.05.001

Wang, Z., Chen, Z., Zhang, L., Wang, X., Hao, G., Zhang, Z., Shao, L., Tian, Y., Dong, Y., Zheng, C., Wang, J., Zhu, M., Weintraub, W. S., & Gao, R. (2018). Status of Hypertension in China. Circulation, 137(22), 2344–2356. https://doi.org/10.1161/circulationaha.117.032380

Wendt, C. (2009). Mapping European healthcare systems: a comparative analysis of financing, service provision and access to healthcare. Journal of European Social Policy, 19(5), 432–445. https://doi.org/10.1177/0958928709344247

WHO. (2003). The Domains of Health Responsiveness A Human Rights Analysis. https://www.who.int/healthinfo/paper53.pdf

WHO. (2018, June). Towards a roadmap for the digitalization of national health systems in Europe. World Health Organization. https://www.euro.who.int/__data/assets/pdf_file/0008/380897/DoHS-meeting-report-eng.pdf?ua=1

Wong, J. C. (2019, July 17). Elon Musk unveils plan to build mind-reading implants: “The monkey is out of the bag.” The Guardian. https://www.theguardian.com/technology/2019/jul/17/elon-musk-neuralink-brain-implants-mind-reading-artificial-intelligence

World Bank. (2018). Age dependency ratio (% of working-age population) - China | Data. World Bank Data Bank. https://data.worldbank.org/indicator/SP.POP.DPND?locations=CN

World Economic Forum & Boston Consulting Group. (2017). Value in Healthcare Transformation for Health System Laying the Foundation. World Economic Forum. http://www3.weforum.org/docs/WEF_Insight_Report_Value_Healthcare_Laying_Foundation.pdf

Wuzhen Internet Hospital. (2019). Wuzhen Internet based Hospital， 乌镇互联网医院 B 端业务，已赋能 1200 多家县域医院，构建基层医疗新生态-动脉网. VC Beat. https://vcbeat.top/ODAxNDhjNDU0YmFkZGViYzU5MmQ5ODNmYTM4ZThmZDY=

Xiaomi. (2018, June 15). Xiaomi Market. https://www.mi.com/index.html

Xiaomi. (2019). Mi Band 4 (in Chinese). Xiaomi Mi Band 4. https://www.mi.com/shouhuan4nfc

Zhou, M., Wang, H., Zeng, X., Yin, P., Zhu, J., Chen, W., Li, X., Wang, L., Wang, L., Liu, Y., Liu, J., Zhang, M., Qi, J., Yu, S., Afshin, A., Gakidou, E., Glenn, S., Krish, V. S., Miller-Petrie, M. K., … Liang, X. (2019). Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet, 394(10204), 1145–1158. https://doi.org/10.1016/s0140-6736(19)30427-1

华为穿戴 - 华为官网. (n.d.). Huawei Wearables. Retrieved April 10, 2019, from https://consumer.huawei.com/cn/wearables/

# *Chapter 2*

## *Developing the innovation ecosystem: a case study on the Chinese tech industry*


### Abstract

**Background:** Digital platform ecosystems (DPEs) make it easier for new firms and MNEs to expand into new business, to overcome territorial constraints, and to develop new business models. Compared with traditional multinationals, DPEs have become more agile, lean and aggressive, making it easier for DPEs to create value, re-capture value and create new ways of delivering value to customers. Knowledge transfer and use between partners of the DPEs also become easier. Meanwhile, partners of the DPEs are exposed to risks brought by open platforms such as security, feasibility to use, privacy and legal risks. There is a need to extend, revise, and redevelop the theoretical framework designed for traditional MNEs as digital platform ecosystems differ from the traditional business model.

**Objective**: The paper aims to validate and reinforce the existing theoretical framework on digital platform ecosystems.

**Methods:** The chapter uses case study of Xiaomi, Huawei and Bytedance to update the existing international business theoretical framework on multinationals ecosystem.

**Results:** This chapter presents a theoretical framework with empirical evidence based on the success of Chinese tech giants such as Alibaba and Xiaomi in the past 20 years. Alibaba has become a conglomerate in e-commerce, finance, logistics, transportation, healthcare, cloud computing, AI and IoT. Xiaomi has started from a smart phone producer and developed one of the largest IoT ecosystems in the world in terms of connected devices; most companies invest heavily on start-ups overseas and domestically to build up their empire..



**Keywords**: Digital-ecosystem-platform; Tech Companies; China;

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## 1. Introduction

The theoretical framework supporting the emerging markets digital ecosystem developments need an update to correspond with new empirical evidence in business models and governance structures used by tech firms from emerging markets such as China. Chinese firms were chosen as the target of case study for the smart health industry as the market is highly capitalized and competitive (Financial Times, 2020). Novel and flexible business models and financial schemes are created to enable firms to tackle intense competition and engage customers.

Not so long ago, the smart phone market was still dominated by Apple, Samsung, Nokia and Blackberry; Chinese companies such as Huawei or Xiaomi were unknown to customers. Today these two companies are the world's leading smart phone manufacturers (IDC, 2020). Other Chinese companies, such as Alibaba, were once seen as the copycats of Ebay and Amazon. The Alibaba ecosystem now is going beyond e-commerce, whereby the business originated from; it had created and embedded a business model and ecosystem envied by its western counterparts. Nowadays Alibaba is leading in the entertainment and finance sector in China; meanwhile, it has started to navigate in healthcare, an area with sophisticated technology and added value, with AI and cloud computing.

In the Internet of Healthcare Things[1] industry, Xiaomi and Huawei are the world's top five wearable producers by shipment volume (IDC, 2019). Both companies made heavy investment in sports and healthy living life-style related products. Alibaba has developed solutions for both individual users and institutional healthcare service providers. These solutions focus on reducing waiting time for healthcare services, improving healthcare quality and promoting healthcare efficiency. More specifically, their work focused intensely on lowering processing time of medical images, improving diagnosis efficiency and accuracy for healthcare organizations; for individual customers, their services comprise largely of selling healthcare services and products online. The Alibaba online to offline medicine sale is growing rapidly, with sales from online to offline medication sales jumping by 296.8% from 2017 to 2018 (Alihealth, 2019). Private insurance companies such as Ping An and public insurance schemes are barging in now to acquire, analyze data on a population health management scale, and offer policy advices on public healthcare issues. The outbreak of coronavirus has proven the essentialness and boosted the demand for smart healthcare services.

The paper aims to elaborate on how Chinese firms has transferred their competitive advantage to new sectors such as healthcare and AI based on the digital ecosystem platform theory and the emerging market internationalization theory. The paper establishes a theoretical framework based on the case studies from Alibaba, Huawei and Xiaomi. Case studies are developed from interviews conducted with investment and business managers from leading Chinese tech firms such as Alibaba, Huawei and Xiaomi.

[1] Internet of Healthcare Things (IoHT), refers to identifiable devices connected to the Internet and able to communicate with each other, used for healthcare purposes. Comarch, 2020, available at: https://www.comarch.com/iot-ecosystem/internet-of-healthcare-things/.

## 2. Literature Review

### *2.1 Digital platform ecosystem theory*

By using google scholar and searching for past literatures on the subject of digital platform ecosystems, comparative advantage, emerging market enterprises, literatures were surveyed. Literatures published at 2003 was referenced as it is a highly downloaded and referenced article.

#### *2.1.1 The dynamic capabilities of DPEs*

Digital platform ecosystems (DPEs) are leading the technological revolution in our era (Teece, 2018). DPEs are often multi-sided, providing interfaces for two or more groups of economic actors from different sides of the platform (Healfat and Raubitschek, 2018). The platform refers to the ones which facilitate and mediate transactions and communications between actors. A multifunctional digital ecosystem consists of platform leader, actors on different sides of the platform, and infrastructure providers for the platform (Healfat and Raubitschek, 2018).

Healfat and Raubischek (2018) pointed out that digital multi-side digital ecosystems can generate the cross-side effects for users. The service quality of the platform, hence the value for one side of the party depends on the number and qualities of parties on the other side of the platform. Cross side effects of the digital platforms can be both positive and negative. Healfat and Raubischek (2018) identified three types of dynamic characteristics critical for platform leaders: innovation ability, environmental scanning and sensing ability, and integrative ability for ecosystem organization.

Based on Teece (2007) on dynamic capabilities, Healfat and Raubischek (2018) defined three dynamic characteristics necessary in generating strategic changes for DPEs.

Firstly, identifying new market opportunities and threats.

Secondly, taking use of new opportunities with innovation in business models and strategic investments.

Thirdly, adapting the existing business models and strategies.

In Helfat and Raubitschek (2018), the three capabilities are essential for profiting from innovation in digital platform-based ecosystems. The authors had distinguished between general capabilities and dynamic capabilities. General capabilities refer to the ones related to regular operations of business. The dynamic capabilities differ from general capabilities in that these capabilities lead to strategic changes, at organizational level and individual level (Helfat and Raubischek, 2018). The authors pointed out that dynamic capabilities are the ones which allow firms to create, extend, modify the value creation process. These capabilities can enable changes internally and externally, e.g. modifications of business model, intangible and tangible assets and operational capabilities. This differentiates dynamic capabilities from the capabilities to operate the business daily (Helfat and Raubitschek, 2018).

1) Innovation capabilities

By innovation, Healfat and Raubischek (2018) mean by product sequencing, which entails linking new and existing product, services, associated knowledge and capabilities in time and overtime. The product sequencing process does not include just upgrading the core products in the ecosystems but also the features of the whole ecosystem. Multi-team software innovation

capabilities of platform leaders are necessary for the innovations in the eco-systems. Platform leader, which sits on the top of the ecosystem, can benefit from routines with the cross-function teams and the ability to coordinate between the innovation teams.

2) Sensing/scanning capabilities

On the institutional level, the sensing capabilities requires the platform leader to know the core products and the complementary products well. The ability to gain market access (Helfat and Winter, 2011), which include those for interacting and obtaining feedback from customers through sales and service teams is part of the environmental scanning function. On an individual level, top managers can also sense opportunities and threats from the feedback received from customers, stimulating the product sequencing process. The scanning and sensing capabilities are key for identifying market threats such as complementary assets providers for competitors; or key for identifying market opportunities, such as creating new channels to reach the customers.

3) Integrative capabilities for resource orchestration

Excepting creating, placing the new product and setting the platform rules, platform leaders are also engaged in coordinating resources around DPE (Helfat and Raubischek, 2019). Strong digital ecosystems are characterized by the cross-side network effects. For platform leaders, the success of the business model is heavily dependent on the number of users and the quality of contents on both sides of the platform. Network effects determines the value of the platform. By organizing the governance rules for ecosystem members, the DPEs ensure the quality of complimentary resources they provide. By routinely communicating with different teams, the platform leader can organize internal resources efficiently, detect problems and make the required strategic changes. In the process, DPEs may get involved in new asset acquisition, assembling and coordination of resources of the platform. *Figure 2.1* explains the important components of digital platform ecosystem theory.

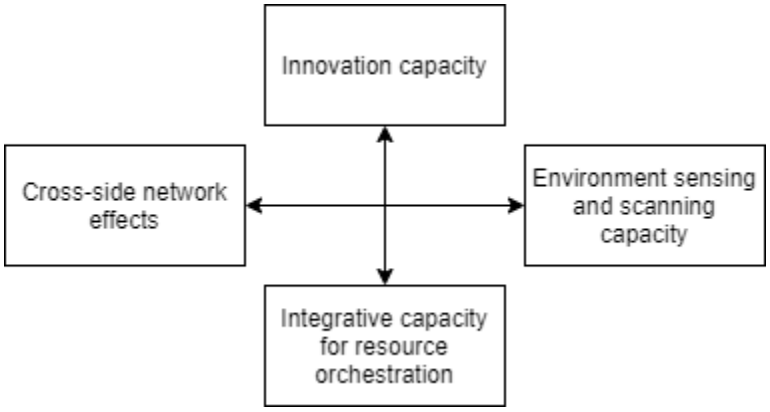


Figure 2.1. Digital platform ecosystem theory, author's illustration; Source: Teece, 2017; Helfat and Raubischek, 2019;

DPEs differ from traditional multinationals in digital platform ecosystems (DPEs) being more adaptive to market needs. This characteristic makes it relatively easy for DPEs to access new markets, adapt to existing markets and get rid of products with low market shares and low returns. The product, or value created, exists in a digital format, which can be easily tested with customers and changed accordingly. The time it takes for DPEs to adjust strategies and due diligence process takes less time than traditional multinational enterprises (MNEs). This makes the business model

of most DPEs more flexible than traditional DPEs. It is also easier for DPEs to access a foreign market.

As DPEs, companies are able to become "born global" with the product often launched in several markets and platforms at the same time. With a large customer base, it became relatively easy to get new partners onboard (Nambisan, Zahra and Luo, 2019). According to Sharma and Blomstermo (2003), the born global multinationals follow an internationalization model which supports the path dependency theory. In elaboration, the internationalization entry model and established internationalization networks are usually based on weak ties and knowledge that firms gathered at the domestic market and the network established at the domestic market. The network refers to the number of users accumulated in the domestic market as the resource which can be leveraged for partners in the foreign market. The knowledge refers to the capability to improve the attractiveness of the platform and get more users on board.

Without much tangible assets, DPEs do not need to be physically present at a market to access the customers. With a large customer base, firms without previous internationalization experiences can also access the international customers via DPEs. This is particularly beneficiary for start-ups, small and medium size firms with limited resources. DPEs provide SMEs with a ready to function platform which allows SMEs to access the global customer resources. (Nambisan, Zahra and Luo, 2019). For manufacturing firms, it is also easier for find suppliers for services with DPE platforms.

### *2.1.2 DPEs and network effects*

DPEs offer MNEs, SMEs, start-ups and individual suppliers with a ready to plug-in platform with a large customer base (Nambisan, Zahra and Luo, 2019). With all the data about supply and demand, DPEs makes it easier for firms to locate market demand. This challenges the traditional market order such as the parental-subsidiary ranks, making it possible for the emergence of multiple cost centers independent from one another (Nambisan, Zahra and Luo, 2019). Social networks such as Twitter, Facebook, Instagram, Weibo and Tik Tok offer brands more opportunity to create virtual online campaigns and interact with customers directly.

The vast network created by DPEs allow participants to adjust to market needs more flexibly. As a collective actor, DPEs often has the operational and structural flexibility in dealing with market turbulences. This allows DPEs to identify new opportunities in the market which will benefit individual members of the platform.

Banalieva and Dhanaraj (2019) tries to explain that digital networks have become one of the firm specific advantages for digital service multinational firms. Networks have become a governance mode and strategic resources for digital platforms. The advantages brought by network advantages are strategically important for DPEs while the traditional asset-based advantages. Banalieva and Dhanaraj (2019) made the following arguments regarding the role of digitalization in firms' internationalization process.

Firstly, digitalization enables firms to separate firm specific advantages into technology and human capital. This makes it easier for them to reconcile between advanced skills and common more generic skills in the foreign market.

Secondly, digitalization increases the transferability of a firm's technology firm specific advantages, by enhancing technology's modularity and the promote the bundling with local firms. Module here refers to the integration of multiple layers of technology. As advanced skills such as

coding for algorithms is hardly obtainable in certain developing market, digital platforms make it easier for them to deploy algorithms in the foreign market, while employing local employees with more generic skills (Banalieva and Dhanaraj, 2019).

Thirdly, digital platforms may increase the risk for firm specific advantages to be copied across borders. Meanwhile, digitalization also enhances firm's ability to contain imitation by integrating complex technology proprietary and network effects.

Fourthly, digitalization increases a firm's ability to bundle its advanced (generic) human capital firm specific advantages. Digitalization may increase specification of advanced human capital skills and demote firm specify of generic human capital skills.

Fifth, digitalization enhances a firm's ability to exploit its core (peripheral) tech firm specific advantages in foreign markets with a more (less) centrally controlled digital networks.

Sixthly, digitalization enhances a firm's ability to exploit advanced (generic) human capital firm specific advantages in foreign markets at lower costs.

Overall networks, hence the number of users and the quality of contents on the platform, had become a competitive advantage for digital service multinational firms. Large networks provide more diverse datasets which enable more precise business insights, compares to smaller networks with non-integrative datasets. In summary, Banalieva and Dhanaraj (2019) claims that networks connect organizational design theorize asset-light internationalization, enable firms to make governance choice predictions, increase knowledge transferability and risk of appropriability. They tested their theory based on the emergence of network-based platforms.

Hennart (2019) pointed out that contrary to what Banalieva and Dhanaraj (2019) argues, networks are not governance structures. Hennart (2019) insists on using the traditional international business theory such as OLI paradigm (Ownership, Location, Internationalization) proposed by Dunning and Ludan (2008) to explain digital platforms going abroad. Hennart (2019) uses the case of McDonald's franchising all chain restaurants to paraphrase the relationship between UBER and its contracted drivers. In such as hierarchical relationship, Uber controls the behavior of the drivers by inserting controlling mechanism in the app and discontinue the contract with the driver if necessary.

According to Hennart (2019), the network exists as there are interdependency between firms on the value chain; multinational digital platforms try to internalize the cost of transactions (the exchange of outputs) and thereby establish the network on the value chain. The digital platforms, like traditional firms, try to protect their reputation via trademarks. The digital platforms still follow traditional business models such as B2C, B2B, C2C, C2B while networks exist as the business model on the industry level. Besides, the effects of the network model can only be observed ex-post instead of ex-ante. Network effects can only work for first comers when switching costs are high. Therefore, network effects cannot be calcified as the firm specific advantage.

There are valid points made by two authors. Two-side or multiple-side network effects and the Moore Law are two phenomenon which detonates the success of tech firms whether it is in Silicon Valley or in Shenzhen, China. However, whether network effects and Moore Law can become firm specific advantages depend on a lot of factors. The platform such as Facebook or linked in dominate the social network with over 2 billion monthly active users (MAU) and 303 million MAU each.

The switching costs are already high enough that everyone who wish to shed their privacy is immediately excluded from the network provided by these two platforms.

The three authors try to use examples from developed economies such as Uber, McDonald's to validate their theory. Digital platforms from emerging markets were mentioned such as Didi and Alibaba in Hennart (2019) briefly; However, there lacks in depth empirical work done based on emerging market digital platforms and compare their business model with their counterparts in the developed markets.

### *2.2 Emerging market multinationals (EMMs) internationalization theory*

#### *2.2.1 The defected path-and-context based framework*

Traditional OLI framework developed by Dunning explaining foreign direct investment (FDI) was developing during 1950s and 1970s (Knoerich, 2019). These theories were formed to explain multinational firms from developed countries making investment in developing economies. The multinationals were mainly seeking low labor costs and large markets in developing economies. Today the foreign direct investments made from emerging market economies in the overseas market are obviously made for different reasons in very different settings.

Today the dominating theory seems to be path-dependent theories where authors trying to explain the foreign direct investment firms in a context and institutional based manner (Liu, 2019; Deng, 2019). However, based on the summary on the literatures listed below, the authors are still trying to understand the changing political, economic, social and technological settings in developing economies and the interactions with specific firms. Therefore, I try to contradict and compete with existing theories regarding EMMs making OFDI decisions from the country, industrial and firm level explaining the changes occurred in political, economic, social and technological settings in China and the impact it has on tech firms from the semi-conductor, AI and internet industries when they are going abroad.

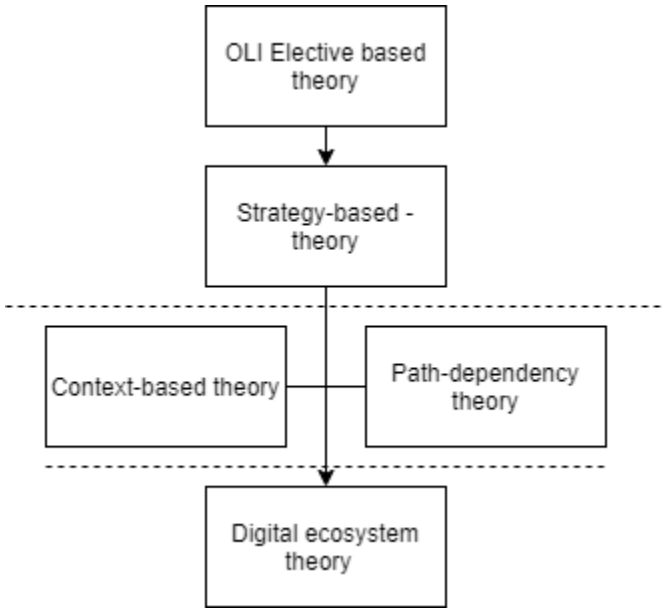

Figure 2.2 The evolution of International Business Models explaining digital platforms; Source: Dunning various publications; Deng et al, 2019; Knoerich, 2019; Liu, 2019; Nambisan, Zahra and Luo, 2019; Hennart, 2019;

As emerging markets digital platforms (EMDPs) grow stronger, they started to navigate foreign market as domestic market became gradually saturated, mature and competitive. EMDPs expand overseas for a larger customer base, stronger domestic brand perception, obtaining international talents and adapting to and subsequently shaping international standards. The existing theories take expanding overseas as a strategic decision and did not take into the unique features of digital platform ecosystems on their appetite for more users, contents, algorithm and design. The conditions determining the development of digital ecosystems on institutional level, industry level and country level are different from traditional businesses expanding in the overseas market.

Hereby gives a summary of traditional theories explaining EMMs and their OFDI strategy. In the next part, I will elaborate on the features of digital ecosystem platforms and their motivations in going overseas.

In Deng et al (2019), the authors identified five characteristics of EMMs.

Firstly, weak domestic institution setting. The author uses an example of Huawei of how the company cannot separate itself from the state.

Secondly, the strong government influence in firms' decision to go abroad. The Belt and Road initiatives can be a case which prompt state-owned firms to explore the overseas market.

Thirdly, the authors identified the lack of superior technological and managerial resources as one of the characteristics for EMMs to go abroad.

Fourthly, the authors pointed out that MNCs are going through an early stage internationalization. By early stage, the author pointed out a lack of superior technological and managerial resources as the key feature of EMMs.

Fifthly, they summarize close ties to the location of their origin as one of the key features of emerging market multinationals.

There are several valid points made by Deng et al (2019) which pointed out that the internationalization of EMMs contradicts the traditional theory of OLI paradigms. Indeed, the OLI paradigms were developed in the 1960s based on the traditional internationalization path of developed country originated multinationals (Knoerich, 2019). These multinationals typically seek investments for labor intensive and cost intensive markets which can lower production cost. This has shaped the formation of the global value chain as it is today. The context-based framework developed by Deng et al (2019) partially makes sense given the geopolitical environment that EMMs are in today such as the impact of trade war between U.S. and China. There are some points worth of further discussion such as weak domestic institution, lack of superior technological and managerial resources as the characteristic for emerging market multinationals going abroad.

First of all, China, has shown strong institutional capacity in the domestic setting by supporting large scale projects; some scholars might argue the competitors of Chinese company, such as Google, Amazon, Apple, Ericsson, Nokia, have stronger domestic institutional settings. However, when it comes to economy of scale, the big Chinese tech companies enjoy the huge domestic market, supportive government policies such as tax subsidies; full supply chain, complete set of

infrastructures (water, electricity, 5G network, credit lines, et). Even foreign tech companies such as Tesla, got the first car out of the production line from the manufacturing plant "Mega Factory" in Shanghai in December 2019 (Financial Times, 2019); It took 168 days for Tesla to get the permits for construction and get a finished factory. Compared with the fate of the Tesla factory in Berlin, the Chinese government has offered cheap financing from state-backed lenders, amounting to RMB11.25bn (USD 1.6bn) for the Mega Factory in Shanghai (Bloomberg, 2019). Strong institutional setting and supportive industrial policy is indeed necessary for economic development. In part 3, policy settings towards wearables industry development will be discussed in details.

Secondly, given the high level of maturity of the Chinese tech market and the intensive competition, the Chinese companies who went overseas are seeking alternative markets and higher returns overseas. Most Chinese companies made foreign investments are survivors and has often acquired a dominant position in the Chinese domestic market. Usually the global headquarters of Chinese multinationals are still based in China. The Chinese headquarter is serving as the coordinator of global resources and also as the engine for driving global innovations for different types of business. The overarching concept that emerging market multinationals do not have superior technological and managerial resources should be rectified.

Thirdly, the high-profile technological companies such as Alibaba, Tencent, Huawei and Xiaomi are privately owned in China as opposed to state-owned firms; the motivations of foreign direct investment by Chinese firms remain profit driven. In the process, the Chinese companies may be associated with the Chinese government, and its motivations. This leads to conflicts of state interest and business interest. Does the government policy such as One Belt One Road (OBOR) plays a role in Chinese foreign investment? To a certain degree, yes. However, OBOR projects are mostly related to infrastructure. Tech companies rarely make investments in regions such as central Asia, Pakistan or Horn of Africa to align themselves with state interests. Instead, all the investments made by tech companies are related to strategic development and ecosystem development.

Fourthly, the success of Chinese firms going global strategy started with Haier, a privately owned home appliances business (People.com, 2000, in Chinese. Haier started investing in the U.S. in greenfield style with an industrial park in 1999 (Haier, 2020). 20 years have past and Haier has made M&A in New Zealand and Japan and its products are available in China, U.S. and Europe. In the age of IoT, Haier has also shown off its pilot connected kitchen in CES Asia 2019. Haier has won the award for innovation in management theory and framework at the National Management Conference. Haier, as a Chinese company has accumulated 20 years of knowledge and network in internationalization. Lack of superior technological and managerial resources does not seem to fit in the case of Haier.

Fifthly, any multinationals going abroad maintain close ties with their origin. Take Tech companies from the U.S. for instance, Google, Amazon, Facebook were recently heavily fined by the European Commission for breaking the anti-competition, tax and privacy related laws and regulations. The current U.S. president Donald Trump showed his support by not only sending several tech officials to CES but also blaming the European Commissioner, Margrethe Vestager as "She hates the U.S." (Financial Times, 2020). By supporting Qualcomm in the court case for patent, and sending Huawei to court for stealing "U.S. Technology" (Financial Times, 2020), the current U.S. government certainly supports U.S. companies in building 5G networks around the globe by bending the U.S. legal system to state interests.

### *2.2.2 Buckley and three layers of factors affecting firm internationalization*

In Buckley (2019), the author identified three layers of factors affecting Chinese firms going abroad. The author considered national (provincial and city) level policy factors, industrial level factors and firm level factors. The author identified the historical phases of Chinese firms going abroad, with phase one started 1979 with the Chinese government opening door policy, phase two government encouragement, phase three expansion and regulation, phase four the go global phase, phase five, the post-WTO stage. The author identified the trends of Chinese firms overseas foreign direct investment in the format of M&A.

Firstly, Buckley (2019) seems to consider the defected Chinese capital market as one of the factors which affect the overseas M&A activities for Chinese firms. The abundance of Chinese capital invested in advanced economies such as the UK, Australia, Canada, the U.S.A, are causing local media and government attention for Chinese seeking strategic assets or stealing foreign technology. This on a national level causes counter Chinese investment measures in the U.S., Australia and the UK (Financial Times, 2019) on using Chinese suppliers for 5G network construction. On an industrial level, Huawei was nearly banned as IEEE reviewers and from participating in standard setting on 5G. On a company level, the Huawei CFO was arrested in Canada, which on a personal level attacked the founder of Huawei who is the father of the CFO. This proves on that the interest of Chinese private businesses and Chinese national interests does not align. As a communist country, China is seen a rival rather than alliance in most advanced economies. With the rise of populism, the Chinese people, investment are viewed as threats rather welcomed as boost to local economy.

Secondly, Buckley (2019) suggests that Chinese firms launch overseas investment in markets with close ties to the Chinese government with high risks. Considering the large-scale infrastructure projects in Myanmar, Pakistan, Ethiopia, this may be true. When it comes to the foreign direct investments made by tech firms, the incentive for COFDI is always related to profit. One of the biggest incentives is to acquire new markets given the domestic Chinese market is highly mature with abundant tech infrastructures in urban regions and intensive competition. Xiaomi is marketing in rural areas of China. Successful tech companies, such as One Plus chose to expand in South East Asia market like India. Huawei set up R&D centers in Europe to acquire and use foreign design talents; interestingly most foreigners view Huawei as a threat yet the infrastructure of T Mobile, Vodafone, and several other telecommunication providers are all equipped with Huawei switches. Huawei went to the Africa market to obtain market shares, obtain dominant positions and become market leaders. The other purpose is to train the talents of Huawei in one of the most difficult environments on the earth to do business, Uganda (WSJ, 2019; World Bank Doing Business Index, 2020). Uganda is a low-income country in Africa which ranks 169$^{th}$ on the World Bank doing business index. In contrast with what western media described as providing tools for surveillance for its citizens (WSJ, 2019), Huawei provides critical communications infrastructure for the population in Uganda. Without companies such as Huawei, the African population cannot use basic mobile services.

Thirdly, Buckley (2019) noticed that COFDI (Chinese outward foreign direct investment) flows to tax havens. The situation is explained by the ineffectiveness of the Chinese capital market and the attenuation effects of tax havens in orchestrating resources between different locations. When it comes to the three surveyed firms, Huawei, Xiaomi and Ali-health, Huawei is registered in Shenzhen, China; Xiaomi is registered in the Cayman Islands; Alihealth is registered in Bermuda. Except Huawei, Xiaomi and Alihealth are both registered in tax havens. This may relate to the fact that Huawei is a privately owned firm while Alihealth and Xiaomi are publicly listed in Hong Kong.

Strategically, public listed companies need to display their revenues, earnings in their quarterly report. This may force the firm to focus more on short-term interest if they do not have enough cash holdings to counteract the fluctuations in the stock market.

Fourthly, Buckley (2019) argues the lack of transparency as one of the key features of Chinese firms' overseas M&A. In case of state-owned and privately owned firms, this might be true. However, when it comes to publicly listed firms, all their behaviors must be reported to the stakeholders quarterly. Therefore, this assumption does not apply to most tech firms in China, which is either listed overseas or domestically.

### *2.2.3 The benefits of overseas M&A: exchange of knowledge and networks*

In He et al (2019), the author identified technology as one of the firm level advantages for the internationalization of Chinese firms. He (2019) used three case studies to confirm his theory, namely BYD, Sany Heavy Industry and CSR China. All three are heavy manufacturing firms in automobile (electric cars/buses/railway cars and electronics), construction equipment and railway/metro cars industry. He (2019) used secondary data to support his theory of Chinese firms' internationalization. Among them, BYD, a privately owned firm started as a battery manufacturer, and expanded business in electric cars. Now it has expanded from China to the Netherlands, Singapore, U.S.A, Brazil, Ecuador, Chile, and Colombia. Sany, a privately-owned Chinese firm, had expanded to Russia, Latin America, South America and Africa. CSR China, a state-owned firm now has production lines in the U.S. and has expanded business there as well. All the data collected was second handed in the He et al paper. Undeniably a few years ago, the Chinese metro and railway construction was still using technology from Hong Kong, Germany for construction of its metro and railway. Now Chinese firms are exporting such technology in Africa, the Netherlands, and the U.S.A, which proves Chinese firms are able to learn, transform, and provide low-cost solutions fast.

The interesting fact is western media cannot separate private Chinese firms and state-owned Chinese firms. They believe all firms in China are related to the Chinese government and the Chinese government has control of all data collected by all firms in China according to the national security law carried out by the Chinese government. In reality, the Chinese firms go abroad based with the same incentive of their western counterparts, to acquire users, to expand their product ecosystem, to acquire knowledge and networks.

In Liu (2019), the author used the M&A case of Goldwind in Germany and Envision Energy Co., Ltd.as examples of Chinese firms catching up in the manufacturing of wind turbines. Both case studies were conducted based on interviews with managers from Goldwind and Envision. The only difference is the Goldwind is an established firm while Envision started with a few investment managers from London with ambition and vision to build wind turbines. The knowledge and network accumulated during their experience as fund managers for wind industry proves to be effective to start an enterprise.

To summarize the research gaps identified by the previous authors, the current study of network model. the digital ecosystem model and the internationalization theory needs to be further reinforced with the reality of Chinese tech firms. Therefore, with the study conducted on smart health industry in China, the author of this paper hopes to expand and extend the international business theory.

## 3. Theoretical Framework and research methodology

Chinese tech firms joined the top tier manufacturers in the Internet of Healthcare Things industry. After 20 years of industrial policy focusing on upgrading Chinese firms on the value chain, the policy started to pay off. The Chinese government promulgated “Made in China 2025”, “Healthy China 2030” projecting using big data and cloud computing to upgrade the Chinese healthcare system and to counteract the effects of aging population (. Take the value chain for wearables as an example, it can be roughly divided into 8 parts (Wearable Technology, 2019);

Firstly, chip vendors, component or material. For instance, companies such as Texas Instruments, 3M, NXP, Bosch, Intel, Qualcomm are categorized as chip vendors, components and materials (Wearable Technology, 2019). Companies such as Alibaba and Huawei have recently started to develop their own chips called Hanguang and Ryzen. Companies such as Texas Instruments, Intel, NXP design and manufacture semiconductors from silicon (Intel, 2020; NXP, 2020); NXP also provide IoT, automobile solutions based on semi-conductor. 3M provide soft materials, equipment and machines for product manufacturing (3M, 2020). Qualcomm has accumulated a large number of patents in chip design (Qualcomm, 2020). Bosch produce sensors which can be incorporated with the IoT system (Bosch, 2020).

Secondly, Electronics Manufacturing Service (EMS), Design, Embedded Systems, integrators, original equipment manufacturer (OEMs), Original design manufacturer (ODMs). Companies like Accenture, Foxconn, Cosmo Supply Lab go into this category (Wearable Technology, 2019). Accenture serves as a consulting firm which focuses on design smart ecosystems (Accenture, 2020). Foxconn’s business lies in assembling different parts in the smart phones and other wearables (Foxconn,2020).

Thirdly, standardization Test Houses; Huawei now has become an important part for standard setting, with research staff volunteering for IEEE; the recent turbulences caused by the trade war even led IEEE to ban Huawei staff members to participate as reviewers and editors. Zigbee, Wifi and Bluetooth and other standardization testing houses are also related to the development of the IoT industry (Wearable Technology, 2019). More and more Chinese firms are actively participating in the standard setting process for technological development. For facial recognition standard setting, for instance, Chinese firms such as Sensetime is leading a consortium of tech companies in setting global standards at the UN (Financial Times, 2019). This has caused a panic in the US as US government believes Chinese firms are taking a lead in setting global technology standards for facial recognition. Subsequently CIFUS banned US companies from cooperating with Chinese companies such as Sensetime, Yitu on national security grounds.

Fourthly, network providers. In China, state-owned network providers dominate the market; for national security reasons, China Telecom, China Mobile, China Unicom dominate the broadband internet and mobile service market. There are 1.578 billion individual mobile users with 113.8% market penetration rate (World Bank, 2019). Among the 1.5 billion users, China Mobile accounts for about 9.35 billion, the three service dominators take up to 99% of the mobile service (data, calls, and text message) in China (China Mobile, 2020). In Europe, Telecom, Vodafone, O2, Wind offer internet and mobile data services. In the US, companies such as Verizon, AT& T take the lead in providing mobile services.

Fifthly, Cloud Services. Alibaba, for instance, has become a strong player in the field of cloud storage and computing. It provides both private and public cloud services in data storage, computing, algorithm optimization and other services related. Google cloud and Microsoft 365 solutions offer similar solutions. Alibaba are selling its cloud services to its ecosystem partners in South East Asia (Financial Time, 2020) such as Lazard to expand the market share of its cloud services. Tech companies such as Xiaomi have data stored in Singapore, the US, and China depending on the local law (Xiaomi, 2020). Baidu as a tech company also offers cloud solution for both individual users and institutional customers (Baidu, 2020). Huawei offers similar service as well (Huawei, 2020). Almost all significant Chinese tech companies offer such services and subsidize individual users significantly with free services in the hope of using the vast amount of data to train their algorithms.

Sixthly, services providers B2B & B2C. Nike, Runtastic, Apple, ING, Mastercard, Google Pay, Alipay, ING, Paypal, go to this category. Nike, Rubtastic (Adidas sponsored) offer personalized training advice. Apple IOS offers digital platform for app developers. ING, ABN AMRO, Alipay, Google Pay, Paypal offer digital payment services.

Seventhly, Product Solutions. Huawei, Philips, Huami, Garmin, HTC, Adidas belong to this category. Huawei, Philips, Huami, Garmin, HTC, Adidas provide users with wearables, phones, shoes, medical devices, etc. Therefore these companies are product focused companies.

Eighthly, distribution. Apple Store, Amazon.com, Bestbuy, Huawei Flagship Store, Xiaomi Flagship Store belong to this category. Retailers are the point when users get in touch with the brand first. The distribution plays a significant role for brands to know customer's preference and accommodate to customer's needs by adjusting brand image. The theoretical framework was established by Wearable Technology (2019) to evaluate the position of firms in the value chain. Alibaba has started from the bottom of the value chain as distributors; then it moved on to product solutions providers, to service providers, cloud service providers and chip venders. Huawei has started as product solution providers, then moved up to service providers, network providers and standardization test house.

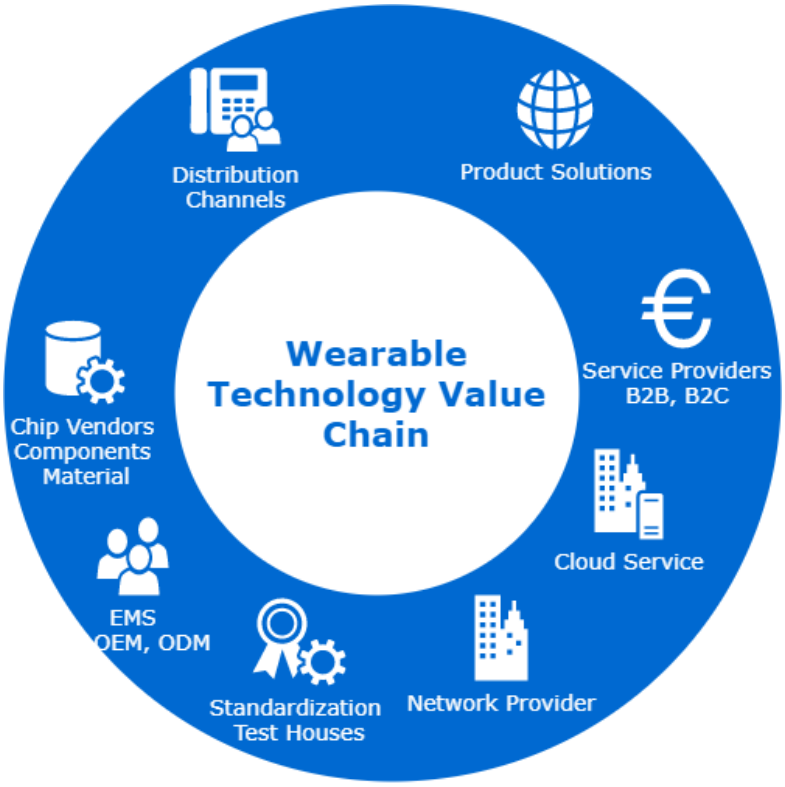


Figure 2.3. Wearable Technology Value Chain. Source: Wearable Technology, 2020; Author's design

To summarize the above-mentioned factors, there are unanswered questions about factors affecting the tele-health industry development and how Chinese tech companies upgrade their positions in the value chain in the tele-health industry during a short period of time. To answer the research question for the paper, case studies based on the Chinese smart health industry are presented below.

To answer the research questions described in the previous paragraph, the case study was designed with the guidance from Yin (2017) and Eisenhardt, K. M (2012), to study the ecosystems of tech companies and their incentives in exploring the digital health industry. The three companies Huawei, Xiaomi and Alibaba were considered.

Semi-structured interviews were held with Business Manager for Alihealth – Medical Brain Unit, Business Manager for Huawei Wearables and Sports Health Unit, Business Manager for Xiaomi Wearables Unit and Investment Manager of MIUI Investment Division in an anonymous manner.

These interviews aim to get insights from tech companies involved on barriers and strategies on implementing smart health solutions in China. The data was collected in Chinese, translated by the same researcher in English, and consent was obtained about publication and quotation anonymously.

The interview questions were designed and sent to interviewees in advance. If time allowed, additional questions were proposed to get questions answered thoroughly. The questionnaires are attached as annexes to this paper.

## 4. Innovative Business Model Case Study based on Huawei, Xiaomi and Alihealth

The smart health industry in China is a burgeoning market, offering opportunities for foreign and domestic tech companies alike significant chances of growth. Table 2.1 list start-ups in China and in Germany, offering services such as improving diagnosis efficiency, proactive health management and personalized medicine. The startups have potential to upgrade the smart health industry with their technology, business models and digital network.

Table 2.1. Services offered for selected smart health start ups; Source: Sensetime, 2020; Yitu Technology, 2020; Linkdoc, 2020; Keep, 2020; Burning Rock, 2020;Mobvoi, 2020; Inveox, 2020; Wegene, 2020; Infervision, 2020;

| | **Cloud Computing Platform for Developers** | **AI applications in Diagnosis** | **Personalized medicine** | **Genetic Test** | **Internet Hospital** | **Wearables** | **Personalised Training Program** | **Partenership with insurance companies** | **Business Model** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sensetime*** | X | X | | | | | | | B2B |
| ***Yitu Technology*** | X | X | | | | | | | B2B |
| ***LinkDoc*** | | | | | X | | | X | B2B |
| ***Keep*** | | | | | | | X | | B2C |
| ***Burning Rock Dx*** | | | X | X | | | | | B2B & B2C |
| ***Mobvoi*** | | | | | | X | | | B2C |
| ***Inveox*** | | X | | | | | | | B2B |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Wegene*** | | | | X | | | | X | B2C |
| ***Infervision*** | | X | | | | | | | B2B |

Sensetime and Yiyu are tech start ups which work on image recognition. Mobvoi provide voice assistant with its wearable products in different user settings. Linkdoc work on internet based hospital solutions and offer AI support for pharmaceutical companies. Burning rock aims to identify genetic linkages with cancer and provide personalized medicine solution.

Table 2.2. Financial Ownership and business network of other Chinese firms in the telehealth industry

| Competitor | Public | Private | Pension Systems Integration | Partenership with Insurance Companies |
|---|---|---|---|---|
| We Doctors Limited Holdings | | X | X | X |
| Tencent | X | | X | X |
| Ping' An Healthcare and Technology Ltd | X | | | X |
| Huawei | | X | | |
| Xiaomi | X | | | |
| Alihealth (Alibaba) | X | | | X |
| Microsoft | X | | | |
| Samsung | X | | | X |

Interviews were conducted with Huawei, Xiaomi, and Alihealth. Other companies were studied based on their public profile such as company website, news and public information disclosure (quarterly and annually) if they are listed in the stock market. In Table 2.2, Huawei and Wedoctor are privately owned companies given their positions in the digital infrastructure in hardware and software. Tencent, Ping An, Xiaomi, Alihealth, Microsoft, Samsung are public listed firms. We Doctors and Tencent Clinics offer services which can be partially reimbursed by the basic employee medical schemes and some private medical insurance schemes. Tencent Clinics, We Doctors, Ping An, Alihealth and Samsung have collaboration relationships with private insurance companies. The partnership implies users can be diverted from the above-mentioned service platforms to insurance schemes, or offer collaboration service packages with fellow insurance companies so as insurance companies can dive into health-related data while users get more services and less choice from the same package.

### *4.1 Case Study on Huawei*

Huawei as a firm has received wide public attention lately because of the US – China trade war (WSJ, 2020; BBC, 2020; Financial Times, 2020; Bloomberg, 2020). Huawei has obtained a portion of market share globally in IT network infrastructure, which attracts attention in the upgrade for 5G given the national security concerns of western governments (see Figure 2.5). For the smart phone category, Huawei also obtained a considerable market share (see Figure 2.6). Huawei's ecosystem also incorporates wearables (Bands, Watches), Apps, smartphones and home appliances for individual users. In the smart health industry, for institutional users, Huawei offers e-Hospital solutions, regional Health Connection Solution, regional healthcare information network solution, telemedicine, multi-Channel HD Telemedicine Solution. This solution was used during the COVID-19 for hospitals in Wuhan to enable tele-conferencing for experts from other provinces to call doctors from the designated hospitals which hosts about 700 patients with COVID-19.

IoT Connection Management Platform

Cloud Reshape Enterprise Communication Value


TE30 All-in-One HD Videoconferencing Endpoint

TP3206-55 Panovision Telepresence System

Figure 2.4. Huawei Ecosystem Display for individual users and institutional users; Source: Huawei Consumer Wearables, 2018; Huawei Healthcare Solutions, 2018; Developers Huawei, 2018; Research and Innovation, Huawei Europe, 2018;

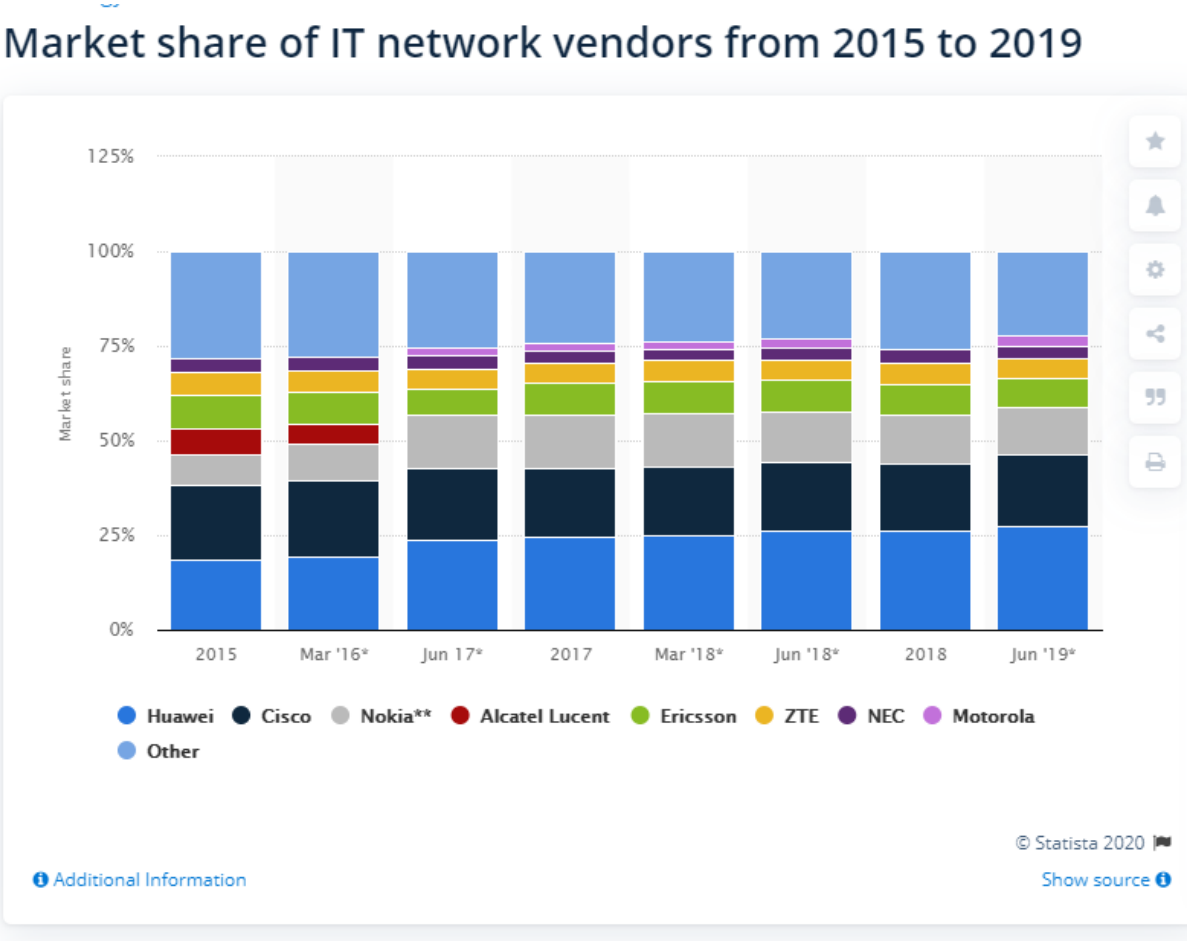


Figure 2.5: Market Share of IT Network Vendors, 2015-2019, Source: Statista 2020;

Huawei has a wide customer base including children, working professionals and institutions. Their sales channels include online, offline, social media campaigns via Weibo. The Huawei brand has become from a merely Chinese brand to an international brand in the past 20 years. Huawei was created to sell switches to telecom service suppliers.

Huawei follows a hardware-based strategy where it started with switches for telecommunication in the 1990s. During the process, Huawei was almost obtained by Motorola; Huawei later started to etch in from the top of the supply chain to the bottom to supply chain. The investment in R&D and human resources are huge which is probably why Huawei never went public. In 2018, Huawei devoted RMB 101.5 billion/ USD 14.48 to R&D, accounting for 14.1% percent of its annual gross income (Xinhua, 2019). Huawei also obtained 5405 patents (Xinhua, 2019) The solid redemption packages offered by Huawei attracts a large number of young and old recruits to join the firm. The youngest VP in Huawei was 27 when he was promoted for solving major technical challenges such as developing new types of switches. In the beginning the competition was fierce between Huawei and other major telecommunication equipment suppliers such as Bell.

Huawei has expanded globally at a remarkable speed, owing to the fact that Huawei sent its staff to areas such as Uganda and Greece alike. The markets which were previously ignored by the western firms such as Nokia, Ericsson, Qualcomm, etc. There has been closely aligned with the low human resources cost and production cost of Huawei.

Since Huawei has obtained a large market share in the upstream of the value chain in the ICT industry such as IT standard setting, it has expanded into the downstream of the value chain as well. For instance, in the smart phone industry, Huawei has taken up a large market share (see Figure 2.6).

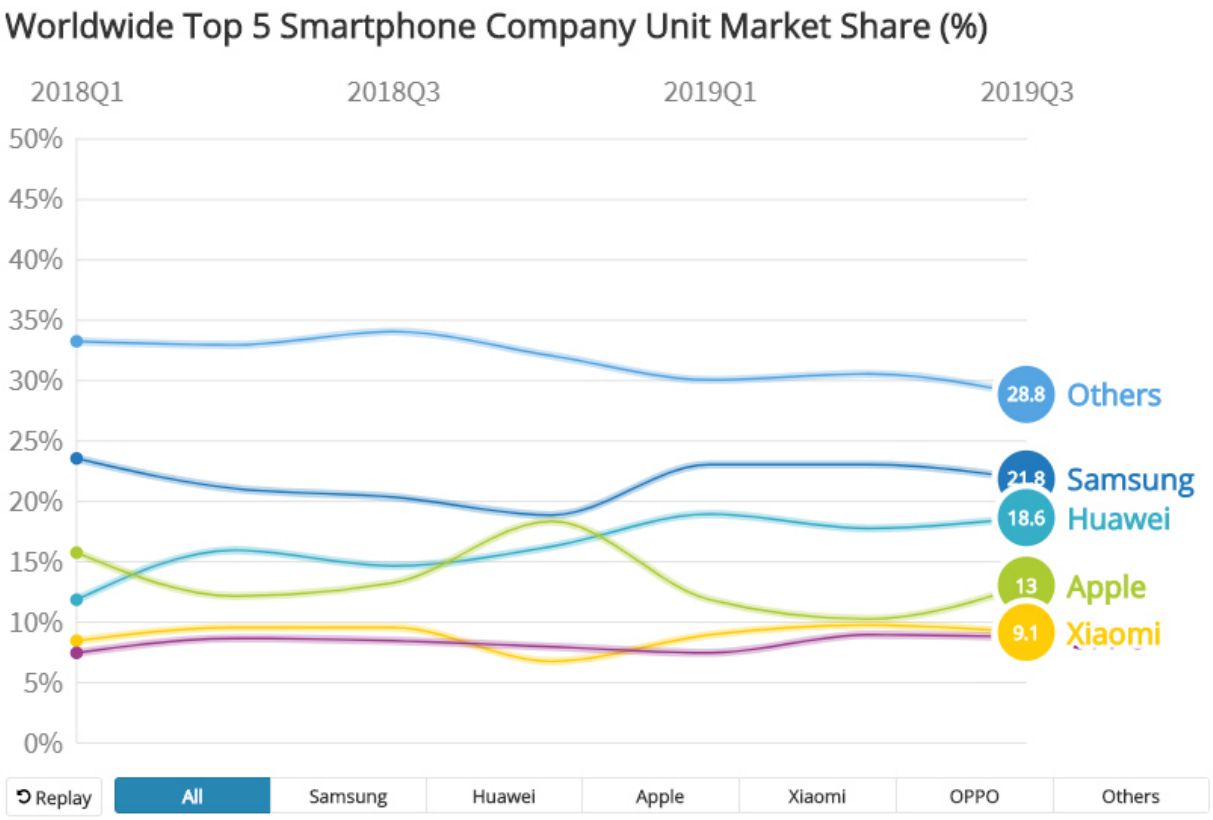


Figure 2.6 Smart Phone Market Share, Source: IDC, 2020;

In the meantime, Huawei has expanded into the downstream of the smart health industry, such as wearables. Even though claiming to have no health focused strategy, Huawei has taken a software plus hardware combined approach to tackle healthcare problems. For hardware, they offer Huawei smartphone, wearables and IoT related smart home products such as sleep monitor (non-medical device), scale and masks. These products are sold via two channels, online and offline. The online channel incorporates Vmall, Taobao, Tmall, Amazon, Weibo etc. Social media campaigns. The offline channel includes Huawei flagship shops abroad and at home. By estimation, in 2018, Huawei has about 2000 offline flagship shops in major shopping malls in China. In Europe, Huawei has set up experience centers in Paris, London, Brussels, and other major cities.

What is worthy of mention is the Huawei pricing strategy. In the beginning, Huawei is seen as a technical solution provider to institutional users. Over 30 years, it has established a solid individual user base in China and overseas among children, professionals, middle-aged user group alike as a reliable brand. The brand image has switched from a low-end brand to a high-end brand able to compete with Apple and Samsung in the smart phone market. In overseas Chinese market, Huawei is focuses on selling smart phones and wearables as package to promote the use of wearables by Huawei. For instance, the smart bands offered by Huawei has a price range in China by RMB 129 to RMB 459 (Euro 17.9 to 61.19); the Huawei Smart Watches prices range from RMB 449 to 4988 (Euro 59.86 – 665); the Smart Sleep Monitor costs about RMB 999 (Euro 133.08) while Smart Scale cost around RMB 113 (Euro 15.05). The Smart Masks costs around RMB 249 (Euro 32). (Source: Vmall, 2018).

In Europe, Huawei has about 1900 R&D staff. To take use of the European innovation capacity, Huawei has established around 18 R&D centers in Europe by 2018 (Huawei, 2018). For instance, Huawei has R&D center in Germany because of its industrial design capacity and has since promoted the Huawei Mate Porsch series phones for the high-end market (Huawei, 2018)

For the internet of healthcare things, Huawei tries to develop the ecosystem with its partners in the platform. The IoT smart home products within Huawei brand contains humidity, temperature sensor and smart scale. The other products available on Vmall are developed by ecosystem partners. Huawei creates a connecting platform called Hi-link to connect more than 50 different kinds of IoT products covering 4 categories: sports & health, entertainment & office, connected cars, and smart home products. The wearables targeting the aging population are still in development stage; possible functions include fall detection, humidity and temperature sensors, GPS, heart rate, blood pressure monitoring. Regarding data sharing within user group, Huawei explicitly point out the need to obtain user consent.

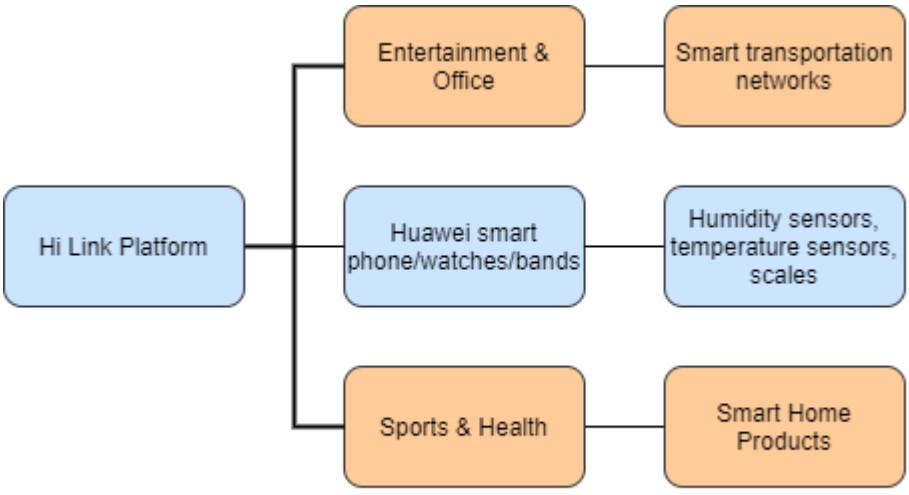


Figure 2.7 Huawei IoT ecosystem, Source: Interview with Huawei, author's design

Huawei aims to offer preventive healthcare services, post-treatment and long-distance patient care in the future. These solutions include developing algorithms for nutrition automatic detection on smart phone cameras, and edge-based computing for health-related data (weight, heart rate, sleep, sports). Huawei currently works on developing its own algorithm and chips for edge computing. Huawei also explores data-sharing based business model by working with an insurance company in South Africa, serving user with free wearables to give users incentives for exercising with adjustable premiums.

Huawei identified some barriers in implementing smart health solutions such as: there exist no separate technology admission standards for wearables application in medicine sphere in China; so far there exists no national level of patient profile platform; there are culture-related barriers for marketing and developing user-based function in Europe; Huawei offers basic tracking function for wearable products selling in Europe, limited third-party partners such as internet based hospital.

To go into the details for the Huawei ecosystem, Huawei uses phones, pads, and sports watch, the Huawei Sports app, Hlink App and router to interact with users. Huawei Hi Link App has been designed for smart application scenarios in home entertainment, home lighting, smart health, energy management, home security, automation, routers, smart TV boxes, lighting, environment, interior design, all coverage routers, Wifi, kitchen, audio, smart sleep monitoring, etc. There are about 50 core partners.

Huawei has promoted the use of interaction depending on the maturity of the technology. Now Huawei is focusing on delving into the health-related function for wearables and terminals (telephones). For instance, there are temperature sensors on phones, and in the future can detect temperature inside and outside home. The same design is planned on smart watches. Meanwhile, there are temperature and humidity sensors on smart home devices. Huawei is working with third party partners, such as Omron and Dnurses to track blood pressure and blood sugar level changes. Huawei mainly use its terminals to keep track of the biometic indicators.

In China, Huawei smart phones is pre-installed with Wedoctor, DXY, Chun Yu Doctor apps to make it convenient for users and give users better healthcare experience and to offer one-stop health services. In the overseas market, such as Europe and the US, wearable devices manufactured by Chinese companies face strict regulations. Meanwhile to develop health related functions, it is necessary to consider the local culture. Therefore, it is not possible to delve in the value for wearables compared with the Chinese market. The development process is oriented at users in the Chinese market. There are few restrictions to launch the sleep and sports related function in the overseas market. The functions are not going into the medical directions yet. Whether in the future there will be restraints towards wearbles and medical related functions embedded is yet to see.

Now the South Africa insurance company- Discovery is working with Huawei to offer free wearable devices, which charges users on a term basis. When users reach a certain number of steps daily, the monthly term payment can be exempted. Users can lower their insurance premium by using the device long term. In the meantime, it is possible to lower health risks for users.

As a multinational, Huawei Headquarter in Shenzhen took up the coordination of resources function. The wearables are mainly developed in the domestic market. The Huawei HQ in China

is a coordination center to manage all the businesses for Huawei overseas growth. The location choice for the overseas development center was chosen based on technology, for instance, like the algorithm development center in Finland, and the hardware development center in Germany, and the design center in France (for fashion), etc. The sample in the labs for developing algorithms is relatively small. It is mainly developed in labs and does not use data from users, and will not transfer data from China to overseas labs or transfer data from overseas to China. It is possible to update the algorithms later at the clinical trial or commercialization stage with larger size of data.

### *4.2 Case Study 2: Xiaomi*

Xiaomi has become a leader in the Chinese IoT market. Xiaomi also produces Mi Band, a smart health device which offers coaching advices for users in different scenarios.

**Top 5 Wearables Companies by Shipment Volume, Market Share, and Year-Over-Year Growth, Q3 2019** (shipments in millions)

| Company | 3Q19 Shipments | 3Q19 Market Share | 3Q18 Shipments | 3Q18 Market Share | Year-Over-Year Growth |
|---|---|---|---|---|---|
| 1. Apple | 29.5 | 35.0% | 10.0 | 23.0% | 195.5% |
| 2. Xiaomi | 12.4 | 14.6% | 7.4 | 17.1% | 66.1% |
| 3. Samsung | 8.3 | 9.8% | 3.2 | 7.4% | 156.4% |
| 4. Huawei | 7.1 | 8.4% | 2.3 | 5.4% | 202.6% |
| 5. Fitbit | 3.5 | 4.1% | 3.5 | 8.0% | 0.5% |
| Others | 23.8 | 28.1% | 16.9 | 39.0% | 40.4% |
| **Total** | **84.5** | **100.0%** | **43.4** | **100.0%** | **94.6%** |

Source: IDC Worldwide Quarterly Wearables Tracker, December 5, 2019

Figure 2.8: Market share of wearables unit shipments worldwide by vendor from 1Q'14 to 1Q'19, Source: IDC Research, 2020;

By Xiaomi started off as a smart phone manufacturer in 2010 in Beijing. Founded by Leijun, an entrepreneur who had multiple years of experience as CEO for a software corporation Jinshan. Jinshan specializes in offering WPS (a Chinese version of Office) solutions. By 2018, Xiaomi has become the world's leading IoT device manufacturers. In China, Xiaomi's marketing position has been low-end and middle class. Therefore, their major marketing campaigns focus on young people and students. In the overseas market, Xiaomi targets middle class and high-end market.

Xiaomi's products cover several categories: Wearables, which include band, watch and shoes (Customization/Prosumer Design); Home Appliances, which include smart scale, smart air purifier, smart toothbrush/lights/water purifier, etc. Smart Phones, which include Red Mi targeting young users, smart phones for pets, elderly and children, with only GPS tracking and voice communication functions. Xiaomi's market share is the world's second largest by shipment for band.

| Quarter | 2018Q1 | 2018Q2 | 2018Q3 | 2018Q4 | 2019Q1 | 2019Q2 | 2019Q3 |
|---|---|---|---|---|---|---|---|
| Samsung | 23.5% | 21.0% | 20.3% | 18.8% | 23.0% | 22.9% | 21.8% |
| Huawei | 11.8% | 15.9% | 14.6% | 16.2% | 18.9% | 17.7% | 18.6% |
| Apple | 15.7% | 12.1% | 13.2% | 18.3% | 11.8% | 10.2% | 13.0% |
| Xiaomi | 8.4% | 9.5% | 9.5% | 6.7% | 8.9% | 9.7% | 9.1% |
| OPPO* | 7.4% | 8.6% | 8.4% | 7.9% | 7.4% | 8.9% | 8.7% |
| Others | 33.2% | 32.9% | 34.0% | 32.0% | 30.1% | 30.6% | 28.8% |
| **TOTAL** | **100.0%** | **100.0%** | **100.0%** | **100.0%** | **100.0%** | **100.0%** | **100.0%** |

Figure 2.9. Smartphone Market Share, IDC Report, Source: IDC, 2019

One interesting case study is about Xiaomi, a leader in the Chinese IoT market and also produces Mi Band, a smart health device which offers coaching advices for users in different scenarios. Figure 2.10 displays Xiaomi's IoT business strategy.

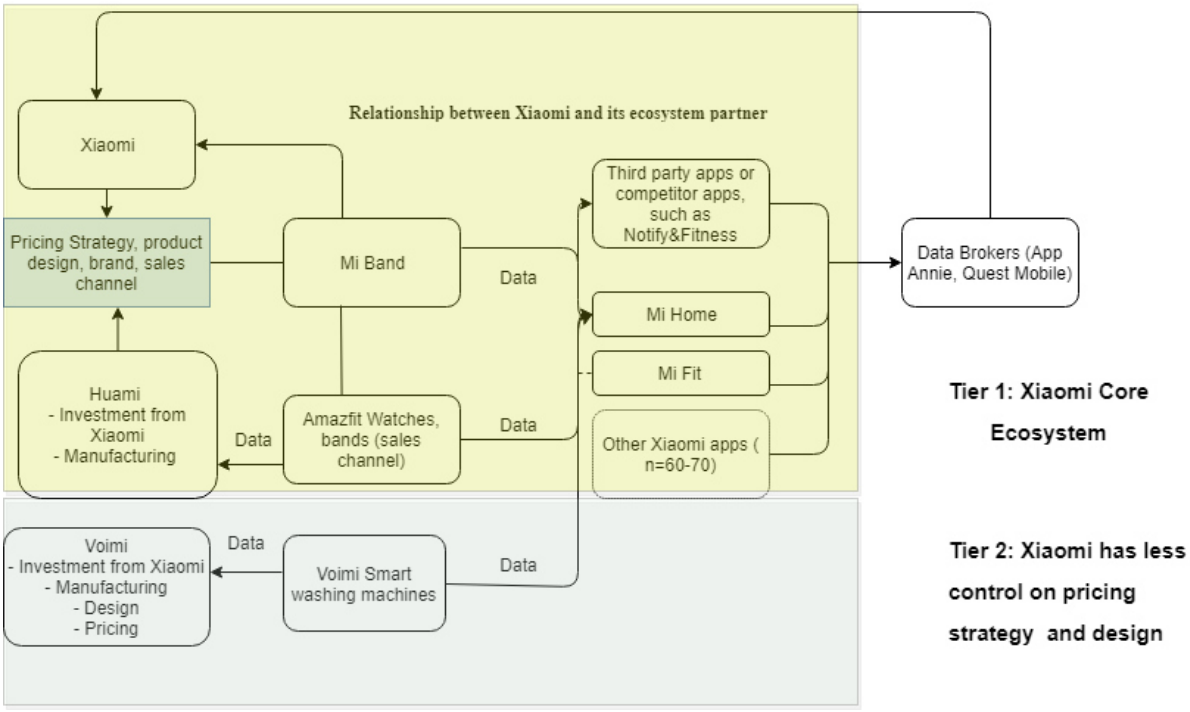


Figure 2.10. Xiaomi IoT business strategy. Source: Author's design, Interview with MIUI Investment Director

Xiaomi has created partnership with insurance companies for two purpose, to increase the user stickiness to Mi Band and to promote the products with a separate user group by diverting users from Mi Fit to Zhong An Insurance for Steps Sharing Insurance. In this way, users can trade steps

walking per day with the day insurance premium payment to Zhong An. The partnership has stopped because of GDPR and the P.R. China Privacy Law (Chen et al, 2020).

To build the IoT product matrix efficiently at a low cost, Xiaomi has followed the strategies.

Xiaomi focuses on 80% of users and their 80% of needs instead of focus on the entire user group population. Xiaomi reduces cost and offer standardized products. Therefore, Xiaomi users do not have the luxury of personalization of products. The Xiaomi brand is seen as a low-end and middle-class brand targeting young user group in China compared to Huawei's more sophisticated brand image. Xiaomi focuses on core products and strategy design. The ecosystem brands are responsible new dimension in IoT matrix (Chen et al, 2020).

Xiaomi has also identified barriers of going into the IoHT market as the data sharing with doctors over healthcare data and personalized healthcare solutions can be difficult in China given the scarce medical resources in China. The CFDA processes can slow down new health related function development. Xiaomi is conservative regarding sharing data collected from wearables with others Besides Xiaomi, there are a few attempts to test the data driven business models for smart health solutions.

For example, users share steps data with insurance companies to trade for premiums for critical disease insurance. Others can trade steps for term payments of wearables. Some companies decide to rent smart home devices and offer coaching advices for elderly. Users pay for services for fixed terms and in the end get the device for free.

Xiaomi users are getting used to paid services with IoT products serving their needs, and now it is not the time to harvest the value. The current investment project is mainly to focus on complement Xiaomi existing internet-based businesses, to create synergy value, or to fill in the gap for up/downstream businesses. Xiaomi has invested in 51Yund.com[2], Ximalaya.com[3], Ofo[4] etc. Now Xiaomi offers internet services-mainly advertising, and Internet value-added services[5], currently accounting for 9% of the annual income. Investing in these apps, which come with a large user base, can potentially complement Xiaomi's current internet services, as Xiaomi cannot offer all services on the smart phone. Xiaomi now has a large user group, with users demanding a vast amount of services. The unmet needs from users can be met with the apps Xiaomi invested. Xiaomi offers the startups with funding and platform; as the businesses grows, it can be profitable for Xiaomi to get returns from the ecosystem businesses, and to also profit from diverting users to these apps from Xiaomi. The business model is about diverting users or to complementing services for Xiaomi. The value of the business model lies in complementing Xiaomi's services, creating synchronized value and profit from shareholding of ecosystem firms.

[2] 51Yund.com offers sports coaching services.

[3] Ximalaya.com offers music, audio books, education services.

[4] Ofo.com offers bike sharing services.

[5] Xiaomi.com, http://blog.mi.com/en/2018/08/06/the-internet-reimagined-xiaomi-provides-tailored-internet-services-to-meet-evolving-consumer-needs/

In India, Xiaomi takes up a localized brand image by nominating Manu Kumar Jain as Head of Xiaomi India. The move was to impress the Indian consumers with the Xiaomi brand and takes up a high-end brand image as Manu Kumar Jain is seen as an aristocrat in India. Xiaomi remains popular with young users in India with the large android market offering a wide choice of apps to analyze data collected from Mi Wearables. This seems to be a common marketing strategy in Asia whereas middle-class brands in Korea and Japan become high-end brands in China whereas middle-class brands in China become high-end brands in India.

### *4.3 The use of smart health solutions in monitoring epidemics*

Big tech companies such as Google has used smart health solutions to monitor epidemics such as flu back in 2013. Then Google Health API monitors flu trends by the number of search results (standard deviation from baseline) in several countries. The API allows public health experts to monitor the rise and fall of flu cases in the country selected and compare the trends between different healthcare systems. Take the Netherlands, Germany and Belgium for instance. One can observe from Figure 2.11 that the flu search results spiked from Jan to Feb every year except 2009, where the peaks appeared in both Jan 2009 and Nov. 2009. This can be explained by the H1N1 epidemic in 2009. The differences in intensity of searching activities can possibly be explained by the variance in the responsiveness of the public health systems in the Netherlands, Belgium and Germany. Another factor which plays a role is the attitude of the healthcare system towards epidemics such as flu. In Belgium, flu patients are advised to seek consultation and get subscription from doctors; while in the Netherlands and in Germany, patients are often advised to stay at home and perform self-enforced quarantine. The last factor which may explain the difference in search activity can be the various level of trust of public healthcare system in Belgium, the Netherlands and Germany. Due to the higher level of hierarchy and the lack of transparency, the lack of trust in government organizations can be explained.

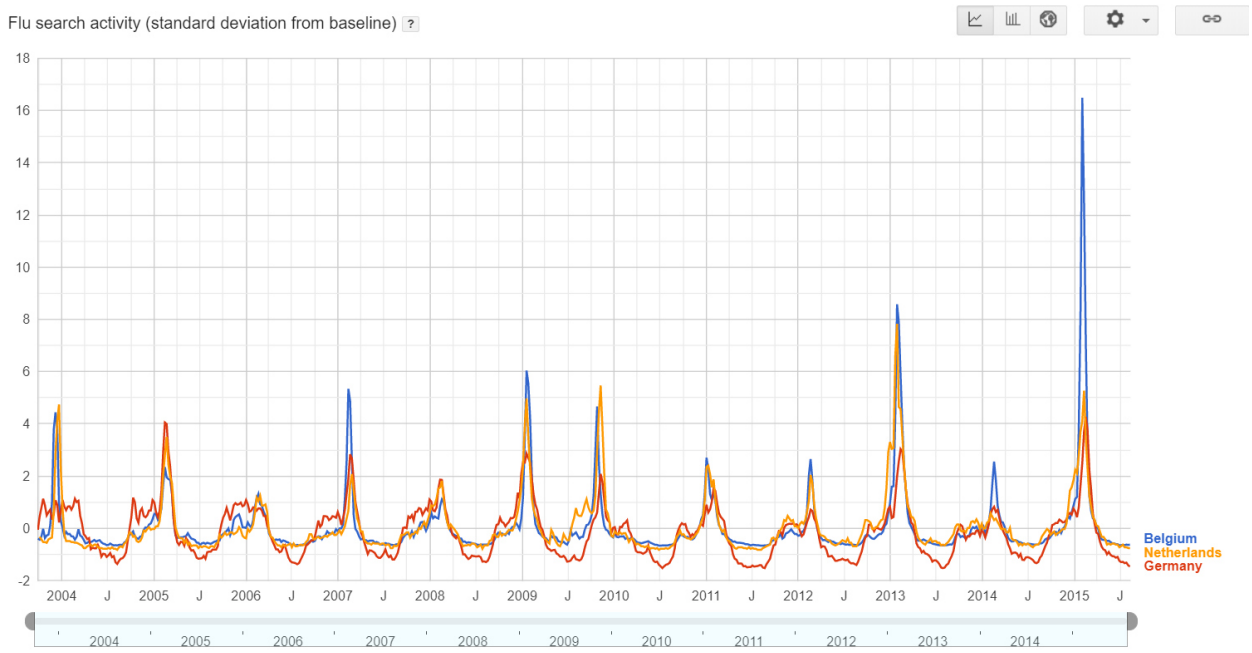

Figure 2.11. Flu Search Activity – Standard Deviation from baseline, 2004-2015 in Belgium, the Netherlands and Germany; Source: Google Inc.

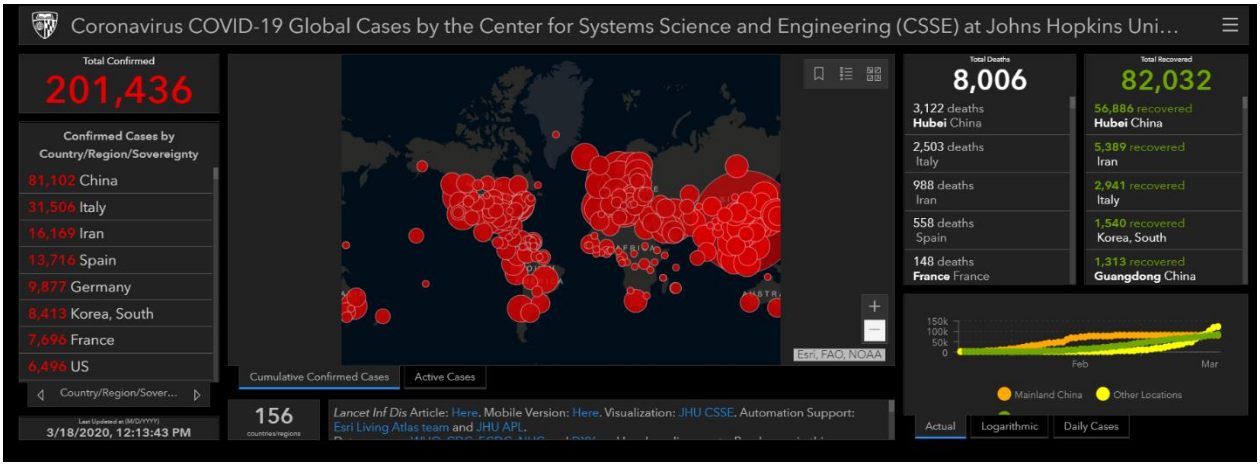


Figure 2.12 Global COVID 19 cases by March 18th, Source: John Hopkins University, 2020

With the COVID-19 outbreak around the globe, the infection in China has reached 80303, with 507 suspected cases and 2947 deaths reported in China (Alipay, 2020). The use of smart health solutions can be observed in epidemic monitoring, online consultation, CT image screening to improve diagnosis efficiency, medication sale and payment. The outbreak of COVID - 19 has promoted the trustworthiness of smart health solutions. Because of the government enforced quarantine, residents are forced to stay at home. They use online resources to track the epidemic and to take precautionary measures. Going to supermarkets, hospitals and pharmacies are seen as risky behavior or are not allowed. Residents of China resort to online platforms to shop for groceries, order medication, masks and goggles. Because of the quarantine, people are encouraged to report their sickness via the app mini programs, apply for travel permits, apply for masks, and report price distortions, and search for real-time information regarding COVID - 19.

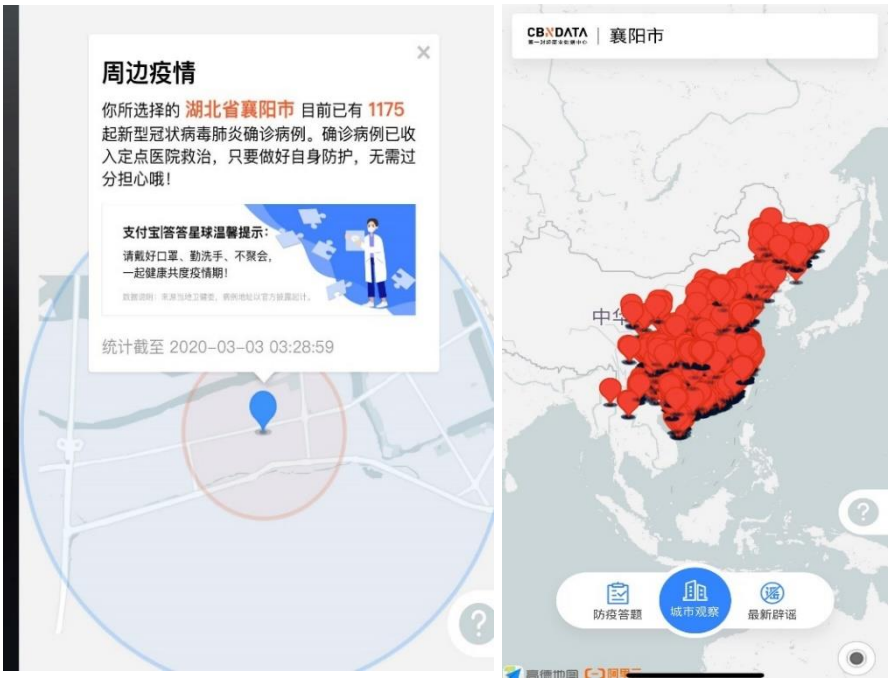

Figure 2.13. Real-time COVID-19 cases in Xiangyang, Hubei, China by March 3rd 2020. Source: Alipay, 2020;

Figure 2.12 and Figure 2.13 give two examples of how the app can be used to monitor the epidemic. Figure 14 displays the real time monitoring of global COVID cases developed by John Hopkins University. In the case of Italy, currently there are around 31,506 confirmed cases of COVID 19 by March 18th 2020 (JHU, 2020).

Figure 2.13 displays a real-time map of COVID 19 cases in China. In the top search bar, one can put in a city name and get the number of confirmed corona virus cases. Figure 2.13 shows in Xiangyang, Hubei Province, the search results display a real-time feedback of 1175 confirmed COVID-19 cases; it also informs the general public that all confirmed cases are treated at the designated hospital and reassures them to stay at home to avoid further public panic.

There are complaints from the western society and panic fuming as people start to accumulate groceries such as toilet papers. The panic can be caused by the lack of trust in the data about coronavirus disclosed by the government. In this epidemic, there are major issues of the public healthcare system disclosed by the government. For the citizens in China, the COVID 19 cases have been disclosed rather lately with risks unclarified in the beginning. For the citizens in Europe, there are reasons to believe that the public healthcare system reacted slowly and rather irresponsibly to control the disease spread. In China and in Italy, when it comes to disclose public information, both governments whether at a local and national level show a number of inconsistencies. The Chinese government has learnt from its own mistakes, changed the head for the Hubei Province Health Commission and Wuhan Municipality. Public information disclosure was made via the apps subsequently. After a national level quarantine, remote working is widely spread in China with major satellite map shows a major decrease in nitrogen related pollution (NASA, 2020). The level of industrial activity is shown to have decreased significantly. The quarantine enforced has caused wide downward economic projections around the globe. The European Commission is taking measures to reduce exposure of COVID 19 to the economy (European Commission, 2020).


Figure 2.14. Shanghai Hospital Online Consultation by March 3rd 2020. Source: Alipay, 2020;

Figure 2.14 shows the free public consultation service offered by Level 3 hospital in Shanghai e.g. Ruijin Hospital affiliated with Shanghai Jiaotong University, Shanghai Public Health Center Clinical Center, Shanghai No.1 Maternal and Infant Care Center, Shanghai Chinese Medicine Hospital Yangpu District, Shanghai International Medical Center, Yueyang Chinese Medicine and Western Medicine Center, etc. The consultation service offered by chat (by text and picture) with the doctor is free.

There are reports from Italy indicating such methods are also used, the effectiveness of which cannot be judged as italian hospital ICU beds are not enough for patients in need of intensive care (JAMA, 2020). With a significant aging population, the death toll from COVID 19 is projected to be higher for Italy than for China.

### *4.4 Byte Dance and its business model*

The Byte Dance business model shows how a short video app can spread globally in a relatively short period of time. Byte Dance was founded in China in 2012 with the Tik Tok app launched, and now has accumulated over 400 million daily active users. Byte Dance has had trouble with contents on its popular social media short-video app, Tik Tok in India. So far, Tik Tok has obtained about 120 million users in India. The Indian government had then decided to temporary ban the

app in App Store in App Store by IOS and Google Play System following decisions made by the Madras High Court (Findlay, 2019). As a company whose main profits came from advertisement and targeted marketing, the app ban posed a major threat to the Byte Dance business model. In order to adapt to the challenge, Byte Dance had taken various measures to adjust its market strategy in India within 3 months of the ban. After the India flood and tornado, Byte Dance had sent its Public Relations and Corporate Social Responsibility Team to India, delivering poverty reduction and disaster resolution materials. In addition to such humanitarian efforts, Byte Dance had tried to set up a data center in India to smooth the relationship with the India government. Moreover, the company had taken an education initiative, launching an English learning app "Gogokid" and a learning app called "Haohaoxuexi". Realizing the potential in education-tech market, Tik Tok had started to collaborate with the local partners. It had worked with the "Testbook", an app which helps test candidates to prepare for exams. Tik Tok had taken up the strategy for two purpose. Firstly, to create more use cases by diverting the business from mere entertainment, getting to the core needs of users and increasing user stickiness. Secondly. to win the trust from the local India market, including regulators. Since collaborating with Tik Tok, "Textbook" has around 10 million users diverted (Findlay, 2019). To summarize, with a large user base, and customer acting as an important partner for Tik Tok, it became relatively easy for Tik Tok to get new partners.

For the Chinese solutions internationalization Figure 2.15 describes the amount of export in ICT related products (in thousands USD) from China.

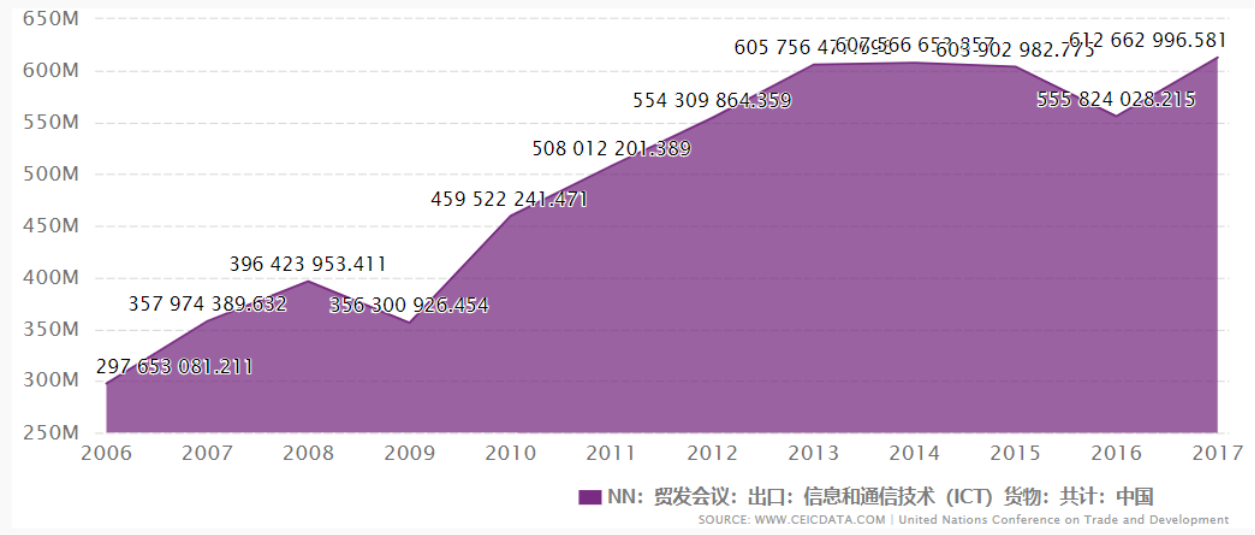


Figure 2.15 Export from China in ICT (Information and Communication Technology, 2020); Source: UNCTAD, 2020; China Industrial Economic Database, 2020; Unit: Thousand USD;

## 5. Conclusions and policy implications

To summarize key findings of the Chapter, based on interviews conducted with tech companies, there are four types of incentives for tech firms to implement smart healthcare solutions (Chen et al, 2020).

Firstly, financial incentives. For instance, tech companies wish to improve market share, or to promote brand value, to go into a new business sector, to promote sales and look for new profit source. For government to control healthcare cost.

Secondly, tech companies wish to improve on data accuracy and interoperability and build algorithms in assist healthcare service providers to make decision.. Governments wish to improve healthcare efficiency by connecting different data sources and allocate limited financial resources efficiently by identifying the most urgent challenge..

Thirdly, government policy. Tech companies need to answer government policy initiatives for Internet+ Health, Healthy China 2030 Initiative, etc, participate in smart city initiatives to build high profile, and to maintain good relationship with the government. Government contracts are rather lucrative and high-profile; winning government contracts suggests the company is reliable and trustworthy with its solutions, thereby promoting the publicity of their relevant smart city solutions.

Fourthly, special incentives. Governments have the incentive to create more employment and drive human resource development in AI. Hospitals have the incentive to improve healthcare quality for patients.

The DPE theory had laid a foundation for analyzing of digital platform ecosystem in China. The growth of the Alihealth and Xiaomi reinforces with the DPE model. Alihealth had invested in several offline medication retailers in Gansu, Shandong, Hubei, Guizhou and Anhui to strength its online-to-offline (O2O) business model. (Alihealth, 2019) Alibaba and Xiaomi can be both seen as multi ecosystems where they serve as platform leaders. The success of these two platforms depends on the quality of participants of the platform. Both companies had proved their success in adapting to the changing market demand, in innovation and ecosystem orchestration.

Alibaba, the mother company of Alihealeth, has expanded into the South East Asia market, by investing and eventually buy up Lazard; Tiktok went into India market, and subsequently North America and European market; Huawei has developed business in Africa, Europe and North America, establishing research centers across the world. Xiaomi opened its flagship shops across Europe to promote its brand. Most of the expansion happen after firms establish dominating positions in the domestic market.

On national level factors affecting Chinese firms going abroad, even though the domestic institution setting for doing business is improving, China still lags behind developed economy in factors such as the ease of access to a loan. For instance, China ranks 31 in the ease to do business ranking (World Bank, 2019). However, the ease of access to a loan for private firms in China remains an issue compares to state-owned enterprises.

On industrial level, the Chinese government tries to promote national champions in different industries. This can bring advantages and disadvantages for Chinese firms to go abroad.

The One Belt One Road initiative has prompted Chinese firms to expand into the overseas market. Even though most firms which went abroad focus on infrastructure development in south east Asia, Africa, Latin America, more and more agriculture businesses are looking for opportunities overseas.

Tech firms such as Alibaba and Tencent, for instance, have invested in the multiple startups, both domestic and overseas. To get into the Indonesia market for instance, Alibaba has invested in Lazada and Tokopedia to ensure full access to the market.

Yet for companies like Huawei, it has become a victim for the nationalist internationalization strategy of China losing contracts in all developed markets because of it.

On firm level, Chinese tech companies have certainly moved up the value chain and developed innovative business models and new strategies for expanding into the IoT market.

By market capitalization, Alibaba, Tencent, Ping An Insurance ranks first, second, and fourth in China, with a market value of $453 billion, $436 billion and $ 283 billion respectively (Business Insider, 2019). Roughly 20 years ago, companies such as Alibaba, Xiaomi and Huawei have climbed up the value chain. These firms have experienced hurdles in their expansion and internationalization process. They have benefited from the Chinese internationalization policy yet suffered from the recent nationalist government internationalization strategy. The businesses have climbed up the value chain for sure and established different business models exploring the Internet of Things market. For further research on this subject, the author provided a good example for studying Chinese tech companies and a new angle for seeing Chinese firms.

**References**


3M. (n.d.). 3M Science. Applied to Life. 3M United States. Retrieved March 14, 2020, from https://www.3m.com/

Accenture. (n.d.). How we work with SAP. Retrieved March 14, 2020, from https://www.accenture.com/nl-en/services/intelligent-platforms-index

ALIBABA HEALTH Information Technology Limited. (2019). ALIBABA HEALTH Information Technology Limited 2019 Annual Report (18). Retrieved from http://doc.irasia.com/listco/hk/alihealth/annual/2019/ar2019.pdf

Alipay (2020-03-10) [Computer software]. (2020). Retrieved from https://mobile.alipay.com

Banalieva, E. R., & Dhanaraj, C. (2019). Internalization theory for the digital economy. Journal of International Business Studies, 50(8), 1372-1387.

Baidu. (n.d.). Baidu Cloud Services. Retrieved March 14, 2020, from https://cloud.baidu.com/campaign/Annualceremony-2020/index.html

Bosch Global. (2020, March 12). Guided parking with parking sensors in the smart city. Retrieved March 14, 2020, from https://www.bosch-connectivity.com/

Buckley, P. (2019). China goes global: provenance, projection, performance and policy. International Journal of Emerging Markets, 14(1), 6–23. https://doi.org/10.1108/ijoem-01-2017-0006

Burning Rock. (n.d.). Burning Rock Medical. Retrieved March 18, 2020, from https://www.brbiotech.com/home/index

China Industrial Economic Database. (2018, June 1). China Export of ICT related products (in Chinese, translated by the author). Retrieved March 14, 2020, from https://www.ceicdata.com/zh-hans/indicator/china/exports-ict-goods

Cesuroglu-de Langen, T. (2016). Integration of a personalized health care model into health systems and policies in Europe.

Deng, P., Delios, A., & Peng, M. W. (2020). A geographic relational perspective on the internationalization of emerging market firms. Journal of International Business Studies, 51(1), 50-71.

Dunning, J. H. (2001). The eclectic (OLI) paradigm of international production: past, present and future. International journal of the economics of business, 8(2), 173-190.

Dunning, J. H., & Lundan, S. M. (2008). Institutions and the OLI paradigm of the multinational enterprise. Asia Pacific Journal of Management, 25(4), 573-593.

Eisenhardt, K. M.(2012). Kathleen M. Eisenhardt on Case Study Research Methods. edited by Li (Chinese Translation), P. P., Cao (Chinese Translation), F. Peking University Press.

Financial Times. (2018, March 19). Alibaba invests another $2bn in south-east Asia’s Lazada. Retrieved March 14, 2020, from https://www.ft.com/content/44f3a1fe-2b44-11e8-9b4b-bc4b9f08f381

Financial Times. (2019, December 6). Facial recognition: how China cornered the surveillance market. Retrieved March 14, 2020, from https://www.ft.com/content/6f1a8f48-1813-11ea-9ee4-11f260415385

Financial Times. (2020, March 13). Huawei Technologies. Retrieved March 14, 2020, from https://www.ft.com/stream/254cd19f-4724-4c89-9230-926e8201a823

Findlay, S. (2019). TikTok launches education push in India. Retrieved from: https://www.ft.com/content/a729232a-eff2-11e9-ad1e-4367d8281195. (Last Accessed: October 21st 2019).

Foxconn. (n.d.). Foxconn Profile. Retrieved March 14, 2020, from http://www.foxconn.com.cn/GroupProfile.html

Grasselli, G., Pesenti, A., & Cecconi, M. (2020). Critical Care Utilization for the COVID-19 Outbreak in Lombardy, Italy. JAMA. https://doi.org/10.1001/jama.2020.4031

GSM Association. (2019). Development with the Mobile China Economy. Retrieved from https://www.gsmaintelligence.com/research/?file=f3b217bd4616654f710854b0735b0c00&download

Helfat, C. E., & Raubitschek, R. S. (2018). Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems. Research Policy, 47(8), 1391-1399.

Helfat, C. E., & Winter, S. G. (2011). Untangling dynamic and operational capabilities: Strategy for the (N) ever-changing world. Strategic management journal, 32(11), 1243-1250.

He, S., Khan, Z., Lew, Y. K., & Fallon, G. (2019). Technological innovation as a source of Chinese multinationals' firm-specific advantages and internationalization. International Journal of Emerging Markets, 14(1), 115–133. https://doi.org/10.1108/ijoem-02-2017-0059

Huawei. (n.d.-a). Healthcare — Huawei solutions. Retrieved March 14, 2020, from https://e.huawei.com/uk/solutions/industries/healthcare

Huawei. (n.d.-b). Huawei Cloud Service. Retrieved March 14, 2020, from https://hcs.huawei.com/portal/en-us/

Huawei. (n.d.-c). Who we are. Retrieved March 15, 2020, from https://huawei.eu/who-we-are

Huawei Vmall. (n.d.). Huawei Vmall Wearables . Retrieved March 15, 2020, from https://www.vmall.com/list-59

IDC Market Research. (2020a, January 20). IDC - Smartphone Market Share - Vendor. Retrieved March 14, 2020, from https://www.idc.com/promo/smartphone-market-share/vendor

IDC Market Research. (2020b, February 11). IDC - Wearable Devices Market Share. Retrieved March 14, 2020, from https://www.idc.com/promo/wearablevendor

IDC (March 5th 2019). IDC Reports Strong Growth in the Worldwide Wearables Market, Led by Holiday Shipments of Smartwatches, Wrist Bands, and Ear-Worn Devices. Retrieved from: www.idc.com/getdoc.jsp?containerId=prUS44901819. (Last accessed: October 21st 2019).

Infervision. (n.d.). Infervision. Retrieved March 18, 2020, from https://global.infervision.com/

Intel. (2020, March 14). Intel® CoreTM Processor Family. Retrieved March 14, 2020, from https://www.intel.com/content/www/us/en/products/processors/core.html

INVEOX. (2019, August 9). inveox - rethinking pathology. Retrieved March 18, 2020, from https://inveox.com/about-us/

John Hopkins University. (2020, March 18). Coronavirus COVID-19 Global Cases by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. Retrieved March 18, 2020, from https://coronavirus.jhu.edu/map.html

Keep. (n.d.). About us, Keep. Retrieved March 18, 2020, from https://www.gotokeep.com/about

Knoerich, J. (2019). Re-orienting the paradigm: path dependence in FDI theory and the emerging multinationals. International Journal of Emerging Markets, 14(1), 51–69. https://doi.org/10.1108/ijoem-04-2017-0123

Linkdoc. (n.d.). Smart Assistant Diagnosis System. Retrieved March 18, 2020, from https://www.linkdoc.com/product/AI

Liu, J. (2019). The roles of emerging multinational companies' technology-driven FDIs in their learning processes for innovation. International Journal of Emerging Markets, 14(1), 91–114. https://doi.org/10.1108/ijoem-07-2017-0232

Mobvoi. (n.d.). Mobvoi.com - TicWatch smartwatch TicPods Free . Retrieved March 18, 2020, from https://www.mobvoi.com/nl/types/wearable

McGee, P. (2019). As iPhone 11 looms, Apple looks beyond the smartphone. Retrieved from: https://www.ft.com/content/789b745c-d096-11e9-99a4-b5ded7a7fe3f. (Last Accessed: October 21st 2019).

Nambisan, S., Zahra, S. A., & Luo, Y. (2019). Global platforms and ecosystems: Implications for international business theories. Journal of International Business Studies, 50(9), 1464-1486.

NXP. (n.d.). Processors and Microcontrollers, NXP. Retrieved March 14, 2020, from https://www.nxp.com/products/processors-and-microcontrollers:MICROCONTROLLERS-AND-PROCESSORS

Qualcomm. (2020, February 25). Flagship Qualcomm Snapdragon 865 5G Mobile Platform Powers First Wave of 2020 5G Smartphones. Retrieved March 14, 2020, from https://www.qualcomm.com/news/releases/2020/02/25/flagship-qualcomm-snapdragon-865-5g-mobile-platform-powers-first-wave-2020

Remuzzi, A., & Remuzzi, G. (2020). COVID-19 and Italy: what next? The Lancet. https://doi.org/10.1016/s0140-6736(20)30627-9

Ruehl, M. (2019, October 8). China's leading AI start-ups hit by US blacklisting. Retrieved March 14, 2020, from https://www.ft.com/content/663ab29c-e9bd-11e9-85f4-d00e5018f061

Sensetime. (n.d.). Medical Image Analysis-Core Technologies-SenseTime. Retrieved March 18, 2020, from https://www.sensetime.com/en/Technology/medical.html

Sharma, D. D., & Blomstermo, A. (2003). The internationalization process of born globals: a network view. International business review, 12(6), 739-753.

Teece, D. J. (2018). Business models and dynamic capabilities. Long Range Planning, 51(1), 40-49.

Teece, D.J. (2018). Profiting from innovation in the digital economy: standards, complementary assets, and business models in the wireless world. Research Policy, 47, 1367-1387.

Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strategic management journal, 28(13), 1319-1350.

UNCTAD Statistics. (2020, March 14). UNCTAD . Retrieved March 14, 2020, from https://unctadstat.unctad.org/wds/?aspxerrorpath=/wds/ReportFolders/reportFolders.aspx

Wearable Technology. (2019, October 23). Wearable Technologies Show 2019 MEDICA.

Waltze, S. (2019). Strategy Analytics: Apple Watch Captures Half of 18 Million Global Smartwatch Shipments in Q4 2018. Retrieved from: https://www.businesswire.com/news/home/20190227006074/en/Strategy-Analytics-Apple-Watch-Captures-18-Million. (Last Accessed: October 21st 2019).

Retrieved October 23, 2019, from https://www.wearable-technologies.com/events/wt-wearable-technologies-show-2019-medica/

Wegene. (n.d.). WeGene - Personal Genetic Testing Platform. Retrieved March 18, 2020, from https://www.wegene.com/en/

World Bank. (n.d.). World Bank Databank. Retrieved March 14, 2020, from https://databank.worldbank.org/Mobile-penetration-/id/5494af8e

Xiaomi. (n.d.). Xiaomi Privacy Policy. Retrieved March 14, 2020, from https://www.mi.com/global/about/privacy

Xinhua Newsnet. (n.d.). Huawei has invested hundreds of billions in R&D (in Chinese). Retrieved March 15, 2020, from http://www.xinhuanet.com/tech/2019-03/30/c_1124303527.htm

Yitu Technology. (n.d.). Smart Health Yitu Technology. Retrieved March 18, 2020, from https://www.yitutech.com/cn/business/yitu-heathcare

Yin, R. K. (2017). Case study research and applications: Design and methods. Sage publications.

**Appendix:**

**Interview Records with VP of Wearables and Health Unit of Huawei**

**Part I: Personal Health related products and smart home products**

1. **What are the products offered by Huawei for sports coaching, health monitoring, and health risk prevention? Do Huawei products offers continuous monitoring and chronic disease management functions, particularly for the aging population? Is there any design for the elderly to live independently at home, particularly for fall detection?**
   The main business model of wearables in Huawei is focused on hardware. The products targeting the elderly is in design, with the main design philosophy targeting at user demand. The plan is to transfer some of the functions of the children's watch to the devices designed for elderly, for instance, the GPS location function. Possible other functions to add to the design include fall detection automatic alarm, heart rate monitoring, etc. There is a smart care plan designed for the elderly.

   Huawei will increase interaction with elderly, and try to take in suggestions from the elderly users, and co-develop with users targeting at their needs.

2. **In the previous stage of study, I read about delve into the value of he wearables. It plans to do so by improving life quality, enhancing environment sensibility, promoting user experience. Huawei has proposed establishing the digital twin of users, and to realize digitize the environment of human beings, and to improve the interactions with the environment of users, and to warn patients of healthcare risks. Are these concepts which has been used in product design?**

   Normally we use phones, pads, and sports watch, the Huawei Sports app, Hlink App and router to interact with users. Huawei Hi Link App has been designed for smart application scenarios in home entertainment, home lighting, smart health, energy management, home security, automation, routers, smart TV boxes, lighting, environment, interior design, all coverage routers, Wifi, kitchen, audio, smart sleep monitoring, etc. There are about 50 core partners, and in the future, it is possible to design a comprehensive platform, for instance to add humidity and temperature sensors into smart phone and smart watch design.
   Huawei has promoted the use of interaction depending on the maturity of the technology. Now Huawei is focusing on delving into the health related function for wearables and terminals (telephones). For instance, there are temperature sensors on phones, and in the future can detect temperature inside and outside home. The same design is planned on smart watches. Meanwhile, there are temperature and humidity sensors on smart home devices.

3. **Now the wearables can perform sports coaching, smart sleep monitoring, smart sleep, stress management, BMI management, skin management. What are the functions used most by users? What are the feedbacks?**

   The most used functions are sports functions. Now sports management, sleep, stress monitoring, skin management can be achieved with Huawei Phones, other products with Huawei brand or under the Huawei ecosystem. Now it is possible to detect characteristics of skins, and to differentiate between red areas and brown spots. The devices distinguish between pore, blackhead, lines, color spots and red areas. Afterwards, it will grade the skin quality of users, and offer skin care advices for users.

   Now the data about sports, and sleep related functions can be processed on device chips with edge computing to update the algorithms. The data is protected on devices, chips and in cloud. Only photos and insensitive data are uploaded to the cloud. With finger print, weight, sports, sleep, and heart rates and other sensitive data is processed on the device.

   The sleep monitoring band (Reston) was developed with third-party partners, with smart weight scale developed independently by Huawei.

   The edge computing advantage is in its flexibility and security regarding privacy. The 5G network is helpful for developing edge computing. With Huawei's own chips, and algorithms, it is helpful to perform edge computing.

**4. Do Huawei and other ecosystem businesses offer systematic health risk monitoring and health life advices, and to predict health risk for users?**

The monitoring center is based on phones. In the meantime, there is Huawei sports app which connect Huawei devices and partner devices. Now there is no comprehensive platform to monitor health risks for users. The main problems are among all the methods to perform blood pressure monitoring, the CFDA only approves blood pumping. Monitoring blood pressure 24/7 over blood pumping will disturb users particularly their sleep. It is not possible to commercialize the blood pressure monitoring function on Huawei watches and bands.

**5. Has Huawei formed the IoT device ecosystem? Has Huawei formed an IoT device platform controlling all devices? What is the control terminal?**

With the Huawei smart phone as the IoT ecosystem devices, now there are a few application scenarios: smart office/ smart gaming, connected cars, smart health and smart home. The control terminal is the smart health app on the phone. Home smart devices can be controlled via smart audio devices (Little Yi). Huawei routers can keep the devices online with the Hi Link app connect devices.

**6. What are the smart home and smart health (nutrition analysis, smart audio, sleep monitor, smart scale, smart mask) devices offered by Huawei? What is the control terminal for Huawei smart home devices?**

The advantage of Huawei is about its terminal devices and the strength in telecommunication (I assume they are referring to 5G). There are devices which the Huawei can involve, but will offer interfaces for connection. Now the nutrition analysis function can be realized via Huawei Mate 20 smart food detection. It is possible to use camera and distance detection to identify how many calories are contained in an apple. The algorithms can automatically tell the size of the object and the amount of calories contained.

For smart home devices, Huawei is planning on commercialize smart TV, and hope to include all smart health functions on smart phones.

7. **Huawei is planning on offer personal health records services for users? If there are such plans, how to realize real time EHR system update?**

Huawei offers the solution packages for user to realize healthy living and disease prevention. The function is realized via Huawei hardware terminals to monitor heart rate, sleep, sports, and via connecting third party devices to monitor blood pressure and blood sugar level. In the meantime, Huawei hopes to help users to perform chronic disease management, and outpatient long-term rehabilitation plans for users. Huawei also hopes to offer telemedicine for patients who need long-distance services. In the meantime, there will be issues because currently doctors only rely on patients to describe their conditions, and the descriptions performed by patients can be objective and inaccurate.

Huawei is carrying out experiments for application of wearables in medical scenarios with Beijing 301 hospital (military hospital) in the area of cardiovascular health research. In the future, Huawei hopes to perform preventive healthcare, to lower the burden for hospitals and patients. Now the

function has already been commercialized on smart watches. The AI automatic warning for irregular heart rates can only be commercialized after the CFDA certification.

Now there is no user personal health records functions. It is because user health data is sensitive in the sense of privacy. In the meantime, the industry of wearables have not set up technology standards. Now the CFDA use the same medical device technological standards to determine whether wearables can be used in medical scenarios. It takes about 5-10 years to get the CFDA approval; this long waiting time had resulted in the lack of commercialization for certain functions. For instance, the two-point ECG monitoring cannot be commercialized. In many practices, for instance, the blood pressure monitoring requires continuous monitoring; but there are not relevant technical standards for wearables to perform health monitoring. The only legal method of monitoring is to use blood pumping for the monitoring. The 24-hour continuous monitoring will disturb the sleep of users. Normal users do not necessarily need such precise data which comes with blood pumping . Now there is no such technical standards. It is a loss for users, and for the doctors.

To thoroughly evaluate users' health risks, it is necessary to evaluate blood oxygen, heart rate, and life style, etc. Such system will be available with the efforts from Huawei and other institutions. Huawei is telecommunication device manufacturer, and cannot independently finish the EHR system construction. The partnership with individual hospitals was formed on an individual basis with hospitals. Without a uniform EHR system on a national level, electrification of medical resources and interoperability of data between different hospitals, establishing EHR for users does not have much value.

**8. Does Huawei take use of data collected from users to train algorithms to offer personal health risk monitoring? Are these algorithms running on devices or on cloud platforms?**

The data and algorithms trained in labs of Huawei may not fit to individual users. Therefore, by update algorithm with data collected from users, the algorithms become more precise. Before the algorithms become available to users, there will be 1-2 years of clinical trial programs at institutions such as Harvard Medical School. After obtaining the missing data samples from users, algorithms will be updated or updated with certain data subjects with diseases.

Huawei has carried out data processing following GDPR standards in China and in European markets after GDPR was carried out.

Health data will only make sense when continuous monitoring is performed, in the meantime, it is necessary to conduct correlation analysis for health related data. Huawei as a tech company alone cannot perform such tasks. There is a need to form partnership with more institutions for instance, with governments to share health related data on a regional and national level. For instance, blood sugar, blood pressure needs to be monitored on a daily basis at the same time. Before establishing the national level EHR system, it impossible to perform population health management. Therefore it is necessary to have national and regional level EHR system.

**9. Can Huawei's products connect with third party platforms? Will Huawei share data with third party partners? or share analytical results? Does Huawei share data siwth insurance companies, clinics, hospitals, hospitals, governments and other institutions? Is there any**

**related business model about data sharing? What is the business model to partner with Omron, Yu Yue, Biolight, Dnuse and Johnson and Johnson?**

It is sensitive to share data with third party manufacturer. Even with users consents, and sharing health related data can be legal, it is impossible to ensure third party partners adhere to laws and regulations. Therefore, Huawei is exploring business model based on data.

Huawei is working with third party partners, such as Omron and Dnurses to track blood pressure and blood sugar level changes. Huawei mainly use its terminals to keep track of the biometic indicators.

Huawei smart phones is pre-installed with Wedoctor, DXY, Chun Yu Doctor apps to make it convenient for users and give users better healthcare experience and to offer one-stop health services.

Now the South Africa insurance company- Discovery is working with Huawei to offer free wearable devices, which charges users on a term basis. When users reach a certain number of steps daily, the monthly term payment can be exempted. Users can lower their insurance premium by using the device long term. In the meantime, it is possible to lower health risks for users and form a positive feedback system.

Now the partnership with medical institutions is mainly for research purposes.

**10. Has Huawei established a data centered business model for wearable devices?**

There is unlimited value embedded in wearables. Now the value detected has been only a tip of the iceberg. In the future, possibly everyone will have 1-2 wearable devices. Therefore it is valuable to mine the value from the data collected from wearables.
Now there is no such business models, because there is no clear legal definition regarding the ownership of the data. Huawei has listed establishing a data based business model in the business development plan. Finding a data based business model has gained consensus for the IoHT industry.

**11. How to protect health related data of users? After the launch of GDPR, did Huawei take additional measures to protect users health relate data? Did GDPR affect the sale of Huawei wearable devices in Europe?**

Wearable devices collect and store data. After the launch of GDPR, processing and storing data has become slower and more intricate. The **AF detection and blood pressure monitoring** will possibly not be commercialized in Europe after being developed. Now the function most used in Europe is sports related function. Now the wearable devices offered in domestic (Chinese) and overseas market are almost the same. The overseas devices do not come with apps preinstalled such as Wedoctor, DXY, and Chun Yu doctor. In the future, there might be difference. In the European market, Huawei devices connected with less third-party devices, and mainly performs health data tracking (writing data down, but no coaching) functions.

**12. How much of the overseas market sale account for the total sale of Huawei wearable devices?**

When Huawei develops its overseas market, the development is mainly for domestic consumers. The path usually taken is to learn from the advanced concepts and to develop new functions based on the users needs in the domestic market (the Chinese market). Then Huawei tries to promote the products in the overseas market.

Wearable devices of Huawei are sold both on the domestic and overseas market. The functions are not the same. Wearables sold in the overseas market can lose some of the functions to connect with third party products. For instance, the smart watch sold in the EU market only has the basic function of health tracking, but not coaching.

**What are the advantages and disadvantage factors to develop the overseas market?**

In Europe and the US, wearable devices manufactured by Chinese companies face strict regulations. Meanwhile to develop health related functions, it is necessary to consider the local culture. Therefore, it is not possible to delve in the value for wearables compared with the Chinese market. The development process is oriented at users in the Chinese market. There are also price and function related concerns. Huawei adhere to the local regulations strictly, and therefore it is not possible to restraint the sale of Huawei products legally (seems to contradict the trade war).

There are few restrictions for the sleep and sports related function in the overseas market. The functions are not going into the medical directions yet. Whether in the future there will be restraints towards wearbles and medical related functions embedded is yet to see.

**What are the role of overseas development center for Huawei?**

The wearables are mainly developed in the domestic market. The Huawei HQ in China is a coordination center to manage all the businesses for Huawei overseas growth. The location choice for the overseas development center was chosen based on technology, for instance, like the algorithm development center in Finland, and the hardware development center in Germany, and the design center in France (for fashion), etc. The sample in the labs for developing algorithms is relatively small. It is mainly developed in labs and does not use data from users, and will not transfer data from China to overseas labs or transfer data from overseas to China. It is possible to update the algorithms later at the clinical trial or commercialization stage with larger size of data.

**13. What are the roles played by wearables in the value based healthcare system?**

The center of establishing a value based healthcare system in based on data. Without data, it is difficult to perform preventive healthcare. Therefore, smart wearables plays an important role. Data needs to be precise and cover a wide range of categories to realize extracting data from wearables.

Now the commercialization of wearables in the hospital use scenario is limited.

The ideal condition is there is a national wide health data sharing platform, where all doctors and hospitals can see the data. In the meantime, there is a unified EHR system on a national basis. In

this way, it is possible to use wearables on a precise, wide and useful basis. With no technical standards for wearable use in the healthcare industry, doctors would shake their heads (and use the wearables) when they see devices without CFDA approval.

It is not realistic to ask the basic medical insurance schemes in China to cover the cost of wearables. If they try to cover the cost, the total amount of expenses may grow.

Huawei is just a device manufacturer. Our goal is to lower the price of our devices. while offering the best quality as we can to consumers. The China National Development and Reform Commission is running a trial program in Qing Dao to test 5G city and require the establishment of telemedicine user case scenarios.

## Xiaomi Interview Records with investor director of MIUI Business Unit

**Personal Users, Wearables and smart home devices**

1. **What are the continuous health monitoring products for personal users?**

Smart blood pressure monitor, smart thermometer, smart humidity monitor which can turn on and off automatically for home humidifier, or air conditioner), and smart scales are produced by Xiaomi ecosystem enterprises.

Wearables ecosystem is made up of software and hardware, software is usually developed by Xiaomi ecosystem enterprises, with the data collection made on the software end. The software do not belong to Xiaomi, and all the data are connected by software developed by Xiaomi ecosystem enterprises. Xiaomi watch and bands are manufactured by Huami. As far as I know, Xiaomi has not obtained the data from the ecosystem enterprises and performed user profile analysis.

All the wearable software services are in the integrated in the Mi Home platform. Xiaomi has not developed a business model based on data. Now the data collected from Xiaomi band is controlled by Huami. The company may perform user profile analysis with the data collected. There has not been a business model which allows Xiaomi to recommend weight control or sports related service packages to users for overweight users.

Xiaomi now has a business model based on hardware sale. The service based business model has not been promoted. Take the Xiaomi watch for example, Huami has used a double brand strategy, where they try to promote both Amazfit and Xiaomi Watch as the brands for the Amazing Fit watch. When Xiaomi decided to invest in Huami, there was no consideration about delving into the data centered business model on the backstage. The business model is to sell hardware (except smart phones and television boxes) to attract users, and to nurture the user habits, and to attract users to the Xiaomi platform. In the early stage of internet based business, the business model is about get users to use a certain product, and to nurture user habits (for instance, Tencent acquired a large amount of users via platforms such as QQ). The band's main market is focused on the domestic market, and some are also sold in the overseas market.

All the IoT products belong to Mi Home brand. There are over 20.3 million active users per month. There are over 60-70 terminals offered by Xiaomi and over 10 active platforms has more than 1 million daily active users. There are two platforms covering IoT businesses, like Mi Home and Mi Sports. Xiao Ai (Like Siri, is the voice assistant for Xiaomi ecosystem products) is an extension, with Xiao Ai able to control smart cleaning robots. Xiao Ai can learn about the language habits of users and adjust its

communication style. Xiao Ai can also connect with the voice to text translation software, but it will not be done via Xiao Ai the extension itself.

2. **Xiaomi has proposed the business plan to improve interaction with users, with the envionrment and to improve life quality of users. Currently Xiaomi products cover a wide category of smart wearables and smart home devices, such as smart scale, smart toothbrush, smart watches, bands, smart lighting system, smart air purifier, smart rice cooker, etc. In the healthcare industry, Xiaomi has invested in Andon Health, and now in the Xiaomi You Pick Online Mall, Andon Hipee Pen, Xiaomi iHealth blood pressure monitor, smart thermometer, smart Gluco monitor are now available for consumers. Does Xiaomi and the ecosystem partners plan to offer systematic health monitoring and smart health advice for users? How to implement the development strategy whereas Xiaomi use wearables and smart devices to enter the telemedicine and big data in health market, and build the health ecosystem with users?**

When Xiaomi make the investments in the field of IoT, it does not include a strategy to focus on healthcare. In the early stage of IoT devices, there is no direction because it is a blank market with a wide category of choices. Xiaomi does not choose a specific industry or the business to invest in, but rather focus on user needs. Xiaomi invested based on the 80%/80% rule, where the product design focuses on meeting the needs of 80% of users and 80% of their needs. It tries to face the mass market and offer standardized choices with a large user base for general use. Xiaomi also tries to focus on the core functions of the product and to optimize the function to save R&D costs (Rice cooker, air purifier, air conditioner, etc).

The internet based business and IoT based business models differ in that Baidu, Alibaba and Tencent (BAT) has their own main business focus. For instance, Tencent focused on social media, gaming and new media; Alibaba is running B2B and B2C platform, and focus on transactions. Xiaomi does not have a major strategy in mind when it made investment for IoT based products. It invested in a wide range of areas, and focus on the area of business with the biggest growth potential. The business unit with the best growth rate receives the most support.

In the early stage of product development, there is a lot of space for growth and it is barbaric style of growth. The investment to develop smart shoes (shoes with chips inside) was made under such business strategy. Now Xiaomi is not just focusing developing smart phones or a specific product; instead Xiaomi is trying to meet all daily needs for Mi fans. In the end, Xiaomi hopes to reach the goal the meet all the daily needs for Mi fans. The trial program of producing smart shoes runs under the strategy that Xiaomi will form a product a matrix for our users.

3. **Does Xiaomi has any plans to provide data from wearables for users to have personal health records?**

Synchronizing data from Xiaomi band takes Xiaomi Health app to do so. Now the app is controlled by Huami. Xiaomi is considering take the app back from Huami and develop it. Now the health related business is not on the Xiaomi priority list. After Xiaomi went public, we are now focusing on businesses which will benefit our balance sheets, such as promoting the sale of online ads. After the listing of Xiaomi stocks, Xiaomi puts a lot of emphasis on KPI.

4. **How does Xiaomi handle data from wearables? Does Xiaomi use algorithms developed by Xiaomi to analyze the data? Are these algorithms running on the cloud or on the device? Will the collected data used on training algorithms to offer personal health risk monitoring?**

We now acquire data from app ending to analyze our user profile; our partnership with them adds a condition that if the app tries to read users' contact list, then we turn it down. There is no data based business model yet. In the future, the healthcare industry, the elderly care industry and the education industry are going to drive economic growth in China. Therefore Xiaomi will probably invest in these industries in the future.

In the future, there will be a business model focusing on data sharing. Xiaomi might explore the partnership with insurance companies to perform customer segmentation and to share data. The band is mainly on sale in China.

5. **Does Xiaomi share data with third party partners or share the analytical result?**

Now it is possible to share data, with the sharing channels rather simple. For instance, to share the data on the Xiaomi band on a weekly and monthly basis and send it via pictures. There is no way to share the data automatically in the Mi Fit app. In the app, only users can initiate data sharing via simple ways such as send pictures over wechat . Xiaomi has not shared data with third parties such as gyms. In the future, Xiaomi may share data with gyms and doctors.

The main business model for Xiaomi IoT is about selling the product itself, instead of selling services. To attract the users, to develop a product based business model, sell the problems via new retail channels, and internet-based businesses are three main drivers' for Xiaomi's growth. The internet based business mainly comes from advertisement; among the 16 billion internet based businesses, about 10 – 12 billion arise from advertisement related sales. In the app store, it is also divert users from app store (to get users to download an app). The other methods to divert users to share information via browsers, or apps such as Tou Tiao. The Xiaomi ecosystem is supported by the MIUI platform, with the internet based businesses come mainly from service fees, such as listening to songs, video gaming, and streaming videos.

Data is valuable, for instance, to share pictures via taking photos and sharing it via plastic surgery hospitals. Now there is no data based business model.

From the Xiaomi annual report, now the sale for IoT and consumer products is around 43.8 billion RMB. Xiaomi products has reached the sale of around 8.4 million sales globally, with the Mi Band ranks second on the global wearables sales volume. Now the Mi Home platform connects around 150.9 million devices. Third-party devices, such as Ikea lighting devices, has been able to connect to Xiaomi Mi Home platform,

and controlled via Xiao Ai. Now there are about 203 million active users on Mi Home with over 50% of users come from non-Xiaomi smart phones.

For users there is privacy related concern on whether data has uploaded to private cloud or public cloud.

6. **How does Xiaomi deal with the privacy related risks of users' health risks? Did the launch of GDPR in May 2018 affect the sale of Xiaomi wearable products and other health related products? Did Xiaomi take additional measures to protect users' personal health data?**

Making an advertisement promotion demands conversion rates. From the advertiser's perspective, targeting users as accurately as possible means a higher conversion rate, and better effects of the advertisement.

Our legal department will consider whether the specific type of third party services Xiaomi violates privacy protection rule.

After the launch of GDPR, when Xiaomi bought data from quest to analyze the usability of apps, the contract takes 3 months to go through. There is no records to show how the data was collected. In the end, the department analyzing the data has to ensure the department will take all the responsibility for violating data protection law. Domestic Chinese companies are more and more responsible for protecting data. The advertisement is mainly about user profile, and targeting users by name, geography, age. There are many internet focused businesses in China expanding their markets overseas, which makes the firms running the business focusing more and more on privacy. When new users register, they need to be informed of how data will be collected, used and the data flows.

Xiaomi smart home products and bands are targeting domestic markets only, with domestic and overseas users (China and overseas) makes an 1:1 ratio, with about 300 million users in total.

Now Xiaomi and Zhong An Insurance (an internet based insurance company) develops the steps based insurance, with the insurance cuts premiums if the user can reach the steps target per day (measured by their smart phone, wearables, etc). Users can be diverted from Xiaomi platforms to Zhong An (now the cooperation seems to have stopped). The data collected by blood pressure monitor, scale, and bands will be insurance related business in the future.

7. **How does Xiaomi cooperate with Microsoft or Signify to develop a new business model for IoT? Will Xiaomi share data collected from IoT devices with Microsoft? Is Xiaomi mainly responsible for hardware development?**

Data will be of use in the future to develop new business opportunities. Apart from Signify lighting products, Mi Home can also connect to Ikea and other hardware. Our strategy is to build a Mi Home platform first, and to use it as a control terminal for users inflow and the smart ecosystem construction. The data about timing of lights on and off is valuable, but the use it is not yet known. The smart health related data is not that useful for now, because there is no insurance business within Xiaomi. In the future, with such businesses, it will be useful.

8. Xiaomi has promoted Xiao ai as the AI audio assistant (an equivalent of Siri or Google Assistant). Now what are the wearables and smart home devices controllable via smart audio assistant system? Is it

possible to record user sleep, pregnancy weight, food and nutrition analysis? What is the current business model for smart wearables and smart home devices of Xiaomi?

Xiaomi is building an ecosystem with the control terminal as the Mi Home app.

Xiao Ai is another interaction method. When Xiaomi starts to experiment with smart home devices, we tend to believe routers can serve as the control center. Before Mi Home, the Mi Wifi App serves the same function. By December 31st 2018, Xiao Ai has reached a monthly active user of about 388 million.

When Xiaomi started to sell the smart rice cooker, Xiaomi intends to sell rice, nutritional breakfast, and packaged food, and other related products like the rice cooker. Now it is possible to control cooking and warming functions of the rice cooker. Currently the nutrition analysis, and cooking guidance function will be able to commercialize in the next 3-5 years.

For instance, to realize the nutrition analysis function, smart fridges can be a better use case scenario. The cameras inside the fridge or RFID scanner inside the fridge can recommend menus based on personal preferences and remind users to order missing materials based on the dish choices online with fresh vegetable delivery services. It is possible to remind users about the food expiration dates. For instance, there are eggplants and peppers, the fridge will recommend the users to cook Di San Xian (Fried Potato, Eggplant and Pepper in Garlic Sauce). If the users do not have the potatoes, users can order immediately with the fridge.

**9. What are the policy implications for initiatives such as " Health China 2030" for Xiaomi to develop its smart health industry?**

Macroeconomic policy carried out by the Chinese government, which can facilitate the smart health industry development does play a role in Xiaomi's investment decisions. Before making an investment, Xiaomi need to narrow down the market size for the industry, check whether the specific project and the specific team fit into the picture. When Xiaomi invest in IoT ecosystem products, Xiaomi follows a bamboo forest roadmap to invest in a wide category of companies and businesses, to counteract the business cycle effects for tech companies. Xiaomi can only succeed with the ecosystem functions like a bamboo forest, with a multiplication of new shoots to create an ecosystem[6]. In this way, Xiaomi only focused on developing important products smartphones, tablets, TV and routers.

**10. Xiaomi has invested in Ping An Good Doctor (offers patient registration and online medication sale services), DXY.com (Internet based hospital which offers clinic management, online doctor consultation, online forums for doctors and offline clinics, etc), Jeejan.com (elderly care facilities, outpatient management, etc), Ibabycenter (pregnancy prepation online and offline), Fang Cun Doctor (professional outpatient management), Tough Workout.com, 8HSleep.com (smart**

[6] Isabella Gilbert, The ecosystem of a bamboo forest, http://www.voov.co.il/the-ecosystem-of-a-bamboo-forest/, last access June 10th 2019.

**mattress), Miaomiaoce.com (Genetic Testing, Cancer Prevention), Soocare.com (smart toothbrush), and other ecosystem companies in and outside the Xiaomi ecosystem. Does Xiaomi has plan to cover disease prevention, diagnosis, outpatient management, female health (pre-pregnancy and post-pregnancy), and the entire healthcare continuum?**

Xiaomi is not put the focus of investment on the healthcare industry. Xiaomi has invested in several areas, with an attempt to form a product matrix. Whether it is healthcare, transportation, housing, retail user scenarios, Xiaomi hopes to be part of it. When the IoT industry just started, Xiaomi takes a barbaric growth strategy. Now Xiaomi has a strategy (when making investment for IoT related business). Hopefully in the next 3-5 years or 5-10 years, making an investment decision depends on the industry, the competition track, the opportunities embedded and the specific products.

Xiaomi focuses the sports related functions for the wearables and the most important one is to interact with users. Within the 200-300 companies Xiaomi invested in, there are around 20-30 firms focusing on healthy living. Xiaomi has invested in around 150-180 ecosystem companies focusing on IoT related businesses. There is not an investment strategy in there. For instance, when Xiaomi invested in toothbrushes, Xiaomi is not investing in health related segment. The logic embedded in investment was not that clear in the beginning. The investment on smart toothbrush focuses on non-durable consumer goods, instead of smart health industry. The investment logic is to invest in consumer products that can interact with users, which consumers use with high-frequency, with a wide product interest.

## Xiaomi Interview Notes with Business Manager of Wearable Business Unit

## - Wearable Device Data Collection and User Experience

## Part 1: Xiaomi smart watch, band, user experience and major markets

1. **Currently, what is the proportion of users of Xiaomi smart watches and bands in the domestic and overseas market?**

The business scope of Xiaomi for wearables covers Mi Band and Mi Scales.

**Will Xiaomi tries to bundle the data from the watch, band and scale and build user health profile?**

In the long term, data from people's watch, band, weight scale are biometric data which falls under the personal health umbrella theoretically. All the devices falls into the big health umbrella. Taking use of data from multiple devices in the near future would be difficult, which is related to the overall industrial development and practice. Many of our competitors, for instance, Apple, only provide wearables. Only the Xiaomi ecosystem covers many categories of IoT products and we are the only one following such unique business model. Covering as many IoT product category as possible is also the Xiaomi IoT ecosystem, which we are developing. Creating the IoT device network and the link between different devices is not easy, because it involves coordinating very complicated relationships. The forming of the network involves company management and stakeholder interest; therefore, it is not easy to get synergy value from the IoT ecosystem.

The market has not reached the stage of taking use of the network value of IoT ecosystem. Taking use of the under-realized value of the IoT network will happen in the next 3-5 years. Combining various data sources into a single health initiative will be possible, and the market has not reached this stage. In fact, the data can only be useful with the amount of data and the accuracy of the algorithms reaching the threshold. These thresholds have not been reached yet. Xiaomi has not fully explored the commercial value of data.

Huami and Xiaomi are sharing data collected from wearables; the data sharing relationship has been set from the beginning since Xiaomi invested in Huami to become the sore hardware manufacturer. The ownership of the data is not related the manufacturer of the device. All data belongs to Xiaomi theoretically speaking. Xiaomi has invested in Huami. With both companies listed publically, it is not possible to discuss the issues in detail.

**Does the difference in data protection regulation play a role in the sale of Xiaomi wearables in the overseas and local market in China?**

The difference does has an impact on our sales; Xiaomi has upgraded our front-end privacy settings and do not need to worry about violating privacy regulations anymore.

Xiaomi wearables category does not include watches, only bands. Amazingfit is another brand created by Huami, and it has nothing to do with the Xiaomi brand. Huami tries to promote Amazingfit watches as Xiaomi smart watch, and wish to impress consumers with the Xiaomi brand. Xiaomi does not deny it.

Now the overseas market and the domestic market accounts for half and half of Xiaomi wearable sales. The sales of Xiaomi wearables grows at a faster rate in the overseas market than in the domestic market. The Xiaomi products overseas sales is relatively good in the European and the India market. There is a small proportion of sales in the Africa market, with the other markets accounting for the rest of Xiaomi wearable overseas sales. Before the annual report goes public, Xiaomi cannot disclose specific sales data (from the annual sales report, Xiaomi wearable domestic sales accounting for 61% of the overall sales till Q3 2018, compared to 81% from the previous year).

2. **Who are the main user groups for Xiaomi wearables in China? Who are the main users in the overseas market?**

Previously Xiaomi mainly cover users between 16-30 years old, and when it comes to specific products, target user group can expand (for instance, Mi Bunny, etc). The normal user group is between 10- 40 years. Except for children and the elderly, other population subsections all belong to Xiaomi target user group. There is no big difference between target users and the actual user groups.

**Will brand positioning affect Xiaomi user targeting in overseas and domestic market?**

Xiaomi brand stands on the same level as Samsung, with different brand perceptions will affect users' buying decision. In the indian market, it is possible the rich Indians will consider buying Xiaomi. In China, rich Chinese customers will not consider Xiaomi products. In the domestic market, Xiaomi is a commoner's brand. It is like MUJI product positioning in Japan and in China.

When it comes to customer segmentation, Xiaomi would consider user age, gender, and income. Normally Xiaomi would not consider such details in customer segmentation, because there is no use for such detailed analysis. Maybe in the next 1- 2 years there Xiaomi will use customer segmentation for marketing.

3. **What are the differences in design for Xiaomi watches and bands in the domestic and overseas market?**

There is no difference in design in general. In details, there is a difference in Africa and in India, when it comes to heart rate monitoring. Dark skins have an influence when it comes to use ECG to get the real-time the heart rate. There has improvement on software and hardware design because of skin color differences.

**In the beginning, is the design of algorithm based on foreign or domestic users?**

This depends on our algorithm and hardware supplier. In the beginning, they did not consider include selling Xiaomi wearables in the overseas market. As Xiaomi is based in China, the designing and testing is focused more on the domestic market and is based on domestic market demand. Xiaomi only expands in the overseas market when the product proves to be successful in the domestic market.

**Has Xiaomi explored the business model in the overseas market? For instance, to evaluate the health profile of users with insurance companies and provide users with free or discounted devices?**

There has been talks about sharing data with insurance companies not just in the overseas market, but also in the Chinese market. As it involved user privacy issues and sharing data with third parties, Xiaomi is quite conservative about it.

4. **What are the most used features of the Xiaomi band? What are the other user feedbacks on the product?**

The most used function is health related function such as steps and sleep monitoring. There are rarely people who exercise every day. Health covers so many functions, such as steps and sleep monitoring. There are rarely people who exercise on a daily basis. If we put step monitoring under sports related function, then it is the health related function, which is used more often. Initially steps monitoring was considered as part of the sports coaching function, after some internal discussions, it is changed to health function. Walking is no longer taken as a sport.

Step monitoring and sleep monitoring are the two most used functions, with message reading becomes quite popular with users.

There are reasons why payment function is rarely used. Making payments via wearables can happen via QR code or with NFC. NFC only become popular and matures in recent years. Adding NFC payment to wearable devices can incur additional hardware cost. Paying via QR code on wearable devices is difficult because the band and watches have very small screens. Now there is a trend to pay via wearables with some technological barriers. The regulators are generally supportive on adding NFC to wearables.

**How to realize swiping Xiaomi bands on the metro station?**

It depends on the technology and also policy. Currently, Xiaomi realized payment via wearables with NFC. Now it supports around 200 cities. When it is possible to swipe the public transportation card, it is possible to swipe Xiaomi card. The system has received support from large, middle and small cities, to transfer the functions involved in public transportation card to Xiaomi band. Sometimes at convenience stores where it is possible to swipe public transportation cards, it is possible for users to swipe Mi Band now.

**Is it possible for users to monitor health risks continuously? How does Xiaomi deal with the possibility that users will not regularly use wearables?**

Users will not just use Xiaomi wearables because of the curiosity. Users usually continuously to use Xiaomi products because the Mi Band is light, with the power can sustain the use of about 20 days to 1 month. Users can continuously to wear it without feeling big disturbance. Therefore the convenience brought by the band outweighs the trouble brought.

When it comes to Xiaomi smart watch, there will be power issue involved. Because sometimes some smart watches need to be charged on a daily basis, or every 3-4 days, or 1-2 days. In the beginning of the design process, there are requirements for power sustainability to go up to more than 20 days. This requirement was implemented to improve usability of wearables in user frequency and habits.

5. **Will it be possible for Xiaomi to add more health related functions to new products such as automatic fall detection, VO2 changes, and to monitor nutrition conditions with cameras?**

   For sure Xiaomi will have more health related functions added to new products in the future. The timeline however is not clear, maybe it will happen after 1-2 year or maybe after 3-5 years.

   There is an entrance barrier for the health industry, with it is difficult for normal wearable producer to go into the industry.

   The strict regulation for the healthcare industry is not convenient for commercialization of health related functions in the wearables. The entry barrier for the healthcare industry is

high given the strict regulation, with Xiaomi has the qualification and the scale to go into the industry.

**Will the China Food and Drug Administration (CFDA) certification has an impact on the health related functions for Xiaomi wearables?**

The health related functions Xiaomi promotes in the future will involve CFDA certification. With heart rate monitoring does not involve CFDA certification. More health related function will involve CFDA certification. Many health related functions for wearables lie in the grey area with many companies are designing their products like this. For instance, the heart rate monitoring function, if wearables just give the user the real-time read of heart rate, then heart rate monitoring remains a health related function which has nothing to do with medical use; therefore, it is not related for CFDA regulation. When it comes to monitor blood pressure, blood sugar, CFDA may get involved. Fall detection function is only related to detect falls, and therefore it is not medical use related. It belongs to the health function.

**Is it possible to add the nutrition related data to the health related function, and use cameras in wearables to monitor nutrition for users?**

Theoretically speaking, it is good. To realize the function takes time. Although Xiaomi has a hardware based business model, the functions and the products mentioned, if there is enough user demand, Xiaomi will possibly realize it.

**What are the other barriers to realize IoT network synergy value?**

If there is user demand for every new function, Xiaomi, as an internet company will meet the needs. There is no barriers for realizing the IoT network effects, the question remains whether it is the worth to do it. Some user scenarios are not standard user scenario. Xiaomi is sticking to meeting the needs of 80% of users and their 80% of needs. There is cost related to developing each new function, and this is related to the value of Xiaomi. If only 10% of users need the function, then probably it is not cost effective for Xiaomi to develop such function. It is not that Xiaomi does not realize there is a niche market, it is just because it is not worth to invest in the niche market.

**Part 2: Data flow, processing with Xiaomi wearables and associated business model**

1. **What third party devices are Xiaomi wearables connected with? Is it possible to link the sleep monitoring data from users and smart home appliances to create better sleep experience for users?**

Automatic waking up with lights is possible and this solution can share with performers in the market.

The lights Xiaomi treat them as partners (manufactured by Xiaomi ecosystem firms). Third party appliances are manufactured by other firms other than Xiaomi. For Xiaomi ecosystem appliances, we are trying to improve the IoT user experience, and to win user trust. In case we failed to improve on user experience, Xiaomi will end up losing user trust. In the beginning, the Xiaomi IoT platform is not that open to third party apps. Internally, the IoT network involves lights and air-conditioning. It targets customers who have higher requirements for sleep conditions; the air-conditioning and the fan can automatically switch to sleep mode when detecting users switch off the light. The IoT platform is not open to third party appliances and apps.

**How did Xiaomi incorporate Alipay on wearables?**

Alipay provides Xiaomi with solution packages, with Xiaomi proposed to incorporate Alipay on wearables. Alipay is relatively open to this types of solution, not just for Xiaomi.

**Why did you not cooperate with Wechat?**

Wechat is rather conservative in this sense, with all the wearable devices not support wechat payment function. It is also related to how wechat choose their wearables collaborative partners.

**The openness of IoT device platforms for smart home appliances differs in the domestic market. How is the openness level for the IoT industry?**

All platforms are boasting their openness for other brands of devices, but in reality, none of the platforms are doing a very good job. Xiaomi is not bad in this sense. Except for Xiaomi, all other platforms are in the start-up phase, and are promoting their openness, and try to get more users and manufacturers to use their platforms. In the future, the platform is not mature enough, with their prospects of opening to other brands limited, and this is related to their corporation management.

**If users buy different types of smart home IoT devices, can all different types of home appliances get connected to the single IoT platform?**

This is related to the historical development. Judging from the current situation different IoT platforms belong to different brands; these brands have no incentive or reason to build inter-connectivity. In the future, if users want better experience on inter-connectivity, Xiaomi will try to stay open to home appliances from other brands. Now it seems difficult.

The IoT system will evolve with the Matthew effect; with good platforms will become more inter-connected with other brands and bad platforms will gradually disappear. The IoT collect with the downstream users and the content and service providers in the upstream. Only bigger platforms with mature technology and services can connect with more users, with more users attract more services and contents. In the end bigger platforms will attract more users and the market will be of competitive oligopoly.

In the end, if users buy smart home appliances from multiple brands, these different appliances may not be able to connect to a single platform. Unless the Chinese government requires for such interconnectivity and all brands answer the call, it is difficult to have such interconnectivity.

2. **Where are the steps, heart rate, and GPS data processed? On the device or in the cloud?**

   Xiaomi use both methods to process data. Basic data is processed on the device; take power sustainability into consideration, complicated data cannot be processed on the device. More complicated calculations are processed in the IoT platform. For users all data are quite sensitive, and Xiaomi tracks data flow to the cloud and on the device.

3. **How does behavior tagging work in Mi Fit? What was data connected for? Does Xiaomi share the data with third parties?**

   The tagging aims to let improve the algorithms and adjust it according to users' needs. In the future, the algorithm can offer personalized solution for users but now it is not that competent. Xiaomi is very conservative about sharing data with third parties, let alone the tagged data.

4. **Does Xiaomi inform users about sharing data with third parties? For instance, the "Steps taken per day" Health insurance, will users share data other than bio-metrics data?**

Xiaomi will give users notification about privacy policies when users intend to choose certain services which involve sharing data with third parties. If users refuse to accept the privacy policy, then Xiaomi will not provide the services.

5. **Does the user have the right to decide the length of their personal data retaining, sharing parties and the types of data sharing?**

Because of GDPR and the Chinese privacy protection regulation, users can determine the length of personal data retaining, sharing parties and the types of data shared.

The Chinese government has implemented the privacy protection clauses. Now users can communicate with Xiaomi via email, calls, for personalized data request such as deleting data on the server. If users fail to communicate or fail to raise personalized request, Xiaomi will deal with the data with standardized solution. Below is the standardized solution offered by Xiaomi (Source: Xiaomi.com, https://www.mi.com/global/about/privacy/, last access June 19th 2019). The standardized solution is what GDPR requires in Europe, and the data privacy law requires in China. The approach Xiaomi takes is the industrial standard approach.

*INFORMATION NOT REQUIRING CONSENT*

*Xiaomi may share anonymized information and statistics in aggregate form with third parties for business purposes, for example with advertisers on our website, we may share them trends about the general use of our services, such as the number of customers in certain demographic groups who purchased Certain products or who carried out certain transactions.*

*For the avoidance of doubt, Xiaomi may collect, use or disclose your personal information without your consent if it is and only to the extent it is allowed explicitly under local data protection laws.*

**6 . After the implementation of the General Data Protection Regulations, what are the changes to the privacy policy of wearable devices? Does it affect the business model of wearable devices?**

We cannot answer this question.

Through the analysis of the privacy policy of Xiaomi website , Xiaomi does not sell the user's personal information. Xiaomi will share data with third parties and eco-system companies. The scope of third parties involved in data sharing includes communication service providers, data centers, data storage service providers , advertising and marketing service providers . At the same time, Xiaomi did not disclose data sharing with the eco-system businesses.

According the the Xiaomi Privacy policy webpage, the follow changes has been made.

***What is new under GDPR?***

*"Xiaomi has added Data Protection Office r to ensure GDPR compliance (1) Xiaomi set up a Data Protection Officer (DPO) in charge the data protection, and the contact of DPO is dpo@xiaomi.com; (2) procedure like data protection Impact assessment (DPIA).*

*Xiaomi updated the types of personal information that we collected and the purposes of collecting such information. For example, we collected hardware usage information to conduct statistical analysis and optimize the performance of your devices.*

*By complying with GDPR and providing better data privacy protection, we updated the relevant content about users' rights under GDPR, and how we process the personal information for our Europe Union users.*

*Xiaomi updated the relevant content of third parties' products and services which may be involved during the use of our products and services."*

**The impact on business model for Xiaomi wearables**

GDPR does not have big impacts on the Xiaomi wearable business model, with the core of the business have not changed. The hardware based business model did not change. Data related business belong to derivative services in the later stage. Xiaomi has not started exploring data based business model. There is no existent data derived business from Xiaomi.

**7. What is the added value services targeted Mi Band and Mi Smart Scale?**

All the services now provided are included in the price of the hardware. There is no additional service packages which requires users to pay. The membership based value added service is in the stage of exploration stage with no fixed conclusion yet.

**Will Xiaomi analyze data from Mi Fit and Mi Home together and evaluate health risks of users?**

This is a possibility of the direction where we are going, and currently there is no such schemes. We cannot answer whether it is in the development stage. The important thing for us to get the data, analyze and to present it to users.

**Will Xiaomi improve the interaction methodology with users?**

Besides controlling with smart phones or via voice assistance, the other interaction methods such as via eyes, hand movements, or brain waves, will not happen in the near future. Maybe it will happen after 10 or 5 years.

**8 . Smart blood pressure monitor (i-Health), smart glucose monitor (i-Health), smart urine analytics reader (i-Health), can all connect to Xiaomi Mi Home app. Will Xiaomi consider take use of the data from these smart health monitors and build a user smart health profiles?**

I cannot answer this question, as this is a problem of our third party partners. Xiaomi has not control of it. Under the smart health umbrella, Xiaomi would like to analyze data in a comprehensive manner. It is not very certain whether Xiaomi can do it. Some data would be very useful for us, but data collection shall happen within the data protection compliance framework. Xiaomi will strictly follow GDPR or the Chinese data protection policy, with the Chinese government also has strict regulation about bio-metrics data protection.

**9. Is it possible to establish patients' personal health records and share them with doctors to provide personalized health coaching? Is this business model applicable in China?**

This proposal sounds very bright. It is difficult in China. In China, the medical resources are very scarce. In the future, Xiaomi might follow such strategy; in the short term, it is very difficult.

**10. The "Steps Sharing Insurance" allows Xiaomi to share steps users taking per day with Zhong An where users can use the steps to trade for insurance premiums. Besides steps taken per day, what other data does Xiaomi share with Zhong An?**

By the end of 2018, Zhong An has collaborated with many tech groups for the “Steps Sharing Insurane” scheme, allowing users to book insurance plans via 51Yund app or Mi Fit App. On data sharing level. Xiaomi has not shared data with Zhong An or other insurance companies. Zhong An can sell insurance via smart fit apps, that is all.

From internet, among the Steps Sharing Insurance users, 47% are born after the 1990s, 37% are born after the 1980s. Young people have low risks to get fatal diseases, and thereby bearing less risks than other groups of the population and enjoy less premium. The premium of such insurance cost less than other fatal disease insurance plans.

11. **Will Xiaomi consider obtain data from smart rice cooker, and blood pressure monitor, smart blood sugar monitor, and other smart wearables, and analyze the data in a comprehensive manner to provide nutritional and sports advice to users?**

In the future it is a plausible scenario. In this stage of development, it can be difficult. Xiaomi will not start such practice now. There are no many technical barriers; the market is not mature enough. Besides, the ECG function embedded in Apple Watch only obtained the FDA certification in the US. The ECG function cannot be used in China.

**12. Does Xiaomi has plans to promote the blood pressure monitoring via PPG to reduce the disturbance to users via blood pumping?**

The method is still in early development stage (by contrast, such products have emerged in CES Asia 2019). The PPG monitoring is not fit for the current market demand.

13. **What is the view of Xiaomi for the fall detection and prevention function embedded in wearables?**

The function is merely a slogan. Users may find it attractive in the beginning, to realize such function is difficult in reality. It involves collaboration with network provider or the issue of data sharing.

**14 Is it plausible for the business model where insurance companies pay for wearable devices?**

Xiaomi has no problem with such business model. However, the standardization to measure the effectiveness of wearable devices is an ongoing process. It is difficult to measure the value of wearable device in reality, therefore not possible for insurance companies to refund users.

# *Chapter 3*

## *COVID-19 and stakeholder mapping for the tele-health industry in China*


**Abstract**

**Background**: Facing COVID 19, the use of telehealth solutions grows exponentially. However, despite the large amounts of investments made into telehealth solutions, the implementation process remains slow and sluggish. In the pandemic, the elderly suffered the most with the highest mortality rates.

**Objective**: The paper aims to find out about the barriers and incentives for implementation of telehealth solutions via case study over telehealth implementation in China.

**Methods:** 8 semi-structured interviews were conducted with the interactive learning framework (research question defining, participant recruitment, exploratory stage, consultation stage, integration stage, follow up interview). In the exploratory stage, one interview with government official from national health commission and another interview with government official from china disease control Center were conducted. In the consultation stage, one interview with business manager from Huawei Wearable Unit, one interview with business manager from Alibaba Health Brain Unit, one interview with business manager from Xiaomi was conducted. In the integration stage, two interviews with doctors from Fudan University affiliated Huashan Hospital and Fudan University affiliated Zhongshan hospital were conducted; 8 focus group studies with 64 participants from rural and urban Beijing were conducted as well. In the follow up stage, another telephone interview with business manager of Xiaomi wearable unit was conducted as well.

**Results:** Telehealth solutions are designed to assist healthcare providers to realize the triple aim of reducing healthcare cost, improving healthcare quality including staff and patient experience. Governments high incentives to improve healthcare efficiency via telehealth solutions. Yet they have limited resources to make the necessary infrastructure transformation.

To fully realize the potential of smart health devices, heavy infrastructure investment is in need beforehand in the telecommunication network and to nurture the trust over data collected over telehealth solutions. A mature business model incorporating collaboration between various stakeholders and industrial partners is also demanded by the industry to make such investment for infrastructure.

Governments have high interest and significant influence on building the necessary infrastructure for smart health solution implementation in China. Industrial actors have high interest and medium level of power for smart health solution implementation. Users have high interest but lower level of power for the usage of smart health solutions. Doctors have low interest and medium level of power for smart health solutions implementation.



**Keywords**: Elderly homecare; Telehealth; Stakeholder mapping and power analysis

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# 1 Introduction

COVID-19 has posed great challenges for unprepared public healthcare systems with an aging population. The sad truth seems to be countries with an older population of pre-existing chronic disease conditions (hypertension, cardiovascular disease, diabetes) such as Italy, Spain, the Netherlands, the United Kingdom reported higher mortality rates than countries with a younger population such as China. (Johns Hopkins University, 2020; Wu et al, 2020). The proportion of the population which was hit hardest by the population is the poor and the elderly. The public healthcare systems with a lack of hospital beds, intensive care units and qualified trained medical staff can make use of smart health solutions to resolve the challenges encountered in combating COVID-19 (Philips, 2020). Smart health solutions can potentially improve prevention, diagnosis, treatment and recovery efficiency by promoting data accuracy (Hollander JE, Carr BG, 2020).

The World Economic Forum has listed the biggest 7 breakthroughs in the healthcare industry with 'AI can detect skin cancer better than a doctor', 'Your phone will know if you are depressed or not' ranking 3 and 4 in the list[1] (World Economic Forum, 2019). Exciting innovations in smart health industries include, utilizing telemedicine to transfer care to home setting, using AI to reduce physician workload, to divert patients to the right doctor, and the Internet of Things to improve patients monitoring and coaching have left us with the feeling that the healthcare industry is on the cusp of AI revolution[2]. Huge amounts of investment made by the public and private sector have poured in to big data, cloud computing and utilizing such tools in the healthcare continuum. AI seems to promise to bring high value healthcare where it can end our quest for the impossible healthcare trinity of access, quality and cost.

The paper aims to find out on whether AI has achieved such an aim with empirical evidence from China and selected European economies. Chapter 3 consists of 5 parts, part 2 is about concept development, part 3 is about research methodology, part 4 is about stakeholder power mapping results, part 5 is about conclusions and implications.

# 2 Concept Development

## *2.1 COVID-19 Pandemic and its economic impact*

The COVID-19 pandemic spreads globally at a record speed compared to SARS in 2001. Globalization has deepened our connections, making it easier for people to travel and live on a global scale. This renders it difficult to manage the public healthcare crisis on a traditional national basis. Historical events such as SARS, MERS keep reminding policy makers that global warming will make pandemics such as COVID-19 spread more easily (WHO, 2009). It lacks international cooperation and resolution to deal with a global crisis. Regarding management of the crisis, among major economies, Germany and China outperform others in terms of death rate.

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[1] Robin Pomeroy, World Economic Forum, "These are 7 of the most exciting breakthroughs in healthcare today", published on May 8th 2019, available at https://www.weforum.org/agenda/2019/05/healthcare-technology-precision-medicine-breakthroughs

[2] Emanuel EJ, Wachter RM. Artificial Intelligence in Health Care: Will the Value Match the Hype? JAMA. Published online May 20, 2019. doi:10.1001/jama.2019.4914

| Country | Confirmed | Deaths | Case-Fatality | Deaths/100k pop. |
|---|---|---|---|---|
| US | 1,486,757 | 89,562 | 6.0% | 27.37 |
| United Kingdom | 244,995 | 34,716 | 14.2% | 52.21 |
| Italy | 225,435 | 31,908 | 14.2% | 52.80 |
| France | 179,693 | 28,111 | 15.6% | 41.96 |
| Spain | 230,698 | 27,563 | 11.9% | 58.99 |
| Brazil | 241,080 | 16,118 | 6.7% | 7.69 |
| Belgium | 55,280 | 9,052 | 16.4% | 79.25 |
| Germany | 176,369 | 7,962 | 4.5% | 9.60 |
| Iran | 120,198 | 6,988 | 5.8% | 8.54 |
| Canada | 78,332 | 5,903 | 7.5% | 15.93 |
| Netherlands | 44,195 | 5,699 | 12.9% | 33.07 |
| Mexico | 49,219 | 5,177 | 10.5% | 4.10 |
| China | 84,054 | 4,638 | 5.5% | 0.33 |

Figure 3.1 Cases and mortality by country, Source: John Hopkins University, Corona Virus Center, 2020, accessed on March 12th 2020;

The COVID-19 pandemic hit the global economy with strict quarantine methods enforced all over the globe. Public healthcare systems in certain economies such as Italy, the United Kingdom were not prepared. This has resulted high death rate in economies with aging population. The drama caused by ventilators proves the current healthcare system remains unprepared and ill-equipped to deal with such a crisis. Except the limited resources both material and human resources in the healthcare systems, the high death rates among vulnerable groups remain a highly debated topic. It has been clearly that elderly with multiple chronic diseases has been identified as the vulnerable group in the pandemic revealed by Figure 3.2, Figure 3.3, Figure 3.4 and Figure 3.5.

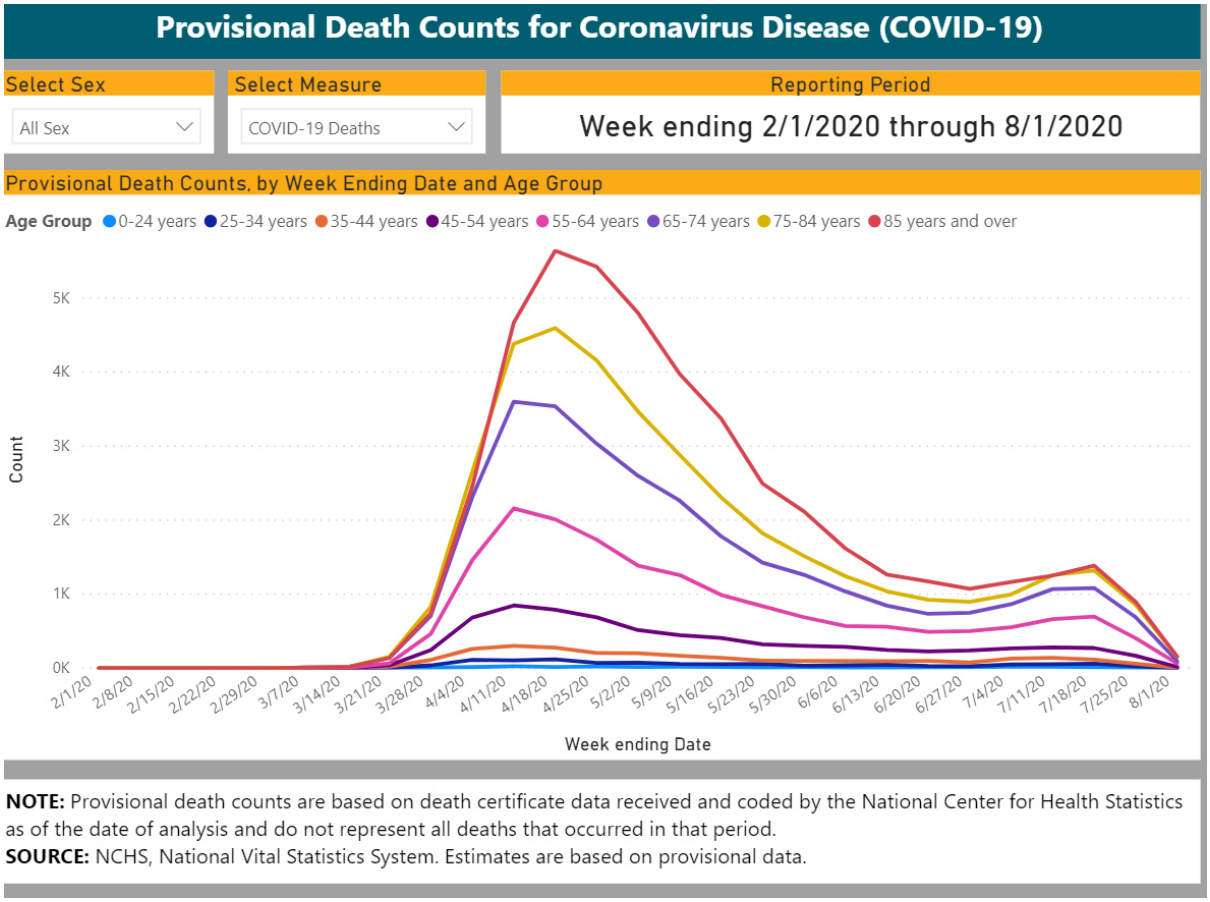



Figure 3.2 Weekly Death counts among different age groups in the United States, CDC NCHS, Last accessed on August 12th 2020;

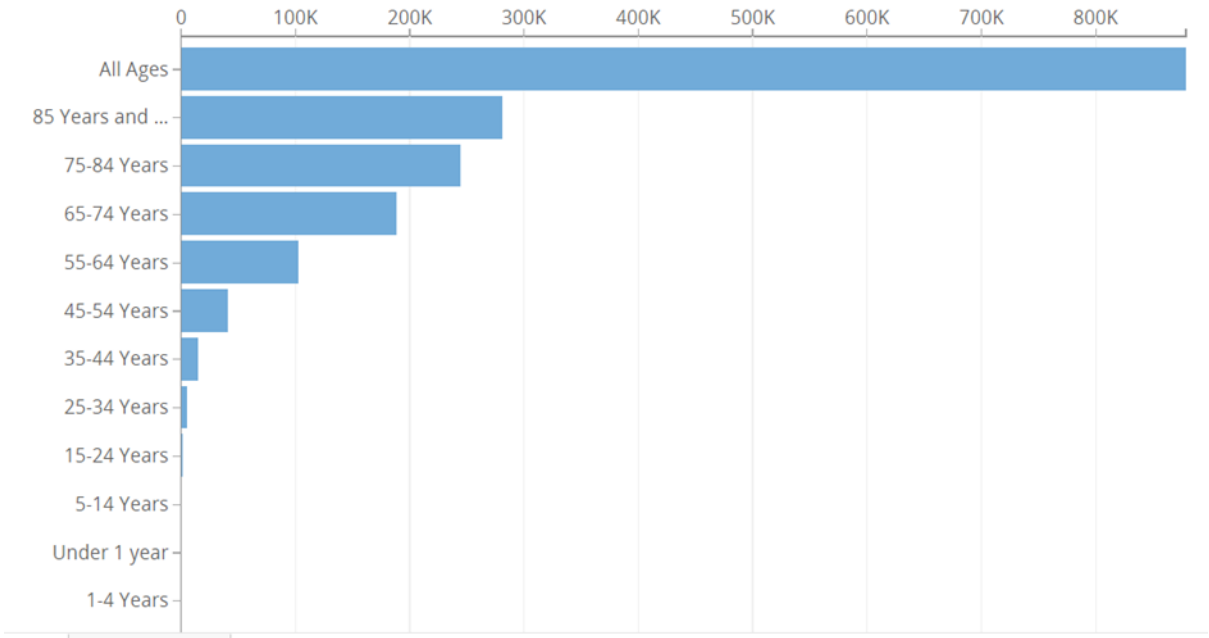



Figure 3.3 Total deaths sorted by age group in the U.S., CDC, Last Accessed on Feb 11th 2021.

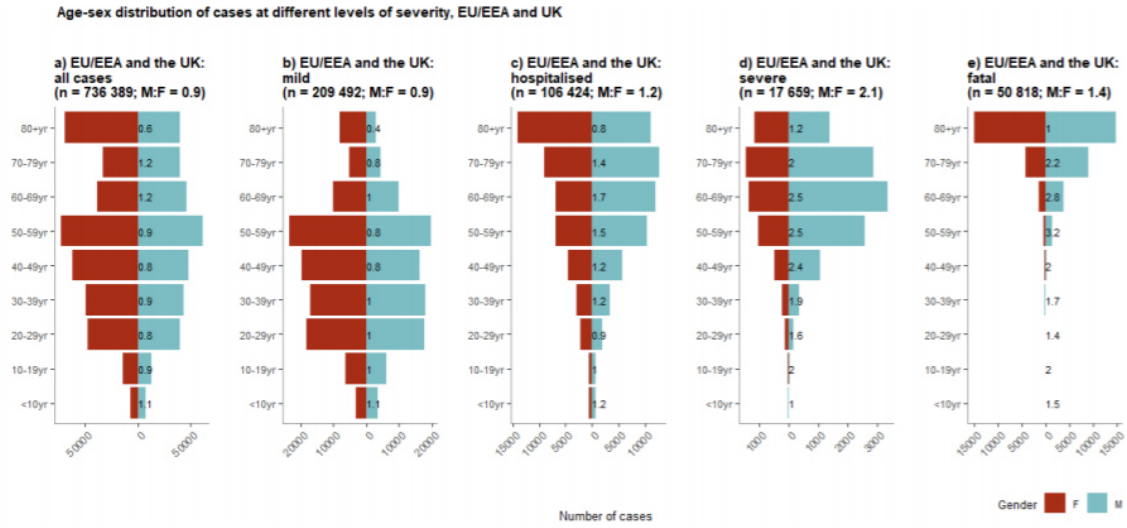



Figure 3.4 Age-sex distribution of COVID-19 cases, EU/EEA and UK, by August 2nd 2020; Source: European Center for disease prevention and control, last accessed on August 12th 2020;

Other healthcare systems issues revealed in the pandemic include lack of coordination among different stakeholders in the healthcare systems. This brings the lack of effective coordination, treatment and prevention measures with the vulnerable groups not informed. In the end, the vulnerable groups have suffered tremendous losses.

| | Deaths | Laboratory-confirmed cases* | Case fatality ratio | | | Infection fatality ratio† |
|---|---|---|---|---|---|---|
| | | | Crude | Adjusted for censoring | Adjusted for censoring, demography, and under-ascertainment‡ | |
| Overall | 1023 | 44 672 | 2·29% (2·15–2·43) | 3·67% (3·56–3·80) | 1·38% (1·23–1·53) | 0·657% (0·389–1·33) |
| Age group, years | | | | | | |
| 0–9 | 0 | 416 | 0·000% (0·000–0·883) | 0·0954% (0·0110–1·34) | 0·00260% (0·000312–0·0382) | 0·00161% (0·000185–0·0249) |
| 10–19 | 1 | 549 | 0·182% (0·00461–1·01) | 0·352% (0·0663–1·74) | 0·0148% (0·00288–0·0759) | 0·00695% (0·00149–0·0502) |
| 20–29 | 7 | 3619 | 0·193% (0·0778–0·398) | 0·296% (0·158–0·662) | 0·0600% (0·0317–0·132) | 0·0309% (0·0138–0·0923) |
| 30–39 | 18 | 7600 | 0·237% (0·140–0·374) | 0·348% (0·241–0·577) | 0·146% (0·103–0·255) | 0·0844% (0·0408–0·185) |
| 40–49 | 38 | 8571 | 0·443% (0·314–0·608) | 0·711% (0·521–0·966) | 0·295% (0·221–0·422) | 0·161% (0·0764–0·323) |
| 50–59 | 130 | 10 008 | 1·30% (1·09–1·54) | 2·06% (1·74–2·43) | 1·25% (1·03–1·55) | 0·595% (0·344–1·28) |
| 60–69 | 309 | 8583 | 3·60% (3·22–4·02) | 5·79% (5·20–6·34) | 3·99% (3·41–4·55) | 1·93% (1·11–3·89) |
| 70–79 | 312 | 3918 | 7·96% (7·13–8·86) | 12·7% (11·5–13·9) | 8·61% (7·48–9·99) | 4·28% (2·45–8·44) |
| ≥80 | 208 | 1408 | 14·8% (13·0–16·7) | 23·3% (20·3–26·7) | 13·4% (11·2–15·9) | 7·80% (3·80–13·3) |
| Age category (binary), years | | | | | | |
| <60 | 194 | 30 763 | 0·631% (0·545–0·726) | 1·01% (0·900–1·17) | 0·318% (0·274–0·378) | 0·145% (0·0883–0·317) |
| ≥60 | 829 | 13 909 | 5·96% (5·57–6·37) | 9·49% (9·11–9·95) | 6·38% (5·70–7·17) | 3·28% (1·82–6·18) |

Crude case fatality ratios are presented as mean (95% confidence interval). All other fatality ratios are presented as posterior mode (95% credible interval). Estimates are shown to three significant figures. Cases and deaths are aggregate numbers reported from Jan 1 to Feb 11, 2020.* Crude case fatality ratios are calculated as the number of deaths divided by the number of laboratory-confirmed cases. Our estimates also include clinically diagnosed cases (a scaling of 1·31 applied across all age-groups, as the breakdown by age was not reported for clinically diagnosed cases), which gives larger denominators and thus lower case fatality ratios than if only laboratory-confirmed cases were included. *Values do not include the clinically diagnosed cases included in our estimates. †Obtained by combining estimates of case fatality ratios with information on infection prevalence obtained from those returning home on repatriation flights. ‡Accounts for the underlying demography in Wuhan and elsewhere in China and corrects for under-ascertainment.

*Table 1:* **Estimates of case fatality ratio and infection fatality ratio obtained from aggregate time series of cases in mainland China**

Figure 3.5 Death ratios among different age groups in mainland China, Source: Verity et al., 2020

Economically, with lockdown measures and social distancing, traveling has become risky.

There are several sectors affected the most during the COVID-19 lockdown: hospitality, transportation, travel. In particular, the small and medium sized businesses are mostly affected; governments and international organizations including IMF and the World Bank around the globe offer funding programs to resolve the illiquidity risks businesses are facing. Still many businesses went bankrupt.

The economic projection for China is 1.9 % for 2020 and will bounce back to 7.9% in 2021 (IMF, 2020), while economic projection for the Eurozone was adjusted to be 3.9% for 2021, bouncing back from -7.3% in 2020 (European Central Bank, 2020) and for the economic projection of U.S. in 2020 was adjusted to -2.3 % and in 2021 4.2% (BEA, 2021; The FED, 2020). Martin Wolf (World Bank, 2020) commented on the drastic economic cost of COVID-19 as unprecedented. It is urgent for the world to find new economic growth leverages and balance among U.S. – China trade war and the shocks brought to the global value chain. Whether AI can become the driver for new economic growth and to what extent they will have an impact on the healthcare systems are widely debated today.

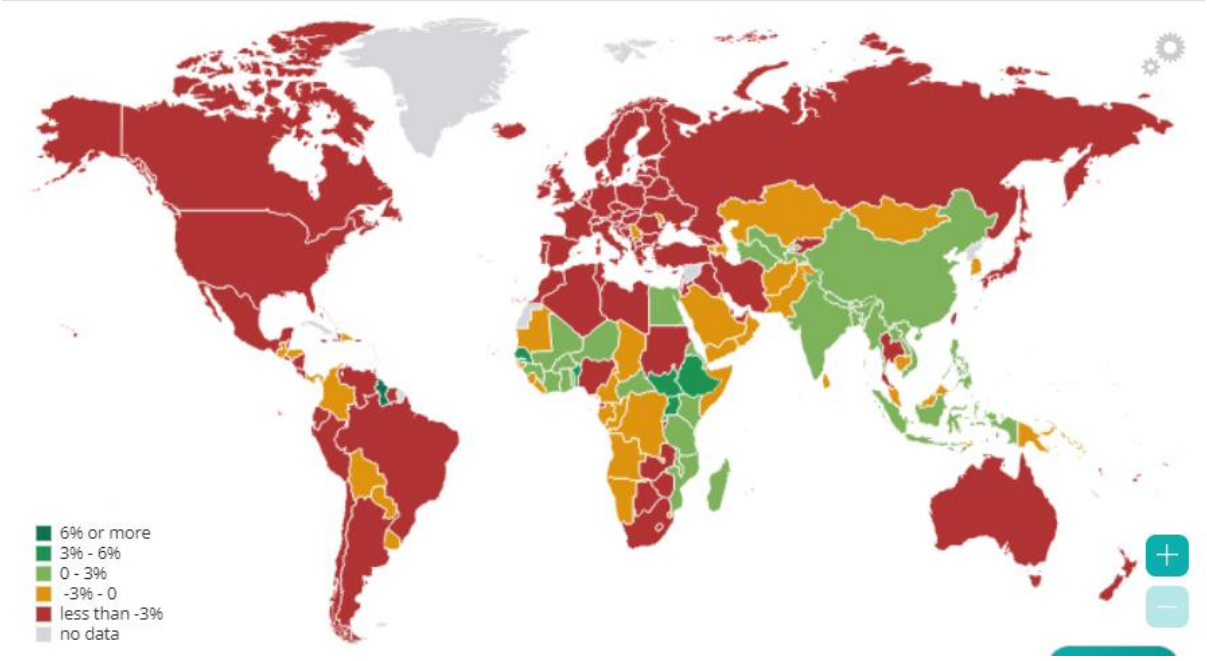



Figure 3.6World Economic Projection Visualization, Source: IMF, last accessed on August 14th 2020;

As healthcare systems in major developed economies suffer tremendous shock because of lack of resources, lack of coordination and material support because of COVID-19. There is clearly a need to rebuild the resilience of the healthcare systems and restore public trust for the healthcare service providers. Until today, the cost for performing healthcare is high in major developed economies while the salary for healthcare workers remain low. The funding cuts and austerity policies made many doctors quit their jobs in healthcare for better life and reward packages in sectors such as consultancy, banking and insurances. The impossible trinity in healthcare – lowering the healthcare cost, improving healthcare quality, improving will not change just because of the application of AI. AI will certainly drive the need for additional talents in programming and demand for more mature solutions from tech firms. The next part of the thesis will discuss how AI will interact with the healthcare systems.

### *2.2 The use of AI and IoT in healthcare*

COVID-19 had pushed the digitalization of healthcare system. Investments on health related projects have grown rapidly. AI has been deployed for detecting disease concentration and spreading, real-time monitoring, predicting pandemic outbreaks and mortality risk (Arora, Banerjee, & Narasu, 2020, p. 718). AI has also been instrumental in diagnosis of COVID-19 by performing image recognition for X Ray and MRI results. For hospital management, AI has become useful in facilitating resource allocation by automize resource management and supply chain management, assisting staff training with VR and AR, maintaining healthcare records and identifying patterns for trend recognition (Arora, Banerjee, & Narasu, 2020, p. 718).

In pandemic tracking and prediction, AI has been useful in collecting data from social media, and identifying disease clusters. In the beginning of the pandemic, Bluedot has reported the disease cluster of pneumonia cases in Wuhan by analysing news reports on Dec 31st, well ahead of public health administrations in China and in other economies (Bluedot, 2020). The Johns Hopkins University Coronavirus Resource Centre collects public available information and visualize the data, making it possible to actively tracking the spread of the disease (Johns Hopkins University, 2021). It is now possible to use Google Map to estimate active COVID-19 cases by country (Google Maps, 2021).

In contact tracing, U.S. universities such as MIT and Harvard have been developing and using contact-tracing apps such as Safe Paths (Safepaths, 2020). Tech companies such as Google and Apple are also working together to develop the contact tracing APIs (Apple, 2020). Mobile apps were developed quickly by different governments and tech companies to facilitate contact tracing, in China with Wechat and in the Netherlands with Coronamelder. Apps such as AI4COVID-19 has enabled detecting of COVID-19 with 3 seconds of coughing and deliver the diagnosis with 2 minutes (Imran et al., 2020, p. 100378).

In early diagnosis of COVID-19, algorithms were rapidly developed and deployed by tech companies in China to identify patients with symptoms of COVID-19 (**错误!未找到引用源。**). After the Chinese New Year where large scale infections were reported, Yitu Technology, developed the algorithms to facilitate the diagnosis and treatment of COVID-19 (Johnson & Johnson, 2020). The software had received clinical approval quickly and was deployed in Hubei and then nationally with healthcare systems whereby the pandemic hit the hardest. The AI assistant received approval from healthcare service staff. Congestion in hospitals was relieved with the deployment of such systems with patients diverted to infectious disease hospitals. Yitu aims to establish the AI assisted paradigm in four stages of the pandemic control process. In prevention stage, chatbots and online consultation can educate users and have users perform self-examination. In the quarantine stage, the system can help doctors to monitor the patient and manage their conditions.

In the patient screening stage, the system can guide patients to the right medical path. In the diagnosis and treatment stage, the algorithm can help to facilitate the diagnosis of COVID-19 from 2 minutes to 20 seconds with the classification of CT images, thereby lowering the cross-infection risk for patients during quarantine/treatment at home periods. The AI assistant also marks the areas in the lung which COVID-19 had impacts on, thereby making it easier to track patient progress. Researchers around the world have delivered at least 5 other neural networks to diagnose COVID-19 patients (Singh et al, 2020; Alom et al, 2020; Li et al, 2020; Soares F, 2020; Farooq M et al, 2020).

In patient management, AI has been deployed at hospitals to automize asset management (Huawei, 2021) and prioritize COVID-19 patients in ICU units for ventilators. AI can also predict the possibility of patient recovery and mortality by monitoring patient daily electronic health records and helping doctors to make the decision for the next step (Arora et al, 2020).
In pharmaceutical development, AI can accelerate drug and vaccination discovery by reducing the time for drug discovery, virtual screening and validation process (Arora et al, 2020) Researchers have quickly obtained genetic information from patients, and offer it to the international community (Sydney University, 2020). AI had made it easier to predict the structure of protein (Deep Mind, 2020). This has given the pharmaceutical companies an opportunity to develop the vaccination for COVID-19 rapidly. For instance, AI has been used to develop m-RNA vaccine by Oxford University and Moderna (HBS, 2020).

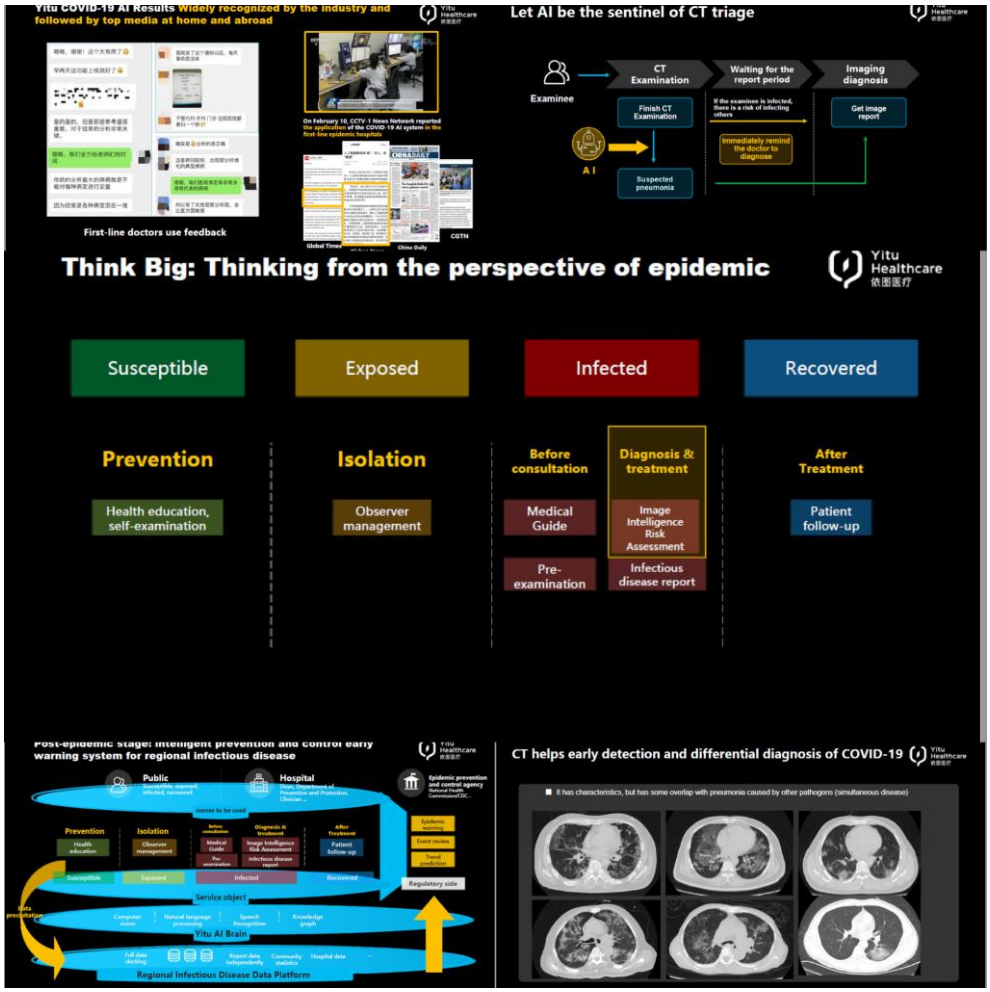



Figure 3.7Yitu Technology on CT Scan Triage on facilitating COVID-19 Diagnosis, Sources:

Yitu Technology, Inc. Johnson&Johnson Innovation JLabs, Presentation on Challenges and

Opportunities for Healthcare Start-ups during COVID-19, Recap

The concept of connecting the healthcare system with the smart city system has been raised ever since the birth of Internet of Healthcare Things concept. COVID-19 with the nature of

air-borne disease, had prompted the new normal globally for online education, virtual meetings and remote monitoring and prevention for the health systems. The need for connecting smart buildings and smart transportation systems with the healthcare systems seems more urgent than ever.

As suggested by the study conducted by Simens (2020), the smart building system can play a significant role today in attracting, and retaining talents. The reason lies in the fact that employee wellness is given more emphasis than before. Retaining employees, given the high mobility of millennials has become a priority for many multi-nationals. Features such as automatic lighting system and window shades, can create a safe and comfortable working environment for employees. Meanwhile the smart quarantine/social distancing rules implemented by many governments around the globe improves the difficulty for maintaining a safe working space. The smart building management system can contribute to keep social distance while protecting the safety of employees (Bloomberg, 2020; Simens, 2020). The smart building system can also help to monitor the air-quality of tenants, thereby prompting the tenants to seek better air-quality from landlords.

The paper seeks to answer the question on whether smart health solutions can perform as they promised by analysing answers from stakeholders from China and from selected countries in Europe.

### *2.3 The digital healthcare readiness in European Economies*

To evaluate how to implement telehealth solution in Europe, there is a need to find out the enablers for digital health solutions with case studies in specific European economies. The case study is conducted with digital readiness for combating diabetes in Europe with the 10 European economies. Considering the vast differences between European healthcare systems, it is necessary to address the issue with a technical framework from legislation, policy, disease guideline, and patient refund for telehealth solutions.

The Economist Intelligence Unit (EIU, 2020) launched a study regarding the readiness of the European economies for digital healthcare. The study analyses the use of digital health solutions to manage diabetes in 10 European economies. There are five enablers to implement telehealth solutions for the management of diabetes. The most important one is the availability of reimbursement pathways, followed by the openness of the evaluation and assessment processes for digital healthcare management tools. It is also important to incorporate digital health management tools in disease treatment guidance plans for diabetes. Meanwhile, there is a need to provide training to healthcare professionals to raise the awareness for digital health tools. Finally, turning digital healthcare policies into reality requires time, funding and the political commitment.

Type I and II diabetes is a growing global healthcare issue. The reason for evaluating the digital capabilities for diabetic treatment is the significant number of patients with Type-I and Type-II diabetes, the vast among of economic cost, the impact of real-time monitoring of glucose level. The number of patients has grown from 151 million in 2000 to 463 million in 2019 (EIU, 2020). In Europe, the prevalence of diabetes is projected to reach 65 million by 2030. Meanwhile, the healthcare expenditures on diabetes was 229 million in 2019. With digital healthcare tools, it becomes more convenient for patients to track their health status, manage the disease together with doctors and lower the cost of treatment.

The study was conducted from several perspective, such as the readiness for digital healthcare for diabetes, the fitness of incentive and payment systems. The study incorporates northern, southern, western and eastern European countries, including Belgium, Denmark, England, France, Germany, Italy, Netherlands, Portugal, Slovenia. With real-time monitoring of glucose level and data sharing, patients can improve sleep quality and well-being, thereby reduce severe hypoglycemia (Polonsky & Fortmann, 2020, p. 4).

The score was developed based on the following questions regarding Covid-19 response, "Is there a national eGovernment policy?", "Is there a national eHealth policy or strategy?", "Is there a national health information system (HIS) policy or strategy?", "Is there a national health information system (HIS) policy or strategy?", "What are the funding sources for eHealth?", "Are key legal eHealth frameworks e.g. jurisdiction, liability, data privacy, present? (None, Some, Most, All frameworks)", "Is there a national EHR system?", "Is there legislation governing the use of the national EHR system?", "Which types of health facilities are using EHRs? (primary, secondary, tertiary)"," Is there national infrastructure for remote patient monitoring?", "Is there a national strategy to ensure system interoperability within the health system?"," Is there legislation governing the sharing of data among private companies (e.g. device manufacturers) and government?", "Is there a policy or strategy governing the use of big data by private companies?, "Is there eHealth training for health professional pre- and post-qualification?", "Are digital tools included in health technology assessment (HTA) for medical devices?", "Are digital tools included in reimbursement pathways for medical devices?". Base on these questions, the surveyed European economies were ranked and compared. Here is the data visualization results. It is observed that Germany, Italy and Denmark, ranks high in the overall score for the digital readiness regarding the management of diabetes during COVID.

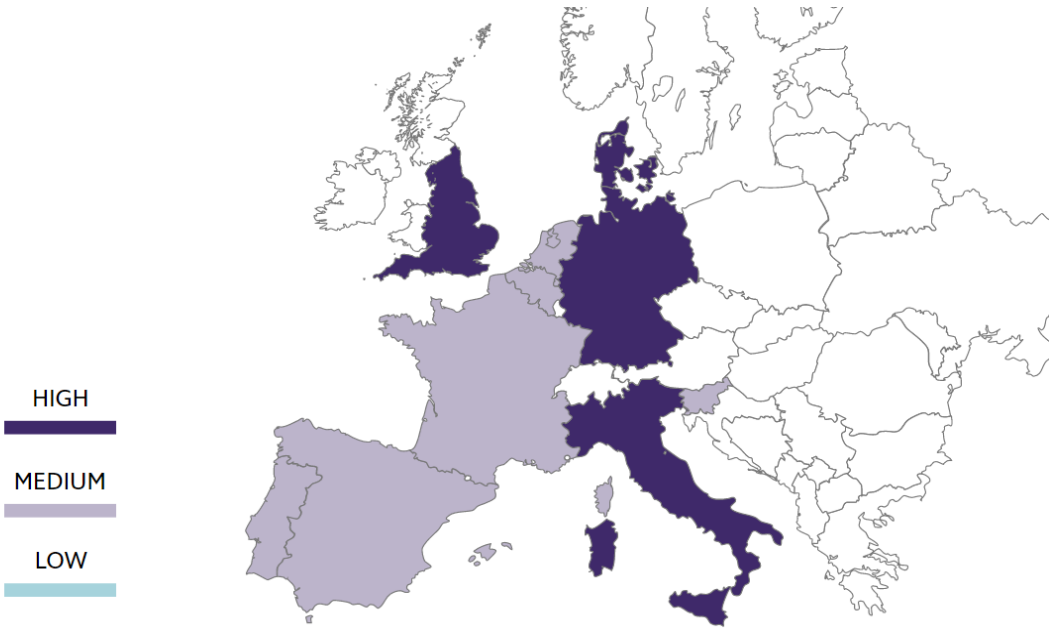



Figure 3.8 Overall Score, European Healthcare System, Source: Economist Intelligence Unit, 2020

Among the surveyed economies, another part of the study focuses on the readiness of the European economies for digital diabetic care. The following questions were asked, "Is there an operational policy/strategy/action plan for diabetes?", "Does the national diabetes plan include digital diabetes?", "Is there a national diabetes registry?", "Are digital diabetes tools recommended in national clinical guidelines for diabetes?". "Are relevant healthcare

professionals trained on digital diabetes tools? (None, Some, or All relevant HCPs)". For the "Are digital diabetes tools recommended in national clinical guidelines for diabetes?" question, only Spain, England, Italy and Germany responded yes.

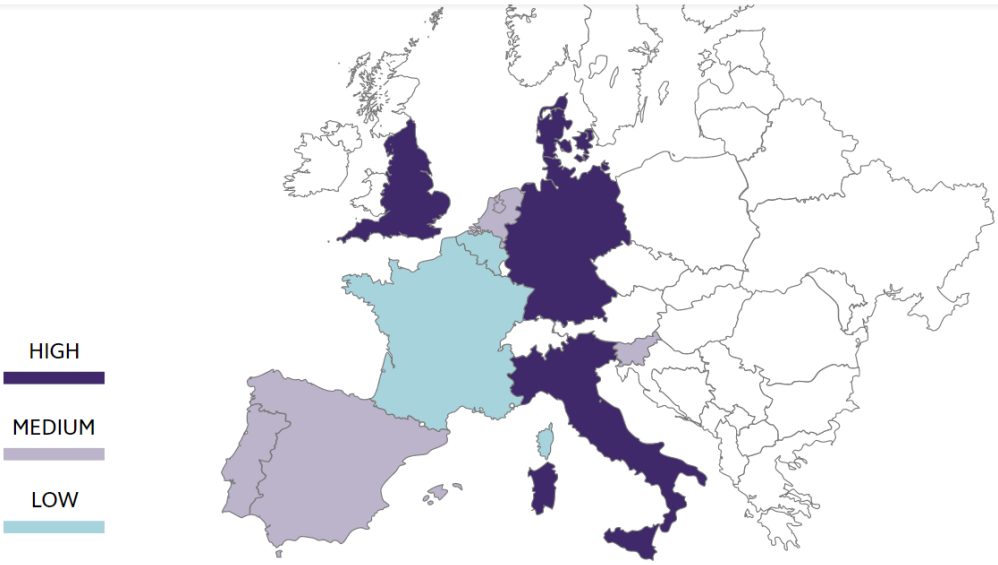



Figure 3.9 Digital Diabetic Care Readiness among surveyed European Economies, Source: Economist Intelligence Unit, 2020

In Demark, many patients were initially worried about the management of diabetes if infected with COVID. Due to the strong digital healthcare infrastructure, Demark was able to introduce online consultation software for diabetic patients at primary care and specialist care level. However, due to the fact that digital consultation was not included in the national diabetic treatment guideline, the digital treatment was picked up differently across the country (EIU, 2020).

Germany is a leader in offering reimbursement for telehealth apps (Bamer, 2019) yet lacks a national level EHR system. There are areas where the country can improve on digital diabetic care, such as offering online prescription and pharmaceutical service. Most patients still need to go to pharmacies physically to pick up medication and insulin (EIU, 2020).

The Italian healthcare system appears to be highly regionalized. The connectiveness of the healthcare system remains a problem. Even though digital pathways for treating diabetes has been included in the national diabetic strategy and clinical pathways, the access for digital tools remain restricted due to regional differences. Reimbursement for most key digital tools are open. However, during the pandemic, there is no significant difference in the health outcome of real-time monitoring data for glucose during the pandemic (EIU, 2020). The impact of COVID-19 is yet to be observed.

## 2.4 *Stakeholder analysis for the implementation of telehealth solutions in developing economies in the case of South Afric*a

The implementation for telehealth solution in developing economies may encounter different problems than in high-income economies. When analysing the available literature review, it is therefore necessary to address the challenges posed by the healthcare system in emerging or developing economies. In this paragraph we consider, as an example, the case of South Africa.

Lack of infrastructure and trained medical care staff (Eze, Gleasure, & Heavin, 2018, p. 200; Avgerou, 2008; Xiao, Califf, Sarker, & Sarker, 2013) has been known to be a hurdle for providing healthcare service in developing economies. Telehealth solutions can become a means for providing health interventions (Chang et al., 2011; Dammert, Galdo, & Galdo, 2014; Mars, 2013; Varshney, 2014b), preventing communicable disease and improving the health literacy for healthcare workers and patients.

In studying the stakeholder view for the implementation of telehealth (mhealth) solutions in developing economies, the author took a meta study methodology, and surveyed 108 papers in the area to analyse the interactions between different stakeholders for implementing telehealth solution in developing economies.65% of all sample papers are from Africa countries. Most of the initiatives in Africa are funded by public-private partnerships, NGOs or overseas initiatives (Istepanian & Woodward, 2016, pp. 1–3). Around 26% of the sample papers come from Asia while 9% come from America. The stakeholders are put in five categories, patients, healthcare workers, facilitators, knowledge base and system developers. The perspective of each stakeholder was then investigated for the interaction with other stakeholders and among themselves. Take the patient group for example, the interactions between patients and healthcare workers, patients and facilitators, patients and system developers, patients and knowledge base, and patients and other patient groups are then investigated.

The meta-study suggests that there are extensive literature on the perspective of healthcare workers; however, there is gap for studying the interaction between patients and other patient groups and most importantly limitation for researching on the interaction between system developers and users. In rural area in developing economies, when patients are trained to care for other patients, the peer-exchange can provide support for counselling and information. (Chang et al., 2013, p. 876). Moreover, the interaction with system developers is key to discover problems early, identify demands and requirements and present solutions for complex problems (Brown & Wyatt, 2010, p. 39; Buchanan, 1992, p. 5). The gap identified in literature suggests there lacks a design context for system developers to identify the needs and demands of healthcare workers and patients. Therefore, there is a need to create an open source mHealth platform to collect data at limited resource setting; The collaborative development approach will create an open source interface which allow encourage telehealth solutions to adopt common standards and solve the data interoperability problem, making it more cost effective ( (Eze, Gleasure, & Heavin, 2018, p. 200).

Leonard et al (2020, p. 5) uses South Africa as a case study on analysing the barriers and facilitators for implementing telehealth solution in resource restricting setting. The study was based on the implementation of a hearing screening device in South Africa over two years. The study analysed the implementation process at four levels: the community level (individuals), the health provider level (healthcare professionals), and the district health system level and the macro health level for oversight.

The study concludes that the need-based innovation improves the possibility of implementation. Meanwhile, changing the device language to local language would improve the device interoperability. Still, having a feedback channel, improving communication with community healthcare workers and having protocols to resolve conflicts has been identified as one key barrier for implementation. Lacking long-term national level political support for the program, and dissemination channel is also one of the barriers identified. On patient level, there is a need to improve health education on hearing and promoting patient mobility. Changing patients' perceived view on the public health system is also important (Leonard et al., 2020, p. 5).

Compared with the Chinese healthcare system where most of the high-quality hospitals are public and the heterogeneity of the population on culture and language, the lessons learnt from the South Africa healthcare system are to promote health literacy for patients and healthcare workers, to offer health education for the use of telehealth solutions, and to build the education and feedback channel of community health workers.

## 3 Research Methodology

In this paper, research methodology inspired by the Interactive Learning and Action approach is used to design the data collection process and the analytical framework developed by Cesuroglu (2016) to perform data analysis.

The study conducted by Dijkman (2015) suggests that value proposition, customer relationships and partnerships are the most important contributes to the business model for IoT systems. The study conducted by Cesuroglu (2016) identified a modified Murray and Frenk's framework (Murray, 2012) to assess the performance of the health systems. The barriers and incentives for implementing telehealth solutions at primary level of healthcare and at hospital level were identified with this framework. By understanding the demand of each stakeholder on national and local level, the study can serve as a guide for the telehealth solution providers to implementing their solution in China.

### *3.1 Study design and data collection*

The study uses an Interactive Learning and Action (ILA) approach to reach patients and healthcare service providers in the decision-making process. The study covers the three phases of the ILA approach: exploration, consultation and integration stages (See Figure 3.10).

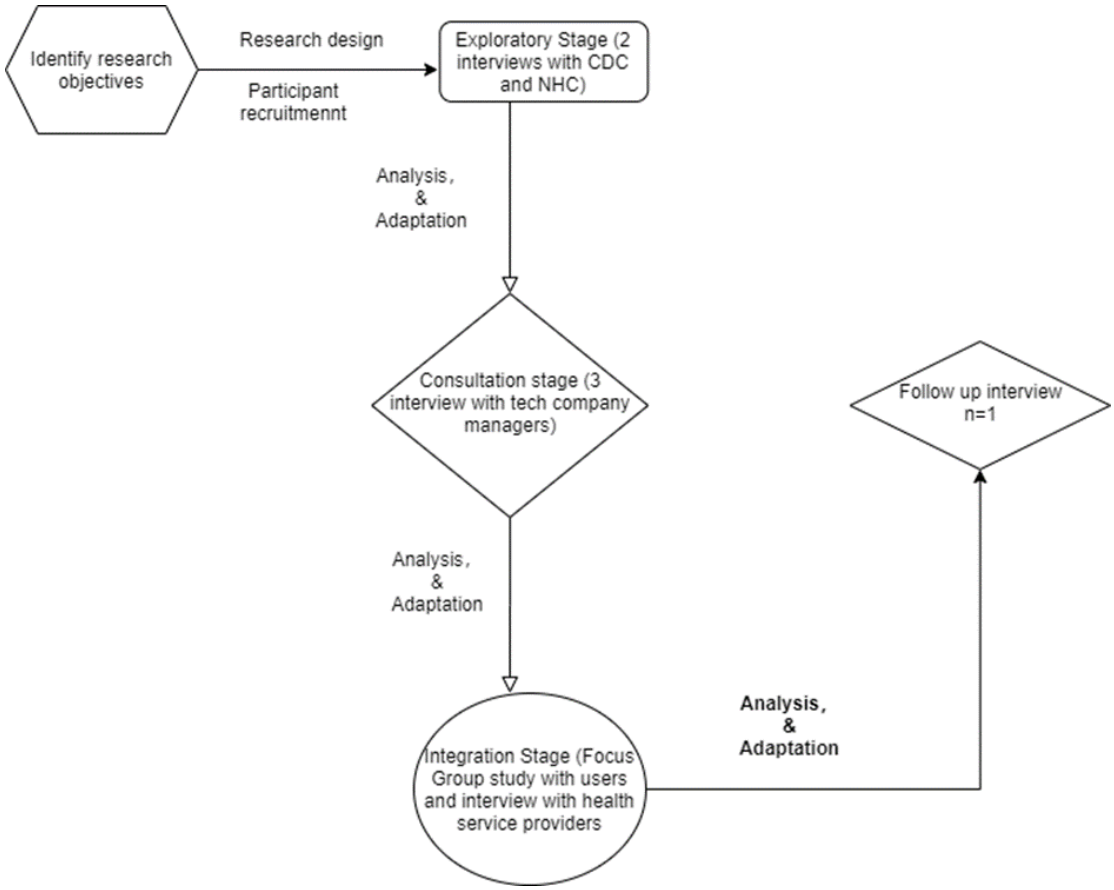


Figure 3.10: Interactive learning and action process in the research design; CDC, China Center for Disease Control, NHC, National Health Commission, Source: author's illustration

The first step of empirical analysis is to get insights from stakeholders for healthcare system in China. The stakeholder mapping and power analysis has deemed to be the essential tool to identify the structure of the Chinese healthcare system. By identifying key stakeholders and their positions, it became plausible to conduct early stage market surveys regarding needs and demands from the healthcare system; moreover, it is key to start with stakeholder analysis to conduct research for business model and market penetration strategy for telehealth solutions in China. 9 stakeholder interview requests were sent with 8 confirmed the interview requests.

In terms of selecting semi-structured interviews with policy makers, I selected the interviewees in the principle of key actors in the telehealth sector including representatives from the government ($n^3$=2, from the tech companies (n=6), from health service providers (n=2), and from individual users (n=64). The list of stakeholders interviewed is presented in Table 4. The data collected fits into stakeholder mapping structure mapped in Figure 3.10.

Table 3.1. List of stakeholders interviewed in China

| Stakeholder Interview List | | |
|---|---|---|
| **Tech Companies** | **Government** | **Doctors/Hospitals** |
| Vice President for Wearables - Huawei | Ministry of Human Resources and Social Security - Director for Social Security Pension Fund | Doctor from Cardiovascular Department of Zhongshan Hospital affiliated with Fudan University Medical School |
| Director for Investment MIUI - Xiaomi | Interview with Chronic Disease Management Center Director | Doctor from Rehabilitation Department at Hua Shan Hospital affiliated with Fudan University Medical School |
| Product Manager for Wearables Xiaomi | Visited Disease Control Center in Hua Rou, rural Beijing | |
| Business Manager for Alibaba Cloud ET Medical Brain | Visited Infectious Disease Control Center in Changping | |

## Exploratory Stage

In the exploration stage of the study, interviews (n=2) were carried out respectively with the vice chief of the basic medical insurance scheme fund in China and the Director for Chronic Disease Management Unit for the Chinese Center for Disease Control and Prevention (China CDC).

At local government level, I conducted a brief interview while visiting the local China China Disease Control Center (CDC) in Qiaozi county at Huairou district in rural district of Beijing. By monitoring national pandemics such as SARS, COVID-19, and non-communicable diseases such as hypertension, diabetes, cardiovascular diseases, etc, the CDC serves as the key policy advising institution for the central government (WHO, 2015).

[3] *n refers to the number of interviewees, not the number of interviews taken place*

The basic structure and the position of China CDC from Figure 11 and Figure 12. As indicated by the graph designed by WHO (2015), the CDC serves under the National Health Commission (previously named the "National Health and Family Planning Committee", hence NFPC). It conducted research and monitoring of communicable diseases and non-communicable diseases in China. The National Health Commission serves under the State Council. By monitoring national pandemics such as SARS, COVID-19, and non-communicable diseases such as hypertension, diabetes, cardiovascular diseases, etc, the CDC serves as the key policy advising institution for the central government.

In recent years, a centralized data monitoring system was established where data was reported from local CDC to their supervisors at the local health commission. This has slowed down the information flow significantly in terms of COVID-19 monitoring and has prevented the local CDC in Wuhan to report the pandemic directly to the central government. Instead, initially the COVID-19 cases were reported by hospitals to the local health commission in Wuhan. This has prevented the effective measures against the spread of the virus. This suggests a power imbalance between local healthcare demand and needs and the management for such as centralized health data sharing platform.

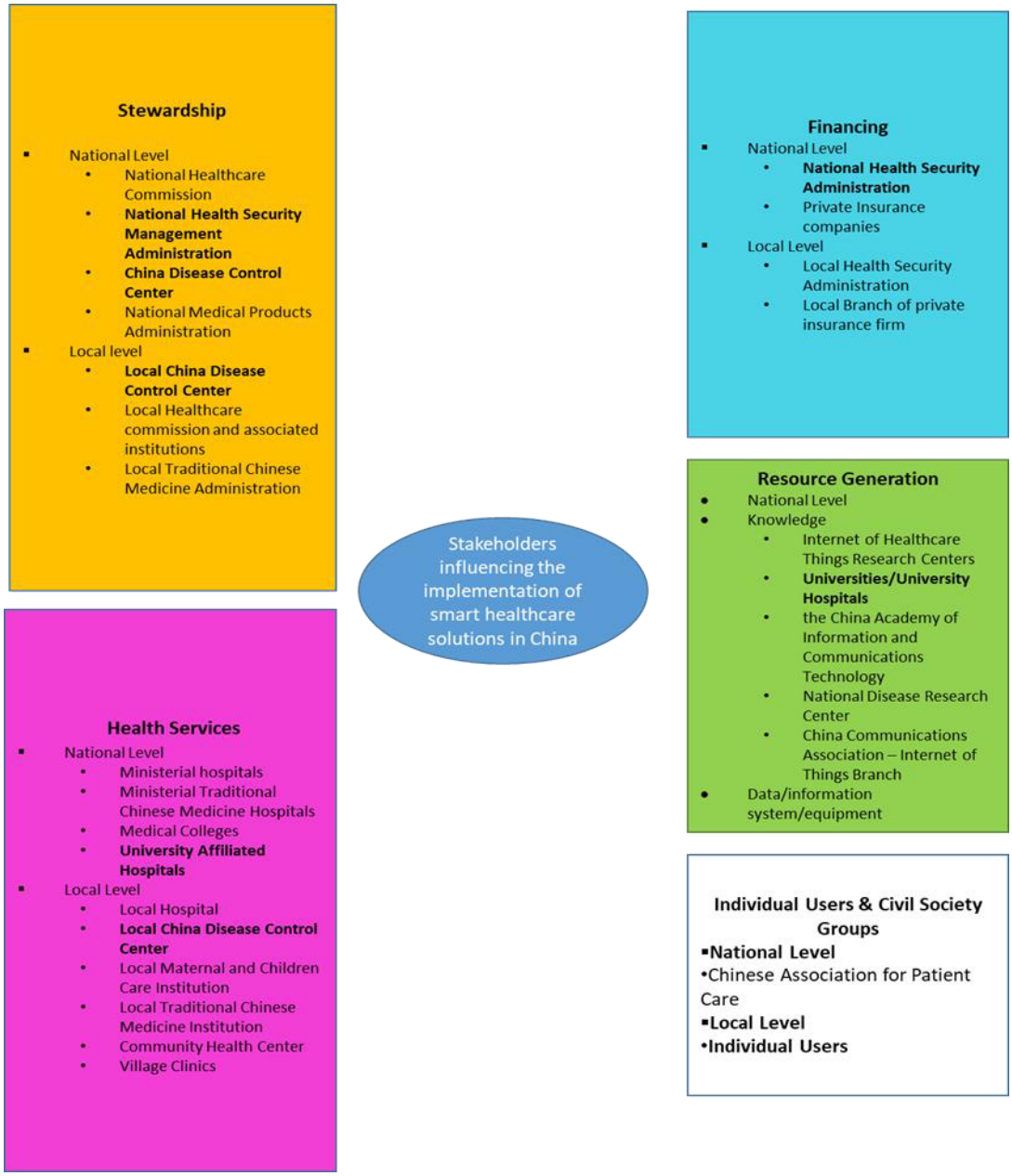
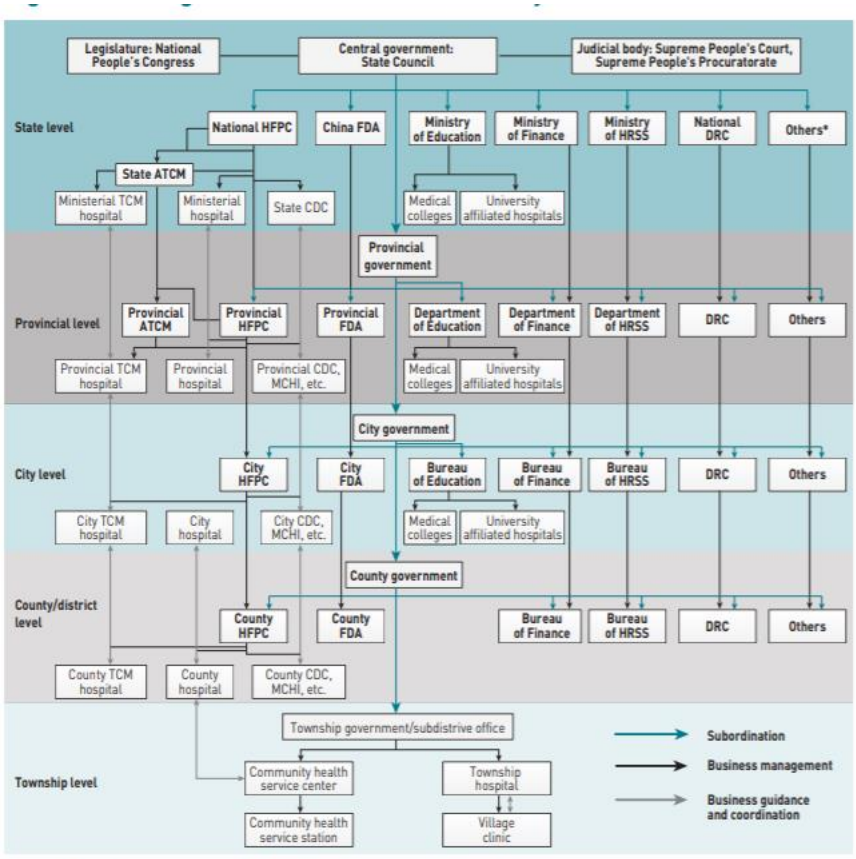



Figure 3.11. Stakeholder Overview for the Chinese healthcare system, source: Author's illustration




* Others include Ministry of Civil Affaires, Insurance Regulatory Commission, etc.
HFPC: Health and Family Planning Commission;
FDA: Food and Drug Administration;
HRSS: Human Resource and Social Security;
DRC: Development and Reform Commission;
ATCM: Administration of Traditional Chinese Medicine;
CDC: Center of Disease Control;
MCHI: Maternal and Children Health Institution.

*Source*: developed by the authors

Figure 3.12, Structure of the Chinese Healthcare System, Source: WHO, 2015

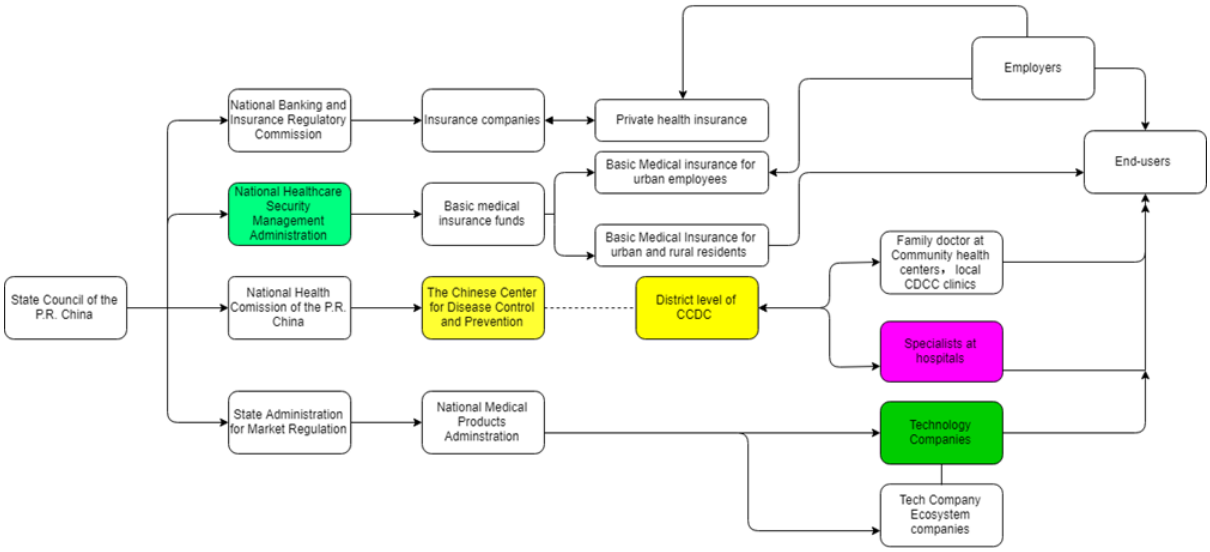


Figure 3.13. Simplified structure of the Chinese healthcare system, Source: Author's illustration

**Consultation Stage**

In the consultation stage of the study, interviews with tech company wearable and AI business units managers (n=6) from Huawei (n=2), Xiaomi (n=3) and Alibaba (n=1) were carried out. With Xiaomi, as the first interview was carried out by MIUI Huawei, Xiaomi and Alibaba are the biggest software and hardware ICT related suppliers in China. Other tech start-ups follow the lead of Alibaba, Huawei and Xiaomi. Tech companies dominating the market are often challenged by tech start-ups. Then tech giants chose to acquire start-ups who try to challenge their positions. Alibaba and Tencent have effectively become the most aggressive venture capital funds in China.

For instance, Huawei has developed a data based driven business model for its wearables and has taken the business model overseas to South Africa.

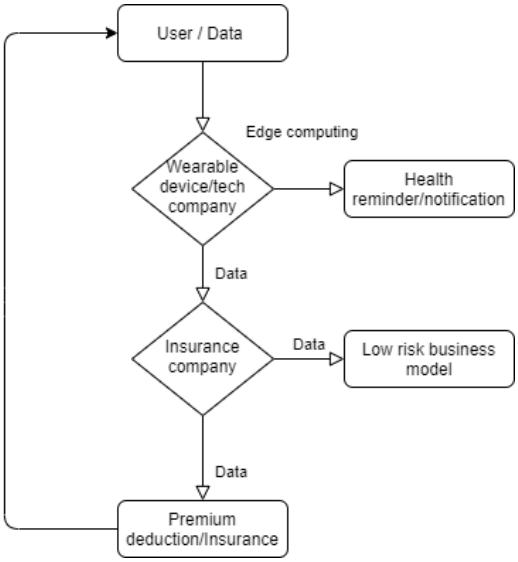



Figure 3.14. Data-driven business model developed by Huawei, Source: Author's illustration

**Integration Stage**

In the integration stage, two interviews with health service providers (specialists) were done at Rehabilitation department at Zhongshan Hospital (Shanghai) and Cardiovascular disease department at Huashan Hospital (Shanghai).

These interviews aim to get insights from stakeholders involved in implementing tele-health solutions in China. Also, 8 focus group studies were conducted with end-users divided into urban and rural groups for four use-cases, elderly care, chronic disease management, healthy living, and access for healthcare services.

The study was carried out in Beijing with the help from University of Chinese Academy of Sciences (Feb 25th, 2019 – April 5th, 2019) and in Shanghai with Philips China and Fu Dan University.

The data collected fits into stakeholder mapping structure mapped.

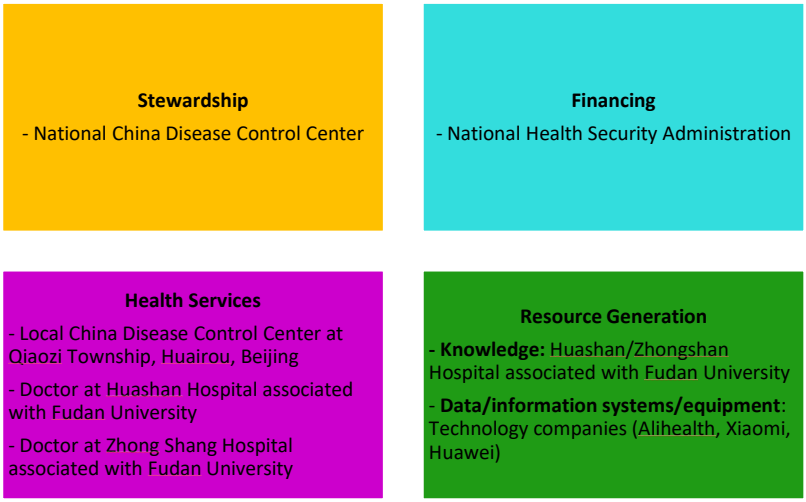



Figure 3.15. Place of stakeholder (interviewed) in the healthcare system, source: Author's illustration

In the era of GDPR, users have the ultermost saying in the successfulness of IoT ecosystems. Therefore, the section focuses on presenting factors affecting users' preference and use of smart health solutions in four aspects. These four areas are access to healthcare, healthy living, elderly care and chronic disease management.

To explore the attitudes of individual users towards smart health solutions, focus group study has been conducted in Beijing with the support from the research group at University of China Academy of Science and Beijing Cinso Consulting Co,ltd. The data subjects were recruited by Beijing Cinso Consulting and the study was conducted on the premise of beijing Cinso Consulting from March 29th 2019 to April 4th 2019. Beijing Cinsos Consultant Co., Ltd is located at Third floor, Yi Qin Business Center,West Shui Jing Hu Tong, Chao Nei District, Dong Cheng District, Beijing.

There are 4 discussion groups forming on the topic of access to healthcare, healthy living, elderly care, and chronic disease management. Each group consists of 16 members, 8 from urban Beijing and 8 from rural Beijing.

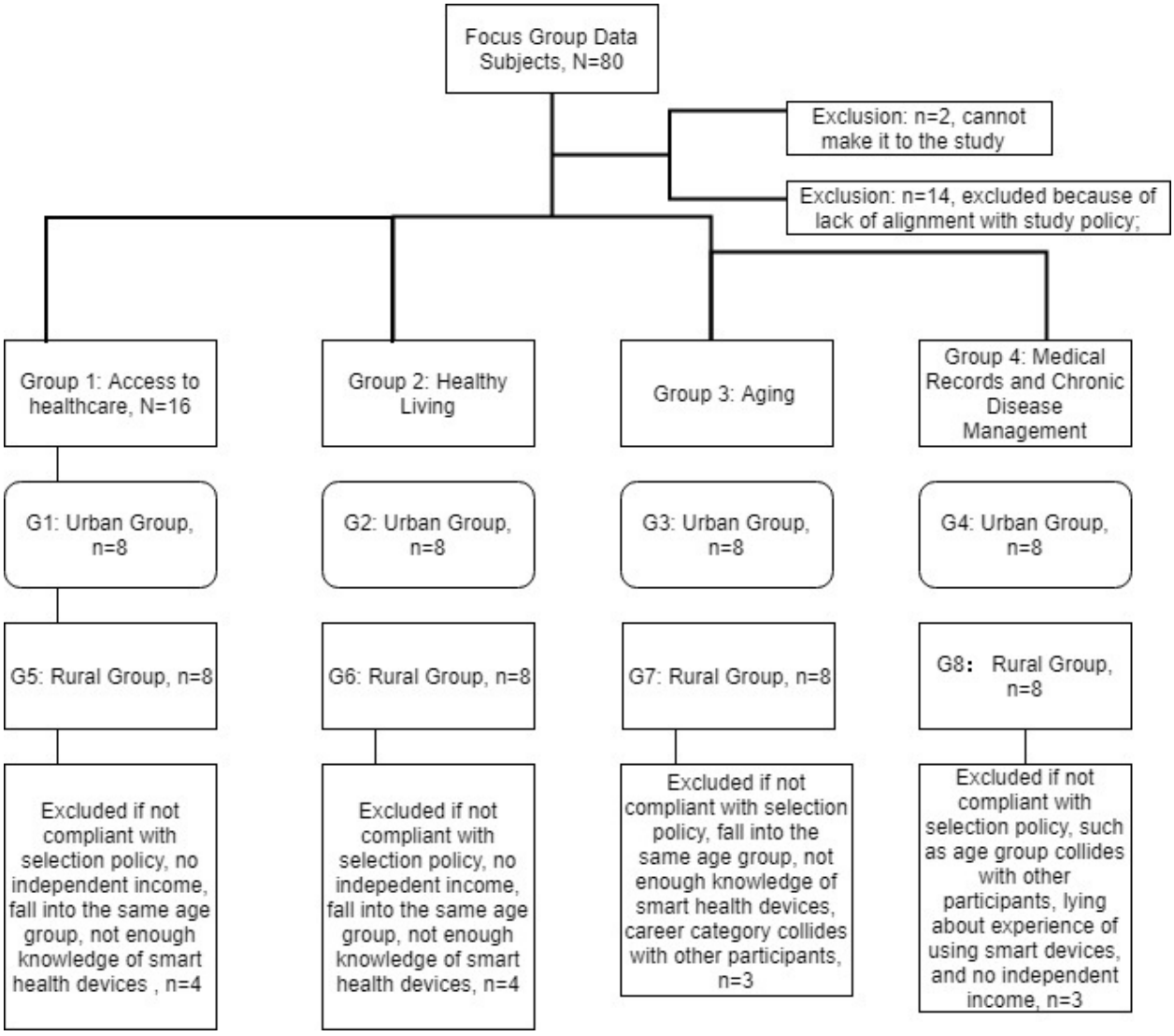


Figure 3.16 Focus Group Study data subject selection procedure, source: Author's illustration

### *3.2 Ethics Approval*

The stakeholder interviews do not collect any personal or sensitive data therefore there will not be ethics issues incurred. The questionnaire study and focus group study has went through ethics procedures at University of Macerata. Philips ICBE does not apply here. Both informed consent form and background information are provided, both in English and Chinese.

Following GDPR requirements on individual data collection, all participants were informed of the study purpose – scientific research, the study procedure, the data formats and the processing procedure. The data subjects of the study were informed that the participation was on a voluntary basis and the fact that they can leave the study at any time on a voluntary basis. The participants were also informed that all data will be processed anonymously. Participants were offered RMB 400 to compensate for their time and transportation. The group discussions were recorded in video and voice with transcripts taken onsites. All data were stored in the online storage space created by KU Leuven (The Box). Vulnerable groups, such as children, and elderly more than 60 years old are not selected. Some participants in discussion group 3 (elderly care) and group 4 come with chronical conditions such as obesity, hypertension or diabetes. Their health conditions were collected to identify whether health factors can count as a factor affecting their attitudes towards using smart health solution services and products in

different user case scenarios. The study has obtained ethics approval from University of Macerata.

### *3.3 Stakeholder power analysis*

In the paper, stakeholder have both influence and impact over the implementation of telehealth solutions. Influence of stakeholder refers to power of stakeholders for pushing for policies and regulations advantageous for implementation of telehealth solutions. Impact refers to the power of stakeholders for promoting the use of certain telehealth solutions. There are three levels of power (Bally & Cesuroglu, 2020, p. 13), high level influence/impact, medium level of influence/impact, and low level of influence/impact.

Bally & Cesuroglu (2012) defined the three levels of influence as 1) Control; The stakeholder has the power to control the implementation of telehealth solutions or stop the integration process. 2). Influence. The stakeholder can influence the integration of telehealth solution with the healthcare system. Compared with the control level stakeholders, the stakeholder is important but have no decision making power. 3). Interest/Concern. The stakeholder is interested in the use of telehealth solutions but has no significant influence over the integration process.

To perform the power analysis for the stakeholders related to telehealth solution in China, the interest, influence and impact of each stakeholder is presented. Meanwhile, to understand the attitudes of each stakeholder towards internet hospital, continuous health management at home setting, value-based healthcare payment system, interoperability of healthcare data is analysed.

## 4 Stakeholder Analytical Results

In this section results of the focus group study from urban Beijing are presented. The demand for telehealth solutions for accessing healthcare services is analysed in section 4.1, while in section 4.2 and 4.3 the stakeholder power mapping framework is used to analyse the facilitators factors and barriers for implementing telehealth solutions in China.

### *4.1 Focus Group Study findings*

Table 3.2 Focus Group 1- Access to Healthcare, Urban Residents Results Summary, Source: Author's illustration

| **The interviewee number** | **4** | **1** | **3** | **7** | **2** |
|---|---|---|---|---|---|
| **Private Insurance** | Y (Yes) | NO | YES | NO | YES |
| **Career** | TR (Tech related) | NTR | NTR | NTR | NTR |
| **Health awareness** | Y (Yes) | Y | Yes | Yes | Yes |
| **Knowledge of smart health solutions** | H (High) | Medium (M) | | Medium | High |

| | | | | | |
|---|---|---|---|---|---|
| **Marriage Status** | MWK (Married with kids) | Single | MNK（MarriedNokids) | MWKE | MNK |
| **Chronic Disease Status** | Yes | No | Yes | Yes | No |
| **Health Status** | Sub-optimal health status | Sub-optimal health status | Sub-optimal health status | With chronic disease (diabetes, hypertension) | Sub-optimal health status |
| **Health knowledge** | High | M | Low | Medium | Low |
| **Use frequency of smart health devices** | High | not mentioned | High | Medium | High |
| **Past experience in using smart health devices** | Yes, hospital registration (Wechat) | Yes (Wechat) | Yes (Wechat, AI guided patient registration, online consultation) | Yes (Wechat, AI guided patient registration, medication reminder) | Yes (Wechat patient registration, Ping An Online Consultation, Medicination reminder ) |
| **Community healthcare/Family doctor** | Yes | Yes | Yes | Yes | No |
| **Trust of family doctor** | High | | High | Low, only to get prescriptions | Low |
| **Prefer online service** | Yes | Possible | Yes | Yes | Yes |

| | | | | | |
|---|---|---|---|---|---|
| **Pay for online family doctor service** | No. | NM (Not mentioned) | Yes (prefer service packages or pay for outpatient service) | Yes, pay by the number of times used | Yes, depends on the quality of service |
| **elderly care service door to door** | Yes | Not mentioned | Not mentioned | Not mentioned | No |
| **Prefer Service offered transfer to specialist at tier-3 hospitals** | Yes | Yes | Yes | | Yes |
| **Expected Family doctor type** | Experienced ones, retired doctors | Save the time for registration with hospitals. | Serving the whole family, offer service such as make appointment with doctors, pricing mechanism: yaerly base+multiple times payment | | Already use Ping An Good Doctor: Pay 199 RMB for health management package. |
| **Sharing data with insurance company (trust)** | No. | not mentioned | No, can share with doctors. | No, for privacy reasons, do not wish to disclose medical information with insurance companies. willing to share with family | Yes, current insurance scheme promotes data sharing with insurance provider |
| **Age** | 3 | 2 | 3 | 5 | 3 |
| **Gender** | Female | Male | Female | Male | Female |
| **Household income** | H (High) | High | H | H | H |
| **Sharing data with healthcare providers** | Yes (there is no alternative) | Not mentioned | Yes | | |

| | | | | | |
|---|---|---|---|---|---|
| **Private insurance coverage** | Yes | Not mentioned | Yes | No | Yes |

Participants indicated their use of smart health solutions, which include smart phone apps, monitoring devices (cameras, smart audio systems), and wearables, are due to a number of reasons.

First of all, the smart health solutions have utility function value. This means smart health solutions (devices or services) offer

1. Convenience by saving time, efforts and money of users

2. Offer remote monitoring for users

3. Offer environment monitoring functions such as air quality monitoring

For instance, to monitor the brother who has suffered from cardiovascular attack, one participant had installed smart camera at home. To monitor the condition of elderly parents, one participant has installed smart camera at home. One participant has grandmother with hypertension and diabetes; he uses Mi Band to monitor daily steps taken and sleep quality for his grandmother even though they live together. For those who do not live together, communications happen through wechat, telephone calls. Some bought smart bands for their parents. Some elderly find it troublesome to use as it needs to be charged all the time.

For smart home devices, some participants result to smart plug or switches to control devices at home for safety reasons. Some use smart cookers to prepare meals in advance. Some use smart home cameras to monitor their kids doing homework. Some use smart floor sweepers for cleaning. When air-pollution in Beijing is bad, some use smart air purifier to monitor air quality and clean air at home. Some use smart home cameras to talk with pets at home. Some use the camera to monitor people near the door.

There are community projects in rural China where government offered services to check the health of elderly people regularly by calling, visiting, medical check ups and offering lectures for public health purposes.

Most participants do not trust online hospital consultation, and other tech companies. Some call it fraud, untrustworthy, profit-originated service, etc. They rely on the services mainly to register at hospitals. For participants from rural areas, waiting time at tier-2, tier-3 hospitals range from half an hour to 2 hours before seeing doctors. They find it difficult to know the specific doctor to reach in the hospital as there is no general practioner consultation happening before. Medical services offered for chronic disease treatment is in general expensive and time-consuming.

No long-term relationship exists between patients and doctors for almost all participants. Trust between doctor and patient is low as patients find doctors unaware of their past problems and unaware of their life styles to offer any related advices.

All participants were covered by the basic medical insurance schemes offered by the government such as Basic Medical Insurance scheme for Rural Residents, Basic Medical Insurance scheme for Residents, Basic Medical insurance scheme for Employees. Some

participants have private insurance coverage, which offer additional services such as free Ultra-sound scan, free genetic test, fast-track tier-3 hospital registration, family doctor consultation services, etc.

Secondly of all, hedonistic value.

For instance, some participants buy VR goggles to watch movies, play online games. Some buy smart cameras for the fun to use. Some have smart audio systems for entertainment during dinner time to prevent kids from watching TV.

For factors affecting buying decision of smart devices, most consider factors such as function, price, brand and convenience to use. For prices of services, participants report price acceptance between RMB 10- 3000 per month, depending on the service quality offered and whether it is personalized or not. For devices, their price acceptance level ranges from RMB 100 to 30,000, depending largely on the brand. Participants show a wide knowledge of local brands such as Xiaomi, Huawei, Alihealth, Chun Yun Doctor, as well as foreign brands such as Philips, Apple, Sony, Samsung, Simens, etc.

Participants who own multiple smart home devices are more likely to use smart health devices such as sports bands. They also have a tendency to exercise regularly and maintain a healthy living style. There is no significant difference between rural and urban residents given many work in urban areas and live in rural areas in Beijing.

Other factors affecting the use of smart health devices include, trust over data collected from smart devices. For instance, users find the data collected from wearables and smart blood pressure monitor inaccurate or find it impossible to share with doctors. This corresponds with interviews with stakeholders where doctors mention they do not trust internet hospital service nor data collected from smart medical devices at home.

Regarding sharing data with insurance companies, about 70% of users do not want to share data collected from wearables and smart home devices with insurance companies. They believe insurance company will surely increase premium once they find out about health problems. They also do not trust insurance companies in keeping data safe. However, some are willing to share data with insurance company for the benefits of family doctor, free insurance package, reduced/eliminated term payments of wearables, coverage for expensive diseases such as cancer.

Regarding sharing data with tech companies, most participants acknowledge that tech companies are collecting their data thoroughly and may share with third parties. They acknowledge they have no control of the data once it has been collected.

Regarding sharing data with governments, some indicate they want to benefit from the services offered with sharing. Others want to know the purpose of collection.

Most participants want to share data anonymously when it comes to health-related data.

### *4.2 Stakeholder power mapping*

Among all the stakeholders, except the demand for individual users, the attitudes of institutional stakeholders are important to evaluate as well. The digitalization of the healthcare system creates demand from government and healthcare service providers for telehealth

solutions. Before discussing the implementing of certain specific telehealth solutions, it is thus beneficial to find out the barriers and facilitators for telehealth solutions in China.

Compared with the European telehealth solution implementation process, the Chinese medical data are shared more between different stakeholders. Both European and Chinese governments have national level digital health development strategies. China leads in providing online medical consultation and prescription services long before the pandemic yet the trust level is low. In the pandemic, more AI related image recognition software were fastly deployed in China to facilitate COVID-19 diagnosis and treatment. Large scale data monitor via mobile phone apps were deployed tracking COVID-19 cases and prevent the disease from spreading.

### *4.2.1 Stakeholder identification*

Key stakeholders involved in implementing the Internet of Healthcare Things are categorized into 5 main groups:

1. Stewardship group
2. Financing group
3. Health services group
4. Resource Generation Group
5. Individual users and civil society groups which represent their interests (Cesuroglu, 2016)

Groups 3 and 5 are directly influenced by smart health solutions. Group 1, 2, 4 can influence the integration of the Internet of Healthcare Things solutions. The stakeholder groups can facilitate the development of smart healthcare solutions by providing infrastructure (such as 5G network), regulation framework, financing, and knowledge to help the healthcare system function.

Among all the stakeholders, 8 semi-structured interviews were conducted to explore attitudes, user experiences, and needs of stakeholders for smart health solutions.

### *4.2.2 Stakeholder positioning*

The Chinese healthcare system is a top-down system consisting of several layers, the central government level, the provincial government level, the prefectural level, the county level, and the village level. Top hospitals such as Peking Union Medical College Hospital and China-Japan Friendship Hospital are supervised and financed directly by the National Health Commission. Provincial and prefectural hospitals are supervised and largely financed by the designated provincial and prefectural health commissions. Village clinics are largely self-funded with a small amount of public financial support.

Urban residents spend more on healthcare than rural residents. Residents in Tier-1 cities such as Beijing and Shanghai spend more than the national average on healthcare services. Meanwhile, local government accounts for most of the healthcare costs. This renders developed regions in China with more healthcare resources than less developed regions in China. The local government and local health commission often have larger role to play in providing immediate response for pandemics such as COVID-19 than central government. Given the many layers of hierarchy between local and central governments, it may explain why in the beginning of the pandemic, the disease was not recognized a major public crisis when the first case was reported to the health commission in Wuhan.

Local governments set prices for healthcare services at public hospitals while set the coverage of public health insurance schemes. Different regions also have different health insurance coverage standards and refund percentage.

The National Health Commission performs stewardship function, making healthcare policies and supervising health service providers, collecting public health-related data. The National Healthcare Security Management Administration aims to become a strategic buyer for healthcare services in China and denotates the coverage of public healthcare insurance schemes. The Basic Employee Medical Insurance Scheme and the Basic Resident Insurance Scheme currently cover 92% of the population in China. Private insurance schemes complement the public health insurance scheme by offering coverage for medical incidents not included in the public health insurance package. Employers can pay for coverage for both private and public insurance coverage for employees. The State Administration for Market Regulation supervises medical devices including smart medical devices. Most services tech companies offered land in the lifestyle domain and are not subject to medical device regulation procedures.

To summarize, there are four types of incentives for institutional stakeholders to implement smart healthcare solutions.

Firstly, financial Incentives. For instance, companies may wish to improve the marketshare of the company, promote brand value, go into a new business sector, or to promote sales and look for new profit source. The government may wish to control healthcare costs.

Secondly, efficiency. Healthcare efficiency may increase by connecting different data sources. Algorithms used for assisting healthcare service providers to make the decision may also improve healthcare efficiency. Governments may wish to allocate limited financial resources in healthcare more efficiently.

To win government contracts and support. Companies feel the need to answer government policy initiatives for Internet+ Health, Healthy China 2030 Initiative, etc. Companies may also want to participate in smart city initiatives to gain support from government relationships.

Thirdly, special incentives: Government agencies may wish to create more employment opportunities. Hospitals and companies may wish to obtain more expertise in AI to improve healthcare quality for patients.

### *4.3 Stakeholder Power Analysis*

In the interviews, each representative estimated the power of each stakeholder in implementing smart health solutions. To estimate the power of each stakeholder, three levels of influence were used.

High influence: The stakeholder has the power to control the adaptation of new technology, or facilitate it. It also can stop the integration of smart healthcare solutions.

Medium level of influence: The stakeholder plays an important role in the adoption of smart healthcare solutions, but has less control of the process. It can influence the process of adaptation.

Low level of influence: The stakeholder is interested in the adoption of smart health solutions but has little and no significant impacts on adaptation development.

The most relevant quotes from stakeholders' interviews are presented here.

*Resource Generation (Tech Companies):*

"Currently, profits come from online drug sales. This is because in the short term, it is difficult to transfer users from offline to online to seek healthcare help."

"It is not an industry wide approach to integrate all the healthcare related data of users into a single platform. There is no industrial agglomeration effect."

"The ownership right of the user's personal data is not clear. …data collected from personal medical devices cannot be shared on third-party platforms"

"Doctors are not threatened by smart health solutions. They are getting used to it, with the hospital management team willing to use such solutions. "

⋯different hospitals and different doctors have various standards for interpreting test reports."

" the medical regulation system in China is a top-to-bottom system. There might be data accuracy issue in the top-to-bottom system."

"No separate technology admission standards for wearables application in medicine sphere in China"

'No national level of patient profile platform"

*Stewardship/Financing (National Health Commission, China Disease Control Center):*

"The family doctor system and the smart health solutions is in the early stage of development."

"⋯the supply side of GP services is small (with 309,000 doctors in China, around 2.2 GPs per 10,000 people at the end of 2018 ), with little recognition level from the society, and little trust from patients."

"Seeing a doctor is not as easy as uploading the blood pressure data online. Treating patients demand more communication."

"It is key to improve access for healthcare for urban and rural residents. "

"Wearable devices and other IoT devices cost will not be covered by basic medical insurance schemes lately.

"The basic healthcare insurance schemes in principle does not cover preventive healthcare costs."

"It requires a lot of capital to develop IoT and its application in the healthcare industry, a type of solution in its early stage of development."

“In the current healthcare system in China, the doctors in public hospitals do not have the time communicate with patients online. Communicating with patients is usually done via nurses.”

“Hopefully within 5 years, every family can have a qualified GP to provide services with every citizen has an EHR record.”

“In the future, the health security administration plans to become the manager to choose medical services supply, and to set medical services price level, to administer the incentive system for healthcare institutions, to supervise medical services quality and to coordinate medical resources allocation.”

“ it depends on the effects. Market forces, industrial firms are supposed to lead the development of smart health solutions instead of government”

“For chronic disease management, primary level of healthcare facilities shall play the main role with the large amount of patients with COPD.”

“No standards for evaluating the effectiveness of smart healthcare solutions

There is no knowledge on “How to calculate the value (quantity) for the solution offered”, “How to establish the payment standards”, “How to motivate wide usage of patients, doctors and hospitals”. “Smart health solutions are unable to offer patients humanized care and to improve communication between doctors and patients”.

*Health Services (Hospitals/Doctors):*

“From our perspective, the data from medical devices at home settings is very valuable.”

“I would like to consider such data and take it as a reference when I make my diagnosis.”

“The premise for use of data obtained from wearables, except for the convenience provided, is data accuracy. The most important aspect for medical devices is accuracy.

“The wearable device is at least a few hundred yuan, and the patient may not spend more than ten yuan in the hospital.”

“…the elderly will not use smart medical services. Patients do not trust Internet medical services.”

“the hospital has no motivation to unify the medical record standards”

“These are problems at the national level and are not problems that frontline doctors can solve.”

“I do not trust diagnosis, treatment methods of other doctors”

“I have doubts about skills, qualifications, willingness and capability about family doctors performing outpatient management and chronic disease management.”

“Separate technological standards for medical use of wearables are necessary.”

“Wearables must go through CFDA approval process before doctors can read data from them”.

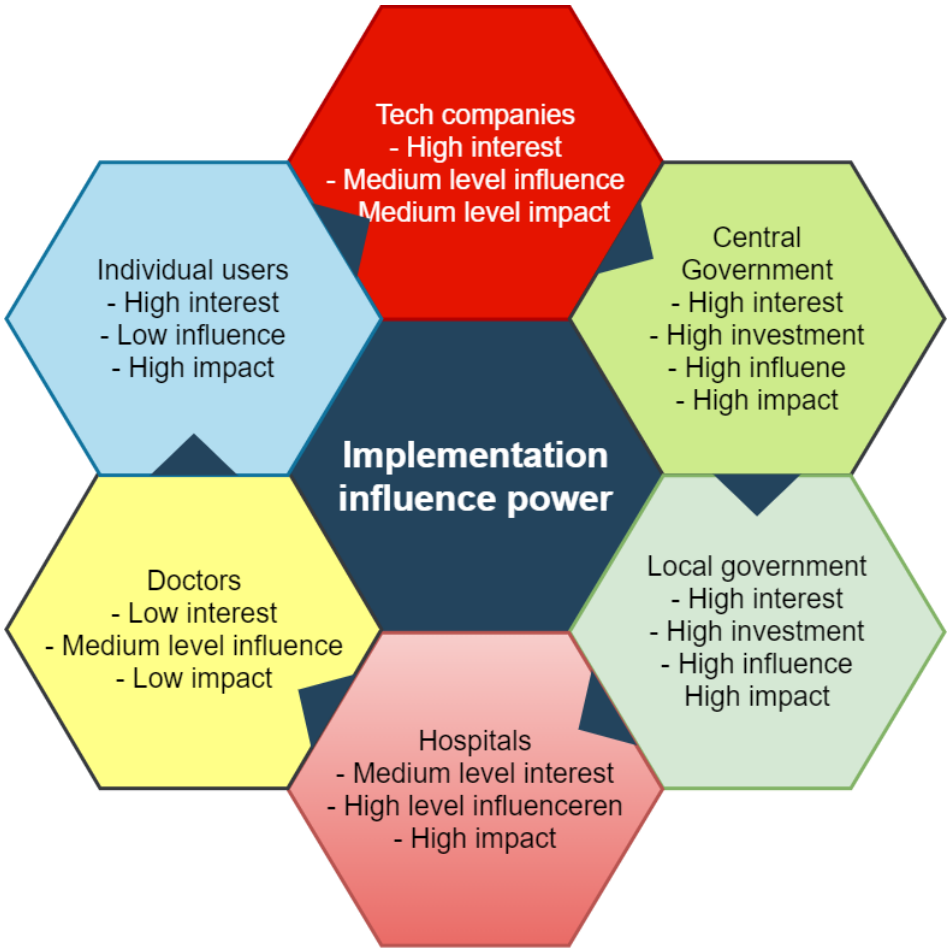



Figure 3.17 Stakeholder power analysis on implementation of smart health solutions, source: Author’s illustration

Figure 3.17 describes the stakeholder power analysis including their influence, their interest, and the impact they may have for implementation of solution such as personalized electronic health records, value-based payment system for healthcare services, etc.

Tech companies have high interest in the integration of telehealth solutions but medium level influence and medium level of impact. Tech companies train the algorithms with hospitals and doctors and also participate in technical standard setting process. Tech companies cannot decide whether telehealth solutions can be integrated or not. Therefore, tech companies have medium level influence in standard setting and medium level of impact in telehealth solution integration.

Tech companies are subject to strict regulation from the National Medical Products Administration (NMPA) when it comes to developing and commercializing telehealth solutions. NMPA is responsible for approval of medical devices, in-vitro diagnostic solutions, pharma products, cosmetics, health food, infant formula and food for special medical purposes. The NMPA has promulgated “Medical Device Adverse Event Monitoring and Re-evaluation

Management Measures" in August 2018. In 2019, the NMPA issued the "Key points and explanation of deep learning-assisted decision-making medical device software review standards" (NMPA, 2019).

When it comes to the use of AI for diagnosis and triage, tech companies need to obtain Level II or Level III certificates. Level III devices cover the following categories active surgical medical devices, passive surgical devices, neuro and cardiovascular surgical instrument, medical imaging equipment, devices for blood transfusion, dialysis and cardiopulmonary bypass, active implants, passive implants, infusion, recovery, and protective devices, ophthalmic instrument.

The standards point out that any AI assisted diagnostic software need to submit applications regarding the data source, data collection, data processing, and algorithm design, algorithm performance, and go through clinical trial and adverse studies to NMPA for approval. In 2020, only 9 solutions from 8 companies were able to obtain Level III certificates (Jiankangjie, 2020). These algorithms cover cardiology, neurology, endocrinology, orthopedics, thoracic surgery. COVID-19 has certainly accelerated the approval process.

From the analysis above, central government in China can set the standards for the use of AI and IoT devices for medical setting while local governments can decide the budget for such solutions. Therefore, both central government and local governments have high influence and impact.

Hospitals care more about misdiagnosis and the prevention of medical accidents. Therefore, they have medium level of interest in the integration of telehealth solutions. The director of hospitals usually decide whether the hospitals will spend on telehealth solutions. Therefore hospital management has both high influence and impact regarding the integration of telehealth solutions.

Doctors care about reducing workloads and publishing papers and getting involved in research projects. They cannot decide whether a hospital can purchase or integrate telehealth solutions. However, top-doctors can participate in the policy making process while has a medium level influence regarding the formation of policy and standards. Doctors have low level of influence on such integration process as they do not have the financial resources to decide the use of such solution at hospitals.

Individual users are highly interested in using such solutions to save the trouble from going to hospitals or waiting in huge queues for treatment. However, they often do not participate in setting technical standards nor making policies regarding developing telehealth solutions. Yet individual users can decide whether to use telehealth solutions at home and therefore has low level of influence but high level of impact when it comes to the integration of such solutions.

Table 3.3. Stakeholder position on adoption of smart health solutions, source Author's illustration

| Key points of view | Tech companies | Doctors | Government Organizations | Consumers |
|---|---|---|---|---|
| General Attitudes about smart health solutions | + | + | Neutral/- | Neutral |
| Interact with patients via internet based hospitals | + | - | - | - |
| Personalized Electronic health records | + | Neutral | + | Neutral |
| Family doctor service for chronic disease management | - | - | + | + |
| Continous health monitoring with home devices | - | - | + | - |
| Share health related data with insurance companies | - | - | Neutral | - |
| Using public medical insurance to pay for smart health solutions | + | Neutral | - | + |
| Using private medical insurance to pay for smart health solutions | - | Neutral | - | - |
| Value-based healthcare payment schemes | Neutral | - | + | + |
| Separate approval process for medical use of wearable devices | + | +/Neutral | - | Neutral |
| Interoperability of Hospital Information System | + | +/Neutral | - | + |

The stakeholders point out the challenges for realizing smart health solutions in China.
First, strict regulations for medical use leads to difficult commercialization of health related functions for wearables. Relevant approval usually takes 5-10 years depending on the country and specific function for approval. Some of the monitoring methods like pumping, in blood pressure monitoring disturbs user sleep and therefore cannot be used for 24/7 monitoring. Still this is the only method acceptable for the medical device regulators. New ways of monitoring blood pressure via PPG, however, cannot be commercialized due to strict regulations on medical use for bio-metrics data monitoring.

Second, most doctors do not recognize data collected via wearables or other IoHT devices at home.

Third, there are no national and regional level healthcare data sharing platforms.
Fourth, social security system does not cover the cost of wearables. There are no standards for the evaluation of the effectiveness of wearable devices for chronical disease on a population level. It is difficult for patients to get refunded from the public insurance system.

Fifth, consumers often find it untrustworthy to share bio-metrics data. Whether it is with doctors or with insurance providers, or family and friends, users are not willing to share their data. Most people, however, don't know how their data collected on wearables are stored, shared, and used; data can flow to Facebook, Apple, Google, Baidu, and Amazon without users noticing it, let alone giving consent. This leads to the monopoly of tech companies in data storage and processing. These companies already have the most robust computing power, storage units and the best algorithms.

Lastly, there is no clear legal definition on the ownership of personal data. Users may find they have lost the rights to their data to data controllers easily. Given the wide industrial approach of uploading data and processing on the cloud, it is almost impossible to track the flow of data once it left the device.

## 5 Summary and policy implications

To fully implement IoT solutions in healthcare industry, healthcare service providers need to work with government to build up data sharing platforms, eliminating duplicated procedures and facilitating access to medical records. Medical devices regulators shall adapt the technology standards along with technology development.

Local authorities shall be given more authority to test the healthcare programs based on their own priority and get involved with the retired population which may return to workforce. Employers may find the elderly to be more patient, careful, trained and trustworthy than imagined In this way, healthcare quality variation can be adjusted, and optimal pathway can be promoted. When it comes to new drugs and new technology approval, population health assessment based on big data will make it possible for more policy makers to say yes or no to new drugs and treatment methodologies with much more efficiency.

Rising healthcare costs associated with the aging population has led to concerns that the retired and the old may cause great stress for the welfare systemi. Wearable devices may make it possible to monitor the health conditions for the elderly and allow them to live independently as long as possible. By interacting with technology and initiating data sharing, life quality of the elderly may also improve. There are barriers on data interoperability, technology standards, privacy and safety concerns involved for the medical use of IoT devices. Policy makers may need to follow up more closely with technological development to adapt the technology usage standards and improve public awareness about data storage, usage, and sharing involved in wearable technology and AI for medical use. A clear definition about data ownership would also help to determine the ethical and legal methods of personal bio-metrical data collection in the coming era of Internet of Healthcare Things.

**Reference:**

Alzubaidi, M. A., Otoom, M., Otoum, N., Etoom, Y., & Banihani, R. (2021). A novel computational method for assigning weights of importance to symptoms of COVID-19 patients. *Artificial Intelligence in Medicine*, *112*, 102018. https://doi.org/10.1016/j.artmed.2021.102018

Arora, N., Banerjee, A. K., & Narasu, M. L. (2020). The role of artificial intelligence in tackling COVID-19. *Future Virology*, *15*(11), 717–724. https://doi.org/10.2217/fvl-2020-0130

Apple. (n.d.). Privacy-Preserving Contact Tracing - Apple and Google. Retrieved December 16, 2020, from https://covid19.apple.com/contacttracing

Avgerou, C. (2008). Information Systems in Developing Countries: A Critical Research Review. Journal of Information Technology, 23(3), 133–146. https://doi.org/10.1057/palgrave.jit.2000136

Bally, E. L. S., & Cesuroglu, T. (2020). Toward Integration of mHealth in Primary Care in the Netherlands: A Qualitative Analysis of Stakeholder Perspectives. *Frontiers in Public Health*, *7*, 1–17. https://doi.org/10.3389/fpubh.2019.00407

Bloomberg. (2020, July 8). Bloomberg, The Future of Smart Cities: Smart Cities 2.0. Bloomberg's Smart Cities 2.0 Virtual Event. https://onlinexperiences.com/scripts/Server.nxp?LASCmd=L:0&AI=1&ShowKey=97803&LoginType=0&InitialDisplay=1&ClientBrowser=0&DisplayItem=NULL&LangLocaleID=0&SSO=1&RFR=https://onlinexperiences.com/Launch/Event.htm?ShowKey=97803

Brown, T., & Wyatt, J. (2010). Design Thinking for Social Innovation. Development Outreach, 12(1), 29–43. https://doi.org/10.1596/1020-797x_12_1_29

Buchanan, R. (1992). Wicked Problems in Design Thinking. Design Issues, 8(2), 5. https://doi.org/10.2307/1511637

Center for Disease Control and Prevention. (2021, February 11). Provisional COVID-19 Death Counts by Sex, Age, and Week. Retrieved February 11, 2021, from https://data.cdc.gov/d/vsak-wrfu/visualization

Chang, L. W., Njie-Carr, V., Kalenge, S., Kelly, J. F., Bollinger, R. C., & Alamo-Talisuna, S. (2013). Perceptions and acceptability of mHealth interventions for improving patient care at a community-based HIV/AIDS clinic in Uganda: A mixed methods study. *AIDS Care*, *25*(7), 874–880. https://doi.org/10.1080/09540121.2013.774315

Cesuroglu, T. (2016, January). Integration of a personalized health care model into health systems and policies in Europe. Maastricht University. https://cris.maastrichtuniversity.nl/ws/portalfiles/portal/754541/guid-d34cba94-a25e-442a-b936-e01facdfadd0-ASSET1.0.pdf

Dammert, A. C., Galdo, J. C., & Galdo, V. (2014). Preventing dengue through mobile phones: Evidence from a field experiment in Peru. Journal of Health Economics, 35, 147–161. https://doi.org/10.1016/j.jhealeco.2014.02.002

Dijkman, R. M., Sprenkels, B., Peeters, T., & Janssen, A. (2015). Business models for the Internet of Things. *International Journal of Information Management*, *35*(6), 672–678. https://doi.org/10.1016/j.ijinfomgt.2015.07.008

Emanuel, E. J., & Wachter, R. M. (2019). Artificial Intelligence in Health Care. JAMA, 321(23), 2281. https://doi.org/10.1001/jama.2019.4914

Economist Intelligence Unit. (2020). *Digital Diabetes Index: Enhancing diabetes care through digital tools and services*. The Economist Intelligence Unit Limited. Retrieved from https://digitaldiabetesindex.eiu.com/index

European Central Bank. (2021, January 7). Economic Bulletin. Retrieved February 11, 2021, from https://www.ecb.europa.eu/pub/economic-bulletin/html/eb202008.en.html

Eze, E., Gleasure, R., & Heavin, C. (2016). How can mHealth applications that are developed in one area of the developing world be adapted for use in others? *Journal of Decision Systems*, *25*(sup1), 536–541. https://doi.org/10.1080/12460125.2016.1187414

Eze, E., Gleasure, R., & Heavin, C. (2018). Mobile health solutions in developing countries: a stakeholder perspective. *Health Systems*, *9*(3), 179–201. https://doi.org/10.1080/20476965.2018.1457134

Gross Domestic Product, 4th Quarter and Year 2020 (Advance Estimate) | U.S. Bureau of

Economic Analysis (BEA). (2021, January 28). Retrieved February 11, 2021, from https://www.bea.gov/news/2021/gross-domestic-product-4th-quarter-and-year-2020-advance-estimate

Student, J. (2020, November 25). AI puts Moderna within striking distance of beating COVID-19. Retrieved January 22, 2021, from https://digital.hbs.edu/artificial-intelligence-machine-learning/ai-puts-moderna-within-striking-distance-of-beating-covid-19/

Huawei. (n.d.). Overview of the Healthcare IoT Solution - S5700 and S6720 V200R012C00 Configuration Guide - WLAN-AC - Huawei. Retrieved January 25, 2021, from https://support.huawei.com/enterprise/en/doc/EDOC1100038361/c8152cf2/overview-of-the-healthcare-iot-solution

Hollander, J. E., & Carr, B. G. (2020). Virtually Perfect? Telemedicine for Covid-19. New England Journal of Medicine, 382(18), 1679–1681. https://doi.org/10.1056/nejmp2003539

IMF. (2021, January 6). IMF Executive Board Concludes 2020 Article IV Consultation with the People's Republic of China. Retrieved February 11, 2021, from https://www.imf.org/en/News/Articles/2021/01/06/pr211-china-imf-executive-board-concludes-2020-article-iv-consultation

Imran, A., Posokhova, I., Qureshi, H. N., Masood, U., Riaz, M. S., Ali, K., … Nabeel, M. (2020). AI4COVID-19: AI enabled preliminary diagnosis for COVID-19 from cough samples via an app. *Informatics in Medicine Unlocked*, *20*, 100378. https://doi.org/10.1016/j.imu.2020.100378

Istepanian, R. S. H., & Woodward, B. (2016). *m-Health: Fundamentals and Applications (IEEE Press Series on Biomedical Engineering)* (1st ed.). New Jersey , U.S.: Wiley-IEEE Press.

Imran, A., Posokhova, I., Qureshi, H. N., Masood, U., Riaz, M. S., Ali, K., … Nabeel, M. (2020). AI4COVID-19: AI enabled preliminary diagnosis for COVID-19 from cough

samples via an app. *Informatics in Medicine Unlocked*, *20*, 100378. https://doi.org/10.1016/j.imu.2020.100378

International Monetary Fund. (2020, June 24). World Economic Outlook Update, June 2020: A Crisis Like No Other, An Uncertain Recovery. IMF. http Jiankangjie. (2020, November 23). 9 AI assisted medical device obtained Level III certificates from NMPA. Retrieved January 29, 2021, from https://www.cn-healthcare.com/article/20201123/content-546502.html

s://www.imf.org/en/Publications/WEO/Issues/2020/06/24/WEOUpdateJune2020

Johns Hopkins University. (2020, March 12). Mortality Analyses. Johns Hopkins Coronavirus Resource Center. https://coronavirus.jhu.edu/data/mortality

Johnson & Johnson, JLabs. (2020, May 12). Challenges & Opportunities Post COVID-19 - Mandarin. JLABS. https://jlabs.jnjinnovation.com/videos/challenges-opportunites-post-covid-19-mandarin

Leonard, E., de Kock, I., & Bam, W. (2020, June). Investigating the barriers and facilitators to implementing an eHealth innovation into a resource-constrained setting: A South African case study. In 2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC) (pp. 1-7). IEEE.

Mars, M. (2013). Telemedicine and Advances in Urban and Rural Healthcare Delivery in Africa. *Progress in Cardiovascular Diseases*, *56*(3), 326–335. https://doi.org/10.1016/j.pcad.2013.10.006

National Medical Products Administration. (2019, July 3). Summary of Review Standard for Deep Learning Assisted Medical Device Software. Retrieved January 29, 2021, from https://www.cmde.org.cn/CL0030/19342.html

MENG Qingyue, China Center for Health Development Studies, Peking University YANG Hongwei, China Nat. (2015). People's Republic of China Health System Review (7th ed., Vol. 5) [E-book]. World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/208229/9789290617280_eng.pdf?sequence=1&isAllowed=y

Murray, C. J. L. (2012, June 16). A framework for assessing the performance of health systems / C. J. L. Murray and J. Frenk. Retrieved January 1, 2021, from https://apps.who.int/iris/handle/10665/57320

National Medical Products Administration. (2019, July 3). Summary of Review Standard for Deep Learning Assisted Medical Device Software. Retrieved January 29, 2021, from https://www.cmde.org.cn/CL0030/19342.html

Philips. (2020, May 19). Philips telehealth solution supports self-isolating COVID-19 patients in Australia. https://www.philips.com/a-w/about/news/archive/standard/news/articles/2020/20200428-philips-telehealth-solution-supports-self-isolating-covid-19-patients-in-australia.html

Polonsky, W. H., & Fortmann, A. L. (2020). Impact of Real-Time Continuous Glucose Monitoring Data Sharing on Quality of Life and Health Outcomes in Adults with Type 1 Diabetes. Diabetes Technology & Therapeutics, 23(4), 1–8. https://doi.org/10.1089/dia.2020.0466

Soares F. A novel specific artificial intelligence-based method to identify COVID-19 cases using simple blood exams. MedRxiv (2020).

Simens. (2020, July). New Criteria for a New, Smart Building Era. Simens Smart Building White Paper. https://new.siemens.com/global/en/products/buildings/contact/smart-building-whitepaper.html

Singh, D., Kumar, V., Vaishali, & Kaur, M. (2020). Classification of COVID-19 patients from chest CT images using multi-objective differential evolution–based convolutional neural networks. *European Journal of Clinical Microbiology & Infectious Diseases*, *39*(7), 1379–1389. https://doi.org/10.1007/s10096-020-03901-z

Student, J. (2020, November 25). AI puts Moderna within striking distance of beating COVID-19. Retrieved January 22, 2021, from https://digital.hbs.edu/artificial-intelligence-machine-learning/ai-puts-moderna-within-striking-distance-of-beating-covid-19/

The World Bank. (2020, July 15). Martin Wolf CBE. World Bank Live. https://live.worldbank.org/experts/martin-wolf-cbe

The Federal Reserve. (2020, December). *Summary of Economic Projections*. Retrieved fromhttps://www.federalreserve.gov/monetarypolicy/files/fomcprojtabl20201216.pdf

University of Sydney. (2020, March 27). COVID-19: the genetic quest to understand the virus. Retrieved January 25, 2021, from https://www.sydney.edu.au/news-opinion/news/2020/03/27/genetic-quest-to-understand-covid-19-coronavirus.html

van Ginneken, B. (2020). The Potential of Artificial Intelligence to Analyze Chest Radiographs for Signs of COVID-19 Pneumonia. *Radiology*, 204238. https://doi.org/10.1148/radiol.2020204238

Verity, R., Okell, L. C., Dorigatti, I., Winskill, P., Whittaker, C., Imai, N., Cuomo-Dannenburg, G., Thompson, H., Walker, P. G. T., Fu, H., Dighe, A., Griffin, J. T., Baguelin, M., Bhatia, S., Boonyasiri, A., Cori, A., Cucunubá, Z., FitzJohn, R., Gaythorpe, K., … Ferguson, N. M. (2020). Estimates of the severity of coronavirus disease 2019: a model-based analysis. The Lancet Infectious Diseases, 20(6), 669–677. https://doi.org/10.1016/s1473-3099(20)30243-7

Varshney, U. (2014). A model for improving quality of decisions in mobile health. Decision Support Systems, 62, 66–77. https://doi.org/10.1016/j.dss.2014.03.005

Xiao, X., Califf, C. B., Sarker, S., & Sarker, S. (2013). ICT Innovation in Emerging Economies: A Review of the Existing Literature and a Framework for Future Research. Journal of Information Technology, 28(4), 264–278. https://doi.org/10.1057/jit.2013.20

World Economic Forum. (2019, May 8). These are 7 of the most exciting breakthroughs in healthcare today. https://www.weforum.org/agenda/2019/05/healthcare-technology-precision-medicine-breakthroughs

World Health Organization, World Meteorological Organization, & United Nations Environment Programme. (2003). Climate Change and Human Health (pp 16-17 ed.). World Health Organization.

Wu, C., Chen, X., Cai, Y., Xia, J. ’., Zhou, X., Xu, S., Huang, H., Zhang, L., Zhou, X., Du, C., Zhang, Y., Song, J., Wang, S., Chao, Y., Yang, Z., Xu, J., Zhou, X., Chen, D., Xiong, W., … Song, Y. (2020a). Risk Factors Associated With Acute Respiratory Distress Syndrome and Death in Patients With Coronavirus Disease 2019 Pneumonia in Wuhan, China. JAMA Internal Medicine, 180(7), 934. https://doi.org/10.1001/jamainternmed.2020.0994

**Appendix** :

**Ali Health Interview Notes**

**1.The major businesses for Alihealth currently originates from health product sales and online business platforms, medication origination trace services, smart medical and personal health management services. How does Ali Health balance the input and output of the three business sectors to establish a sustainable business model?**

1.Currently, the main user groups for three different platforms vary, they include patients, healthcare givers (doctors and nurses). hospital managers, so it is difficult to compare user behavior and business model of three business segments.

2.Ali offers health care services in Alipay app and Taobao app, and has a large user base. It is easier to develop B2C businesses. (Business to Customer business).

3.Currently, profits come from online drug sales. This is because in the short term, it is difficult to transfer users from offline to online to seek healthcare help. Now Ali’ s advantages lie in the fact that it has a large product platform and provides different types of services, such as free

healthcare consulting services, so it is possible to attract users from free healthcare consulting and lead users to pay for other types of services, such as purchasing medicines online.

**2. Which types of wearable devices can be collected to Alihealth app? How is it being used now?**

First of all, there are very few people using wearable devices to continuously monitor health related conditions, with only about 1% managed to do so. Users are not accustomed to continuously collecting health related data.

Secondly, it is not an industry wide approach to integrate all the healthcare related data of users into a single platform. There is no industrial agglomeration effect. At the same time, the ownership right of the user's personal data is not clear. This resulted in the fact taht data collected from personal medical devices cannot be shared on third-party platforms. For example, data collected from Omron Glucose Meter cannot be shared with third-party platforms, so it is difficult to form systematic personal medical data. The current business environment is not particularly supportive for user bio-metric information sharing.

Thirdly, the data generated from wearables are scattered, doctors cannot tell whether the data collected by users is reliable or not .If there is a gap between the data collected in hospitals and data from personal devices, doctors are more willing to believe in the data obtained in hospitals.

To sum up, due to insufficient medical information and unsupported business environment, doctors cannot use the data collected from individual wearables. The attempt to use the data collected from wearable devices or medical devices at home has just started. Wearables user experience is easier to improve, with the difficulty often lies in changing users habits.

**3. Currently, smart healthcare services, such as medical imaging processing, outpatient management, improving interoperability of medical institutions, telemedicine, internet-based hospitals, AI assistant for diagnosis and medical resource are offered by services provided by Alibaba. How does Alibaba serve the needs for different levels of healthcare givers? Does the current business model of Alibaba help to facilitate the current medical reforms in China?**

It is hard to tell, because different medical institutions have different demands for various healthcare scenarios.

The reform to establish a gate keeper in the healthcare system has failed, at least it is going on a slow pace. Compared with five years ago, probably only 1 more percent of patients have used the graded healthcare system. Alihealth has not tried to build the platform to facilitate the establishment of the gate keeper in the healthcare system. The main reason is that most patients would flow from lower level hospitals to higher level hospitals, rather than the other way around.

There are several issues embedded in community healthcare centers and township care centers or village clinics. Primary level of healthcare facilities do not have enough equipment or medication choices for patients with more serious disease or symptoms. More importantly,

the training system for GPs (5 years of education + 3 years of training at hospitals) just started a few years ago. China does not have enough GPs to cover demand from patients.

Tencent is trying to connect doctors but there are very few tencent clinics (only in Beijing, Shen Zhen and Chengdu). Ding Xiang Yuan is trying to set up private clinics, where patients need to pay higher out-of-pocket ratios. Therefore, this is against the family doctor or GP notion.

The market for patient registration online is half-full. Almost half of all patients are getting used to make an appointment in advance and get registered online for a session with a doctor.

The nature of the telemedicine is to transfer information. If it is possible to communicate in advance via wechat, then it is possible to perform clinical guidance and medical interventions with the help of tele-communication methods.

Alihealth is developing medical services targeted at various scenarios with AI. It totally depends on how doctors plan to use these tools. For instance, the AI assistant for voice input will be more useful when doctors need to write down a large amount of patient records. Edge computing is more useful for updating algorithms in cardiac pacemakers.

Demand of primary level healthcare clinics lies in AI assisted diagnosis system and AI assistant for making prescriptions. Doctors are getting used to AI assistants. They are willing to use AI guide for doctor registration services or hospital bed needs projection system based on algorithms analysis. In Zhejiang province for instance, almost 80 percent of primary level hospitals are now equipped with AI assisted medical image recognition system.

**4. How has the smart health solutions provided by Alihealth is helping to realize value based healthcare, and promoted the patient centered, data-based decision making process? Has the smart health solutions improved patient satisfaction, lower medical cost, promoted diagnosis efficiency and precision, and helped to avoid doctors' burning out?**

Alihealth currently provides service packages on a half-consultancy, half solution packages basis. The services provided is on a highly personalized basis. Different hospitals usually have very different requests. Hospitals do not get standardized solutions, with only 70 to 80 percent of the services provided are standardized. Now there is a strong market demand for the service packages offered. This is due to the fact that there are seldom any consulting firms offering standardized services, and there is no consulting firm focusing on healthcare services only. At the same time, some management teams of the hospitals are not willing to accept the service packages.

For instance, Alihealth is able to offer services which can improve two KPIs significantly– the standardization level of the patient records and reduction in patient infection rate. We were able to improve standardization level of the patient records from 20 – 30 percent to 50-60 percent; we can also lower patient infection rate by about 30 percent. However, there is no clear standards for value evaluation for the services we offered. We do not know if it is because the management team for the hospital paid attention for these indicators, or it is because our solution packages have worked.

Meanwhile, we offer systematic solutions for certain points of the services provided to hospitals.

Currently we only have sporadic and unsystematic solutions for NCD management and aging population.

We offer services to local governments and the public finance system pays the cost.

**5. What is the acceptance level of smart health solutions with patients, doctors and hospitals?**

Doctors are not threatened by smart health solutions. They are getting used to it, with the hospital management team willing to use such solutions.

**6. Alihealth is currently offering the smart care service package, aiming to target the entire health continuum; for instance, the health secretary to automatically answer questions about healthcare related issues. Are doctors willing to sacrifice part of the privacy to upload their data. What are the acceptance level for different types of monitoring technology?**

Currently, there are very few users which consult doctors online. Mainly users complain about sex related issues (for instance, andrology or gynecology related issues) and other issues which may cause embarrassment in face-to-face interactions. Meanwhile, online consultation are mainly about offering advices and recommendations, it belongs to consultancy related services. Alihealth does not offer electronic prescriptions. All the services are paid out of pocket by patients; the services may not suffice for refund from the basic medical insurances. The main argument is to get users to use medical services online, and to attract users to use Alihealth services. For instance, users who get accustomed to use free consultancy services online may buy services such as medical examination or losing weight services.

There are several barriers for establishing personal portable EHR system.

First of all, data does not belong to patients in China. Instead, data controllers such as doctors who perform medical examinations, medical device producers, hospitals and regulatory agencies all have the power to deal with data as they wish. Because of this, rarely hospitals would provide electronic medical records for patients. If patients demand such information, there might be hospitals which provide such information. However, patients seldom demand such all of their electronic health records. Most likely patients would demand CT images or test reports. Possibly the hospitals at their home city do not have such equipment to perform those tests. In this case, they get tests done in big hospitals in big cities, and then show the reports to doctors at home hospitals.

Secondly, different hospitals and different doctors have various standards for interpreting test reports. Patients can get examined at Peking Union Medical College Hospital with the results not recognized by 301 Military Hospital (another top-tier university hospital in China). In the meantime, doctors may order a test in different contexts, usually based on their own experiences. After a few months, patient's condition may evolve. Because of this, public EHR system is difficult to establish.

Thirdly, allergies of patients are private information of the patient. It only shows on the summary report when patient leave the hospital. Because of regulation, and patient complaints, it is difficult to upload such information to the internet.

Fourthly, whether users for medical services shall share information or not is contentious. Not all related stakeholders are willing to share such information.

Fifthly, the medical regulation system in China is a top-to-bottom system. There might be data accuracy issue in the top-to-bottom system. In comparison with healthcare associated infection rate of about 3 percent in the EU, U.S. and South East Asia countries, China maintains a rate of about 0.5 -1 %. There are cases of concealing and mis-representation for data reporting. Data about chronic disease can be an over-statement of reality as well.

**7. How does Ali solve the problem of data isolation in hospitals? How is the population health management business doing now? Who are the main customers? How to balance various stakeholders in the population health management business? Which stakeholder is the main driver?**

Some local governments put a lot of emphasis on data integration in smart city. If the head of the local government or the local party's leader decided for a project, then the public finance would pay for such services. By only relying on the local municipal health commission, it is difficult to break the current chain of interests. For instance, the city of Hai Kou now plans to use smart city brain to process all the data about transportation, tourism, medical services, IoT, mobile office. Hai Kou plans to implement smart city brain solution to improve the operation efficiency and capacity of the city. The current project involves computing platform, data resources platform, security platform.

Alihealth offers services in data integration and processing, and improve the usability of data with AI. The core problem is not about technology, but about data operation.

Take an example of allergy condition of the patient, the patients' records might exist in doctors' treatment records or nurses' logs. The data can be quite scattered from different sources. Alihealth uploads all the related records from doctors and nurses to the cloud, and seize more sensitive information in the cloud platform.

The B2B services are mainly offered for governments or hospitals and other institutional users. The services are mainly about data processing platform. We can promote the electrification of the hospital information system of the hospital from 20-30 % to 60%.

**8. How long would it take for algorithms for image recognition, voice recognition, OCR to apply in medical related scenarios.**

Currently, the capital + technology model is very mature. It takes about 3 months to finish the design of the UI. It is mainly about the users' needs and scenarios. It is difficult to identify the core needs of users in medical related scenarios. For instance, voice recognition is not the core needs in telemedicine.

The needs for primary level of healthcare facilities is to reduce cost. Therefore, 80% of all healthcare facilities in Zhe Jiang Province are equipped with AI assistants for image

processing. At the same time, the utilization rates for AI assistants for prescribing and diagnosis platform is relatively high.

**Interview Records of the Chinese Center for Disease Control and Prevention in China**

**1. What is the role of primary level healthcare institutions (community healthcare centers, village clinics, county-wide hospitals) in the healthcare continuum? How to strengthen the role of primary level healthcare institutions in the ongoing reform for the healthcare industry? How to alleviate rising costs for healthcare services and improve access to health care services for the Chinese population.**

The grading of the healthcare institutions played a role in history for instance, barefoot doctors. The system has its advantages.
For chronic disease management, primary level of healthcare facilities shall play the main role with the large amount of patients with COPD.
The low utilization rate is due to the fact that patients do not trust primary level of healthcare facilities. Patients do not recognize the value of primary level of care either. In the meantime, the nurturing of good habits for seeking medical services and to improve the security of public health policy. The UEBMI, URBMI (now the urban and rural residents basic medical insurance) can improve the utilization rates of primary level healthcare facilities and leverage the use between third-tier hospitals and primary levels of hospitals.
The primary level care facilities are tackling the shortage of medical equipment and the lack of medicine supply.

**2. What is your attitude towards smart health solutions and its future application in China?**

Utilization of smart health solutions can be related to the technology matureness level of the tools, how to use tools and the recognition level of the tools.

Now with the advancement of technology, the sensitivity of wearables is improved. In the meantime, the role played by AI still yet to be seen. Whether policy makers shall use AI and wearables as an assistant, or to replace human beings is upon discussion. China does not have the entry standards for wearables and AI use in the medical industry. The cautious attitudes towards use of AI in the medical industry should be taken.

Family doctor and GPs should effectively act as gate keeper in the healthcare system. We are currently improving the role of family doctors played in the healthcare industry. Relevant efforts include reforming the GP education system in China, implementing the 5+3 model (5 years of clinical courses + 3 years of standardized clinical training) and the improve wages for the family doctors. To transform the system where the family doctors acting as gate keepers can change the habits of patients accessing medical help. It can effectively help to resolve the chaotic situation in medical access. The interviewee has a positive attitudes .

**3. What is the role played by EHR in the healthcare system in China? How to establish the EHR which can be synchronized with HIS and patients' home medical devices ? How to make sure EHR interoperable in different healthcare institutions.**

Some regions, such as Beijing has implemented the solution of ' Jing Yi Tong', which allows patients to carry one card and use it in some third-tier hospitals. Meanwhile, third-tier hospitals can recognize the test results from one another, and allow doctors to access patients' allergy history, family medical history and operation records.

**4. What is the current application and cases of big data in population health management and disease prevention? Which parts of China has done a better job to monitor population health with big data?**

Yi Chang – Hubei Province, Ning Bo- Zhe Jiang Province, Shanghai and Beijing has a more thorough health related data collection system. Different health issue regulation authorities departments has made it possible medical data to be shared and inter-operable. In the meantime, it is possible make decisions based on data projection. It is possible in some communities to monitor patients with NCD.

The National Health Commission has a migrant population service center to manage healthcare related issues for groups such as farmers who lost their land and flow in to the city.

Realizing data interoperability should be realized step by step, it will start with experimental programs in certain regions and then the system can be promoted nationwide.

**5. How to realize the value-based healthcare system and the included integrated healthcare service, big data in healthcare, and health education and health promotion in China? Currently, what is the role played by preventive healthcare and outpatient management services in chronic disease management?**

Value based healthcare programs matter, because it will make healthcare process more standardized, find better solutions and is the trend for the future.
Chronic disease management has received more and more attention recently. Now the chronic disease prevention program incorporates early detection, diagnosis and treatment program, vaccination, free health examination programs for the elderly.
It is true there is lack of investment in preventive healthcare services, only about a few percent per year of all healthcare expenditures in China. ( I CANNOT FIND PUBLIC DATA to validate mostly because there is no data on how much does the government spent on preventive healthcare, or there is no budget specially devoted to preventive healthcare in China; checked WHO, World Bank, National Statistics Bureau, ).

**6. Is there any practice in China to use IoT devices to collect data to improve patient satisfaction level, improve diagnosis quality and to control medical costs from rising in China?**

The implementation of Internet of Healthcare solutions can be seen from technological standards and legal regulations and several other perspectives.

It takes some time from the technology becomes available and its implementation. In the meantime, the smart healthcare solutions have its advantages and disadvantages. It may bring medical accidents.

The implementation of IoT in the healthcare industry needs to be taken with caution. There is a limit amount of role which can be played by technology and it cannot replace human beings. In some respects, such as preventing elderly from falling at home or to realize tele-medicine, it can be very useful.

**7. What are the prospects of using IoT and big data in disease prevention, diagnosis, treatment and home care?**

In CCDC, we mainly used big data for academic research. Currently, the analytical results have been applied in policy making. Currently, the implementation process shall start with some experimental programs.

Data collection for NCDs starts with empirical research from top to bottom, sample taking, and check for missing and mispresented data. Also, there exists data reporting from bottom to top.

For communicable disease management, CCDC use a real-time monitoring system. NCD data collection comes by month, season or year. It can take 1-2 years for the data to become publicly available. Because it requires a lot of work to verify the data and check for missing data. In the meantime, the data is summarized by each department in CCDC annually.

8**.Can you please share practices to promote healthy living style with IoT devices via controlling diets, exercises to prevent and manage chronic diseases (hypertension, cardiovascular disease, obesity, and asthma et al)?**

It depends on specific cases of usage. Technology shall not intervene and change the original life style of the population. Instead it should nudge users to change bit by bit.

Chronic disease shall be prevented via controlling diets, exercises, smoking, alcohol control and vaccination. Early detection of disease also should be emphasized. Risk factors leading to disease shall be identified.

Community healthcare centers should play a more important role in chronic disease prevention. CCDC is responsible for diverting the population to healthy living style.

It is difficult to ask the medical insurance funds to pay for the IoT solution packages. Because the basic medical insurance schemes (UEBMI, URBMI, the NCMS, the latter has been integrated since 2016) usually cover inpatient costs. In the future, private insurances may cover the cost of the devices.

The control and manage NCDs via smart healthcare solutions shall be gradually implemented.

The leading NCDs in China ranked by incidence rates are hypertension, diabetes, cardiovascular diseases, and cancer. The leading NCDs ranked by death causes are cardiovascular disease (top 1 death rate) and cancer (top 2 death rate).

**Interview Records Zhongshan Hospital China - Smart Health Solutions for Chronic Disease Management**

**Do you think that the current use of wearable devices, watches, bracelets, etc. is helpful in preventing chronic diseases (cardiovascular disease, diabetes, high blood pressure, osteoporosis, etc.)? For example, the use of wearable devices for monitoring user's exercise data, diet data, and the like.**

The so-called wearable devices have the advantage in convenience of use and data monitoring continuity.

**If so, do you think the medical community accepts the data obtained from wearables?**

The premise for use of data obtained from wearables, except for the convenience provided, is data accuracy. The most important aspect for medical devices is accuracy. To monitor heart rate – slow or fast, or during sports sessions is a function also used by healthy population. For patients who are sick, data accuracy is more important than convenience of monitoring. If there is a method to monitor data both accurately and conveniently, it will be the best.

**Currently, use wearable devices in medical settings need to follow the approval of medical devices. Is it necessary to set the technical standards for wearable devices use in medical settings separately?**

It is definitely necessary, of course, it is necessary. For the accurate and convenient use of wearable devices in the medical setting, separate technical standards for wearable devices must be available.

**For example, patients with hypertension can obtain the two-point based ECG from the Apple Watch 4, or the changes of blood pressure in the last month from the family blood pressure monitor; do you think you will consider this type of data?**

I would like to consider such data and take it as a reference when I make my diagnosis. Whether the devices can provide accurate data monitoring however demands evidence based studies. There is a need to compare with the traditional/classical way of monitoring. If the data about heart rate or blood pressure can be comparable in accuracy with the traditional way of monitoring, then doctors may take the data into consideration. If the data is highly accurate, then doctors may use the data to make further diagnosis. If the data is not accurate enough, then it makes no sense for doctors to use it. Doctors need to follow the national standards.

Personally, I think ECG is more useful than the mere heart rate readings.

**Now wearables are able to monitor VO2 and heart rates, and also provide nutrition monitoring; for example, smart phones with cameras can automatically analyze nutrition contents for the elderly. What do you think of the value of such functions?**

It is good for patients to have such functions. For doctors at cardiovascular department, what we care most is the blood pressure and heart rate changes. The cardiovascular department

cares less about nutrition of the outpatients than the diabetes department physicians do. Of course we care about blood cholesterol level and diets with low sugar and low salt contents.

**Do you think the medical devices to use in home settings, such as Bluetooth equipped blood pressure monitor, blood sugar monitor, scale are helpful for prevention of chronic diseases?**

From our perspective, the data from medical devices at home settings is very valuable. The cardiovascular department does not cover diabetes, but we care about hypertension. The blood pressure changes at the hospital tests do not embed significant meanings. However, the self-tests from home can be meaningful with the major guidelines recommend blood pressure monitoring from self-test at home. Sometimes physicians do ask patients to come to the hospital to perform the 24 hour continuous blood pressure monitoring. It is a lot of trouble for the patients, which requires making appointments, and take the device down at the hospital. This makes the blood pressure monitoring at home more meaningful.

**If it is helpful, do you think the medical community will accept the data acquired from the medical devices at home?**

The problem is on the testing accuracy. This is the most important factor that the medical community cares about. The

**If you are helpful, do you think the medical community currently accepts data from home medical devices?**

But the accuracy of the problem detection, which is the most critical, is that its data is definitely valuable, just to say how accurate you can be.

Now the country only accepts the oscillometric method to monitor blood pressure , and then only accepts the blood pressure data measured by the pressurized pump . Many users may not need to be so precise , because if he uses a pressure pump to measure blood pressure , the 24-hour monitoring will not be done. to, because the patient may or sleep and normal life will be affected.

Just like we say 24 hour ambulatory blood pressure monitoring. Because I recently gave my husband a 24-hour ambulatory blood pressure monitor, he told me that he was so sad that he had to take a breath every hour and he had to take a breath every hour. He felt that he was often interference.

**Omron offers a G eneration Zero . There is a PPG sensor, then that is may be measured by light pressure pump may not be accurate, but the trend of changes in blood pressure can be measured, but not through the C FDA audit.**

Because the Food and Drug Administration feels that this type of monitoring is not accurate enough, because inaccuracy will affect medical behavior, that is, if thepatient measures it high, is the doctor adding or not taking it ? Inaccurate doctors cannot judge what to do next .

**For patients who already have chronic diseases, do you think that a combination of wearable devices, home smart medical devices, and family doctors can help manage various chronic diseases?**

A chronic disease is that the patient has been suffering from a long-term illness . The doctor at the top three hospital has given you the medicine , and it has been cured by the treatment plan. It is a chronic disease when you are basically stable. Community doctors often let patients take medication stare. Huashan Hospital has cooperation with community hospitals. Huashan Hospital has a chest pain center, which has a radiation surface. Below the patient will turn up, sometimes we will go down to the doctor for training. This is two-way. Sometimes Huashan Hospital feels that the patient can be discharged from the hospital, and the follow-up hospital will continue to manage the patient's condition. The question now is a great degree of patient choice, if the patient is not willing to accept lower hospital services, the latter may still turn back.

The idea of this kind of thing is very good, but there are many problems in practice . The wearable device is at least a few hundred yuan, and the patient may not be more than ten yuan in the hospital . Sometimes I will take the initiative to ask the patient, what should I do if the queue time is too long? However, the elderly feel that they have plenty of time . The cost of going to the hospital to see a doctor plus the transportation fee may add up to 30 yuan. Many older people are thinking about this. It may be necessary to wait until the current group of young people is old, and with the disease, the acceptance of this concept will be higher. But the current acceptance is not that high.

**What are the main plans for hospitals to manage chronic diseases for patients? Have you developed a mobile phone a pp for managing user health, or for remote communication between doctors and patients?**

Basically, the patient came to me on his own initiative . He was willing to come to me when he was willing to come to me. I didn't want me to go there. After the patient was discharged from the hospital, I basically did not communicate with the patient because there was no time. After the patient is discharged from the hospital, we will print a discharge summary for the patient. In the What kind of medicine, medication time to pay attention to what. We have a discharge recommendation, and then the nurse will give him some education outposts for health discharge before leaving the hospital. For example, if you want to do some tests regularly, you should do a small check on the discharge summary for a few months.
The main thing is that Chinese doctors are different from foreign doctors . I think you actually talk to a lot of Internet companies, including Tencent . The problem is thatI don't have time to manage it. That is to say, we cannot rely on us to manage it. I can manage the doctors in the top three hospitals , but it is impossible to manage them in a meticulous manner . Family doctors in the community are not easy; I know doctors in several community hospitals, they are very busy . The main thing is that a doctor manages a lot of patients. There are too many people in China, but the number of doctors is not much. If the family doctor team of six people needs to manage a community of tens of thousands of people (take the Beijing Huairou Bridge Township community as an example) , this is definitely not good, it is the management. When a doctor manages a patient population of one thousand people , it is impossible to see the data of each patient , so it is even less important to manage . When a doctor manages data for thousands of patients, probably I don't necessarily have time to look at it.

After the family doctor signed the contract, taking the Shanghai community as an example, it may be that the lonely old people in the same community could not move. They went to see it. Most of them are uncomfortable to come to me. Doctors have limited energy and the

number of patients who can actively manage is very limited. Currently managing chronic patients, family doctors can come to the door, but there is no energy to carry out on-site service for all patients. Community doctors come to the door,if there is no additional income, there may be no enthusiasm to do it. If the country does not have enough input, the establishment of a family doctor contract can only be a slogan. So now the Internet medical service is to transfer offline medical behavior to the Internet. But the Internet is not good for some older people . It may take 10-20 years to wait until the people who accept Internet services are old, and these Internet medical applications may be better. But now in this situation, the elderly will not use Internet medical services, they can only go to see a doctor. At the same time, patients do not trust Internet medical services. Because many of my patients , that is, using an automatic sphygmomanometer to measure blood pressure, feel unreliable, must be measured by mercury blood pressure. Older patients still have no trust in wearable devices and Internet medical services .

**Is there a data island in the hospital? What do you think about establishing a regional and national patient health data repository?**

Hospital because of financial independence, so the administrative operation is relatively independent. At present, the hospital has no motivation to unify the medical record standards and allow electronic medical records to communicate. I can see the data in the hospital. These are problems at the national level and are not problems that frontline doctors can solve.

**What do you think about the role of electronic medical records in the current diagnosis and treatment process? Do you think that the electronic medical record has increased or reduced your workload?**

When I was writing a medical record, there were fewer patients and slower turnover. Now the patient is more and the turnover is faster. Electronic medical records should always be faster than handwriting.

It would be best if these tools were able to free the doctor from the heavy work. If I just talk about the medical record, I will do it. No, I don't know if this is something that our little doctor can decide. For example, the history of artificial intelligence writing, the hospital agreed to use, I can use. The hospital does not agree to use it, and doctors cannot use it. I didn't have this kind of tool similar to the voice input engine of Keda Xunfei, but I think it is still inconvenient. Because sometimes I still make mistakes, I have to change the mistakes, it is better to type faster.

**Do you think that the role and application prospects of artificial intelligence assistant tools, artificial intelligence assisted diagnosis engine, artificial intelligence medical image processing engine, artificial intelligence voice recording, artificial intelligence medical record processing engine and other artificial intelligence tools in the medical process?**

Like ECG report will have an automatic call me, this report is to analyze the ECG data is automatically made. The electrocardiograph only has measured data that is accurate, such as how wide and how high , but the diagnosis is often inaccurate. So doctors hardly look at these diagnoses.

**What obstacles do you think currently have to achieve population health management? What are the application prospects?**

Currently CDC (C DC) database data, as doctors do not have permission to view, can only be reported. However, at present, we are not reporting chronic diseases. Only cerebral infarction, myocardial infarction and tumor are reported . This situation, like the new diagnosis of high blood pressure , will not be reported. The data of the chronic disease center for the total number of chronic diseases in the country should be obtained through a sample survey. CDC reports cardiovascular disease every year .

**Do you think these data are worthwhile if the data collection on chronic diseases is delayed by 2-3 years ?**

This is at least a trend. The key management in the community is blood sugar, and their blood sugar will look. From a realistic point of view, the incidence of high blood pressure and high blood fat is high now.

**Do you think that smart health care solutions are currently helping the health management of an aging population? What other applications might be in the future? If you want to promote smart healthcare solutions, what problems might you encounter in the future?**

About 20% of my patients - 30% of people can regularly measure blood pressure and blood sugar, and regularly manage blood pressure and blood sugar in a long period.Because I am looking at an expert clinic, my patient's compliance will be relatively better. A normal outpatient clinic may not measure blood pressure in one patient . At the same time, whether it is Internet medical treatment, wearable devices or IoT medical platforms, the patient's consciousness is the most important. These tools, even if the doctor feels valuable, many patients may not be conscious of the use. Just like the patient we were discharged from, the doctor gave the patient a good medicine. Many patients may not have taken this medicine after half a year. Either stop it or reduce it. These precautions are explained in the discharge summary, but the patient will stop taking the medicine or change the medicine. Some patients feel that the medicine is annoying, and taking medicine has side effects. This problem also exists in Europe and America . Now many platforms or a pp do things to remind patients, but the problem is that patients ignore this reminder. Wisdom medical solutions are services in essence, the most important being the main body and direction of use. It is useful to push a patient a lot of things, but some people don't use it.

The people that this thing can be involved are relatively small. First, users who are willing to pay for wearable devices are first of all economically sound. Second, the willingness to use the Internet in this way , willing to use this platform to manage their own healthy users, their own compliance is better.

**What do you think of the construction of a value health care system? What role should hospitals and doctors play in building a value health care system?**

The last time I saw one, A I medical treatment did not actually succeed. However, from the current medical reform situation in China, the burden on doctors is very heavy, but there is no corresponding compensation. The doctor's medical treatment fee does not rise, and the treatment cannot be improved. In this case, the contradiction between the patient and the

doctor cannot be alleviated . Because the results of medical treatment are often not just the reason for doctors. It is also related to the patient's living habits and environmental factors.

**What data is worth collecting in the medical process?**

If the government needs to make a regional, national system, then all the information is worth collecting. Because the patient's information will be scattered, in the records of the doctors, nurses and discharge summary.

**What do you think of the construction of a graded medical system? Can the construction of a grading medical system reduce the burden on the top three hospitals and ease the relationship between doctors and patients?**

China is like this, a lot of good grade before treatment is mandatory for many years, is that you have to look at from the community health service stations, but there is a fixed point, is that you can only go to that hospital. Looking not only to go to the hospital to see a higher level. It was cancelled many years ago . Shanghai all yourhospital you want to go home can go. Then all patients are hoping to come to the top three hospitals . Patients with medicine, he might be willing to go to other hospitals,because it's easy dispensing. However, if the patient is seeing a doctor, because it is not a problem with the equipment, most of them include the level of the doctor , and there is still a gap, so the patient feels that he needs to go to the top three hospitals. And tertiary hospital registration fee unlike the United States, for so cheap it does not matter, queue line up on the patient feel better. Therefore, I feel that the graded diagnosis is actually not so good .

**What is the opinion of the Internet hospital?**

It can only be followed up . Because there are many problems in the initial diagnosis, there are problems with Internet hospitals. This is mainly security. As a doctor, there is no time to communicate remotely with the patient. Because there are many people who come to talk to us about this problem, do a variety of patient follow-up.Because this is a hot spot now, there is a lot of speculation. As a doctor, I hope that the platform can be done very simply. Second, there are actually security issues, and I think it is very likely that patients will be missed. Third, doctors don't have time. Now telemedicine exists between hospitals and hospitals. Before applying, you need to apply for a doctor. I need a doctor there. I am free. The last time I went to telemedicine, I had a heart failure patient. I could only look at him from afar . I couldn’t even see him. All the doctors were holding information and told me. I think that in this case, I can only give a broad recommendation. I can't follow the patient who lives in my ward so well. Still a bit unreliable.

**Interview Records for the National healthcare security administration**

**Part 1: Difficult to access healthcare, expensive healthcare services, and smart healthcare services**

**1. What are the measures and policy responses for the migrant workers and their needs for high-quality healthcare services? Because of fast urbanization in China, a lot of farmers has lost their land with a large amount of them flowing in cities. This has intensified lack of access to medical resources in urban areas of China.**

Currently, there are different medical insurance schemes for different types of residents. China has achieved universal healthcare coverage (UHC), with the basic medical insurance schemes covering around 1.37 billion people, roughly above 95% of all population. The UHC has three vertical and horizontal layers in policy schemes. Three horizontal layers refer to the bottom layer of medical aid, main layer and top additional layer. The bottom layer of medical aid scheme consists of urban and rural medical aid, social charity donations. The main layers consist of urban employee basic medical insurance, urban resident basic medical insurance, and new rural cooperative medical insurance. The urban resident basic medical insurance, and new rural cooperative medical insurance will soon integrate into the urban and rural resident basic medical insurance. The health security insurance system in China will soon turn into a system with three vertical layers and two horizontal layers. The additional top layer is made up of critical illness insurance scheme and out of pocket paid commercial complementary medical insurance.

With rapid urbanization and the migrant population flowing in urban areas, the UHC has managed to cover growing healthcare needs from the migrant population. To meet the demands for the migrant population and their needs for accessing healthcare services, the national healthcare security administration has taken three steps. The first step is to realize municipal level of interoperability for basic medical insurances, the second step is to provincial level of interoperability and the third step is to implement national level basic medical insurance interoperability. The administration has started to implement national level offsite medical settlement services in 2016.

The services for site-off medical treatment mainly covers the healthcare needs for the following segments of the population.

The first category is the re-settlement elderly who also become permanent residents to the city where he or she is moving to. The second category is the elderly who live in the city who lived at another city (without permanent residence registration). The third category is for people work at different cities other than their registration. The fourth category is for patients who are referred to other hospitals and doctors at a different city. These four groups can use their medical insurance cards at designated hospitals located at cities other than their registration for inpatient treatment and get real-time reimbursed. In 2018, there are 1.8 million people who has used such services.

**The system administration:** patients need to file for registration with the local medical insurance administration authority, and inform of the authority about their intended destination of use of the health insurance cards. By registration, they can use the medical insurance card at designated institutions in cities other than their registration and get reimbursement in real-time. The registration is necessary because the system cannot support 1.37 billion people of using their insurance cards on a long distance basis in real time. The fund management administration wish to ensure the patients can be referred to institutions with qualifications and there are about 3.65 million people who have filed for registration.

**Services:** To improve access for healthcare services for the migrant population, the bureau is promoting online registration, registration via telephone, over the app. For migrant workers, their destination for work may not be stable. It will help them to access healthcare services by promoting services conveniences.

**2. What is the attitude of national healthcare services administration towards smart health solutions including online family doctors and offline clinics, and wearables and their monitoring of the population? Are there any plans to integrate family doctor services into the coverage of basic medical insurances?**

The family doctor system and the smart health solutions is in the early stage of development. The services offered by the public health security administration authority is to pay for patients getting treated at public hospitals. The health security administration sits at the end of healthcare continuum, and it mainly secures payment and settlement for healthcare costs. The National Health Security Administration in principle holds a reserved attitude (wait-and-see attitudes) towards new businesses and hope there are standards to measure the effectiveness and quality of services offered by smart health solutions, the amount of services and fee standards. These questions can be answered from practices. Only with a mature service system, the healthcare security fund can catch up with reimbursement.

The GP acting as gatekeeper system has received support from basic medical insurances from the beginning. Currently, the supply side of GP services is small (with 309,000 doctors in China, around 2.2 GPs per 10,000 people at the end of 2018[4]), with little recognition level from the society, and little trust from patients. Some cities offer good GP services, for instance, community healthcare centers in Shanghai, with about 100 Yuan support per person annually. The services need recognition from the insured personnel, with patients willing to go to the services.

**3. What is the policy and measures targeting at the establishment of (hierarchical medical system) and held healthcare services become more accessible and affordable?**

The reimbursement ratio for the insured (referring to public medical insurance schemes) for medical care in a community healthcare center of Beijing is over 90%. Patients over 65 years old do not need to pay a registration fee, thereby making all services almost free. The community health centers in Beijing offer over 800 types of medical supply in their pharmacies.

Personally, I feel community healthcare centers have much more roles to play than treating patients. The system would not work if community healthcare centers only plays the role of treating patients and cure diseases. The main role of community healthcare centers is not treating patients, but instead focusing on caring for the insured. Community healthcare centers cannot compete with tier-3 hospitals from treating patients; only by differentiating from tier-3 hospitals, can community healthcare centers thrive. 30% of the patients attending tier-3 hospitals do not need the specialist services because they cannot find doctors to consult there. Tier-3 hospitals need to be responsible for patients' health conditions.

**How to improve utilization rate for primary level of healthcare services? Is it possible for patients to upload their data online to improve communication with doctors?**

Seeing a doctor is not as easy as uploading the blood pressure data online. Treating patients demand more communication. Internal physicians do more work than just uploading data online. People need care, with technology more advanced, care for people is less and less.

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[4] https://www.thepaper.cn/newsDetail_forward_3374431

The fact that it takes two hours of waiting to see a doctor and two minutes to treat the patients is sad for the doctor, sad for the society and sad for the patient.

**How do you feel about using IoT devices to monitor patients over the long term and help them to control their chronic conditions? What are the institutional barriers for realizing such scenarios?**

Certainly, it would be useful, and it would be indeed be very useful. The implementation however demands for proactive participation of doctors and high compliance level from the patients, accurate and objective data. In the current healthcare system, doctors don't have the time to do such things. Therefore, it is reasonable for community healthcare centers to provide such services.

4. **Currently personal health expenditures account for 29.3% of all health expenditures, while total healthcare expenditures account for 6.2% of all GDP. The Health China 2030 Initiative decides to lower the ratio to around 25%. Compared with about the 15 percent of personal healthcare spending in total health expenditures in the EU countries, how will public healthcare expenditure change in the future?**

Personally, I believe the healthcare expenditures accounting for 6.2% is not a small amount. The key issue lies in the spending structure. Currently insufficient health expenditure and waste both exists.

Healthcare expenditure per capita is about 600 dollars, while it is about 10,000 dollars in the U.S. and about 6000 dollars in the UK. 600 dollars per capita is not low considered the reality of China. Take a decomposition of the expenditures, the pooling for urban employee basic medical insurance has reached around 5000 RMB per capita, with urban and rural resident basic medical insurance reaching about 500 RMB per month. It is key to improve access for healthcare for urban and rural residents.

**5. Currently, the amount of outpatient treatment by tier-3 hospitals in China is on average 1.73 billion annually, the amount of outpatient treatment by tier-2 hospitals is about 1.27 billion, while the amount of tier-1 hospital outpatient treatment is about 0.22 billion. The hospital bed utilization rate for tier 3 hospital is 98.2%, for tier 2 hospital is 845 while it is about 57.5% for tier 1 hospitals. The amount of healthcare facilities and the amount of outpatient/inpatient treatments do not leverage. Is it possible to turn tier 1 hospital into elderly long-term care centers?**

To target the needs for the aging population, now different cities are exploring different options. In every district of Beijing, there are a few elderly long-term care facilities, some tier-1 hospital and community healthcare centers are turning into elderly long-term care centers these days.

**The elderly is easily subject to fall, or amnesia where they lose memory of their location. Is it possible to use IoT devices to help elderly to avoid such scenarios? Is there any chance that the basic medical insurance schemes are going to cover these costs?**

Theoretically speaking, there is implementation potential for such devices. The most important factor here is figuring out how to pay for the devices. The basic medical insurance schemes will not be able to cover these costs. The IoT devices should be paid by whoever is using the

devices. The basic medical insurance schemes cannot meet the needs for patients to get properly treated, and therefore cannot cover the cost of IoT devices.

**Is it possible to rely on commercial insurances to pay for IoT devices? With many high-end elderly care institutions offer door-to-door visits, will ordinary long-term care facilities offer the same services?**

Wearable devices and other IoT devices cost will not be covered by basic medical insurance schemes lately.

**How much does preventive healthcare costs account for in total healthcare expenditures?**

The basic healthcare insurance schemes in principle does not cover preventive healthcare costs. Now primary level healthcare facilities offer basic healthcare services, which covers setting up health records, health education, vaccination and healthcare advices for new-born and pregnant women, elderly care, chronic disease management, severe mental disease obstructed patient care, etc. These public healthcare functions belong to chronic disease management, health management, health consultation, etc. Average subsidy paid by public finance system is about 50 RMB, where 45 RMB is used for prevention and health management functions. Considering the amount of population in China, it is not a small amount for the public finance system in China.

**6. In 2015, about 3.6% of all patients get reimbursed via commercial insurance schemes. Take the decomposition for personal healthcare expenditures in China of 2014, cash payment accounts for 72.4% while reimbursement with commercial insurance schemes account for about 10.2%. Chinese population are not used to pay for commercial insurance premiums and get healthcare costs reimbursed. Is there any plans for the National Healthcare Security Administration to combine the basic medical health insurance schemes and commercial insurance schemes to lower the ratio of personal expenditures in total healthcare costs?**

In principle, the commercial insurance schemes have nothing to do with the basic healthcare insurance schemes. To combine both insurance schemes is wishful thinking.

The core of the problem is Chinese people have no money to pay for the commercial insurances, and secondly, private insurance companies have not developed appropriate products which meet the population needs. (Most private insurance schemes have a quota for reimbursement, and the coverage of such schemes overlaps with basic medical insurance schemes).

The insurance companies in China are in development stage, with private insurances cannot take such responsibilities. Therefore, the basic healthcare insurance schemes in China are getting bigger in scale. With the public healthcare insurance schemes getting stronger, the private insurance schemes lose market share. (Jokingly saying, the healthcare expenditures per capita for Chinese is about 600 dollars. Comparing to health expenditures for US citizens sitting at 10,000 dollars per capita, the value of life for Chinese and U.S. citizen is the same. With the value of life for rich people in China weighs more than common people in the U.S.). If the rich 1% of Chinese citizens could spend 6,000-10,000 RMB on insurance pooling, it will be enough for insurance companies in China, let alone for all of the 1.37 billion people in China.

This is not a problem which can be blamed on a single individual, some groups or institutions. This is simply a process in development. There are many policy initiatives which has been promulgated for the development of commercial (private) insurance schemes; these policy initiatives do not work very well.

**Part II: Inequal distribution of healthcare resources between urban and rural China and smart health solutions**

1. **Currently how does the central and local governments share responsibility over pooling for social security funds, pension funds and medical security funds? Why is there different reimbursement rates for basic medical insurance schemes at different locations in China? Is the resource allocation leverage towards more developed regions such top tier cities and east provinces? Is there anyway to improve access for rural residents for healthcare services and pension schemes?**

For providing medical services and pension related services, the central and local government share responsibilities. For basic medical insurance pooling, the public finance system subsidizes every insured with 450 Yuan. The central government subsidizes poor provinces (Western part of China) in China for about 80% of the 450 RMB per capital subsidy, with the central regions in China receive about 60% for the subsidy; even for affluent areas such as Beijing, Jiangsu, Guangdong and Shanghai, the central government subsidizes about 10% for the 450 RMB subsidy. The central government also pays for most of the pension expenses for urban and rural residents.

| | 2017 |
|---|---|
| Central Government expenditures for healthcare services | 10.76 |
| Local Government expenditures for healthcare services | 1434.303 |
| Unit: Billion RMB | |

2. **Now with the local government pays for a large share for the healthcare expenditures in China, income inequality lead to higher healthcare expenses in cities and regions near the coast rural regions than middle and western regions. This results in the lower life expectancy other low health related indicators in rural areas. For instance, the life expectancy in rural China in 2015 is about 75.6 years and in urban China about 77.9 years. A lot of rural families have fallen back to poverty when exposed to healthcare costs. In the meantime, patients with critical conditions such as cancer, have to ask for loans from the bank, including asking for donations from internet based medical aid platforms. Are there any plans for the National Health Security Administration to improve healthcare insurance coverage for rural residents?**

The difference in life expectancy in rural and urban China is not just because of healthcare issues. It is also related to environmental factors and life style choices. The bottom layer of the social security system has covered poor people in rural areas. Currently the social security system in China tries to cover the living, housing, education and healthcare needs for the poor, with the safeguard measures are in place (to reach the target of poverty alleviation, secure relevant needs for food and clothing, and to secure compulsory education, basic medical care and housing). The critical illness medical insurance scheme is trying to lower the payment threshold for critical illness such as cancer and change the reimbursement rate from 50% to 60%.

The nostalgia for barefoot doctors is kind of sentimental. The lack of medical resources for rural residents is due to lack of marketization; marketization cannot be blamed for the lack of

medical resources for rural residents. The healthcare industry shall adapt to the development of the economy. Government should only intervene when market cannot resolve the problem. Government policy and other administration tools should play a supplementary role rather than become the main controlling methods.

There are a few doctors willing to work in the countryside. The government offers subsidies for doctors working in rural areas. 80% of the subsidies are paid directly to doctors in rural regions via the public finance department on the county level on a monthly basis. (From literatures, different regions have various subsidy standards. Take the example of Guang Dong province, the government selected the doctor in the countryside and pays about 20,000 RMB per year to doctors serving in the countryside of poor regions.) No one has thought about offering more incentives to doctors so they are willing to serve in the countryside.

**Do you think IoT can help to cut medical costs or at least slow down rising healthcare costs?**

It requires a lot of capital to develop IoT and its application in the healthcare industry, a type of solution in its early stage of development. A lot of businesses are burning cash for developing new technology. Utilizing big data to perform population management, for instance, to make projections on trends of disease risk is a single case. In the meantime, telemedicine (long distance operation, etc) can solve high-end problems. AI cannot guide doctors on how they treat patients. The core of the tense relationship between patients and doctors originates from lack of communication. In the current healthcare system in China, the doctors in public hospitals do not have the time communicate with patients online. These work can be done via nurses.

**Part III: Value based healthcare system and IoT**

1**. What are the supporting policy initiatives for realizing value based healthcare solutions, where the reforms focusing on improving patients experience, making decisions based on data, promoting hospital operation efficiency, lower healthcare cost, and promoting diagnosis prevision rate. Are there incentives for hospital and other institutions to focus more on medical results? Do you think the IoT will help to establish the value based healthcare system?**

For patients with NCDs (diabetes, hypertension, pregnant women, patients with critical mental disorders), they can sign up for GP service which will continue to monitor their health conditions. Realizing value based healthcare is not a technical issue, with technology only solving the details part of the problem. The administration hopes to realize the value based healthcare services in 5 years.

Hopefully within 5 years, every family can have a qualified GP to provide services with every citizen has an EHR record. The designated GP to every family and patient will be the core of the services, as then it will be easier to pay by head. With off-site settlement, it is difficult to realize paying by head. The medical equipment manufacturer is in charge of controlling cost with the two invoice system.

**2. The current fee for service system is undergoing some reforms. The reforms propose the settlement based on lump-sum payments based on heads, disease related groups. Is there any chance that the healthcare security fund management administration can**

**control rising healthcare costs, improve service quality, and improve health for the whole population based on the whole healthcare network?**

DRGs (Diagnosis related groups) settlement is based on evaluating the cost treating the group of the patients with similar patient age, gender, disease diagnosis, treatment methods, and patients' conditions. The healthcare security funds will pay in advance to healthcare institutions to cover the costs of certain DRGs.

To realize settlement based on DRGs, it is necessary to budget on healthcare security funds. Now the healthcare security administration is sitting at the end of healthcare services, while the administration is planning on becoming the strategic buyer. The plan is to control the total cost and payment to healthcare institutions and make the reimbursement based on historical data. There have been experimental programs running for settlement based on specific patients and DRGs. (In 2018, the State Council promulgated *Notice on application for Pilot Programs of Payment by DRGs*, and began to test the payment model by disease type in some regions and hospitals. In 2017, the State Council issued *Guidance on Further Deepening the Reform of the Settlement Model of Basic Medical Insurance Schemes*. The document pointed out that, by 2020, the healthcare administration aims to use DRGs to pay to all medical institutions and medical services on a national wide basis. To reach the goal, a multi-layer settlement model medical insurance that adapts to different DRGs and characteristics of different healthcare institutions and services should be widely implemented throughout the country.

In the future, the health security administration plans to become the manager to choose medical services supply, and to set medical services price level, to administer the incentive system for healthcare institutions, to supervise medical services quality and to coordinate medical resources allocation. The healthcare administration departments did not administer the medical resources in the past.

Part IV: Aging, Chronic disease management, Population management and smart healthcare

**1. The aging process in intensifying in China. In 2016 the crude birth rate in China is about 12 per thousand (World Bank, 2018), with the dependency ration in 2030 projected to reach 25%. What are the policy initiatives targeting at the rising healthcare costs associating with the aging population? How does the National Health Security Administration plan to deal with the projection that by 2024 the social security fund will reach a balance deficit of about 735.3 billion RMB?**

The medical security fund now has a balance of around 100 million RMB. The medical services and other services are a combination of necessity goods and luxury goods; and is a combination of both rigid and flexible needs. To realize the control of waste for the medical security fund, the core solution would be to reform the settlement methods. The most important part of the medical reforms is to pay for medical services in packages (by DRGs). The reform aims to change the fee-for-service model whereby the security funds pay afterward whereby services have been incurred to one where the fund pays in advance. Other measures also target at medications with uncertain effects and unnecessary check-ups. The administration hope to establish a supply-side oriented mechanism to give incentive to doctors and hospitals to control cost (if the total amount of costs stay the same, hospitals and doctors need to control the costs other than services to optimize their income).

2. **Urbanization has lead to changes to traditional ways of long-term care for elderly. The solution used to be three generations in the same family live together under the same roof; now the smart home care solutions are emerging for the elderly, with smart care solutions focus on self-management solutions for the elderly, aiming to ensure the elderly live independently at home if possible. With sensors and interaction via audio/video, it is possible to leave the elderly to live independently if possible at home. Is there any plans to cover the smart elderly care solutions in the urban and rural employee basic medical insurance schemes?**

Elderly care is not just responsibility for the family, but also for the healthcare institutions. Some cities are running pilot programs for covering home care costs for the elderly. For instance, Wu Han is drafting ' Home Care Subsidy Solution Guide for the Elderly'. For the elderly who is willing to stay at home, the government is going to pay for the door-to-door services. For the elderly who is willing to stay at care facilities, the government will pay for about 200-800 RMB per month of subsidy depending on the physical condition and income of the elderly. For those with relatively good physical conditions, the government will rely on " Internet+ Home Care" model, and to integrate different kind of elderly care resources, and to use government subsidy to offer " assistant for meals, cleaning, medical services, and long-distance care" services. The goals are to support elderly with professional care, and nursing support at home with virtual elderly care facilities.

**3. What are your opinion towards smart city and smart healthcare solutions targeting at population health management, chronic disease management, and communicable disease management?**

Utilizing smart healthcare to perform health management is a progressive process; ultimately it depends on the effects. Market forces, industrial firms are supposed to lead the development of smart health solutions instead of government. The most important thing is to promote healthy life style for the population.

**4. The amount of patients with cardiovascular disease, hypertension and osteoporosis is growing rapidly in China; this is related to the unscientific diet structure and lack of exercise, and overuse of alcohol and cigarette. Is there any specific policy targeting at the growing population with chronic diseases?**

There are no specific funds targeting at management of NCD. The basic public health service is targeting at elderly people (free PEs for 65 years and older, patients with diabetes and hypertension. The use of alcohol and cigarette is a social problem rather than a medical problem

# *Chapter 4*

## *Elderly user insights on smart health care solutions in China*[1]


### Abstract

**Background**: COVID-19 has rendered the elderly as the vulnerable group with higher death rates in the 50+ age group. In the stereotype, the elderly user group are not willingness nor the skills in need to adapt to the fast technology progress. Wide use of AI in health monitoring and health management such as the use of smart phone for online consultation, or the use of wearables to monitor key bio-metrics suggests the transformation to a prevention-based healthcare model and homecare. Telehealth solution usage has been accelerated during COVID. Yet the trust of elderly users with telehealth solutions are thin with many prefer face difficulties in reality to access and use such tools. The preference for telehealth solutions among elderly users remain unexplored as companies usually see it as the niche market where users are not active.

**Objective:** To explore elderly (>=50 years old) user's preference for smart health solutions in China. The goal is to analyse why users are more willing to use telehealth solutions.

**Methods:** The questionnaire consists of 31 questions and was distributed offline on pad. The questionnaires were collected from Shenzhen, Hangzhou, Wuhan and Yichang randomly with 390 valid data samples. Subsequently, Stata 16.0 and SPSS 23.0 and was used to analyze data. O-logit ordered regression and principal component analysis was the main theoretical model used.

**Results:** Improving the transparency of AI, integrating of telehealth solutions with the EHR system proves to be key for promoting trust of telehealth solutions for elderly users. The next step of research is about how to improve the trust for telehealth solutions by improving the transparency of AI. This can be done by explaining how the algorithm was built and the data sources and whether it is representative of the targeted user group. Meanwhile, there is a need to improve the data interoperability between telehealth solution and hospital EHR systems. Telehealth solution providers have the opportunity the address the gap presented by lack of community healthcare and unstable doctor-patient relationship in China. Therefore, they shall focus on building solutions to improve health awareness and lower health risk for users.



**Keywords:** Telehealth solutions; Elderly users; China; Implementation.


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[1] The statistical analysis presented in this Chapter received support from Liu Pengqi, PhD candidate at University of China Academy of Science; the statistical analysis has served as a basis for writing a joint paper "Elderly user preference analysis for the use of telehealth solutions" with Liu Pengqi, submitted to the Journal of Medical Internet Research. The paper is available at JMIR preprint: http://doi.org/10.2196/preprints.27272

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# 1 Introduction

In the previous three chapters, the thesis discussed the demand for smart health solutions in Europe and in China. The thesis then analyzed the new business model emerged in the smart health solution industry and the value chain for wearables. The thesis also used empirical data collected from institutional stakeholders to find out about the barriers and facilitators to implement telehealth solutions in China with stakeholder power mapping. In this chapter, the paper aims to iterate on the willingness of individual users for telehealth solutions.

The COVID-19 global pandemic has rendered the elderly as the most vulnerable group worldwide. Mortality rate analysis shows the age group of more than 50 years old has higher death rate than other age groups (Koonin, 2020). The reason lies in that COVID-19 has more severe effects on the population with multiple chronic diseases such as hypertension, diabetes and cardiovascular diseases than the healthy sub-population. Aging population health management is tangled with the pandemic prevention and control.

Telehealth refers to the use of telecommunication tools for healthcare continuum, in the prevention, treatment, diagnosis, recovery and homecare process. The use of wearables, and apps for health management and online hospitals for health consultation has become increasingly popular with the wide use of smart phones; COVID-19 has accelerated the digitalization of the healthcare system at a pace unimaginable a few years ago. The use of telemedicine services has increased by more than 1000% in March and more than 4000% in April 2020 (Alexander et al., 2020). Spending on the use of telehealth solutions also increased starting from March by more than 1000 % (Whaley et al., 2020). With the pandemic, many patients with chronic disease are afraid of going to hospitals with the fear of COVID-19 infection. The most recent Journal of American Medical Association paper on telemedicine and patient adherence (Haynes et al., 2020) indicates that using of telemedicine has improved patient compliance and adherence to weight control, thereby lowering the risk for subsequent hospitalization.

In this context, it is interesting to explore user preference for telehealth solutions, particularly for people aged more than 50 years old, for the next 5-10 years who will become the elderly. Given the increased pace of aging and urbanization in the Chinese society and the lack of high-quality medical resources and trained clinicians, there is an urgent need to look for alternative solutions such as telehealth ones. The implementation of telehealth solutions faces challenges among elderly users given their lack of experience with technology and thereby lack of trust. Other factors such as household income, education, the health status of the user may also play a role.

Chapter 4 aims to find out why elderly users in the next five to ten years are willing to use telehealth solutions by analyzing 390 questionnaires collected from four cities in China – Shenzhen, Hangzhou, Wuhan and Yichang. The study uses principle component analysis, ordered logit regression model to analyze likert scale data and tries to find out factors motivating users to choose telehealth solution over traditional health solutions.

The paper is structured as follows. Paragraph 2 provides the literature review on research methodology to study user' willingness for telehealth solutions. Paragraph 3 presents the research design for the analysis, while paragraph 4 presents qualitative and quantitative analysis on questionnaire data and reveals why users choose telehealth solutions over traditional health solutions. The final paragraph summarizes main findings and implications of the paper.

## 2 Literature review

To analyze the state of the art of the research methodology regarding user and physician preference for telehealth solutions, a thorough literature review was conducted.

There have been several empirical researches on patient at all ages and clinician perception regarding telehealth solutions. For statistical analysis, the multinominal logit regression model has become popular in health economics and marketing science (Fiebig, Keane, Louviere, & Wasi, 2010, p. 419). Paired t-test was also used for comparing the preference for traditional health visits with tele-health consultation or tele-physician presence.

Direct-to-consumer (DTC) telehealth solutions roughly incorporate three categories (Welch, Harvey, O'Connell, & McElligott, 2017b, p. 3). The first category covers solutions provided by the same doctor where patients get primary care service from. As the healthcare service is provided by the doctor with whom patients have established a relationship, telehealth solutions can provide convenience to patients while maintaining the care continuity. The second category incorporates solutions provided by doctors from the same institution where patients receive healthcare service but not the same doctor with which the patients have an established relationship with. This allows the patients' record to be updated by the doctor from the same care institution while maintaining the connection with the care home. Meanwhile, patients can receive care on and off-hours. The third category consists of telehealth solutions provided by doctors who have no previous relationship with the patient or the patient's primary care service providers. Many newly emerged telehealth solution providers belong to the third category. Patients can pay for the services provided by insurance claim or out of pocket.

The study organized by Welch et al. (2017b, p. 3) used survey Monkey to send out the questionnaire and organize a nation-wide survey in the U.S.. In total, there are 4345 patients covering different ethnic, age, income groups with various education background and insurance coverage. The surveys aim to find out the willingness of participants to use telehealth solutions and their comfort level with telehealth solutions with the above mentioned three categories of solutions. Results from the generalized estimation equation model shows that patients are more willing to use category I solutions. The willing to use telehealth solutions decline if the provider had no relationship with patients before or if the services were provided by other doctors from the same care institutions. More than half of the patients are willing or are very willing to use telehealth solutions when it is with their own doctor; One-third of all participants are willing to use telehealth solutions when it is provided by other doctors from the same care institution.

Under 20% of all participants are willing to use telehealth solutions when it is provided by doctors with whom they have no previous relationships with. Patients' comfort in using telehealth solutions grow with the attachment to their original care institution.

In the research conducted by Polinski et al. (2015, p. 274), the authors try to analyze patient preference and satisfaction rate with the telehealth program, CVS Minute Clinics. Minute Clinics offer patients video consultation with doctors at collaboration clinics while assisting nurses perform onsite diagnostic tests and use tools such as otoscope, telephonic stethoscope, digital video laryngoscope to assist doctors making diagnosis via reading the image or data on screen. The cost of such treatment is average 59 dollars with life insurance (CVS, 2021)

The survey participants are over 18 years old and agree to use telemedicine service when onsite doctors are busy. The paper uses the logistic regression model to assess the preference of 1734 users of the Minute Clinics services. Among these participants, 94%-99% reported high satisfaction with telehealth solutions. One third of all participants prefer telehealth solutions to traditional health solutions. The author suggested that lack of medical insurance, gender (female) users, self-satisfaction with understanding for telehealth solutions, service quality and convenience. (Polinski et al, 2015), Patients' satisfaction with on-site nurses has adverse relationship with preference for telehealth solutions. The possible explanations are that the more satisfied patients are with on-site nurses, the more they are reminded of the benefits of in-person interactions. Moreover, patients may get the false impression that on-site nurses alone can make the necessary diagnosis and therefore ignore the fact that on-site nurses do not have the license to practice alone.

Miner, Fatehi, Ring, and Reichenberg (2020, p. 4) analyze factors associated clinician's perception regarding the telehealth solutions and if these factors affect their decision to continue to use telehealth solutions after COVID-19. Miner et al. (2020, p. 4) covers doctors from different disciplines, including pediatricians, and doctors focusing on adult patients, surgical and non-surgical doctors, out-patient and in-patient doctors and doctors who focus on both categories. The 220 full responses also cover doctors with and without previous telehealth experiences. The study disseminated a Likert scale questionnaire and used logistic regression to analyze the odds of different factors at a significance level of 95%.

Miner et al (2020, p.4) suggests that ease of use for patients is the most important feature followed by ease of use for clinicians. Physicians' overall satisfaction (Segrelles-Calvo, Chiner, & Fernández-Fabrellas, 2015, p. 611) and perceived ease of use (Rho, Choi, & Lee, 2014, p. 569) also directly affects perceived usefulness. and intention to use telemedicine. Meanwhile, the quality of care and ease of physical examination, beliefs on whether adaptability is an important quality of clinician also play a role in determining doctors' preference for telehealth solutions. Clinicians who are more perceiving rather than judging is also seen as one of the personality factors affecting clinicians' decision to extend their use of telehealth solutions. Moreover, clinician's beliefs on the importance of physical touch has a negative correlation with clinician's decision to extend the use of telehealth solutions.

The study conducted by Miner suggests that clinicians play a significant role in adapting to the digital health trends. Trainings may prove to be in need to help clinicians to continue their telehealth practices after COVID-19.

Tyrrell Burrus et al. (2017, p. 273) studied outpatients' use of internet search on orthopedic information. Authors used a questionnaire consisting of 12 questions and was distributed by doctors to outpatients on office visits. A total of 1161 complete responses were collected and analyzed with a multivariable binominal logistic regression model. Regression results show younger age group is primarily associated with increased use of internet for health information and orthopedic information. Younger patients are also more likely to find the search results related to their current orthopedic problems "very helpful" and "somewhat helpful". Google is the most popular search engine compared to Yahoo and Bing. Patients who visited sports medicine clinics were less likely to use WebMD to search for answers to their orthopedic related questions. Other than this, the type of clinic did not have a significant effect on patients' use of internet. Males were more likely to find the online information very useful than female patients; besides this, gender do not have a significant impact on patient's internet usage. The study seems to suggest that patients seem to conduct research online with search engines more than with the website of the institution where they are being treated.

The study confirms that the use of internet in searching for information among patients while suggesting by providing telehealth solutions, clinics and hospitals shall address the problem where patients rely on search engines to search for answers to medical problems because of lack reliable medical information sources online. Chatbots can offer an alternative for such a problem.

Marconi, Chang, Pham, Grajower, and Nager (2014, p. 328) compared the accuracy of traditional nurse triages and physician tele-presence at an emergency pediatric department. The study used paired T test to analyze the triage time and accuracy (triage utility) differences between traditional nurse triages and physician tele-presence. In total data on 100 families were collected under this study, which took place at a large, tertiary care children's hospital with annual ED (Emergency Department) visits of 65,000. Physician tele-presence was completed with the RP-7i robot, with a built-in stethoscope, after the patients went through the traditional nurse triage. The questionnaire consists of 9 5-point Likert scale questions and one yes/no question to assess the overall experience of using the robot.

At $p<=0.01$ level, there is no difference between triage time between traditional nurse triage and physician tele-presence. There are statistically significant differences between triage accuracy of traditional nurse triages and physician tele-presence. The triage accuracy score of traditional nurse triage is at 71% while the physician tele-presence score is at 95%. Both parents and children have preference score for physician tele-presence and indicate they would choose physician tele-presence at their next pediatric ED visit (Marconi et al., 2014, p. 328).
The study addressed a particular age group of patients – children where the average age of participants are 5.99 years old. The preference was explained by the children prefer new technology. In the ED, time is everything whereas it may be tricky for nurses to make accurate

judgements without enough physicians in the ER. The robotic experience has significantly improved triage accuracy by avoiding missing values of on the triage form which consists of 27 items. This suggest that in a overwhelmed ED room, having physicians tele-presence may help to ease the stress and the avoid mistakes.

Baker, Johnson, Macaulay, and Birnbaum (2011, p. 1691) analyzed the impact of the integrated healthcare buddy project with patients of chronic disease conditions in the U.S.. The study is a collaboration study between two clinics at Washington and Oregon, Robert Bosch Healthcare and American with two groups of patients (intervention group and control group), each composing of 1767 patients with COPD, congestive heart failure or diabetes. The health buddy program gives a free handheld device to patient to use at home and a large screen. The device connects with care managers and allows patients to interact with their care managers about vital signs, symptoms, health related knowledge and behavior. Insurance claim data was used to analyze the cost for managing chronic disease and mortality rates.

The study (Baker et al., 2011, p. 1692) confirms that the effectiveness of harnessing telehealth assistants for chronically sick patients. Telehealth solutions can not only lower the mortality rates by 2.7 rate in the interventionist group over two years, but also save cost for patients between 7.7 – 13.3 percent per patient per quarter ($312–$542). The study uses the multivariate regression to predict the cost reduction for patients who engaged more with the program and patients who do not engage otherwise. The prediction suggests cost saving for patients with COPD $726 per patient per quarter on average over two years ($p<0.05$), for patients with diabetes $511 per patient per quarter ($p<0.05$), for patients with congestive heart failure $1009 per patient per quarter ($p<0.001$). For patients who are engaged the program, the cost saving is $968 per patient per quarter ($p< 0.001$). For patients who did not engage with the program, the cost saving in non-significant.

The paper suggests that indeed there is a need to recognize the value of integrated telehealth solutions for high-risk patients with chronic diseases who incur high costs. Having a device at home allowing patients to interact with care managers not only allow care managers to capture the deteriorating vital signs and to provide interventions in time, but also allow care managers to identify the gap in patients' health knowledge and behavior (Baker et al., 2011, p. 1694).

The discrete choice experiment (DCE) has been a popular tool to identify the preference over telehealth solutions and the different attributes related to the preference (Kaambwa et al, 2017). The study conducted by Kaambwa et al tried to identify the preference of elderly (>=65 years old) in Australia. The Kaambwa study analyzes factors such as distance to nearest clinic and cost of virtual visits and the influence on preference level for telehealth solutions. The study indicates that most of the elderly have never used internet in the past three months, indicating a knowledge gap for elderly users to use telehealth solutions. In the study, 330 respondents were recruited with a mean age of 69 years old. The study concludes that participants would rather use telehealth solutions only as complementary tools with in-person visits. Since the study was conducted in Adelaide, Australia, where age structure, family structure and health status of the elderly is different from China, there is a need to analyze the preference of elderly

user for telehealth for the elderly in China.

In Khairat et al (2019), the choice between m-health and tele-health was studied with the DCE Model over 1403 residents in rural areas. The study suggests that the preference is associated with the gender and setting of users. The distance (access to healthcare) to hospitals and their gender determine if they would like to use telehealth solutions.

## 3 Research Methodology

The questionnaire was distributed among future elderly (50+) years old in Shenzhen, Hangzhou, Wuhan and Yichang. The study follows the discretion choice experiment methodology and went through five stages of designing research question, interview with experts, interview with individual users, pretest, pilot test stage. The questionnaire study was conducted with assistance from University of China Academy of Science and Beijing Cinso Consulting. 390 valid answers were collected from 50-60, 60-70, 70-80,. 80 + age group to analyze individual user's willingness to use telehealth solutions over traditional health solutions.

### *3.1 Ethics Approval*

Ethics approval was obtained in May 2019 with the committee from University of Macerata. Based on the ethics approval results and the analytical results from focus group analysis, questionnaires have been designed to analyse stakeholders' attitudes in China towards whether IoHT solutions can help to amend the gap for the current healthcare system demands.
Summary of data collected is presented in Table 4.1.

Table 4.1. Data collection summary, source: author's design

| **Data** | **Format** | **Storage** | **Transfer** | **Consent** | **Pseudonymization** |
|---|---|---|---|---|---|
| Recording with consumers | WMA, MP3, MP4 | The Box owned by KU Leuven | Data was collected for scientific research purposes and therefore was transferred from China to Europe and stored in cloud; | Question 1 in the questionnaire, see appendix | Yes |
| Questionnaire collected on pads | Word | The Box owned by KU Leuven | Data was collected for scientific research purposes and therefore was transferred from China to Europe and stored in cloud; | Question 1 in the questionnaire, see appendix | Yes |
| Excel Form with summary of data pseudonymized | Excel | The Box owned by KU Leuven | Data was collected for scientific research purposes and therefore was transferred from China to Europe and stored in cloud; | Question 1 in the questionnaire, see | Yes |

| | | | | | |
|---|---|---|---|---|---|
| | | | | appendix for sample | |

### *3.2 Study Design*

The main purpose of the survey was to understand the factors affecting the preference of elderly user for telehealth solutions.

The DCE model based on the randomly utility theory to evaluate the preference for telehealth solutions (Sommer et al, 2020) was used. The DCE method is widely used in studying how patients value different attributes of healthcare services and the potential demand for new services or treatment (Fletcher et al, 2019). The study follows the standard DCE methodology, namely (1) to defining research question, to compile of evidence (2) interview with experts (stakeholders), (3) interview with individual users （focus group studies）, (4) pretest (online questionnaire in Europe, n=31) and (5) pilot test (online questionnaire in Xiangyang, China, n=104). In the pilot test stage, 104 questionnaires were answered, with 55 questionnaires contain usable data (mostly from Hubei region).

The questionnaire consists of 31 questions and 5 parts. The questionnaire starts with a screening question on whether the participant is willing to participate in the survey and share data for scientific research purposes. There are 10 likert scale questions related to the motivation, 7 questions surrounding the demographic information including participants' insurance coverage, 6 questions about the usage of telehealth solutions at the time of survey, 4 questions about the health status of survey participants, 3 questions about whether users want to share data with insurance companies, doctors from community health centres and doctors from hospitals. The degree of influence of each factor is evaluated with Likert scale from 1-7 (1= no influence, 4= neutral, 7=with influence). The questionnaire was written in Chinese and then translated in English for understanding purpose by the author.

The questionnaire has five parts: the first part is about the current situation of telehealth solutions usage by surveyed elderly users.

Telehealth solutions are defined as smart phone apps (such as Alihealth, Ping An Good Doctor, Chun Yu Doctor, Wedoctor, Yue dong quan, etc), wearables (such as Xiaomi Band, Huawei watch and Apple Watch, etc), home use health management tools (such as PICOOC smart scale, Mi Home i-Health blood pressure monitor, Mi Home Hi-Pee Smart Pee Monitor, Smart Sleep Monitor, Smart devices to improve sleep quality, etc.) The section consists of 4 questions regarding the use frequency, reason for starting to use telehealth solutions, if telehealth solutions were used to monitor sleep and if telehealth solutions were used to monitor nutrition.

The second part of the questionnaire is about the health status of survey participants (self-evaluated). The third part asked about the potential benefits of telehealth solutions and elderly users' motivations. The fourth part is designed around the potential risks of telehealth solutions

(price, privacy risk, data accuracy risk, brand &design, resistance to technology and past experience of usage). The fifth part is designed to gather demographic information, including gender, age, residence, household income, education in hears.

13 questions were designed focusing on reasons of users prefer telehealth solutions to traditional health solutions. The following questions are related to F2, the perceived benefits of telehealth solutions: Monitoring Health status (Q13), reducing health risks (Q14, following the doctor's advice (Q15), free provided by insurance companies (Q 18), lack of community healthcare services (Q 20).

There were also questions regarding the perceived risk for telehealth solutions (F3). Data accuracy (Trust) concerns (Q22), privacy concerns (Q23), financial reasons for the price (Q24), design, popularity and difficulty of use concerns (Q25).

Since part of the reasons for using telehealth solutions is about social image, social influence (Q28) is also considered one of the factors which could influence users' preference.

### *3.3 Data Collection*

In our study, we intended to compare participant's willingness to use telehealth solutions among different age groups and residents in different cities, with the data collection target set at each age group (50-60, 61-70, 71-80) containing about 100 data subjects. Data subjects more than 80 years old was set to be 50-100 because of their health conditions limited the number of participants.

In the pretest stage of the study, questionnaires in English were distributed online via Microsoft Forms among Philips Intranet and Facebook Berlin Expat Group. 31 questionnaires were collected. In the pilot testing stage, the questionnaire was then translated in Chinese and distributed online with Wenjuanxing through Wechat. 104 questionnaires were collected with 55 valid answers collected. The pre-testing stage was designed to test the design of the questionnaire, thereby the data collected was not analyzed.

In the distribution stage, questionnaires were disseminated with on Pads randomly among residents of more than 50 years old in Shenzhen, Hangzhou, Wuhan and Yichang with the help of Beijing Xinsuo Consulting. More than 450 questionnaires are distributed, and 402 answers were collected, with a recovery rate of 89%. Among them, 390 are completely valid questionnaires, accounting for 87% of the questionnaires issued and 97% of all the questionnaires returned. The other 12 questionnaires were not used in data analysis because they do not provide complete information or are deemed to have not been filled in carefully.

The data was collected in Chinese language then summarized in an excel form and turned into a pseudonymized value form in excel. Data was then analyzed with SPSS 24.0 and Stata 17.0.

The level of urban development differs with Tier 1, 2, 3, 4 cities; the disposable income of residents in the designated cities vary as well. This may lead to the difference in the preference for telehealth solutions.

Table 4.2. Disposable Income in Shenzhen, Hangzhou, Wuhan and Yichang, Source: CEIC, 2020; National bureau of statistics, 2020;

| | City | GDP in 2019 | Disposable and discretionary income |
|---|---|---|---|
| Tier 1 | Shenzhen | 330 | 7747.459727 |
| Tier 2 | Hangzhou | 190 | 7343.370508 |
| Tier 3 | Wuhan | 200 | 6407.187113 |
| Tier 4 | Yichang | 55.18 | 3565.303594 |
| Notes: GDP valued in 2019, Unit: Euro in billions; Disposable income, Unit: Euro | | | |

Shen Zhen was chosen because it is the headquarter of Ping An Technology. Ping An Technology has worked with the government of Shen Zhen and other stakeholders to provide e-medical insurance scheme. Residents in Shen Zhen are now able to use Ping An Good Doctor app to buy in complementary insurance in addition to the basic medical insurance schemes and get refunded online.

Hangzhou was chosen as the city where Alibaba headquarter locates. During the interview with Alihealth, it is noted that 80% of all primary levels of healthcare facilities in Zhe Jiang Province are now equipped with AI assisted image recognition system.

Wuhan was chosen as an important hub in central China where population grows rapidly in recent years. Recently the Wuhan Municipality has launched several programs promoting the Internet+ Home Care for elderly initiative. There are several exploratory projects running in different districts in Wuhan such as in Dong Xi Hu District and in Wuchang District. There has been several models proposed and tested in Wuhan for elderly care such as the community embedded model, the centralization model and the combinations of proper centralization and decentralization model. Services provided to elderly focus on assisted food service, assisted cleaning service, assisted nursing medical service and long distance care.

Yi Chang was chosen as the level of aging population in Yi Chang is higher than national average. The aging was measured by the percentage of over 60 years old in the whole population and the percentage of over 80 years old in the elderly population. The Yichang municipality is currently developing the community based care centers and rural cooperative elderly care centers. The Yichang Municipality hopes to establish the tele-elderly-care platform in 2019. By utilizing the platform, in 2020, the coverage of tele-elderly-care services should reach all townships in Yichang and cover over 50% of all elderly.

### *3.4 Theoretical model and hypothesis*

To evaluate users' willingness to use telehealth solutions, three hypotheses were made with consideration of demographic factors such as age, education background, income, health status

and user's living habits such as regular social activity and regular exercise. Table 4.**3** describes the theoretical model built to assess users' willingness to use telehealth solutions, the hypothesis and the variables involved in the model. The theoretical model consists of two parts; the first of the model assess likert scale factors and their correlation with user's willingness; the second part of the model assess demographic factors and their impact on the three factors and on the willingness to use telehealth solutions.

Table 4.3 Hypothesis and corresponding variables in the model

| Factor | | Hypothesis | Corresponding question in the questionnaire |
|---|---|---|---|
| Factor 1 | 1.1 Social Influence | 1.1 Social influence (friend and family's opinion) has an impact on the willingness to use telehealth solutions | Q28, likert-scale, value:1-7 |
| | 1.2 Data Accuracy | 1.2 The accuracy of data collected by telehealth solutions has an impact on the willingness to use telehealth solutions | Q22, likert-scale, value:1-7 |
| | 1.3 Price | 1.3 The price of telehealth solution has an impact on the willingness to use telehealth solutions | Q24, likert-scale, value:1-7 |
| | 1.4 Design & Brand | 1.4 The brand and design of telehealth solutions has an impact on the willingness to use telehealth solutions | Q 25, likert-scale, value:1-7 |
| | 1.5 Privacy risk | 1.5 The privacy risk associated with the use of telehealth solutions has an impact on the willingness to use | Q 23, likert-scale, value:1-7 |
| | 1.6 Private insurance/business insurance coverage | 1.5 Private/business insurance plan coverage has an impact on the willingness to use telehealth solutions | Q 18, likert-scale, value:1-7 |
| Factor 2: Health related motivation factors | 2.1 Lower health risk | 2.1 he belief that telehealth solutions can lower health risk is positively related to the willingness to use telehealth solutions | Q 14, likert-scale, value: 1-7 |
| | 2.2 Raise Health awareness | 2.2 The belief that telehealth solution can raise health awareness is positively | Q 13, likert-scale, value:1-7 |

| | | | |
|---|---|---|---|
| | | related to the willingness to use telehealth solutions | |
| | 2.3 Lack of community healthcare for patients | 2.3 The belief that telehealth solution can amend the gap for lack of community healthcare for patients | Q 22, likert-scale, value:1-7 |
| | 2.4 Unstable doctor-patient relationship | 2.4 The belief that telehealth solutions can help to improve doctor-patient relationship | Q 15, likert-scale, value: 1-7 |
| Factor 3: Trust | 3. Data Accuracy | 3. The accuracy of data collected by telehealth solutions has an impact on the willingness to use telehealth solutions | Q 22, likert-scale, value: 1-7 |
| Control Variables | Residence City | Residence city of the participants has an impact on Factor 1, 2, 3 and their willingness to use telehealth solutions | Q3, 1= Shenzhen, 2= Hangzhou, 3= Wuhan, 4= Yichang |
| | Gender | Gender of the participants has an impact on Factor 1, 2, 3 and their willingness to use telehealth solutions | Q30, 0=female, 1=male |
| | Education | Education of the participants has an impact on Factor 1, 2, 3 and their willingness to use telehealth solutions | Q31, 1= Primary school level education (0=6 years), 2= Junior/senior high school level of educaiton (6 -12 years), 3= vocational training (12-15 years), 4= College education (15-18 years), 5= Graduate school education (>=18 years) |
| | Income | Monthly household income of the participants has an impact on Factor 1, 2,3 and their willingness to use telehealth solutions | Q29, 1= no fixed income, 2 = monthly household income < = 5000 RMB, 3= monthly household income >5,000 RMB, <= 10, 000 RMB, 4 = monthly income > 10,000 RMB, <= 30,000 |

| | | | |
|---|---|---|---|
| | | | RMB, 5= monthly income > 30,000 RMB |
| | Health status | Self-reported health status of the participants has an impact on Factor 1, 2, 3 and their willingness to use telehealth solutions | Q11, 1= self reported healthy, 2= sub-optimal healthy, 3= with chronic disease with no significant impact on life quality, 4= jhave chronic disease with significant impact on life quality |
| | Prefered living status | Prefered living situation of the participants has an impact on Factor 1, 2, 3 and their willingness to use telehealth solutions | Q4, 1= Prefer living alone, 2= Prefer living with partner, 3= Prefer living with children, 4= Prefer living with children/ grandchildlren |
| | Regular exercise | Whether participants engage in regular exercise or not has an impact on Factor 1,2, 3 and their willingness to use telehealth solutions | Q9, 1= Socialize regularly, -1= do not social regularly |
| | Regular social activity | Whether participants engage in regular social activities or not has an impact on Factor 1, 2, 3 and their willingness to use telehealth solutions | Q10, 1= Exercise regularly, -1= do not exercise regularly |

Considering that the dependent variable -the willingness to use telehealth solutions is an ordered discrete variable, the ordered logit model is used for regression. Four models were designed to assess the impact of each factor.

$$Y = \beta F_1 + \gamma Z + \varepsilon \quad (1)$$
$$Y = \beta F_2 + \gamma Z + \varepsilon \quad (2)$$
$$Y = \beta F_3 + \gamma Z + \varepsilon \quad (3)$$
$$Y = \beta_1 F_1 + \beta_2 F_2 + \beta_3 F_3 + \gamma Z + \varepsilon \quad (4)$$

Model (1) is used to test the impact of Factor 1, model (2) and model (3) are used to test the impact of Factor 2 and 3. Model (4) considers the influence of the above three factors.

Y represents the designated value for the willingness of participant to use telehealth solutions. In the original questionnaire, the question designated the preference level as from 1 to 7 (1=

preference for traditional health solutions (face-to-face communications), 4=neutral, 7= preference for telehealth solutions). Z represents control variables such as demographic factors, including living city, age, gender, education level, health condition, income, living situation, lifestyle variables (regular social exercise and regular activity).

# 4 Results

## *4.1 Health status of survey participants*

Based on the self identified responses from data subjects, the following catergories were created to identify their health status: healthy, sub-optimal healthy and with chronic disease and self-identified healthy. Then more detailed data, such as the type of chronic disease and the number of chronic diseases of the survey participants, was analyzed.

According to the survey made by the China Disease Control Center (CDC) and Zhou et al. (2019) on the public health picture of the Chinese population, major non-communicale disease (NCD) risks and cause of deaths are hypertension, diabetes (Type I/II), cardiovascular disease, cancer, COPD etc. Among the most commonly reported chronic diseases are hypertension, diabetes, cardiovascular disease, osteoprosis, rheumatic arteritis, eye disease, chronic bowle disease. 117 participants reported to have 1 chronic disease (30%), 64 participants responded to have 2 chronic diseases (16.4%), and 47 partcipants responded to have 3 chronic diseases (12.05%), 17 participants reponded to have 4 chronic diseases (4.36%), 7 participants reported to have 5 chronic diseases (1.79%), 6 participants responded to have 6 chronic diseases (1.53%), 2 participants responded to have both communicable disease and chronic diseases (0.5%) . 110 participants report to have no chronic diseases.

The survey suggests that 71.79% of participants have chronic diseases while only 0.5% participants reported to have communicable diseases. The study conducted by Bloom et al. (2020, p. 100163) suggests the economic cost associated with chronic diseases are estimated to be $7.7 trillion for China. Rapid urbanization has lead to the change in lifestyle. For instance, while tabacco consumption in high-income economies are declining, it is risiing rapidly in China (Bloom et al., 2020, p. 100163). Urbanization also expose the aging population with air, soil and water pollution.

This suggests there is a need to address the chronic diseases issue among the above 50 years old group via behavior change. Telehealth solutions can be a powerful tool to help patients with chronic disease to help them build better communication with doctor and address risky behaviors such as drinking and smoking.

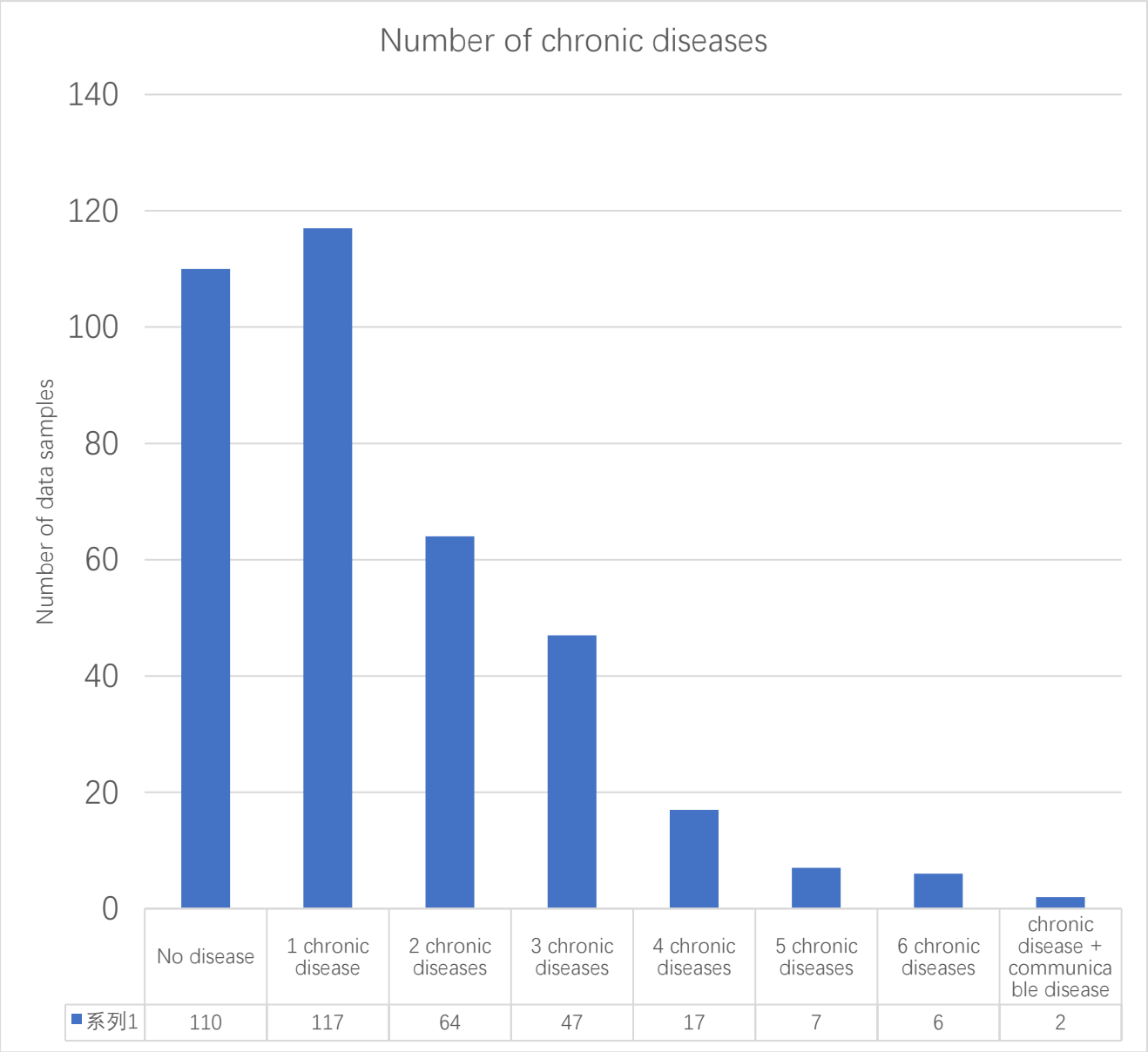


Figure 4.1Number of chronic disease of data samples, Source: Author's design

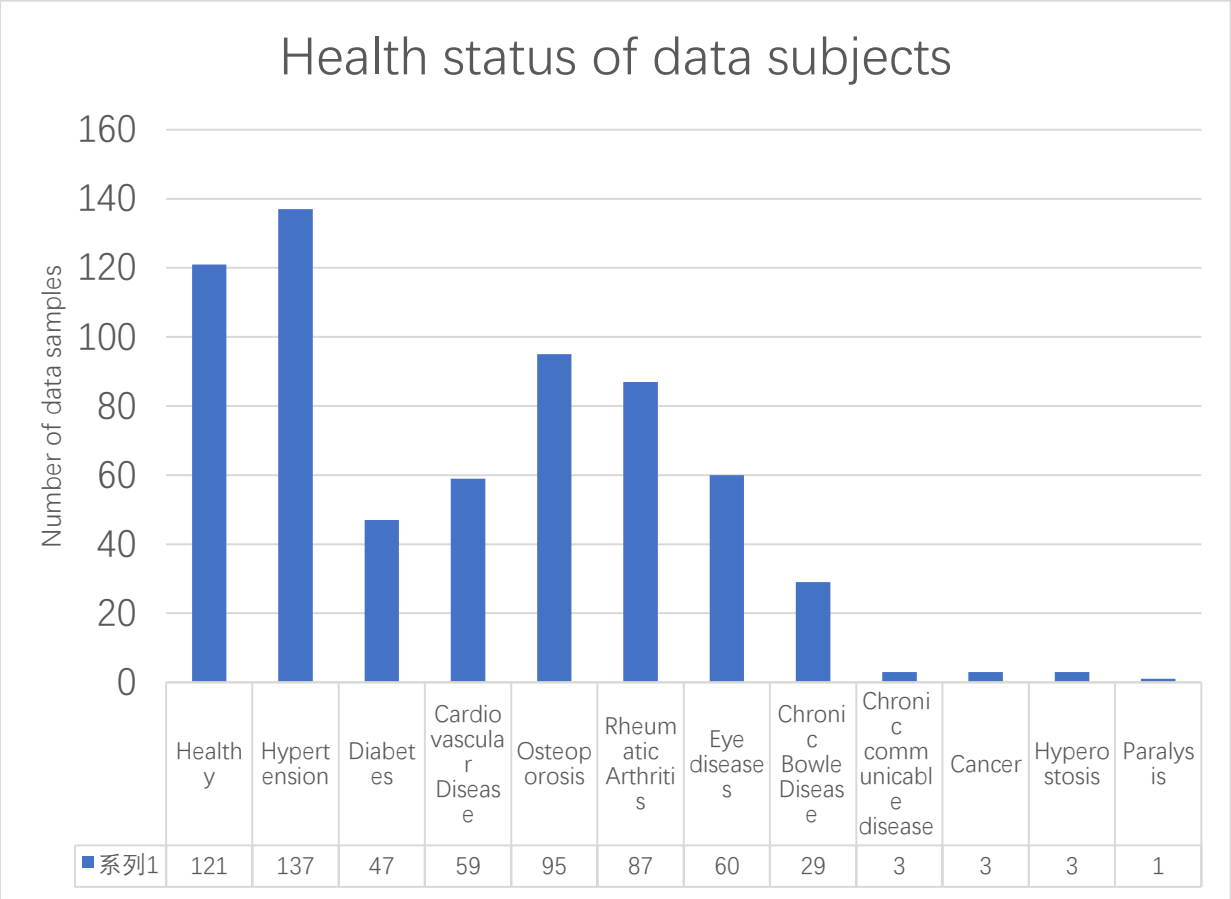


Figure 4.2. Health Status of data subjects, Source: Author's design

### *4.2 Descriptive statistics*

In this section, the qualitative analytical results are presented. All survey participants are over 50 years old as the survey intends to collect information on users' need for the elderly in the next 5-10 years. Among the 390 valid answers, 160 participants indicate they are more willing to use traditional healthcare solutions (41.03%); 167 participants indicate they are willing to use telehealth solutions (42.82%), while 51 participants show neutral willingness.

Table 4.4. Demographic of participants

| | N | Percentage | | N | Percentage |
|---|---|---|---|---|---|
| **Gender** | | | **Years of Education** | | |
| Male | 224 | 57.4 | Primary School (1-6 years) | 83 | 21.3 |
| Female | 166 | 42.6 | Junior/High School (6-12 years) | 246 | 63.1 |
| **Age** | | | Vocational training (12-15 years) | 31 | 7.9 |
| 51-60 | 112 | 28.7 | College graduate (15-18 years) | 29 | 7.4 |
| 61-70 | 112 | 28.7 | Graduate School (>=18 years) | 1 | .3 |

| | | | | | |
|---|---|---|---|---|---|
| 71-80 | 110 | 28.2 | **Health status** | | |
| >=80 | 56 | 14.4 | Healthy | 145 | 37.2 |
| **Residence** | | | Sub-optimal healthy | 99 | 25.4 |
| Shenzhen | 97 | 24.9 | With minor chronic disease | 132 | 33.8 |
| Hangzhou | 95 | 24.4 | With major chronic disease affecting life quality | 14 | 3.6 |
| Wuhan | 108 | 27.7 | **Living situation** | | |
| Yichang | 90 | 23.1 | Live alone | 47 | 12.1 |
| **Household income (RMB)** | | | Live with partner | 156 | 40.0 |
| No fixed monthly income | 21 | 5.4 | Live with children | 177 | 45.4 |
| ≤5000 | 84 | 21.5 | Live with grandchildren | 4 | 1.0 |
| 5000-10000 | 186 | 47.7 | **Health insurance status** | | |
| 10000-30000 | 88 | 22.6 | None | 8 | 2.1 |
| ≥30000 | 11 | 2.8 | Basic resident/employee medical insurance | 309 | 79.2 |
| **Use frequency of telehealth solutions** | | | Private insurance | 7 | 1.8 |
| Often | 264 | 67.7 | Other social insurance schemes | 21 | 5.4 |
| Occasionally | 82 | 21.0 | Public servant insurance | 38 | 9.7 |
| Rarely | 44 | 11.3 | Unknown | 7 | 1.8 |
| **Summary** | 390 | 100 | **Summary** | 390 | 100 |

The number of participants aged 51-60 is 112, accounting for 28.7% of all participants; the number of participants aged 61-70 years is also 112, accounting for another 28.7% of all participants. The number of users aged 71-80 is 110, accounting for 28.2% of all participants. The number of users over 80 years old is limited by their physical conditions, account for 11.4% of all participants.

67.7% of users often use telehealth solutions to monitor health status. Most survey participants (63.1%) received 6-12 years of education, followed by elementary school, accounting for 21.3% of all participants. Given the survey candidate recruitment condition for the elderly more than 50 years old, the education level of participant is in line with reality.

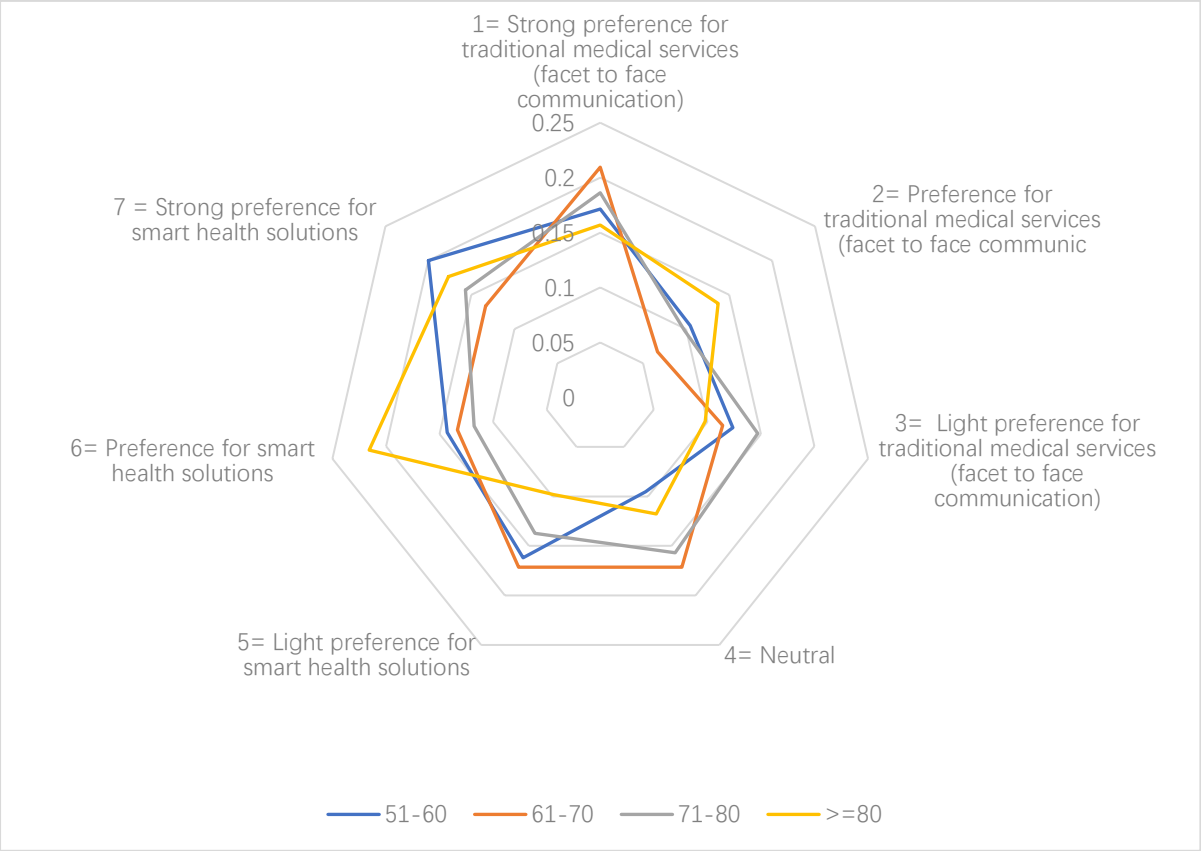


Figure 4.3 The willingness to use telehealth solution sorted by age group, source: Author's illustration

The distribution diagram shows the 51-60 years old group and the >= 80 years old group shows strong willingness or willingness to use telehealth solutions. This may be due to the fact that the 50-60 years old age group are more familiar with technology whereas the above 80 years old age group cannot physically attend in person doctor visits.

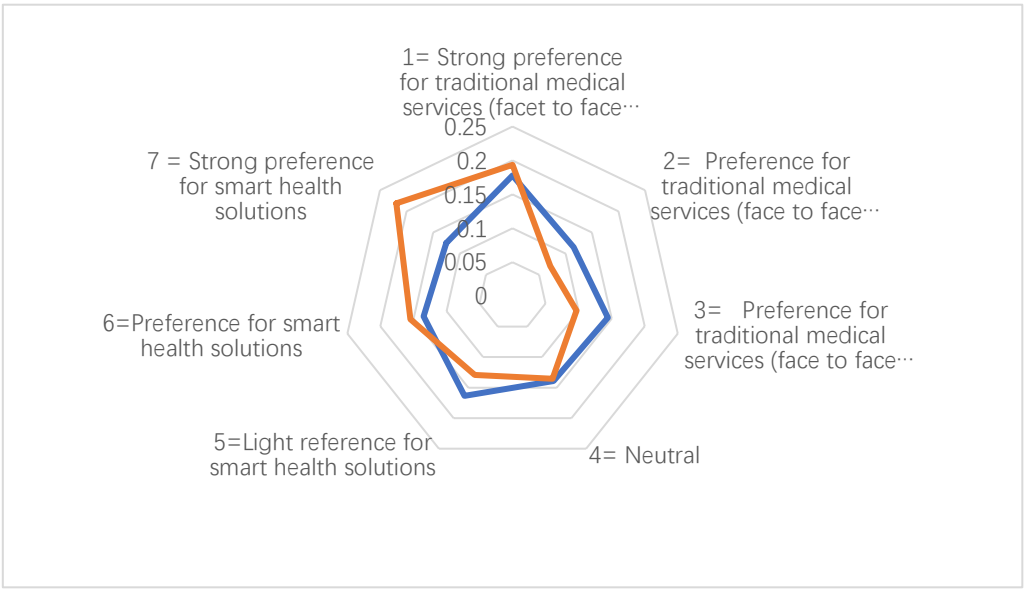


Figure 4.4, The willingness to use telehealth solutions, sorted by gender.

Among the users surveyed, there are 224 males and 166 females, accounting for 57.4% and 42.6% respectively, with the proportion of male users is higher than that of female users (As suggested by Table 4.4). Figure 4.4 suggests female users are willing to use traditional medical solutions while male users are strongly willing to use telehealth solutions. The preference distribution graph suggests that female is more conservative than male in their preference for tele-health solutions. This may relate to income, health education and their tendency to socialize. This will make female users more willing to communicate with doctor face to face and use traditional health solutions.

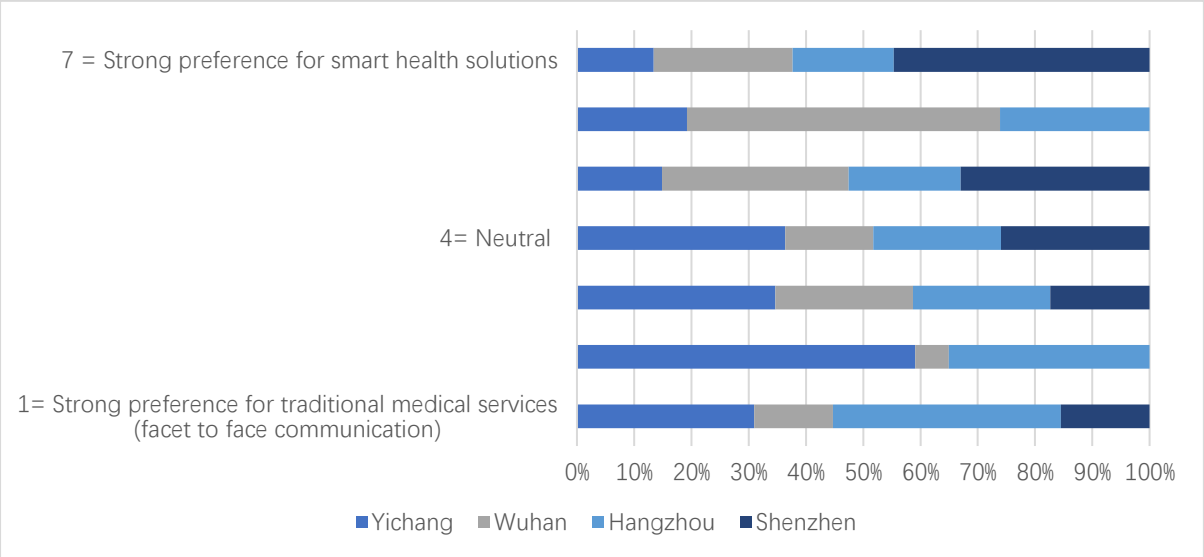


Figure 4.5, The willingness to use telehealth solution in Yichang, Wuhan, Hangzhou and Shenzhen, source: Author's illustration

In accordance with the study design, survey participants are evenly distributed in the four cities. The data samples in Shenzhen, Hangzhou, Wuhan, and Yichang are 97, 95, 108 and 90, accounting for 24.9%, 24.4%, 27.7%, and 23.1% of all data subjects. Figure 4.5 suggests that in Shen Zhen and Wuhan, the percentage for users with preference for telehealth solutions is higher than Hang Zhou and Yichang. Reasons lying behind the differences can be explained by infrastructure differences, for instance, the smart health initiative in Shenzhen/Wuhan and the concentration of hospitals and other medical resources in Wuhan. Shenzhen and Wuhan started early in their big data + Health initiative while other cities started later. The big data health initiative provides the necessary digital infrastructure (HIS) for health system digitalization including the digitalization of hospitals and the connection primary level health service clinics.

There is still the necessity to address the data interoperability issue between hospitals and the primary level health service clinics to ensure patients' care continuity; this may also help to resolve the concentration of patients at hospitals and divert patients back to primary care institutions. After all, doctors at level 3 hospitals have no time to help outpatients to address their lifestyle problems once they leave the hospital. This leaves the room for community care centers to step in and advise patients and monitor patients regularly. The vacuum for community care centers can be filled in by telehealth solutions for patient self-care.

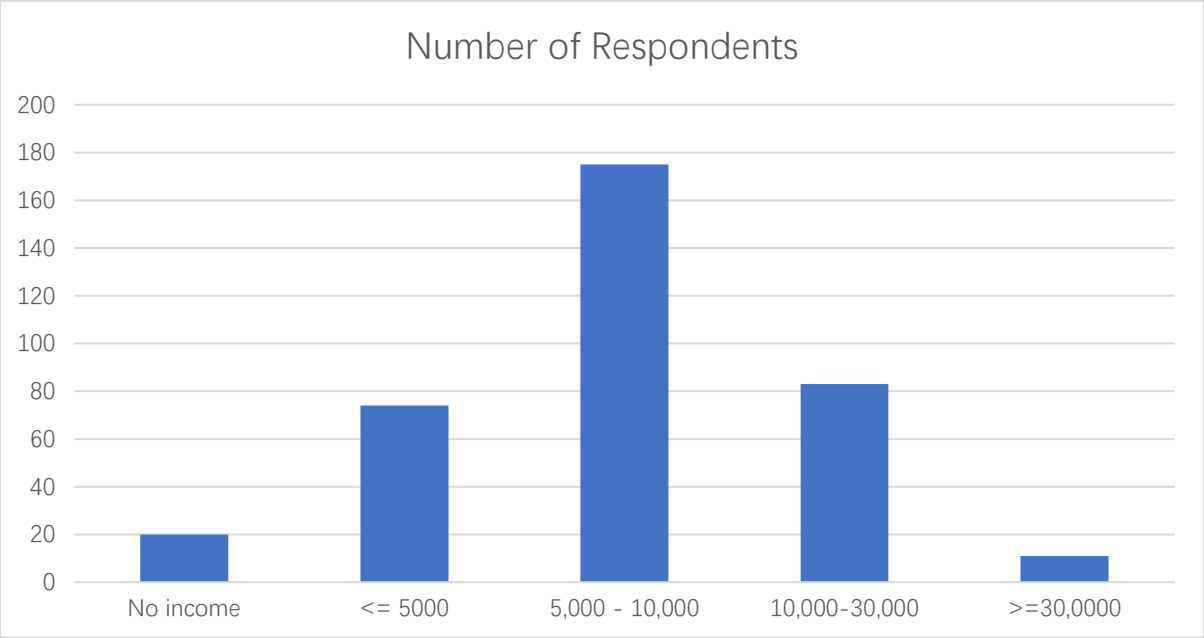


Figure 4.6 Distribution of participants sorted by income, source: Author's illustration

The distribution of income follows the bell curve, with about half (47.7%) of the sample's monthly household income falls between 5,000 RMB and 10,000 RMB, the proportions of samples with household monthly income less than or equal to 5,000 RMB and more than or equal to 30,000 RMB account for only 5.4% and 2.8% respectively. The willingness to use telehealth solutions grow with monthly income as well. Figure 4.7 points out that among the >= 30,000 (RMB) income group, the preference is mainly neutral and above neutral. The lower the income group is, the higher the percentage among all surveyed data subjects with strong preference for traditional health solutions is. This can be observed among the no income and <= 5000 income group.

The preference distribution may exist because communications with doctors are part of the social activity; this type of social activities are strongly related to health education, social influence and health insurance coverage. The lower income groups are subject to less insurance coverage, less health education; they have strong preference for seeing doctors in person and spending hours at hospitals because they have much less other social activities. Higher income groups are subject to better health education, wider health insurance coverage, and a much less willingness to spend time at hospitals. Therefore, since they can afford tele-health solutions, on the premise that tele-health solutions are not covered by the social (employee or resident) medical insurance schemes in China, the higher income groups are more willing to use telehealth solutions rather than wait at hospitals.

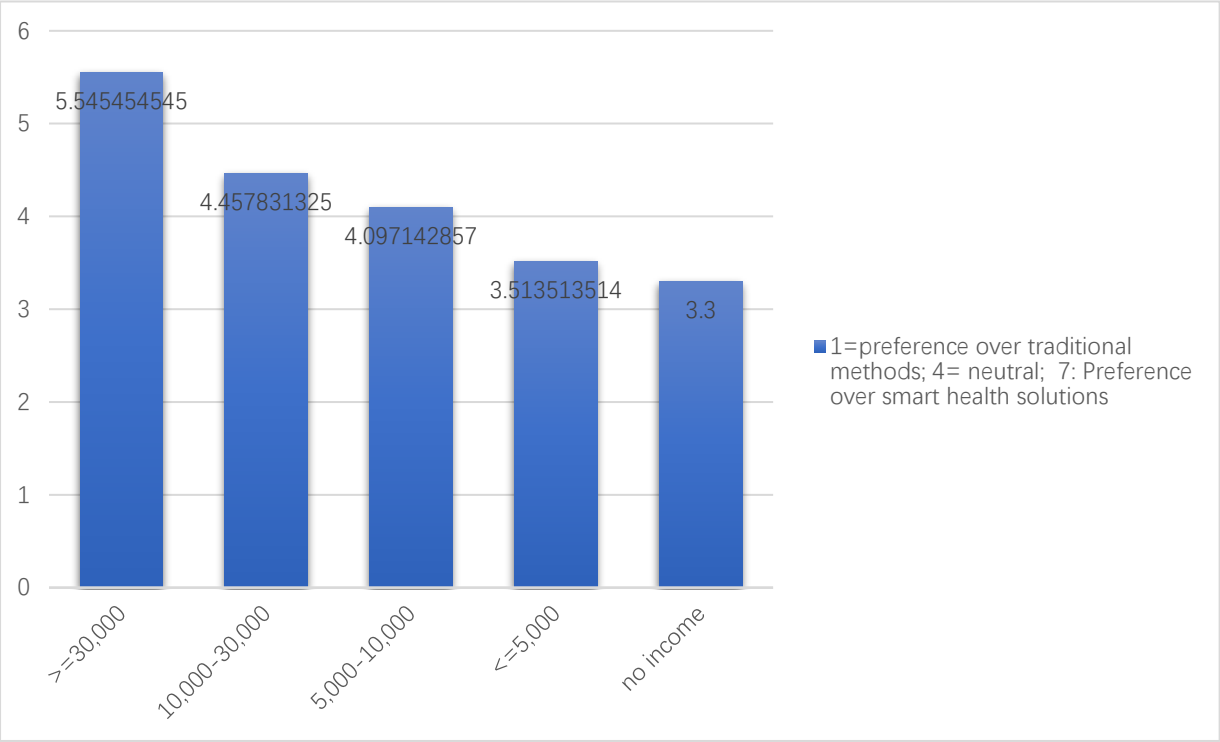


Figure 4.7 The willingness to use telehealth solutions in four income groups of participants, source: Author's illustration

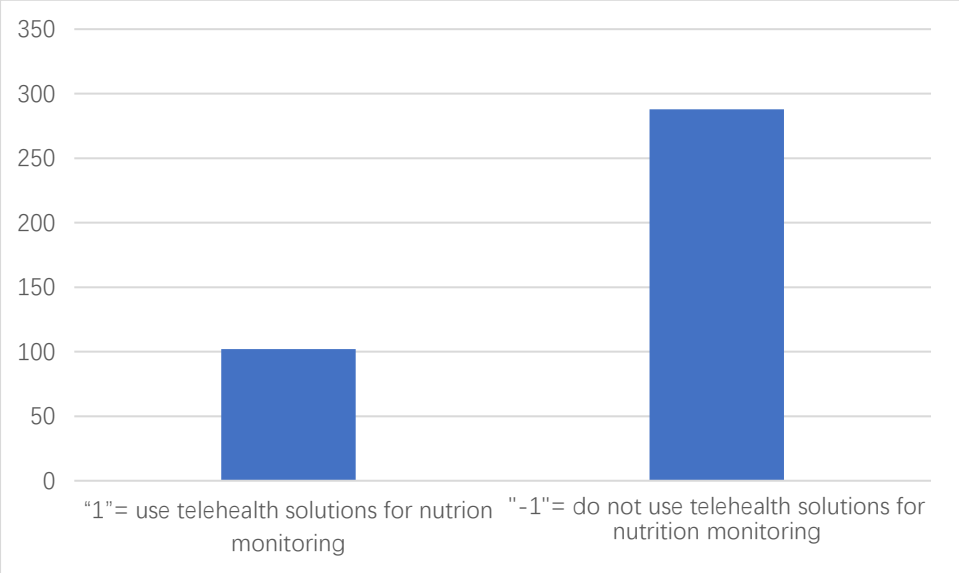


Figure 4.8 Use of telehealth solutions for nutrition monitoring

In terms of using telehealth solutions for monitoring sleep and nutrition intake, as shown in Figure 4.8 and Figure 4.9, the percentage of users who are currently using telehealth solutions for sleep monitoring and nutrition monitoring are respectively 23.07% and 26.15%.

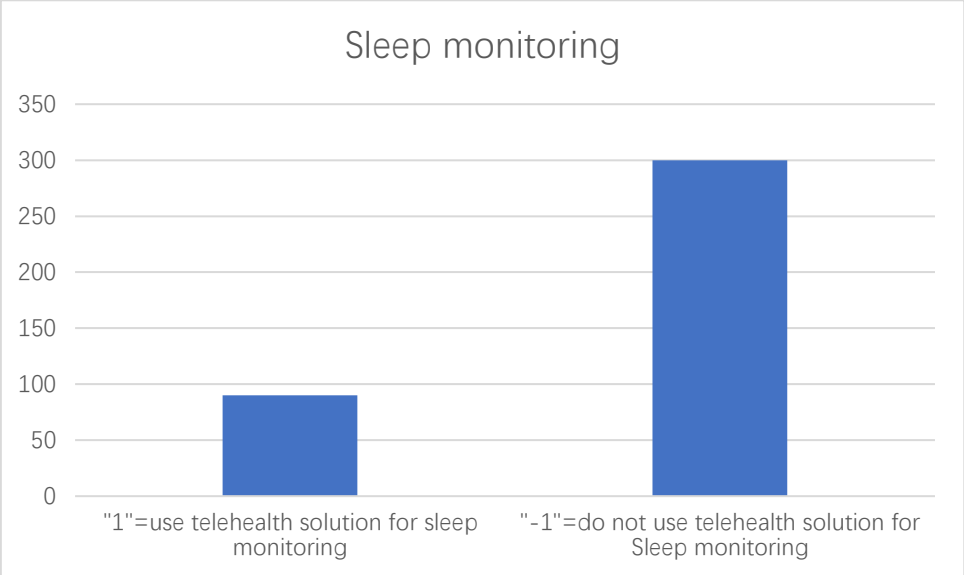


Figure 4.9, Use of telehealth solutions for sleep monitoring

Figure 4.10 indicates the major reasons for using telehealth devices are self-care, following doctor's advice and the free devices and services offered by insurance companies in China or the mix of the three reasons.

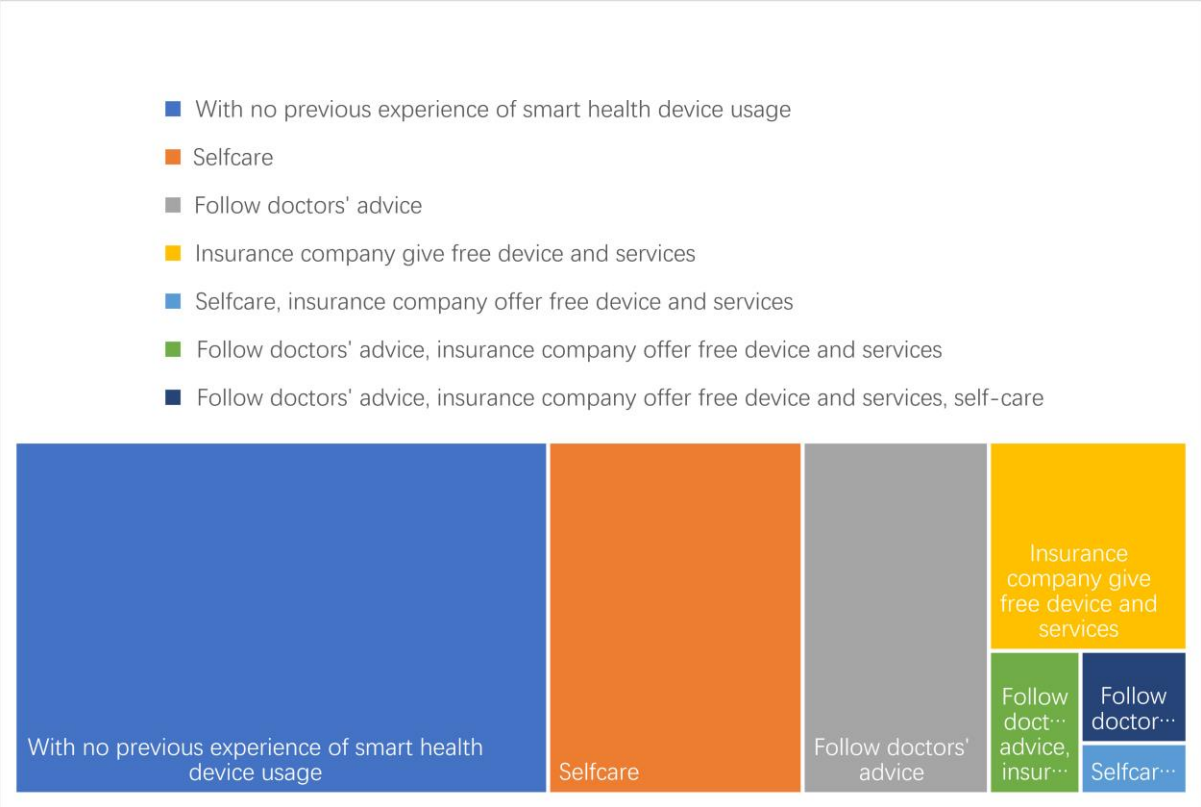


Figure 4.10 Reasons for using telehealth solutions

The factors affecting the willingness to use telehealth solutions are ranked by the mean of each variable (Likert Scale:1-7, 1= No Impact, 4= Neutral, 7= With an Impact) as illustrated by Table 4.5. Among the 10 factors, six of which have mean more than 4, suggesting that these

factors have an impact on the preference for telehealth solutions. The top four motivations are lowering health risks, raising healthcare awareness, lack of community medical services, and following doctor's advice; these variables form the composition for Factor 1.

Factor 2 consists of price, privacy risk, social influence, design and brand of the solution, partcipant's coverage with insurance plans. The mean value of these variables are close to neutral or less than 4, suggesting that survey participants in general do not believe these factors have an impact on their willingness to use telehealth solutions.

The accuracy of data (Factor 3) collected by telehealth solutions is also a key factor. Compared with traditional medical instruments and equipment that have the shortcoming of inaccurate data reading, telehealth solutions collect more accurate health data. However, most doctors and hospitals still do not trust data collected from telehealth solutions and do not use the data source as the basis for diagnosis or treatment. This makes it difficult for users to trust the devices for collecting health data and monitoring health status. Currently, there are more than 120 EHR systems operating in China, making it difficult to integrate the telehealth solution and the hospital/clinic EHR systems. COVID 19 has accelerated the digitalization of the healthcare system. For instance, in CES 2021, Omron showcased the VitalSight system for monitoring blood pressure which connects the data hub at home to the EHR system (Omron, 2021). The data interoperability between telehealth solution and EHR system stays as a hurdle to maximize the health value for telehealth solutions.

Table 4.5 Ranking of factors affecting the willingness to use telehealth solutions among elderly users

| **Factors** | **Ranking** | **Mean** | **Standard Error** |
|---|---|---|---|
| Lower Health risk | 1 | 5.96 | 1.672 |
| Raising Health Awareness | 2 | 5.85 | 1.676 |
| Lack of community healthcare service | 3 | 5.77 | 1.721 |
| Follow Doctor's prescriptions | 4 | 5.27 | 2.032 |
| Price of the solution | 5 | 4.37 | 2.462 |
| Data Accuracy | 6 | 4.07 | 2.314 |
| Design of the solution | 7 | 3.72 | 2.498 |
| Privacy risk | 8 | 3.70 | 2.342 |
| Social influence | 9 | 3.44 | 2.540 |
| Free device offered by insurance company | 10 | 2.77 | 2.157 |

### *4.3 Modeling process*

In this section of the paper, the quantitative analytical results are presented.

To avoid heterogeneity issue, the KMO and Barlett test is run to examine the correlation between the Likert-scale variables. Then the principal component analysis is run to reduce the dimension of the model and the correlation between variables. With the factor loading for each factor confirmed, the Likert-scale variables are then ranked based on the mean value of each

variable. The next step is to test if demographic factors have an impact on the three factors identified by the principal component analysis. This was done with ANOVA and t-test.

The modeling process started with correlation matrix (Pearson's correlation and Spearman's rank correlation) to test if data has multi-collinearity. Then the O-logit model was run in Stata along with control variables. At the final step of the modeling, 10 participants were randomly selected to see if the prediction preference score matched choice made by the participants.

Table 4.6 KMO and Bartlett's test

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .796 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1211.064 |
| | df | 45 |
| | Sig. | .000 |

The KMO and Bartlett's test was run on 10 likert scale factors related to survey participant preference (see Table 4.6). The KMO coefficient is .796 (>0.5) with the Sig of Bartlett sphere less than 0.05, indicating that there is a certain degree of correlation among 10 factors. Dimension reduction among the 10 factors is deemed necessary for further analysis.

Factor analysis is a commonly used dimensionality reduction method. Principal component analysis and varimax right-angle rotation method is used to extract three principal factors. These three principal factors can explain 64.149% of the total variance, with the first, second and third factors explaining 28.364%, 25.196% and 10.589% of the total variance respectively (see Table 4.8Table 4.7). The variables were selected when the factor loading of the variable is greater than 0.5 (See Table 4.7).

Table 4.7 Principal Component analysis

| **Component** | **Factor loading** | **Eigenvalue** | **Variance Contribution Rate** | **Cumulative Contribution Rate** |
|---|---|---|---|---|
| **Factor I** | | 2.836 | 28.364 | 28.364 |
| Price | 0.812 | | | |
| Brand and Design | 0.738 | | | |
| Private insurance coverage | 0.713 | | | |
| Social influence | 0.706 | | | |
| Privacy risk | 0.612 | | | |
| **Factor II Health related** | | 2.520 | 25.196 | 53.560 |

| | | | | |
|---|---|---|---|---|
| **motivations** | | | | |
| Lower health risk | 0.864 | | | |
| Raise health awareness | 0.818 | | | |
| Lack of community healthcare service | 0.771 | | | |
| Unstable doctor-patient relationship | 0.701 | | | |
| **Factor III** Trust | | 1.059 | 10.589 | 64.149 |
| Data Accuracy | 0.762 | | | |

Factor I consists of price (0.812) , design (0.738), the impact of private insurance coverage(0.713), social influence (0.706) and privacy risk (0.612).

Factor II, health related motivations, consists of lowering health risk (0.864), raising health awareness (0.818), lack of community healthcare service (0.771), and follow doctor's advice or prescription (0.701).

Factor III, trust for telehealth solutions, consists of the data accuracy variable. User's trust level for telehealth solutions is influenced by whether data collected from wearables or medical devices at home are accepted by doctors and hospitals. Therefore, trust is influenced directly with data accuracy of the solution (0.762).

Table 4.8 Total Variance Explained

| | Rotation Sums of Squared Loadings | | |
|---|---|---|---|
| Factor | Total | % of Variance | Cumulative % |
| 1 | 2.836 | 28.364 | 28.364 |
| 2 | 2.520 | 25.196 | 53.560 |
| 3 | 1.059 | 10.589 | 64.149 |

Extraction Method: Principal Component Analysis.

ANOVA and T test are used for assessing whether the relative importance of the above mentioned 10 factors differs, depending on the city of residence, age, gender, education level, health status, income, living situation, regular social activity, and regular exercise. The results are shown in Table 4.9.

Table 4.9 One-way analysis of variance and two-sample T test, *p<0.1; **p<0.05; ***p<0.01

| Hypothesis | Variance | Factor1 | Factor2 | Factor3 |
|---|---|---|---|---|

| | analysis | | | |
|---|---|---|---|---|
| Residence city | F value | 5.718 | 2.245 | 4.075 |
| | Significance | 0.001*** | 0.083* | 0.007*** |
| Age | F value | 0.467 | 2.195 | 0.172 |
| | Significance | 0.706 | 0.088* | 0.915 |
| Gender | F value | 0.074 | 2.128 | 7.570 |
| | Significance | 0.785 | 0.145 | 0.006*** |
| Education | F value | 1.186 | 0.180 | 1.374 |
| | Significance | 0.316 | 0.949 | 0.242 |
| Health condition | F value | 1.494 | 1.128 | 3.468 |
| | Significance | 0.216 | 0.338 | 0.016** |
| Income | F value | 1.261 | 4.109 | 1.436 |
| | Significance | 0.285 | 0.003*** | 0.221 |
| Living situation | F value | 1.216 | 1.136 | 2.665 |
| | Significance | 0.301 | 0.341 | 0.022** |
| Regular social activity | F value | 5.998 | 2.508 | 2.083 |
| | Significance | 0.015** | 0.114 | 0.150 |
| Regular exercise | F value | 4.726 | 3.963 | 0.605 |
| | Significance | 0.030** | 0.047** | 0.437 |

First, it is assumed the relative importance of factors varies with the residence city. The results of variance analysis support this hypothesis.

The first factor mainly reflects the attributes of telehealth solutions such as price, privacy risk, brand and design; factor I also considers the impact of social influence and private insurance coverage. There are more telehealth solution providers in Shenzhen and Hangzhou, as well as high-quality hospitals. Doctors and nurses are more acceptable for telehealth solutions in large cities such as Shenzhen and Hangzhou. A wide variety of well-designed and affordable telehealth solution in Shenzhen and Hangzhou. With the fast-pace lifestyle in these two cities, elderly (>=50 years old) users are more willing to use telehealth solutions. Considering the differences in disposable monthly income, it is more likely that residents in Shenzhen and Hangzhou enjoy the coverage of private insurance. Users with private health insurance coverage are more likely to believe that the coverage of telehealth solution has an impact on the willingness to use telehealth solutions (whether positive or negative).

Secondly, the assumption is made that age plays a significant factor in determining user preference. In this study, survey participants are divided in four age groups, 51-60, 61-70, 71-80 years old, and over 80 years old. Considering 71.79% of all survey participants have chronic

disease, users from this age group may consider the relevant health benefits such as raising health awareness, lowering health risk, improving access to healthcare more than other age groups. The results of ANOVA shows that the second factor varies with age (p=10%). The second factor mainly reflects the belief that telehealth solutions can raise health awareness, lower health risk, improving doctor-patient relationship, and amending the gap for lack of community healthcare services.

Gender factor is also one of the key factors affecting user preference. The hypothesis is that male users and female users have perceived value, perceived risk and perceived benefit for telehealth solutions. Considering the binary factor of gender, the T test can verify our hypothesis. The results show that the trust factor is significant at the level of 1%. This suggests that male and female survey participants differ in trust over data accuracy risk related for telehealth solutions.

The survey categorizes users' education level by years into five categories: primary school (1-6 years), high school (6-12 years), vocational school (12-15 years), college education (15-18 years), and postgraduate (>= 18 years). Our hypothesis is that Factor 1,2,3 differs across different education level. However, the results of the ANOVA reject our hypothesis. With data suggests that 84.4% of all survey participants have high school or primary school education, the conclusion is survey participants with less than 15 years of education show no difference in Factor 1, 2 and 3.

In the stakeholder interview stage, a doctor interviewed suggests that elderly people with chronic diseases are more willing to go to the doctor for blood pressure measurement. The willingness to use telehealth solutions are affected by user's health condition. For instance, telehealth solutions can provide users with a large amount of real-time personal health data, such as heart rate, blood pressure, blood sugar and other health indexes. For users with chronic diseases, although the data collected by telehealth solutions has certain reference value, doctors either have no access to the data or do not trust the data collected at home. With little or no integration with the healthcare system, elderly users do not trust the data collected by telehealth solutions. The health status of survey participants is divided by four categories: self-reported healthy, sub-optimal health status, with chronic disease (do not affect life quality), and with chronic disease (affect life quality). The results of variance analysis support our hypothesis. The third factor- trust over data accuracy regarding telehealth solution is statistically significant affected by health status of survey participant.

ANOVA test suggests household income variable has a statistically significant effect on Factor 2, health related motivations. Families with high household income can bear the cost of using telehealth solutions, thereby benefiting from active self-health management. Users who sit in lower household income group pay more attention to factors such as the price of telehealth solutions, often ignoring the need of active health management. Factor 2 varies among different income groups.

Trust over data accuracy regarding telehealth solutions (Factor 3) is also affected by whether

survey participants live with their children or grandchildren. The survey participant's living situation is categorized as prefer living alone, prefer living with spouse, prefer living with children, and prefer living with grandchildren. Usually, it is children and grandchildren living with their parents or grandparents who pay for telehealth solutions and teach their parents/grandparents about using such solutions. The elderly thus benefits from living with their children or grandchildren and trust the telehealth solutions more than those who live alone or who with spouse only.

T-test results suggests regular social activity has a statistically significant effect on Factor 1. Peer pressure from regular social interaction may nudge users to choose telehealth solution over social influence, brand & design, and insurance plans. Survey participants in poor physical conditions often lack social activity, and are subject to less social influence when it comes to use telehealth solutions.

Factor 1 and Factor 2 also differ on whether users exercise regularly. Survey participants exercise regularly are more health aware and are more willingness to spend on telehealth solutions such as wearable and believe in that telehealth solutions may raise health awareness, lower health risks, and amend the gap for community healthcare, and ensure health continuity by improving the unstable doctor-patient relationship.

Table 4.10 explains the correlation among Factor 1, 2, 3 and control variables. The lower-triangular data reports Pearson's correlation coefficients, while upper-triangular data illustrating Spearman's rank correlation. There is no correlation above 0.5 and the average variance inflation factors (VIFs) is well below the acceptable threshold of 10 (Neter, Wasserman, & Kutner, 2003), indicating that data does not have multi-collinearity. The correlation test suggests it is possible to perform ordered logit regression with the explanatory variables.

Table 4.10 Correlation matrix

| | VIFs | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) F1 | 1.04 | 1 | -0.07 | 0.04 | 0.09 | 0.02 | 0.01 | -0.09 | 0.10 | -0.01 | -0.08 | -0.12* | -0.11* |
| (2) F2 | 1.07 | 0.00 | 1 | -0.02 | -0.04 | -0.00 | -0.03 | -0.01 | -0.09 | 0.18* | 0.10 | 0.05 | 0.04 |
| (3) F3 | 1.07 | -0.00 | -0.00 | 1 | 0.13* | -0.02 | -0.15* | 0.06 | 0.14* | 0.02 | -0.08 | -0.07 | -0.05 |
| (4) city | 1.24 | 0.10* | -0.03 | 0.13* | 1 | 0.02 | -0.28* | -0.00 | 0.18* | -0.28* | -0.21* | -0.20* | -0.11* |
| (5) age | 1.24 | 0.03 | 0.01 | -0.02 | 0.02 | 1 | 0.01 | -0.29* | 0.34* | -0.06 | 0.07 | -0.14* | 0.02 |
| (6) gender | 1.12 | 0.01 | -0.07 | -0.14* | -0.27* | 0.02 | 1 | 0.01 | -0.11* | 0.09 | 0.10* | 0.02 | -0.03 |
| (7) education | 1.16 | -0.09 | 0.02 | 0.09 | 0.00 | -0.27* | -0.03 | 1 | -0.14* | 0.16* | -0.04 | 0.14* | 0.15* |
| (8) health status | 1.24 | 0.10 | -0.07 | 0.15* | 0.18* | 0.34* | -0.11* | -0.14* | 1 | -0.03 | -0.05 | -0.08 | 0.04 |
| (9) income | 1.19 | -0.03 | 0.19* | 0.04 | -0.22* | -0.06 | 0.06 | 0.18* | -0.00 | 1 | 0.25* | 0.13* | 0.07 |
| (10) living situation | 1.09 | -0.05 | 0.08 | -0.06 | -0.16* | 0.07 | 0.09 | 0.01 | -0.05 | 0.22* | 1 | -0.01 | -0.00 |
| (11) regular sociability | 1.21 | -0.12* | 0.08 | -0.07 | -0.20* | -0.15* | 0.02 | 0.15* | -0.09 | 0.12* | 0.01 | 1 | 0.33* |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| （12）regular exercise | 1.17 | -0.11* | 0.10* | -0.04 | -0.11* | 0.01 | -0.03 | 0.15* | 0.03 | 0.08 | 0.01 | 0.33* | 1 |

Lower-triangular cells report Pearson’s correlation coefficients, upper-triangular cells are Spearman’s rank correlation

**Factor 1**

Ordered logit regression results suggest that Factor 1 have no statistically significant impact on the preference for telehealth solutions (See Table 4.11, Column 1&4). Hypothesis 1 is rejected.

The homogeneity of direct-to-consumer telehealth solutions can lead to the indifference of users over price, design, privacy risk and brand & design of telehealth solutions. Currently, telehealth solutions providers focus on providing heterogeneous solutions at lower prices. This lowers product profits and deter progress made in data interoperability and the acceptance of telehealth solutions by healthcare service providers. Some solution provider choose to cut core component configurations in order to reduce costs, thus failing to guarantee the quality of the solution. Some solution providers have made active attempts in marketing, such as offering installment interest-free loans to attract users. Although promotion and marketing remains important, equipment manufacturers may consider to improve the competitiveness of their products by promoting the medical value of their solutions , integrating the solution with the EHR system, providing non-invasive monitoring equipment, improving data accuracy and privacy protection.

**Factor 2**

Hypothesis 2 suggests that the correlation between the willingness to use telehealth solutions and the health-related reasons. The regression coefficients of Factor 2 in Model 2 and Model 4 of Table 4.11 are positive at significance level ($p=0.01$). Hypothesis 2 proves to be valid. It suggests that users do believe telehealth solutions can improve health awareness, reduce health risk, amend the gap for community healthcare service, improve care continuity has a positive impact on the willingness to use telehealth solutions. Meanwhile, doctor's suggestions and prescription play a role in driving users to choose telehealth solutions over traditional health solutions as well. Elderly (>= 50 years old) users have strong demand for self-care and health management anytime and anywhere. Telehealth solutions which are easy-to-operate, easy-to-carry, easy-to-learn etc., can effectively meet the demand of elderly users for self-care and health management. Moreover, with the global need for qualified clinicians (Philips, 2021), there is a going to be greater demand for telehealth solutions.

**Factor 3 and preference**

Hypothesis 3 assumes that data accuracy risk has a significant impact on the preference of elderly users. Table 4.11 suggests that the belief on the accuracy of data collected by telehealth solutions is negatively related to the preference for telehealth solutions in Model 3 and Model 4. Compared with traditional health management methods, telehealth solutions offer convenient ways for keeping health record and healthcare management at home. However, elderly users do not trust data collected by telehealth solutions. For example, elderly patients with hypertension prefer to go to the doctor to take blood pressure instead of Bluetooth connected blood pressure monitor at home. With lack of integration of EHR system, doctors cannot use the non-continuous data, even if the data collected by telehealth devices is relatively

more accurate. There are also technical trust challenges on whether the algorithm were trained by accurate data representative of the potential user group. Human trust on the usability of the system, and the regulatory trust related to the ethical, legal and social implications of the use of AI in healthcare issues are also important to address (Philps, 2020). With elderly users, it is quite important to address the system usability issue of telehealth solutions and build human level trust.

Table 4.11 Ordered logit regression

| | (1)<br>y | (2)<br>y | (3)<br>y | (4)<br>y |
|---|---|---|---|---|
| y | | | | |
| F1 | -0.0227 | | | -0.0687 |
| | (-0.2449) | | | (-0.7299) |
| F2 | | 0.4628*** | | 0.4821*** |
| | | (4.7735) | | (4.9667) |
| F3 | | | -0.2554*** | -0.2856*** |
| | | | (-2.7108) | (-3.0028) |
| Living city | -0.0235 | -0.0463 | -0.0062 | -0.0201 |
| | (-0.2604) | (-0.5109) | (-0.0688) | (-0.2208) |
| Age | 0.0151 | -0.0126 | -0.0018 | -0.0354 |
| | (0.1553) | (-0.1291) | (-0.0180) | (-0.3599) |
| Gender | 0.2882 | 0.3820** | 0.2349 | 0.3426* |
| | (1.5150) | (1.9995) | (1.2331) | (1.7801) |
| Education | 0.1317 | 0.1232 | 0.1565 | 0.1432 |
| | (1.0778) | (1.0082) | (1.2692) | (1.1548) |
| Health status | 0.0743 | 0.1365 | 0.1105 | 0.1881* |
| | (0.7034) | (1.2821) | (1.0352) | (1.7290) |
| Income | 0.3707*** | 0.2919*** | 0.3908*** | 0.3124*** |
| | (3.3153) | (2.5934) | (3.4734) | (2.7589) |
| Living situation | 0.0545 | 0.0392 | 0.0446 | 0.0176 |
| | (0.4400) | (0.3158) | (0.3595) | (0.1403) |
| Regular | 0.1871* | 0.1714* | 0.1745* | 0.1477 |

| | | | | |
|---|---|---|---|---|
| sociability | | | | |
| | (1.8191) | (1.6619) | (1.6979) | (1.4264) |
| Regular exercise | -0.0572 | -0.0865 | -0.0739 | -0.1112 |
| | (-0.4688) | (-0.7035) | (-0.6018) | (-0.8957) |
| / | | | | |
| cut1 | 0.2413 | -0.0892 | 0.3436 | 0.0051 |
| | (0.3870) | (-0.1409) | (0.5525) | (0.0081) |
| cut2 | 0.8524 | 0.5444 | 0.9582 | 0.6410 |
| | (1.3655) | (0.8603) | (1.5396) | (1.0176) |
| cut3 | 1.4328** | 1.1476* | 1.5463** | 1.2529** |
| | (2.2905) | (1.8128) | (2.4788) | (1.9874) |
| cut4 | 2.0140*** | 1.7503*** | 2.1378*** | 1.8692*** |
| | (3.2067) | (2.7573) | (3.4116) | (2.9555) |
| cut5 | 2.7125*** | 2.4713*** | 2.8467*** | 2.6050*** |
| | (4.2729) | (3.8550) | (4.4916) | (4.0764) |
| cut6 | 3.5332*** | 3.3192*** | 3.6761*** | 3.4697*** |
| | (5.4793) | (5.1027) | (5.7065) | (5.3477) |
| *N* | 390 | 390 | 390 | 390 |
| Pseudo $R^2$ | 0.0169 | 0.0322 | 0.0217 | 0.0384 |

*t* statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

To validate the model, 10 samples were randomly selected from 390 participants to predict the probability of each participant's preference for telehealth solutions. The prediction made by the model is compared with the answer in the questionnaire for validation. Taking the first randomly selected sample as an example, the model suggests the survey participant is most likely to choose 1 (1= preference for traditional health solutions, 4= neutral, 7= preference for telehealth solutions). The model suggests that the user's preference to use telehealth solution is low, consistent with the user's actual choice (Y=1). Among the 10 selected samples, 8 participant's preference choice were successfully predicted (see Table 4.12). With a prediction rate of 80%, the model is validated.

Table 4.12 Model validation

| No. | p1 | p2 | p3 | p4 | p5 | p6 | p7 | Y | Prediction results |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **0.336** | 0.153 | 0.149 | 0.127 | 0.107 | 0.070 | 0.058 | 1 | yes |
| 2 | **0.437** | 0.158 | 0.136 | 0.104 | 0.079 | 0.049 | 0.039 | 1 | yes |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | **0.174** | 0.111 | 0.139 | 0.153 | 0.163 | 0.131 | 0.129 | 1 | yes |
| 4 | 0.127 | 0.088 | 0.121 | 0.148 | **0.178** | 0.161 | 0.177 | 7 | no |
| 5 | 0.135 | 0.093 | 0.124 | 0.150 | **0.176** | 0.155 | 0.167 | 7 | no |
| 6 | 0.052 | 0.042 | 0.067 | 0.101 | 0.164 | 0.212 | **0.362** | 7 | yes |
| 7 | 0.044 | 0.036 | 0.059 | 0.091 | 0.154 | 0.213 | **0.402** | 7 | yes |
| 8 | 0.130 | 0.090 | 0.122 | 0.148 | **0.177** | 0.159 | 0.173 | 5 | yes |
| 9 | **0.202** | 0.122 | 0.145 | 0.152 | 0.153 | 0.117 | 0.110 | 1 | yes |
| 10 | 0.076 | 0.058 | 0.088 | 0.124 | 0.179 | 0.199 | **0.276** | 7 | yes |

## 5 Summary

The study analyzed questionnaire data collected in Shenzhen, Hangzhou, Wuhan and Yichang over the willingness to use telehealth solutions among the above 50 years old age group.

The analysis started with principal component analysis and categorize all likert scale variables in three factors. ANOVA and T test is used to verify the influence of demographic variables on Factor I, II, III. The ordered logit regression results suggests that F1 has no significant impact on preference for telehealth solutions, indicating the homogeneity of direct-to-consumer telehealth solutions. F2 is positively related to the willingness to use telehealth solutions, and F3 is negatively correlated with the willingness to use telehealth solutions. This suggests there is a need to address the gap for community healthcare and ensure healthcare continuity between different levels of healthcare institutions in China by telehealth solutions. Meanwhile, telehealth solution providers shall focus on improve users' health awareness and lower healthcare risk for chronic diseases by addressing lifestyle changes such as regular exercise and regular social activity. The interoperability between the EHR system and telehealth solutions remain a hurdle in adding value in healthcare for telehealth solutions. The hurdle lies in the fact that doctors cannot make adjustment in healthcare plans nor diagnosis based on data collected by telehealth solution.

The use of AI in healthcare has been rapidly accelerated by COVID-19. Because of social distancing and the highly communicable nature of the disease, the use of telehealth solutions grew exponentially with spending on such solutions increased as well. Growing COVID-19 patients has taken up hospital and medical resources rapidly, leaving many patients with chronic diseases short of medical care. The importance of using tele-monitoring and telehealth solutions in and outside the hospital setting has become more important than ever. 41% of the population has started to use telehealth solutions since the beginning of 2020 (CDC, 2020).

During the pandemic, many technologies which has been sitting on the shelf for years finally went into commercialization such as Omron's PPG based wrist blood pressure monitoring bracelet. Still, for the elderly user group, challenges remain for elderly users to pay for telehealth solutions and improve the usability of such solutions. Improving the transparency of AI, integrating of telehealth solutions with the EHR system proves to be key for promoting trust of telehealth solutions for elderly users.

The next step of research is about how to improve the trust for telehealth solutions by improving the transparency of AI. This can be done by explaining to the public about how the algorithms used by telehealth solutions are built and the data sources and whether it is representative of the targeted user group. Meanwhile, there is a need to improve the data interoperability between telehealth solution and hospital EHR systems. Telehealth solution providers have the opportunity the address the gap presented by lack of community healthcare and unstable doctor-patient relationship in China. The focus on building such solutions can be shifted to improve health awareness and lower health risk for users.

**References**

Alexander, G. C., Tajanlangit, M., Heyward, J., Mansour, O., Qato, D. M., & Stafford, R. S. (2020). Use and Content of Primary Care Office-Based vs Telemedicine Care Visits During the COVID-19 Pandemic in the US. JAMA Network Open, 3(10), e2021476. https://doi.org/10.1001/jamanetworkopen.2020.21476

Baker, L. C., Johnson, S. J., Macaulay, D., & Birnbaum, H. (2011). Integrated Telehealth And Care Management Program For Medicare Beneficiaries With Chronic Disease Linked To Savings. Health Affairs, 30(9), 1689–1697. https://doi.org/10.1377/hlthaff.2011.0216

Bloom, D. E., Chen, S., Kuhn, M., McGovern, M. E., Oxley, L., & Prettner, K. (2020). The economic burden of chronic diseases: Estimates and projections for China, Japan, and South Korea. The Journal of the Economics of Ageing, 17, 100163. https://doi.org/10.1016/j.jeoa.2018.09.002

Fiebig, D. G., Keane, M. P., Louviere, J., & Wasi, N. (2010). The Generalized Multinomial Logit Model: Accounting for Scale and Coefficient Heterogeneity. Marketing Science, 29(3), 393–421. https://doi.org/10.1287/mksc.1090.0508

Gustke, S. S., Balch, D. C., West, V. L., & Rogers, L. O. (2000). Patient Satisfaction with Telemedicine. Telemedicine Journal, 6(1), 5–13. https://doi.org/10.1089/107830200311806

Haynes, S. C., Tancredi, D. J., Tong, K., Hoch, J. S., Ong, M. K., Ganiats, T. G., … Romano, P. S. (2020). Association of Adherence to Weight Telemonitoring With Health Care Use and Death. JAMA Network Open, 3(7), e2010174. https://doi.org/10.1001/jamanetworkopen.2020.10174haynes

Koonin, L. M. (2020, October 30). Trends in the Use of Telehealth During the Emergence ... Retrieved from https://www.cdc.gov/mmwr/volumes/69/wr/mm6943a3.htm

Kutner, M. H., Neter, J., Nachtsheim, C. J., & Li, W. (2004). Applied Linear Statistical Models w/Student CD-ROM (5th International ed.). Boston, U.S.: McGraw-Hill Education.

Marconi, G. P., Chang, T., Pham, P. K., Grajower, D. N., & Nager, A. L. (2014). Traditional nurse triage vs physician telepresence in a pediatric ED. The American Journal of Emergency Medicine, 32(4), 325–329. https://doi.org/10.1016/j.ajem.2013.12.032

Miner, H., Fatehi, A., Ring, D., & Reichenberg, J. S. (2020). Clinician Telemedicine Perceptions During the COVID-19 Pandemic. Telemedicine and E-Health, 1–5. https://doi.org/10.1089/tmj.2020.0295

Omron. (2021, January 19). OMRON Healthcare showcases heart health innovations at CES 2021. Retrieved February 22, 2021, from https://www.omron-

healthcare.nl/nl/general/news-%26-events/omron-healthcare-showcases-heart-health-innovations-at-ces-2021.html

Philips. (2018). Telehealth: Delivering value across institutional and geographical borders. Retrieved from http://images.philips.com/is/content/PhilipsConsumer/Campaigns/CA20162504_Philips_Newscenter/Future_Health_Index_Report_2018_part_3_Telehealth_Delivering_value_across_institutional_and_geographical_borders.pdf

Philips. (2021, January 8). Pat Baird, Head of Global Software Standards at Philips, discusses AI in healthcare at CES 2021. Retrieved from https://www.philips.com/a-w/about/news/archive/standard/news/articles/2021/20210108-pat-baird-head-of-global-software-standards-at-philips-discusses-ai-in-healthcare-at-ces-2021.html?origin=13_global_en_gpo_li_li___gpo_4389460524_&spid=4389460524&utm_source=li&utm_medium=organic_social&utm_content=4389460524&utm_campaign=gpo_li

Polinski, J. M., Barker, T., Gagliano, N., Sussman, A., Brennan, T. A., & Shrank, W. H. (2015). Patients' Satisfaction with and Preference for Telehealth Visits. Journal of General Internal Medicine, 31(3), 269–275. https://doi.org/10.1007/s11606-015-3489-x

Rho, M. J., Choi, I., & Lee, J. (2014). Predictive factors of telemedicine service acceptance and behavioral intention of physicians. International Journal of Medical Informatics, 83(8), 559–571. https://doi.org/10.1016/j.ijmedinf.2014.05.005

Segrelles-Calvo, G., Chiner, E., & Fernández-Fabrellas, E. (2015). Acceptance of Telemedicine Among Healthcare Professionals. Archivos de Bronconeumología (English Edition), 51(12), 611–612. https://doi.org/10.1016/j.arbr.2015.11.007

Tyrrell Burrus, M., Werner, B. C., Starman, J. S., Kurkis, G. M., Pierre, J. M., Diduch, D. R., & Hart, J. M. (2017). Patient Perceptions and Current Trends in Internet Use by Orthopedic Outpatients. HSS Journal ®, 13(3), 271–275. https://doi.org/10.1007/s11420-017-9568-2

Welch, B. M., Harvey, J., O'Connell, N. S., & McElligott, J. T. (2017a). Patient preferences for direct-to-consumer telemedicine services: a nationwide survey. BMC Health Services Research, 17(1), 1–7. https://doi.org/10.1186/s12913-017-2744-8

Welch, B. M., Harvey, J., O'Connell, N. S., & McElligott, J. T. (2017b). Patient preferences for direct-to-consumer telemedicine services: a nationwide survey. BMC Health Services Research, 17(1), 1–7. https://doi.org/10.1186/s12913-017-2744-8

Whaley, C. M., Pera, M. F., Cantor, J., Chang, J., Velasco, J., Hagg, H. K., … Bravata, D. M. (2020). Changes in Health Services Use Among Commercially Insured US Populations During the COVID-19 Pandemic. JAMA Network Open, 3(11), e2024984. https://doi.org/10.1001/jamanetworkopen.2020.24984

**Appendix: English Version of the questionnaire**

**Smart health solutions - factors affecting users' intention to use questionnaire research**

Hi, I am Nuoya Chen, an early stage researcher for the Marie Curie Heart Project. The HEART project is about health related activity recognition system based on Internet of things. My research topic is on strategic marketing, predicting market trends and gaps where the Internet of Healthcare Things can fill in the next 5 to 10 years. Currently, I am doing some research on user experience and applicable business model for the Internet of Healthcare things. If you are interested in my research, can you please help me to fill out this questionnaire? It will take you 5-10 minutes to go through the questions.

Thank you for your help.

Nuoya Chen

For feedback, please email: c.nuoya@studenti.unimc.it

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1. Do you agree to answer this questionnaire and the data collected will be used for scientific research purpose?
   Yes ---------- 1
   No ---------- -1

2. Which one of the following options your age group?
   <= 18 (including 18) ---------- 1
   19-29 (including 29) ---------- 2
   30-49 (including 49) ---------- 3
   >=50 (including 50) ---------- 4

3. In which city are you a regular resident?

   Shenzhen ---------1

   Hangzhou ---------- 2

   Wuhan ---------- 3

   Yichang ---------- 4

4. Which one of the following options do you prefer?
   Living alone -------- 1

Living with my partner --------- 2
Living with my children ---------- 3
Living with my children and grandchildren -------- 4
Other __please write down your answer if you choose other__

**Part I: Basic information regarding the use of smart health management tools**

Smart health management tools include smart phone apps (such as Alihealth, Ping An Good Doctor, Chun Yu Doctor, Wedoctor, Yue dong quan, etc), wearables (such as Xiaomi Band, Huawei watch and Apple Watch, etc), home use health management tools (such as PICOOC smart scale, Mi Home i-Health blood pressure monitor, Mi Home Hi-Pee Smart Pee Monitor, Smart Sleep Monitor, Smart devices to improve sleep quality, etc.).Can you please choose the right answer based on your use experiences?

5. Do you use smart health devices(smart phone apps, wearables, home based smart health devices) to monitor sleep (sleep time, deep sleep time) or to improve sleep quality?

Yes ---------- 1

No ---------- -1

6. Do you use smart health management tools (smart phone apps, wearables, home-based smart medical devices, etc) to control nutrition and diet (such as to follow low sugar and low salt diet)?

Yes ------- 1

No ---------- -1

7. How often do you use your smart health management tools (apps, wearables, online medication websites, e-health records, etc)?

Often ---------- 1

Rarely ---------- 0

Never ---------- -1

8. Why do you feel there is a need to use smart health solutions?

To control my health situation thoroughly -------- 1

To follow doctor's prescription ---------- 2

My insurance company give me a free product (device, services) ----------3

Other reasons (Please indicate your answer if you choose other reasons)

## Part II

Please answer the questions based on your understanding of your health and choose the best answer you feel.

9. Do you have regular social activities?

Yes ---------- 1

No ---------- -1

10. Do you exercise regularly?

Yes ---------- 1

No ---------- -1

11. How is your health situation in general?

Healthy -------- 1

Suboptimal health ---------- 2

With chronic disease (Does not affect daily life) ---------- 3

With chronic disease (Affect daily life) ---------- 4

12. Do you have one of the following categories of diseases?

Cardiovascular diseases ---------- 1

Diabetes I/II ---------- 2

Hypertension ---------- 3

Chronical Bowel Disease ---------- 4

Chronical Communicable Disease (Hepatitis B infection) ---------- 5

Rheumatic Arthritis ---------- 6

Osteoporosis ---------- 7

Eye Diseases ---------- 8

Cancer ---------- 9

No, I am heathy. / Other _____ ( if you choose other, please write down your answer)

13. Do you believe that smart health solutions can help you to become more aware of your health conditions?

| | Not Helpful 1 | Reasona -bly not helpful 2 | Possibly not helpful 3 | Neutral 4 | Possibly helpful 5 | Basicall y helpful 6 | Helpful 7 | |
|---|---|---|---|---|---|---|---|---|
| Not helpful | ○ | ○ | ○ | ○ | ○ | ○ | ○ | Helpful |

**Part III**

Please choose the reason why you use smart health solutions based your experiences.

14. Based on your experience, do you think smart health apps, wearable, smart home medical devices, internet based medical websites, electronic health records, e-family doctor coverage help to reduce your health risks (chronic disease management, elderly healthcare, etc.)?

| | Not Helpful 1 | Reasona bly not | Possibly not helpful | Neutral 4 | Possibly helpful 5 | Basicall y | Helpful 7 | |
|---|---|---|---|---|---|---|---|---|

| | | helpful 2 | 3 | | | helpful 6 | | |
|---|---|---|---|---|---|---|---|---|
| Not helpful | ○ | ○ | ○ | ○ | ○ | ○ | ○ | Helpful |

15. Do you find an unstable patient-doctor Not relationship as a need to rely on smart health solutions? Do you think smart health solutions can help to improve smart health solutions?

| | Not Helpful 1 | Reasonably not helpful 2 | Possibly not helpful 3 | Neutral 4 | Possibly helpful 5 | Basically helpful 6 | Helpful 7 | |
|---|---|---|---|---|---|---|---|---|
| Not helpful | ○ | ○ | ○ | ○ | ○ | ○ | ○ | Helpful |

16. Are you willing to use to share data collected from smart health solutions with hospitals or doctors?

Yes ---------- 1

No ----------  -1

17. What is your health insurance type?

I have no health insurance ---------- 1

Basic medical insurance schemes (Employee / Resident) --------- 2

Private insurance ---------- 3

Other types of basic medical insurance schemes ---------- 4

Free medical services for civil servants ---------- 5

I don’t know the type of heath insurance I have ---------- 6

18. Do you think whether the coverage of a private insurance plan has an impact on your use of smart health solutions?

| | No impact 1 | With reasonable no impact 2 | With possibly no impact 3 | Neutral 4 | With possibly an impact 5 | With a reasonable impact 6 | With an impact 7 | |
|---|---|---|---|---|---|---|---|---|
| No Impact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | With an impact |

19. Are you willing to share bio-metrics data collected from smart health devices with your insurance company (Ping An, Taikang, Zhong'an, etc)?

Yes ---------- 1

No ---------- -1

20. Do you think lack of community healthcare services is why you use smart health solutions? Are smart health solutions helpful in getting convenient health management services?

| | Not Helpful 1 | Reasonably not helpful 2 | Possibly not helpful 3 | Neutral 4 | Possibly helpful 5 | Basically helpful 6 | Helpful 7 | |
|---|---|---|---|---|---|---|---|---|
| Not helpful | ○ | ○ | ○ | ○ | ○ | ○ | ○ | Helpful |

21. Are you willing to share the data collected from smart health solutions with community care facilities or doctors based at community care facilities?

Yes ---------- 1

No ---------- -1

**Part IV**

Please answer the following questions about factors affecting your use of smart health solutions, and choose the best answer based on your experience.

22. Do you think the accuracy of data collected by smart health management tools has an impact on your intention to use smart health solution?

| | No impact 1 | With reasonable no impact 2 | With possibly no impact 3 | Neutral 4 | With possibly an impact 5 | With a reasonable impact 6 | With an impact 7 | |
|---|---|---|---|---|---|---|---|---|
| No Impact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | With an impact |

23. Do you think privacy risk has an impact on your intention to use smart health devices?

| | No impact 1 | With reasonable no impact 2 | With possibly no impact 3 | Neutral 4 | With possibly an impact 5 | With a reasonable impact 6 | With an impact 7 | |
|---|---|---|---|---|---|---|---|---|
| No Impact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | With an impact |

24. Do you think the price of smart health solutions have an impact on you intention to use?

| | No impact 1 | With reasonable no impact 2 | With possibly no impact 3 | Neutral 4 | With possibly an impact 5 | With a reasonable impact 6 | With an impact 7 | |
|---|---|---|---|---|---|---|---|---|
| No Impact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | With an impact |

25, Do you think the brand and design of smart health solutions (look, fashion and ease to use) affect your intention of use smart health devices?

| | No impact 1 | With reasonable no impact 2 | With possibly no impact 3 | Neutral 4 | With possibly an impact 5 | With a reasonable impact 6 | With an impact 7 | |
|---|---|---|---|---|---|---|---|---|
| No Impact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | With an impact |

26. Have you used smart phone, apps or smart home appliances before?
Yes ---------- 1
No ---------- -1

27. In comparison with traditional health solutions (face-to-face communication, and keep a record with pens and pencils), are you more willing to use smart health solutions?

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Willing to use traditional health management approaches | ○ | ○ | ○ | ○ | ○ | ○ | ○ | Willing to use smart health management tools |

28. Do you think your social network (opinions of friends, family and colleagues) has an impact your attitudes towards the use smart health solutions?

| | No impact 1 | With reasonable no impact 2 | With possibly no impact 3 | Neutral 4 | With possibly an impact 5 | With a reasonable impact 6 | With an impact 7 | |
|---|---|---|---|---|---|---|---|---|
| No Impact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | With an impact |

**Part V**

Please answer questions regarding your background, and choose the best answer which fits you.

29. What one of the following options fit into your family monthly income group?

No fixed income ---------- 0
<= 5000 RMB ---------- 1
5000 - 10,000 RMB (including 10,000) ---------- 2
10,000 -30,000 RMB (including 30,000) ---------- 3
30,000 - 50,000 RMB (including 50,000) ---------- 4

30. Which one of the following options fit into your gender?

Female ---------- 0

Male ---------- 1
I do not want to disclose this type of information. (Please leave it blank)

31.Which one of the following options fits into your education background?
Primary School ---------- 1
Junior/Senior High School Diploma ---------- 2
Vocational Training ---------- 3
College Degree ---------- 4
Graduate School (PhD/MBA, etc) Degree --------- 5