ANALYSIS OF FACTORS INFLUENCING THE DIGITAL TRANSFORMATION OF HEALTHCARE ENTERPRISES DURING POST-PANDEMIC ERA OF COVID-19

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ABSTRACT

At present, digitalization in many industries is changing and gradually permeating in all fields of life, of which the digitalization in healthcare has gradually been recognized and entered on the stage. Covid-19 is the biggest "Black Swan Event" in recent years, disrupting the pattern of China and the world. Impacted by Industrial Digitalization Upgrade and the pandemic, the process of digital reform in the healthcare industry has been further accelerated, represented by AI + pharmaceuticals, telecare, and SaaS systems etc.. All these new digital tools and technologies have successively received large amounts of financing in the primary market, and among them, some high-quality enterprises have had successful IPO. Meanwhile, many traditional medical enterprises are also keeping pace with the times through digital transformation, which all indicate the importance of digitalization of medical enterprises. We hope to explore in this paper the factors behind the digital transformation of medical enterprises that have significantly promote the digital reform of enterprises, and whether the factors such as enterprise R&D, enterprise scale, and enterprise digitalization promotion efforts will accelerate the digitalization process. Based on this background, this paper will conduct in-depth research in this direction. First, in the chapters of Research Background and Research Significance, this paper expounds the issues studied in this paper, and points out the relative economic and social significance; and summarizes previous scholars' research in this field, including the application of digital transformation in other industries, the beneficial efforts on business development and the related factors to accelerate the digital transformation of enterprises. Then, it uses relevant theoretical analysis, such as Solow's Neoclassical Growth Model and other theories to explain the issues studied in this paper. At the same time, based on relevant theories and

literature review, relevant hypotheses are being put forward. According to the current literature research, we assume that enterprise scale, enterprise R&D, and enterprise financialization level are crucial factors in promoting the process of enterprise digitization. Therefore, this paper collects relevant Annual Reports of all healthcare enterprises on the listing market which have already completed the digitalization or arecurrently undergoing digital transformation in 2020 and 2021 after this pandemic. In this paper, we use the frequency of the core word "digitalization" in the Annual Report as the Explained Variable to measure the process of digital transformation of the enterprises; concurrently, we use Enterprise R&D Level, Enterprise Scale and Enterprise Product Commercialization Level as Explanatory Variables in this paper and complements the relevant Control Variables to construct a Panel Regression Model. Besides, the Industry Fixed-Effect and Time Fixed-Effect have been used respectively to control the relevant time trend, and the combination of both was called the "Two-Way Fixed-Effect Model". In addition, the research adopts the method of Cluster Robust Standard Error to adjust in the empirical demonstration to reduce the interference of heteroscedasticity. Finally, according to the conclusions verified by the combination of theory and empirical research in this paper, relevant policies and suggestions are included.

Key words: Digitalization; Solo's growth model; Panel regression; Policy recommendations.

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CHAPTER 1：INTRODUCTION

Research Objective

Currently, China's healthcare industry is at a stage of rapid development, with a market size reached at trillions and with industrial growth rate exceeded 20%. However, compared with others, healthcare has still been an industry with relatively slow development, due to the fact that medical products involve ethics and morality, which are related to life, health and safety. The R&D development is slow often with huge investment; and the permeability efficiency of other industries' technologies into healthcare has been always tardy, therefore the industry is relatively more closed. Since 2015, China's digitalization has developed rapidly with the emergence of companies such as Alibaba, Tencent and etc. Upon their mature technology and a large number of talents, many companies seek to infiltrate AI and digital technology into the development of the healthcare industry: The development of mobile Internet - the maturity of artificial intelligence and other technologies such as the enhancement of computing power, big data have advanced the digitalization process of various industries, especially in healthcare. Especially during the pandemic, it promoted online-healthcare and home-detection & home-medical treatment activities, the medical scene started to be anticipated with a lot of digital technologies, such as digital medical treatment, AI+ image, AI +telecare, internet +detection etc. Many start-up enterprises in this field have obtained large amounts of financing with successful IPOs. In the post-pandemic era, online medical treatment, home-medical testing, wearable devices to track heart rate and sleep cycle, AI imaging, and etc are made accessible to clinicians and patients. Digitalization advocates a patient-centered

approach, optimizes healthcare-related policies and processes, streamlines operations, and contributes to building trust among all healthcare stakeholders. Although digital transformation in healthcare is much slower compared to other industries, it already shows positive results. In the post-pandemic era, based on the above characteristics of the industry, this research paper seeks to discover how does digitalization happen in the healthcare industry. Will the healthcare industry with such a high investment in R&D also stimulate the digitalization reform of healthcare companies? If so, what kind of factors help to accelerate the digitalization of healthcare industries and companies?

Research Topics

There are more than 200 subdivisions in the healthcare industry, where new technologies and new industries often emerged, with relative fast technology iteration. Based on this, this paper divides healthcare into three categories: innovative drugs, innovative devices, and healthcare service providers. In the pharmaceutical sector, innovative drugs which occupy the largest proportion have discouraged many start-ups and even listed companies due to the high barriers, high failure rate, slow progress, large investment, and etc. Nowadays, the innovative drugs' development is still in the Me-too and Me-better stage, few in the First-in-class. With the introduction of relevant policies released in October 2021, many 'Me-too' and 'Me-better' companies have begun to align with the 'First-in-class' companies, striving to develop new biomarker and new therapies at domestic and overseas market. Therefore, in the current pharmaceutical field, original technology will be the mainstream in the future, and increasing R&D and product upgrading will be the trend. Under this general environment, R&D and digitalization

complement each other and play an increasingly important role. For example, the AI+ biomarker finding, the accumulation of microbiome databases and other technologies are gradually emerging and are widely financed in the primary market. For example, Jingtai Technology, a unicorn company in the field of new drug research with AI, once reached the highest single medical financing amount. There are many large healthcare companies in the secondary market that have also begun to deploy in this field, forming teams and building databases by using AI as auxiliary means for innovative drug research and development. The above market situation also shows the market's recognition of digital technology in the field of innovative drugs. In the innovative drug industry, which will be mentioned later as chemical pharmaceutical, bio-pharmaceutical and Chinese medical pharmaceutical, will R&D promote enterprises' digital transformation? What kinds of factors will affect the digital transformation? Will digital transformation improve industrial efficiency? This will be the first topic of this research.

From the perspective of the device direction, that is, the field of innovative devices mentioned below, digitalization can promote the industry to take a big step towards Precision Medicine. For example, in the field of in vitro diagnosis, with the support of big data, it is possible to rapidly fix position and screen out potential high-risk groups. In the field of medical devices, digitalization process and relevant influence factors are our second research topic.

At the same time, with the listing of foreign company Pear Therapeutics on NASDAQ, digital therapetuics companies in the medical service industry have also begun to emerge in large numbers, obtaining large amounts of financing in the primary market. With the feedback of real-world research data on medical products and public hospitals,

private hospital HIS system and the promotion of DRG policies, many medical big data companies have also begun to go public, and excellent digital healthcare service companies have also begun to emerge in the secondary market, such as Yidu Cloud and Zero Krypton Technology. Based on this, we believe that digitalization is happening quickly in the healthcare service industry and also plays an important role to promote the upgrading and development of the service industry. Therefore, we also study the application of digitalization in the healthcare service industry, which included in this paper as healthcare business, healthcare service, where what kinds of factors will affect the digital transformation of companies? This will be the third topic of our research.

All three topics above are the key issues of this paper, which will be elaborated through data text analysis, and further regression through the model, empirical analysis of the quantifiable impact, and further confirmation of the theory in this paper.

CHAPTER 2: LITERATURE REVIEW & THEORY

Theoretical Basis

Solow's Neoclassical Theory of Growth

This theory describes that under the assumption of perfect competition, the main driving force of economic growth comes from the input of capital and labor, and the neoclassical production function determines that under the condition of constant labor supply, the marginal product utility of capital decreases; the theory believes that resources are scarce, the growth brought by the accumulation of pure material capital is limited. Under the condition of constant population growth rate and technological progress, the economy will achieve a steady state level of zero growth. This theory is intended to emphasize the two aspects of technological progress and population growth. It is believed that technological progress can significantly improve social productivity and bring positive social development; population growth is the source of power to ensure a country can continue to grow; however, the contribution of capital expenditure to economic growth is limited. The economic growth brought by only capital expenditure is weak and lacks continuity.

The macroeconomic explanation of this theory shows that economic growth depends to a considerable extent on the improvement of labor productivity, on which the factors affecting mainly include human resources, capital, and technological progress. Before 2011, the reason that China's economy could have maintained high growth for more than 30 years was precisely because of the alternating forces of these production factors. But then the contribution rate of these elements began to slowly diminish.

We attribute the contribution of economic growth to the sum of labor quality, total factor productivity and capital density contribution. During the past 30 years, the contribution of labor quality to GDP growth has changed little, while the contribution of capital density (capital/labor quantity) has continued to improve, after the growth rate reached the zenith in 2011, it has continued to decline. But the contribution brought by technological progress has been steadily advancing.

In the past, the huge economic benefits brought by real estate, finance and the Internet have driven the GDP growth rate to maintain a growth rate of more than 5%. But the economic growth brought by the large capital expenditures, is approaching the ceiling; in the future, it shall rely on technological progress, to keep not only a steady growth of China's economy, but also a high-quality growth. Under the pressure of the current geopolitical and macro environment, it has become a consensus in China to develop hard technology and improve social productivity. This trend can be seen from the financial market. Primary market investment often stands at the forefront of the industry and taps the consensus trend that has not yet formed. The author of this paper is engaged in primary market investment and has found that a large number of primary market institutions have begun to shift from the TMT Era to High-Tech Era with technical barriers, a large number of institutions investing in the semiconductor, new energy, and pharmaceutical industries have emerged; Early Investment in hard technological industry has once become a market consensus. China is gradually transforming into the Era of Hard Science and Technology. Under this policy environment, it will be beneficial for domestic enterprises with real technological innovation to usher in better development.

The Solow Model which emphasizes the improvement of social productivity brought by R&D, believes that R&D can maintain a sustainable and continuous economic growth. Therefore, this paper uses Solow's Neoclassical Theory to explain the issues. For the digital transformation of enterprises, R&D plays a key role in the entire transformation process. Healthcare is an industry with high R&D investment. Whether it is innovative drugs, innovative devices, or IVD, innovative therapies and other fields, R&D has always accounted for a considerable amount of proportion. According to statistics, R&D expenses in the field of innovative drugs for the proportion of total revenue at 40%-50%, its large R&D has also brought about the rapid growth of the pharmaceutical industry. Based on this, in the process of a large amount of R&D by healthcare companies, including clinical trial investment, IND application, etc., healthcare companies will invest a lot in new product pipelines, modern technology platform research and development, and will pay more attention to the new technology and new trend, such as digital transformation. The specific performance is that the large amount of R&D enables the innovative healthcare companies to have more innovative perspectives and insights, to identify and cite new technologies, and to improve the overall development efficiency of the companies.

It is typical for existing healthcare enterprises to introduce AI technology to virtually screen targets and compounds through computers due to the difficulty of drug target discovery, which has greatly improved the success of drug screening and reduces drug screening time; under the catalysis of the epidemic, remote-monitoring, and home-monitoring all rely on the accumulation of a large amount of data; IVD companies, related digital therapeutics companies, and AI + Image companies have built their own databases as digital assets through the long-term accumulation of patient data in the industry to

support more accurate product testing, so that the products can be more optimized; another example is the invisible braces represented by the Angel Round, which relies on a large amount of data modeling to construct invisible braces that are more suitable for the patient's oral teeth. The above-mentioned digital cases are common in the healthcare industry. Therefore, we use the Solow Growth Model to emphasize the importance of R&D and believe that R&D can significantly promote the digital transformation of enterprises.

H1: According to the analysis and demonstration in the theoretical model above, the R&D of enterprises has great effects on digital transformation. Based on this, this paper puts forward the first hypothesis: the higher the R&D level of healthcare enterprises, the higher level of digital transformation.

Literature Review

Review of Domestic Literature

Firstly, many scholars have clarified the definition of digitization, which is divided into three stages: informatization - digitization - intelligence, which means that for any enterprise, the first step is the collection and accumulation of information; then by accumulating a large amount of data, it can further analyze data and explord the related the economic meaning, to help enterprises for digitalization. On this basis, it is possible to achieve intelligence by using big data to reduce internal losses, improve the efficiency of product development and help further refinement of products.

According to Yan Zichun, Li Xin (2021), the digital economy has gone through three stages in the world.

The First Stage: the budding period - the innovative development of digitalization (1998-2002), since the 1990s, the user number of global Internet has achieved a leap from 2 million to more than 200 million; information technology, information systems and other E-commerce software have gradually been taken seriously, and a large amount of Data and information began to flow through the Internet, and the Era of Information arrived. During this period, the development is concentrated in Europe and the United States, China is still at the embryonic stage.

The Second Stage: Entering the development period - industrial development based on digital technology (2003-2014). During this period, global broadband technology was updated iteratively, and the Mobile Internet Era with wireless technology as the underlying layer came. The United States and China are the most successful, with world-class companies such as Amazon, Oracle, Microsoft and Apple emerging in the United States and Alibaba, Tencent and Jingdong in China. With the maturity of the Internet Era, the incremental era is no longer. Digital technology begins to spill over to other industries, bringing intelligence to the manufacturing, pharmaceutical and energy industries.

Thus, the digital era has entered a Third Stage of development: from 2015 to the present, starting with the German government's "Industry 4.0 Concept", the digital economy has gradually begun to combine with various industries, with digitalization promoting the upgrading of the industrial end, improving the operational efficiency of the industry and driving up the business value of the relevant industries; digital innovation also promotes the innovation of relevant models in the industry and breeds new ecologies. As the core competitiveness in the digital era lies in using data, discovering customer preferences, and creating demand for customers, thus digitalization has also given rise to

new entrepreneurial entities that use the combination of digitalization and innovation to promote the rapid development of China's industries.

Regarding digital transformation, it is currently among the key research directions of domestic scholars, with more studies in both manufacturing enterprises, light industrial enterprises as well as the service and healthcare industries. Domestic literature is based on enterprises in different industries, and through empirical analysis, verified the role of digital transformation in the process of enterprise development. The main demonstration is that digitalization improves the efficiency of enterprises, promotes the division of labor, significantly reduces the cost of attrition within enterprises, and contributes to the rapid and healthy development of enterprises.

Liu Shuchun (2021) made statistics on 1950 enterprises, collected tracking survey data on the implementation of digital management during five consecutive years from 2015 to 2019. He believed that digital transformation has a positive impact on the improvement of the company's development efficiency, but this impact is significant hysteresis; different enterprises respond to digitalization in different extent. In heavy industry, digitalization accounts for more than 10% of the industry's added value, compared to only 4% in light industry, and there is a large gap between heavy and light industry, in terms of the direction of digital transformation. At the same time, there is an interval in the degree to which enterprises conduct digitization, which is when the critical point of digitization investment is between RMB 1-2 million, the first-mover advantage of digital management of enterprises can be greatly improved.

Yuan Chun (2021) uses empirical and theoretical analysis to explore the impact of digital transformation on the division of labor in enterprises, and concludes that digital

transformation can significantly promote the division of labor in enterprise specialization, and can promote the division of labor in enterprises by reducing the external transaction costs of enterprises, and the effect of digital transformation on the division of labor in enterprises with lower internal control costs, manufacturing industries and competitive industries is more significant, and digitalization can also significantly promote the division of labor and increase the productivity of enterprises.

Using relevant micro data, Liu Zheng (2020) empirically examines the impact of digitization on organizational empowerment behavior and shows that digitization can weaken executive power and enhance power at the grassroots level, helping companies to decentralize power to ordinary employees, enhancing employees' sense of belonging, improving management efficiency, and reducing management costs. Meanwhile, in state-owned enterprises or large enterprises of central government, for example, that bear more policy burden, the role of digitization is relatively weaker than in private enterprises.

Li Xiaoxue (2020) argues that digital transformation is necessary for the development of the retail industry, and that the essence of retail digitalization is the economic value behind the data that can create demand for customers. The change of the production and distribution supply system with consumer demand at its core can drive strategic thinking, streamlined business processes and rational organizational structures in retail enterprises. The article argues that regardless of the stage of digital transformation in retail enterprises, the digital business system is their ultimate ecology.

Wang Chunying (2021) argues that digital transformation is both the integration of traditional manufacturing enterprises with digitalization, which can significantly promote the upgrading of the enterprises' own industries and improve the efficiency of their

operations. At the same time, facing to the problems encountered by enterprise digitalization, he believes that digital transformation is the key to accelerate the process of many traditional enterprises, and the government should also create a digital operating environment for SMEs, to increase the construction of digital infrastructure, deregulate digital enterprises, increase the support for SMEs, and promote cooperation between industry with academy & research to jointly promote the conversion of digital achievements.

Yi Jingtao (2021) shows that digitization also has a positive impact on enterprises' exports, as it can help enterprises to conduct export trade, open supply chains at lower costs and improve their export efficiency in the face of increased competition, insufficient domestic demand, and overcapacity in the industry. Concurrently, he emphasized the policy environment quality may impact on the digitization. The promotion of exports will be more obvious when the economic or policy environment is poor.

Qi Fei (2021) sees the digitization of healthcare as a new scenario of applying information technology to healthcare, and a key development direction and goal within the future public health system. At the same time, digitization will also permeate several segments, jointly promoting the digitization and intelligence of the healthcare industry. At present, healthcare digitization is no longer the traditional internet healthcare, but a broad category including traditional healthcare and new healthcare informatization (informatization), healthcare big data and blockchain technology and application (datafication), healthcare AI and smart hardware (intelligentization), etc, and moreover, it includes digital upgrading and reengineering with all relevant parties in the healthcare industry as the main body.

According to Ma Haoran (2021), data such as medical filing has been also increasing geometrically, and the phenomenon of data redundancy and information silos is widespread. The application of medical digital platforms will provide more accurate analysis and prediction of healthcare big data and provide a rational basis for medical decision-making.

Hu Zhao (2022) argues that digital healthcare helps to facilitate the management of DRG systems, which stands for Diagnosis Related Groups, the sum of disease-based cost classification, case group-based management systems, payment methods, etc., and is used as a set of tools for performance evaluation of healthcare services and cost management. The article argues that digitization can help hospitals to analyze their systems at a more granular level, helping them to improve their DRG systems and optimize their in-hospital management.

Wu Chong and He Jichun (2021) argue that digitization can improve healthcare efficiency and help companies control costs by eliminating data opacity and information silos caused by different systems, helping doctors and patients to better utilize and tap into the value of data, improving clinical diagnosis efficiency and patient awareness; at the same time, based on the construction of information technology, costs and payment segments can be more standardized; using a large amount of data, doctors can refine their diagnosis and choose medical treatments that are more conducive to patients' recovery. However, the overall situation is still at a early stage of application.

Nai Cunjian (2015) argues that although China has made significantly improves in the development situation of medical informatization in recent years, there is still a large

gap between the overall process and foreign countries; China's informatization system is still in the initial stage, with varying levels of infrastructure.

Wu Ziyan (2018) believes that the Era of Medical Big Data and Informatization is more conducive to accelerate the overall efficiency of the medical industry, improve the accuracy of doctors' diagnosis, and help doctors to refine the management of patients; however, due to the special nature of the healthcare industry and the confidentiality of medical data, it is difficult to collect relevant structured data, and the desensitization of data and the meticulousness of granularity requirements are all constraints to the development of informatization in the healthcare industry. At the same time, the traditional consciousness of some healthcare workers as well as patients has led to the fact that medical digitization has been in a slow development process.

Zhao Feng (2018) and others point out in their article that digital technology has been applied in several fields in the healthcare industry, among which the field of ophthalmology is more significant. The current applications in ophthalmology are mostly focused on digital screening, such as Eagle Pupil Technology's AI+ fundus oculi screening device, which can improve the accuracy of disease screening through the accumulation of enormous amounts of data, such as for screening diabetic retinopathy and for improving the accuracy of fundus disease examination.

Liang Yimin (2019) believes that digitalization is increasingly being used in the healthcare industry and is also gradually bringing breakthroughs in a number of emerging areas, such as the most basic integrated management of outpatient registration and queuing; the emergence of electronic medical file to realize the informatization of medical data; radiology information systems and transmission systems, etc. and their negative-free and

wireless station; remote monitoring technology for home-care, 5G telemedicine technology; digital technology with biomedicine, such as digitization of oral treatment, AI + new drug development, digital therapy, etc.

Tong Yu (2022) believes that digital transformation in the manufacturing industry is imminent, and the factors that influence digital transformation in the manufacturing industry are mainly executive education, enterprise scale as well as R&D investment and financial support; from the empirical research by industry, R&D investment has the biggest impact on digital transformation in labor-intensive industries, while enterprise scale has the biggest impact on digital transformation in capital-intensive industries; executive education has the greatest impact on the biggest impact on digital transformation in labor-intensive industries.

H2: Based on this, then, this paper proposes a second hypothesis: healthcare enterprises' size is proportional to digital transformation; the larger the enterprise size, the higher the total assets of the enterprise, the higher level of its digital process transformation.

According to Xu Han (2021), digital transformation can significantly improve social productivity, which is manifested as digital transformation can help enterprises slim down and improve their operational efficiency; accelerate the commercialization process of enterprises and help to expand the revenue, and on the basis of expanding revenue, enterprises further carry out digital fine operations, thus leading to an increase in the productivity of the whole enterprise. From a macro perspective, digital transformation helps enterprises to improve the overall productivity of society.

Zhang Xin, Xu Yaoyu and Ma Liang (2022) argue that digital transformation is not driven by a single factor but by a combination of several external factors, because a single

factor cannot lead to digital transformation but must be the result of a combination of factors, with the characteristic of "multiple concurrency". The authors also verify this conclusion from an empirical perspective, and the results of the study show that: digital strategy, top management, policy support and partnerships play decisive roles in the process of digital transformation; for enterprises, digital transformation must be a comprehensive, specific and systematic work, in this process, technology is a very important part, but the construction of the digital ecology of the enterprise is more important. But for the all-round digital transformation of enterprises, it shall consider the issue of revenue balance, and often, enterprises with larger revenue scale are more willing to conduct digital transformation.

H3: Based on this, this paper proposes a third hypothesis, namely: the higher level of commercialization of healthcare companies' products, which is the higher the sales revenue, the higher the digital transformation level.

Review of Foreign Literature

Foreign literature considers digital transformation as a digital form of entity value, and many scholars have made initial explorations around digital transformation in terms of driving elements, paths, and values.

Vial (2019) argues that digital transformation of an enterprise is the process of improving an entity by triggering significant changes in its attributes through a combination of information, computing, communication, and connectivity technologies, specifically through digital form, visualizing parts of the business online and making

corresponding predictive models for subsequent and continuous revision of the models to improve the quality of business operations.

In their study, Kane G et al. (2015) argue that the application of digital technology alone is not sufficient to drive digital transformation, and that a company must have an adequate strategy of digitalization, culture, and talent development to ensure the success of digital transformation.

Eller (2020) and others state, most of the existing studies are generalized and descriptive summaries of firms' digital transformation practices, but some scholars have also used empirical methods to examine the direct or indirect impacts of certain antecedent variables on digital transformation, for example, factors such as R&D and company size, which can facilitate the digital process and help companies to undergo digital transformation.

Gurbaxani and Dunkle (2019) argue that digital strategy, top management, policy support, partnerships, and value co-creation mechanisms play a core role in the digital transformation process of SMEs and drive the digital transformation of SMEs through synergistic linkages with other elements, which further validates the powerful effect of organizational readiness and external resources on the digital transformation of enterprises.

Bharadwaj et al. (2013) argue that digital strategy is the key to the success of digitization transformation program, by emphasizing digital leadership, agile and scalable digital operations, digital customer experience and emerging digital innovation, and coordinating the digital transformation process, digital strategy can support organizational transformation and achieve the desired goals of digital transformation.

Relevant scholars emphasize the importance of management to the digital transformation of enterprises, and they believe that management should first have digital transformation awareness, be the first to perceive market changes and make relevant decisions; at the same time, to conducted based on building a digital transformation framework.

TedSaarikko et al. (2020), after researching three categories of technology-, product-, and service-oriented companies, suggest that digital transformation should be a priority for top management; that management keeps companies one step ahead of the transformation journey by becoming digitally aware; and that any company seeking to leverage digital technologies must have the will to adapt its strategies and capabilities to new ways of perceiving and creating value.

In general, digital transformation enables companies to reallocate resources and drive them to value realization through leadership with authority. Managers, in turn, need to be leaders and receivers with relatively elevated levels of acceptance and speed of change to be more likely to drive action and ensure not lose the marketplace.

Hess et al. (2016) argue that the success of a company depends heavily on the motivation and ability of top management to successfully reorganize resources. Accenture's data shows that 58% of the leaders interviewed said that their digital build-up is the responsibility of senior management, which also shows that the most critical among them is the top management of the company. On the one hand, the more senior executives support digital transformation, the less resistance there will be to the internal integration process, the better it will be for increasing the company's investment in digital transformation, capturing the benefits of digital transformation and the ability to anticipate

future growth. On the other hand, managerial leadership is the primary factor in the success of digital transformation.

Karimi and Walter (2015) stated that the ability of managers to continuously monitor market trends, perceive and seize technological opportunities and turn them into business opportunities is more important than ever, by allocating resources appropriately, enabling the successful implementation of digital transformation.

H4: Then based on the previous study, this paper proposes a fourth hypothesis: Team level, i.e. the higher the executive's education level, the higher the digitalization of the company.

Some scholars also emphasize the necessity of digital transformation, suggesting that with the arrival of the Internet Economy, the Digital Era is also gradually accelerating in perspective, and the digital technology behind is a key factor to support digital transformation.

Kane et al. (2015) argue that technical resources and capabilities are not necessary core conditions for SMEs to achieve digital transformation. For enterprises, digital transformation is a holistic, global, and systematic project. In the entire process, technology is an important part of the transformation; but more important is the management of changes and the construction of supporting ecology in the process of enterprise transformation. Only in this way, can better work together to promote the digital transformation of enterprises.

Wade (2015) also suggests that with the gradual acceleration of IT infrastructure construction, mobile tools and applications, shared data platforms and collaboration

applications, etc. provide technical support for enterprise digital transformation, and digital technology has been considered as one of the main drivers of digital transformation.

Proksch et al. (2021) argue that companies need a digital strategy to coordinate all mandatory resources to achieve and enhance competitiveness; instead, the absence of a digital strategy leads to poor decisions and wasted resources.

Maria et al. (2019), in exploring the concept of data technology, point out that digital products, infrastructure, and digital platforms can not only provide communication, collaboration, and computing capabilities with technological tools and systems, but also enable the digitization of services through product service systems, reducing costs, improving internal efficiency, and increasing service orientation. Thus, companies should pay attention to the innovation and optimization of internal digital technologies to seize the opportunities for change and achieve leapfrogging development.

Some scholars also identified and recognized the positive effects of digital transformation on enterprises, and believed that digital transformation could bring a variety of advantages to enterprises, specifically: improving organizational efficiency, reshaping business models, fundamentally improving business processes, etc.

Morton (1991) argues that effective internal implementation of digital technology will lead to a fundamental transformation of the enterprise, and that digital transformation can help the organization can be more efficient, use digitalization to respond more comfortably to market changes, and make relevant adjustments in a timely manner.

Hanelt (2021) and others argue that digital transformation can bring the benefits to organizations, including improving organizational processes, enhancing customer value

propositions, reducing product and service costs, and achieving breakthrough innovation and competitive advantage.

John et al. (2018) also argue that digital transformation contributes to business model reengineering, mainly because, first, digital technologies not only fundamentally disrupt industries but also enables core products or services to be replaced by new digital forms, creating new businesses; secondly, product value delivery methods are reconfigured and the roles of products, services and data in the value chain are changed.

Karimi and Walter (2015) argue that digital technologies, digital innovation, and digitization are fundamentally changing business processes, products, services, and relationships and driving companies to change the business way and employees' mindset, forcing them to restructure in order to survive.

China's Digital Healthcare Development

With the development of the mobile Internet in 2013, digitalization began to officially enter China, but due to the closure of the medical system, the penetration of digitalization in the medical industry has been relatively slow. The digitalization process of China's healthcare industry is divided into several typical stages: In 2010, WeDoctor's predecessor "Registration Network" opened the first step of Chinese healthcare digitalization. In 2015, WeDoctor Internet Hospital was established, creating many precedents such as online prescription, remote medical consultation, online follow-up, etc., and the "Internet + medical health" ecology was formed. In 2020, digital therapeutics entered China, initially known as computational medicine, which used big data to treat diseases, and later changed its name to digital therapeutics as overseas companies went

public. From 2010 to 2020, the development of digital healthcare enterprises has been in a slow exploration stage.

With the outbreak of the pandemic in 2020, the digitalization of healthcare has been significantly accelerated, which can be manifested in several ways:

(1) Supply side: The establishment of China's Internet hospital has accelerated. According to the data, the number of Internet hospitals in China was 32 in 2016, 92 in 2017, 118 in 2018, before the pandemic in 2019, the number of Internet hospitals in China was only 315, and in 2020, with the pandemic, it reached 1,000, and climbed to 1,600 in 2021, which has shown that the pandemic has greatly catalyzed the process of digital healthcare in China.

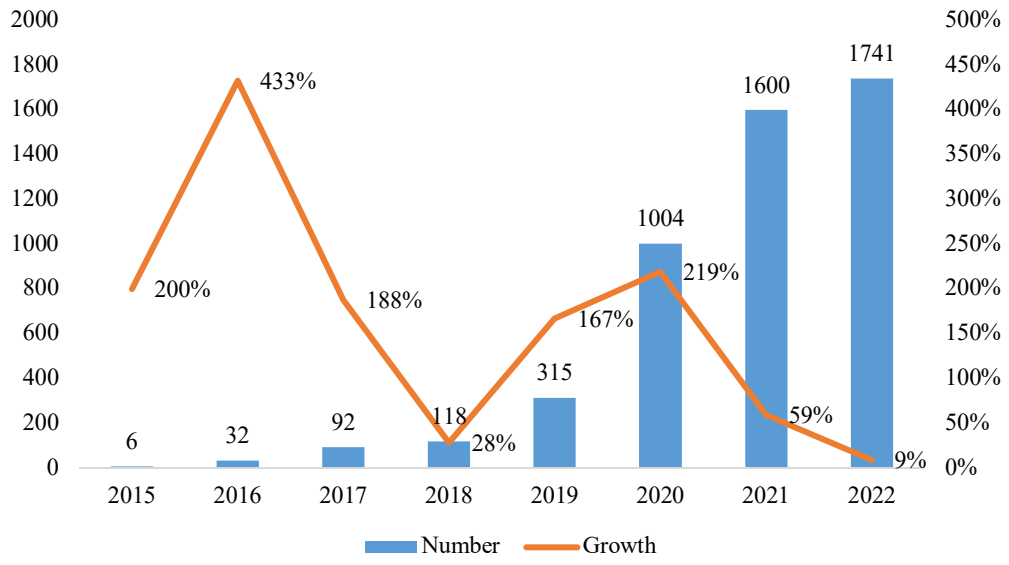

Figure 1 Number of mobile Internet hospitals in China

After 2020, during the pandemic, digital therapeutic became a popular buzz word in 2021, with more than 30 M&A happened including companies like Best Covered、IBIT Infi Brain Tech received more than 100 million financing. The way to provide online healthcare through digitalization is gradually being recognized and accepted by the public.

(2) Demand side: online medical consultation is becoming popular among users and patients who originally accustomed to receiving traditional offline medical services. From the picture shown below, we can also see that in 2016 China's Internet hospital online medical consultation market was almost 0, in 2017 only 30 million people participated in online medical consultation, in 2018 it was 90 million, and in 2020 China's Internet hospital consultation volume reached 900 million, in 2021 it hit a record high, reaching 1.6 billion consultations. It can be seen that the pandemic has greatly accelerated the development of the digital healthcare industry.

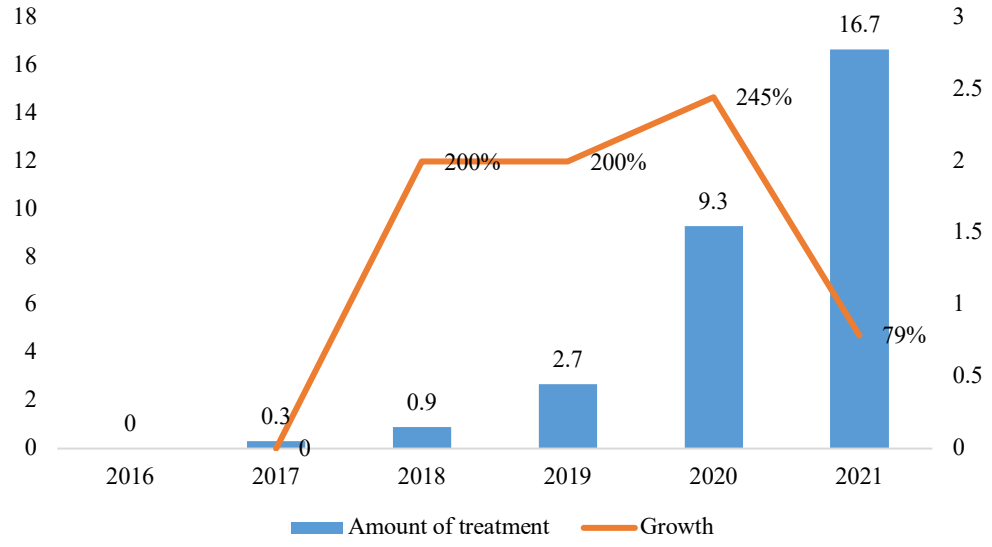

Figure 2 Changes in Internet hospital volumes

CHAPTER 3: INTRODUCTION OF MODEL

Data Collection and Analytical Methods

This article selects 2020 and 2021's A-share listed companies in healthcare as a research sample, the original data of the companies' annual report from Tonghuashun(Flush), financial and other data from Oriental Wealth (Choice). According to the industry classification on Flush, it is divided into medical devices, medical services, medical business, traditional Chinese medicine, chemical pharmaceuticals, and biological products.

At the same time, before the test of the model, the following technical processing treatments are carried out: First, excluded the companies that were delisted in the ST category and the sample period. Second, excluded enterprises with serious lack of relevant financial data. Third, the presence of singular values in the data can interfere with the regression accuracy of this study, which was smoothed with 1% and 99% quantiles for all data (except dummy variables), and all non-ratio variables were added to 1 and logarithmic, that is, ln (X+1).

Model Description

In this paper, Two-Way Fixed-Effect Model is in use. In addition, to alleviate the interference of heteroscedasticity, the study adopted the method of clustering robust standard error in the empirical test.

To explore the influencing factors affecting the digital transformation of healthcare enterprises after the epidemic, this paper establishes the following panel model:

$$DT_{i,t} = \beta_0 + \beta_1 RD_{i,t} + \beta_2 MG_{i,t} + \beta_3 OR_{i,t} + \beta_4 Fin_{i,t} + \beta_5 X_{i,t} + \mu_{i,t} + \lambda_{i,t} + \varrho_{i,t}$$

Among them, where i represents the enterprise, t represents the time, DT is the Interpreted Variable, that is, the level of digital transformation of the enterprise, R&D is the Explanatory Variable representing the degree of innovation, and MG is the Explanatory Variable representing the cultural level of the enterprise executives. OR represents the Explanatory Variable of operating revenue, Fin represents the Explanatory Variable of the total assets of the enterprise, and X is a series of Control Variables μ_i, indicating the enterprise effect, λ_t representing the year effect, which $\varrho_{i,t}$ is a random error term.

Variable Descriptions

Interpreted Variables

This paper uses the degree of digital transformation (DT) as the Interpreted Variable of this paper, and the research on the digital transformation of enterprises mostly stays from the perspective of qualitative analysis (Chen Chunhua et al., 2019; Xiao Jinghua and Wu Xiaolong, 2021), there is few literatures on quantitative measurement of enterprise digital transformation. He Fan and Liu Hongxia (2019) used the "0-1" Dummy Variable of "whether to carry out digital transformation in that year" to measure the digital transformation of enterprises, but this technical processing method cannot effectively show the "intensity" of enterprise digital transformation, nor can it see the evolution of digital transformation in time series, which is very likely to lose a lot of detailed information on the digital transformation of enterprises.

Objectively speaking, it is difficult to capture the degree of digital transformation of enterprises from public financial data alone. However, in general, the management will disclose its implementation process in the "digital transformation" in the Annual Reports,

which represents the strategic positioning of the senior management for the current and future development, thus it reflects the effect of highly guiding operation and development of the enterprise.

Therefore, the study collects the word frequency involving "enterprise digital transformation" from the Annual Reports of listed companies to characterize the intensity of their digital transformation. Select and count the keyword frequency of "digital transformation" in the Annual Report of listed enterprises as a Proxy Variable for enterprise digital transformation. This article obtains the above data in four steps: First, frame the text search thesaurus. Secondly, the Python crawler function was used to collect and sort out the Annual Reports of all A-share listed companies, and the frequency of the keywords related to "digital transformation" in each Annual Report was extracted through Python. Again, read the relevant sentences of the "digital transformation" keyword one by one and cleanse the data. Finally, the frequency of these keywords is collected, and the final total word frequency is formed as a measure of the "intensity" of the enterprise's digital transformation. Because of the typical "right-skewed" nature of such data, the study has logarithmically processed them to obtain a holistic picture of the digital transformation of enterprises.

Explanatory Variables

1) Level of innovation (RD): Represents the technical level of the enterprise; This article uses the R&D expenses in the Annual Report to measure R&D investment of enterprises.

Table 1 Explained variables key indicators

	Keywords
Digital technology	Information Systems, Blockchain, Big Data, Data Mining, Cloud Computing, SPD, Database, Data Center, Data Collection, Data Cleaning, Text Mining, Natural Language Processing, Neural Networks, Deep Learning, Information Security, Network Security, Cloud Servers, AI, Artificial Intelligence, Machine Learning, 5G, 4G, Visualization, Digital Technology, Computer Technology, Information Technology, Intelligent Technology, DBMS.
Digital Commerce	Digitalization, intelligence, data, digital science, business intelligence, business intelligence, Internet, industrial Internet, new retail, new type retail, smart retail, intelligent retail, online retail, new business type, SaaS, PaaS, IaaS, IoT, P2C, P2P.

2) Level of commercialization (OR): The level of products commercialization is defined by the sales revenue of the enterprise, which is measured by the amount of operating revenue in the Annual Report.

3) Team quality (MG): Use executive qualifications (MG) to define the overall level of the team. This article obtains data through the "General Manager's Education" information in the introduction of executives of listed companies. Using Dummy Variables, 0 for undergraduates and 1 for undergraduates and above.

4) Enterprise size (fin): The total assets of the enterprise (enterprise size) (Fin) are used to define the size of the enterprise, which is measured by the total assets amount in the Annual Report.

Control Variables

Enterprise age and its square (Age, Age2), characterized by the natural logarithm of the difference between the sample year and the year of establishment of the enterprise; Return on Total Assets (Roa), using net profit as a percentage of total assets; Return on Equity (Roe), using net profit as a percentage of net assets; Financial leverage (Lev),

expressed in terms of asset-liability ratio, that is, the ratio of total liabilities to total assets; audit, the value taken when the audit opinion is a standard unqualified opinion is 1, otherwise it is 0.

CHAPTER 4: EMPRICIAL REGRESSION ANALYSIS

Descriptive Statistical Analysis

The Explanatory Variable DT's minimum value is 1, maximum value is 268, standard deviation is 30.894, which indicate a large difference in digitalization among the healthcare companies in the sample. The Explanatory Variable R&D's minimum value is 0, maximum value is 0.222 and standard deviation is 0.033, which indicate a large difference in R&D among the healthcare companies in the sample. The Explanatory Variable OR's minimum value is 17.136, maximum value is 24.845, and standard deviation is 1.4, which indicate a larger gap in operating revenue among the healthcare companies in the sample. The Explanatory Variable FIN's minimum value is 17.879, maximum value is 25.82, and standard deviation is 1.119, which indicate a large gap in total assets among the healthcare companies in the sample. In addition, all Control Variables are also significantly different, indicating that these Control Variables are effective in controlling them for a large gap in the operating efficiency of healthcare enterprises.

Table 2 Descriptive analysis of variables

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
DT	Level of digitization	743	26.402	30.894	1	268
MG	Executive education	743	.616	.487	0	1
RD	R&D investment	724	.032	.033	0	.222
OR	Operating revenue	743	21.262	1.4	17.136	24.845
FIN	Total assets of the enterprise	743	22.06	1.119	17.879	25.82
age	Date of establishment	679	21.131	5.943	8	40
age2	Founded time squared	679	481.794	263.737	64	1600
ROA	Return on total assets	743	7.575	11.782	-28.224	65.537
ROE	Return on equity	743	10.146	17.74	-62.027	91.623
LEV	Financial leverage	743	31.024	18.253	4.009	81.144
Audit	Audit Opinions	743	0.964	0.187	0	1

Variable Correlation Analysis

Table 3 Correlation matrix of Explained Variables and Explanatory Variables

Variables	(DT)	(MG)	(RD)	(OR)	(FIN)
DT	1.000				
MG	-0.030	1.000			
RD	0.006***	0.148***	1.000		
OR	0.271***	0.025	-0.246***	1.000	
FIN	0.211***	0.063*	-0.176***	0.874***	1.000

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

From the correlation matrix, it shows that R&D investment, enterprise size and total assets are positively correlated with digitalization. In contrast, executive education shows a negative correlation here and is not significant. Therefore, we can predict in advance that executive education is not a significant influencing factor on the digitization of healthcare companies and may show weak or no correlation results.

Table 4 Correlation matrix of Explained Variables and Control Variables

Variables	(DT)	(age)	(age2)	(ROA)	(ROE)	(LEV)	(Audit)
DT	1.000						
age	-0.051	1.000					
age2	-0.054	0.980***	1.000				
ROA	0.062*	-0.093**	-0.088**	1.000			
ROE	0.104***	-0.066*	-0.068*	0.951***	1.000		
LEV	0.179***	0.185***	0.164***	-0.305***	-0.251***	1.000	
Audit	0.035	-0.063*	-0.054	0.179***	0.222***	-0.146***	1.000

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

From the correlation matrix, it can be obtained that there is some correlation between the Control Variables and the Explained Variables, indicating that the selected

Control Variables are reasonable, and the correlation coefficients are not large, so the possibility of multicollinearity is small.

Regression Results

Benchmark Regression of Panel Data

In the benchmark regression results table, models (1)-(7) include different Control Variables to control industry effects, and time effects respectively for the benchmark regression measures. As can be seen from the data of these seven regression models, the models are robust, with no substantial changes in the results under different Control Variables, and the original results are robust.

From the regression results, the coefficient of executives' education on the digitization level is not significant, indicating that the influence of executives' education on digitization level is relatively low. The effect of technological innovation on the level of digital transformation is positive and shows a strong positive correlation in the regression results of (1)-(7), which is significant at the 5% level, indicating that the more R&D investment, the higher the level of digital transformation. This also confirms the Solow Growth Model mentioned earlier, which essentially shows that R&D has a significant impact on the digitalization of the entire healthcare industry. Operating revenue is also positively correlated with digital transformation and is significant at the 1% level, indicating that the higher the revenue, the higher the level of digital transformation. The total asset of the enterprise is negatively correlated with the digitalization level and is significant at the 10% level, which is a weak correlation and initially defines that the correlation between total assets and the level of digitalization is not strong.

Table 5 The result of regression

VARIABLE	(1) DT	(2) DT	(3) DT	(4) DT	(5) DT	(6) DT	(7) DT
MG	-2.167	-2.664	1.545	2.501	-1.520	0.250	-2.608
	(-0.86)	(-1.10)	(0.67)	(0.99)	(-0.67)	(0.10)	(-1.03)
RD	82.960**	89.624**	77.705**	71.530*	66.845*	73.292*	73.529**
	(2.20)	(2.25)	(2.37)	(1.89)	(1.93)	(1.87)	(1.98)
OR	8.687***	9.049***	6.391***	7.849***	7.697***	7.632***	9.390***
	(4.65)	(4.94)	(3.89)	(3.74)	(3.88)	(3.08)	(3.73)
FIN	-3.779*	-3.746*	-3.633*	-4.294*	-3.952*	-4.767*	-4.726*
	(-1.66)	(-1.68)	(-1.82)	(-1.76)	(-1.69)	(-1.76)	(-1.71)
age		-0.575***	1.284	1.341	0.094	0.221	-2.436**
		(-2.72)	(1.32)	(1.29)	(0.10)	(0.21)	(-2.25)
age2			-0.031	-0.035	-0.010	-0.013	0.041*
			(-1.41)	(-1.55)	(-0.44)	(-0.54)	(1.69)
ROA				-0.055	-0.312	-0.722*	-0.571
				(-0.50)	(-0.95)	(-1.93)	(-1.59)
ROE					0.242	0.446*	0.430*
					(1.04)	(1.79)	(1.79)
LEV						0.069	0.097
						(0.83)	(1.13)
Audit							-2.005
							(-0.31)
Constant	-76.238***	-74.207***	-48.786**	-62.486**	-51.557**	-35.045	-41.067
	(-3.02)	(-2.97)	(-2.01)	(-2.39)	(-2.09)	(-1.29)	(-1.43)
Industry effect	YES	YES	YES	YES	YES	YES	YES
Time effect	YES	YES	YES	YES	YES	YES	YES
Observations	724	672	672	672	672	672	672
R-squared	0.69	0.74	0.60	0.70	0.76	0.75	0.86

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

The results with all Control Variables added in column (7) show that R&D investment is especially important for digital transformation with an impact coefficient of 73.5, which is much greater than the impact of other factors and has a positive coefficient.

Regression Results from Two Years of Data

The data of 2020 and 2021 were respectively analyzed by regression.

Table 6 Regression results of digital transformation of healthcare enterprises in 2020

	(1) DT	(2) DT	(3) DT	(4) DT	(5) DT	(6) DT	(7) DT
MG	-1.4838	-2.2998	-2.4309	-2.5653	-2.7581	-2.5077	-2.5270
	(-0.4525)	(-0.7057)	(-0.7429)	(-0.7825)	(-0.8447)	(-0.7693)	(-0.7739)
RD	-1.8974	-2.6613	-2.7292	-3.2049	-2.9300	-1.6103	-1.6776
	(-0.6228)	(-0.8789)	(-0.8995)	(-1.0359)	(-0.9503)	(-0.5074)	(-0.5260)
OR	12.0786**	12.9614**	13.1960**	11.3285**	9.7344**	7.4980**	7.4474**
	(2.9742)	(3.2144)	(3.2487)	(2.4155)	(2.0551)	(1.5276)	(1.5139)
Fin	2.6618	4.8294	4.8250	7.2085	8.3623	7.5518	7.6578
	(0.4406)	(0.8010)	(0.7994)	(1.0699)	(1.2421)	(1.1219)	(1.1338)
age		-0.8166***	-1.5399	-1.3691	-1.3142	-1.2543	-1.2567
		(-2.8136)	(-1.0807)	(-0.9497)	(-0.9155)	(-0.8759)	(-0.8763)
age2			0.0166	0.0135	0.0121	0.0108	0.0109
			(0.5185)	(0.4155)	(0.3756)	(0.3354)	(0.3392)
ROA				0.1149	-0.6945	-0.5260	-0.5053
				(0.7979)	(-1.6170)	(-1.1956)	(-1.1273)
ROE					0.5794**	0.5205*	0.5030*
					(1.9991)	(1.7876)	(1.6784)
LEV						0.1801*	0.1839*
						(1.6773)	(1.6937)
Audit							1.9862
							(0.2523)
_cons	-96.6083**	-1.0e+02**	-96.1876**	-1.0e+02**	-99.7883**	-88.8458**	-90.8547**
	(-3.0176)	(-3.2124)	(-2.8547)	(-2.9485)	(-2.9274)	(-2.5667)	(-2.5545)
N	341	341	341	341	341	341	341
adj. R^2	0.072	0.091	0.089	0.088	0.096	0.101	0.098

Note: t statistics in parentheses： $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

Judging from the regression results in 2020, the coefficients of enterprise executives' academic qualifications, technological innovation, and total assets on the degree of enterprise digitalization were not significant, indicating that the influence of enterprise executives' academic qualifications, technological innovation and total assets on the degree of enterprise digitalization was relatively low. In the regression results of column (1)-(7), the impact of technological innovation on the degree of digital transformation was positive, and it showed a positive correlation at the level of 5%,

indicating that the more operating income of enterprises, the higher the degree of digital transformation of enterprises. The result of adding all the control variables in column (7) shows that operating income is more important for digital transformation, with an impact factor of 7.44.

Table 7 Regression results of digital transformation of healthcare enterprises in 2021

	(1) DT	(2) DT	(3) DT	(4) DT	(5) DT	(6) DT	(7) DT
MG	-0.3973	-0.6631	-0.8047	-0.7295	-0.6515	-0.6984	-0.6680
	(-0.1325)	(-0.2207)	(-0.2656)	(-0.2399)	(-0.2141)	(-0.2289)	(-0.2185)
RD	10.7644**	9.4502**	9.3127**	9.2013**	9.5573**	9.5503**	9.7411**
	(2.8289)	(2.3904)	(2.3437)	(2.3050)	(2.3813)	(2.3762)	(2.3977)
OR	11.4472**	12.4789**	13.0549**	14.0699**	13.4220**	14.1944**	14.1975**
	(2.2399)	(2.4104)	(2.4255)	(2.2953)	(2.1734)	(2.1332)	(2.1308)
Fin	-13.1061*	-11.9182	-12.2587	-13.0727*	-13.2697*	-13.7091*	-13.9019*
	(-1.7763)	(-1.6024)	(-1.6353)	(-1.6624)	(-1.6862)	(-1.7129)	(-1.7304)
age		-0.3120	-0.7925	-0.8575	-1.0038	-1.0105	-1.0479
		(-1.2141)	(-0.6415)	(-0.6854)	(-0.7951)	(-0.7992)	(-0.8246)
age2			0.0107	0.0117	0.0150	0.0152	0.0160
			(0.3977)	(0.4321)	(0.5487)	(0.5530)	(0.5813)
ROA				-0.0503	-0.4659	-0.4729	-0.5104
				(-0.3476)	(-0.9477)	(-0.9596)	(-1.0099)
ROE					0.3029	0.2892	0.3186
					(0.8846)	(0.8367)	(0.8936)
LEV						-0.0338	-0.0382
						(-0.3145)	(-0.3528)
Audit							-3.2232
							(-0.3441)
_cons	-41.6519	-45.1459	-41.0230	-40.4300	-33.7617	-35.3614	-31.4570
	(-1.3552)	(-1.4636)	(-1.2592)	(-1.2376)	(-1.0067)	(-1.0410)	(-0.8773)
N	331	331	331	331	331	331	331
adj. R^2	0.046	0.047	0.045	0.042	0.042	0.039	0.036

*Note: t statistics in parentheses： * p < 0.1, ** p < 0.05, *** p < 0.01*

Judging from the regression results in 2021, the coefficient of enterprise executives' academic qualifications on the degree of digitalization of enterprises is not significant,

indicating that the academic qualifications of corporate executives have a relatively low impact on the degree of digitalization of enterprises. In the regression results of column (1)-(7), the impact of technological innovation on the degree of digital transformation was positive, and both showed a strong positive correlation at the 5% level. It shows that the more R&D investment, the higher the degree of digital transformation of enterprises. The operating income of enterprises is also positively correlated with digital transformation, and it is significant at the level of 5%, indicating that the higher the enterprise revenue, the higher the degree of digital transformation of enterprises. The total assets of enterprises are negatively correlated with the degree of digitalization, and they are significant at the level of 10%, which is a weak correlation, and the correlation between the total assets and the degree of digitalization is not strong. The result of adding all the control variables in column (7) shows that research investment and operating income are very important for digital transformation, with impact factors of 9.74 and 14.20, respectively.

The regression results in 2021 are closer to the panel regression results, and in the regression results in 2020, only operating income has a significant role in promoting the digital transformation of enterprises. Therefore, we speculate that enterprises may have been hit harder by the pandemic in 2020. The first thing most companies needed to consider was the survival of their business. Only companies with good revenues have more power to promote the digital transformation of their enterprises. In 2021, with the stable control of the pandemic, the R&D investment and operating income of enterprises have a significant positive effect on the digital transformation of enterprises.

Heterogeneity Analysis

To determine whether there is industrial heterogeneity, the paper will refer to the Flush's classification and classify healthcare companies into medical devices, healthcare services, medical business, Chinese medicine, chemical pharmaceuticals, and biologics, and then analyze the differences in the factors affecting the level of digitization of these listed companies, and the regression results are shown in the table below.

The study found that the factors influencing digital transformation in healthcare companies are highly heterogeneous, and the level of influence varies widely for different industries. However, for executive education, it remains insignificant across industry segments. In summary, the results show that the effects of R&D, operating revenue, and total assets on the level of digitalization in different industries are significantly different.

In the medical device industry, corporate revenue is positively correlated at the 5% significance level; R&D investment is weakly correlated at the 10% significance level. This is because R&D is more on the design of the product itself and clinical trials, with less investment in digitalization; however, when the enterprise reaches a certain scale and the product starts to be commercialized, that is, when the product starts to have sales revenue, medical device enterprises start to seek digital transformation. Taking IVD as an example, when the relevant reagents start to be commercialized, enterprises start to focus on the accumulation of database behind to increase the detection accuracy. However, this paper needs to emphasize that the amount of effective data in this industry is only 15, indicating that the overall digitalization level of the medical device industry is not high.

Table 8 Heterogeneous regression results

VARIABLE	Medical devices	Medical Business	Health Services	Chinese medicine	Chemical pharmaceuticals	Biologics
	DT	DT	DT	DT	DT	DT
MG	-4.175	-45.513	-26.319	1.460	-3.027	1.365
	(-0.73)	(-2.01)	(-1.32)	(0.31)	(-1.52)	(0.42)
RD	258.550*	-31,753.844**	1,629.464	340.322*	73.554**	98.219*
	(1.89)	(-2.86)	(1.71)	(1.91)	(2.08)	(2.02)
OR	22.827**	268.923***	-4.151	-12.246*	3.144*	4.983**
	(2.51)	(-4.56)	(-0.18)	(-1.74)	(1.68)	(2.57)
Fin	-15.656*	233.837***	13.816	18.084**	3.297*	-7.321***
	(-1.69)	(4.13)	(0.61)	(2.38)	(1.71)	(-3.38)
age	1.255	-57.545	12.050	-1.815	-0.210	-2.766
	(0.42)	(-1.87)	(0.76)	(-0.68)	(-0.23)	(-1.62)
age2	-0.055	1.698*	-0.251	0.065	-0.003	0.065
	(-0.75)	(2.04)	(-0.63)	(1.11)	(-0.16)	(1.64)
ROA	-0.818	-49.415*	-0.842	-1.496	-0.075	-0.951**
	(-0.56)	(-2.35)	(-0.39)	(-0.93)	(-0.23)	(-2.37)
ROE	0.038	21.893**	0.623	1.847*	0.120	0.552
	(0.04)	(3.20)	(0.66)	(1.74)	(0.65)	(1.68)
LEV	0.054	-5.543	0.323	0.043	-0.049	-0.113
	(0.19)	(-1.65)	(0.53)	(0.20)	(-0.67)	(-1.10)
Audit	11.246	4.275	-0.497	27.153	-9.243**	-1.703
	(0.35)	(1.42)	(-0.02)	(0.99)	(-2.03)	(-0.27)
Constant	-113.349	1,779.466***	-342.257	-149.629**	-109.226***	97.440**
	(-1.36)	(3.64)	(-1.37)	(-2.26)	(-5.06)	(2.55)
Individual effect	YES	YES	YES	YES	YES	YES
Time effect	YES	YES	YES	YES	YES	YES
Observations	15	184	27	126	244	76
R-squared	0.171	0.864	0.328	0.327	0.242	0.459

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

In the chemical-pharmaceutical industry, R&D investment is significant at the 5% level with a coefficient of 73.5; operating revenue and total assets are both significant at the 10% level of significance, and this paper concludes that the correlation between these

two variables and the digitization level is weak. This may be due to the fact that chemical pharmaceuticals are essentially an R&D-driven industry, and the proportion of R&D in the whole life cycle of healthcare companies has been at the highest, while traditional bio-healthcare companies have a slow R&D cycle. With the power of AI, healthcare companies can significantly accelerate their R&D progress, so R&D promotes the digital transformation of enterprises, and digital transformation in turn accelerates the R&D of enterprises. From this perspective, this paper argues that corporate research can significantly contribute to the digital transformation of chemical pharmaceuticals. Therefore, in this regard, this paper concludes that R&D investment can significantly contribute to the digital transformation of companies.

For chemical pharmaceutical enterprises, especially large molecule drugs and small molecule drugs, the core of enterprise success lies on whether the R&D team can complete the milestones within the corresponding time, such as different financing rounds, requiring the enterprise's R&D product progress to clinical phase I, II, III, etc.; many pharmaceutical enterprises are only in clinical phase II or clinical phase III when they go public, and for such enterprises, listing does not require operating revenue but the core lies on the predictability of their R&D and the future commercialization path of their products. Since the whole cycle takes a long time, there is a high potential risk. In the whole research and development process, the cycle of 5-10 years, the traditional Me-better class of drugs, there have been already foreign products introduced, and if domestic companies produce generic drugs, the whole process will be much less, the pre-target screening, molecular structure design, etc. on the basis of the original drug, to develop further; and with the NMPA introduced relevant policies, China began to require biohealthcare companies to go for

First-in-class, from new targets, new molecular institutions, new innovative therapies, etc., sitting on the real global innovation, to encourage enterprises license-out, to become global innovative pharmaceutical enterprises.

Under the change of the above major trend, the original long cycle and high risk of biopharmaceutical industry is further aggravated, from the latest target discovery to drug development and then to the final commercialization of the product, the whole process lasts for at least 10 years, then in this process, enterprises need to rely on continuous financing to live, to ensure the next round of clinical trials, the whole process of the R&D cycle is slow and risky; if once any milestone is not reached, then the next round of financing will face great difficulties, and the lack of funds will make it even more difficult for companies to continue, and they will not be able to promote the next step of R&D, thus leading to a vicious circle.

Based on the above situation, many companies have started to explore the application of digitalization in the whole biopharmaceutical industry, trying to explore whether it can accelerate the whole biopharmaceutical R&D cycle through digitalization. A more representative example is Pharma with AI. In 2020-2021, catalyzed by the epidemic, the whole AI +Pharma industry is very hot, with more than 200 companies involved in AI +target research and AI + molecular structure design; and more than 50+ companies have received large funding. Traditionally, when a biohealthcare company develops a new target, it needs to find out the best drug design by searching a large number of molecular structure designs in the public database and its own database through experimenters. This usually involves a lot of data search work, data screening work and multiple repetitive experiments by experimentalists, often costing a lot of money and time.

In the form of AI, through the accumulation of data in the public database and the construction of its own database, we can train AI tools with a large amount of data to build a virtual screening model, and then apply different molecular structures to the model to achieve online screening; and then do experimental studies on several molecular conformations through screening to further confirm the molecular conformation. The online screening process significantly reduces the screening time and screening complexity, reduces the R&D cost of healthcare companies, and accelerates the R&D progress, which also reduces the cost of R&D. Therefore, the actual case of AI +chemical pharmaceutical companies also support the fact that for chemical healthcare companies, the impact of R&D on the digitalization process is more obvious.

For medical business, R&D investment is significant at 5% level of significance and is negatively correlated; operating revenue is significant at 1% level and is positively correlated; total assets are positively correlated at 1% level of significance. This is because: medical business is more about business model innovation, the core lies on the management of business operations capabilities and other commercialization capabilities, the urgency of digital transformation is not strong. For pharmaceutical distributors, when the business revenue growth is high, the enterprise seeks new growth points and seeks to slim down the enterprise, then it will increase the urgency of need for digital transformation. Through digitalization, real-time supervision of relevant product sales changes and feedback to the back office, on the one hand, can shrink inventory costs; on the other hand, according to digital trends, can reasonably arrange product categories and increase sales revenue. The overall market of medical business does not require high investment in R&D

and pursues more business model changes as well as agency channel, and digitalization provides a good perspective for transformation.

For the Chinese medicine industry, total asset is positively correlated at the 5% significance level, indicating that the Chinese medicine industry is also starting to undergo digital transformation one after another.

For the biopharmaceutical industry, total assets are significantly and negatively correlated at 1% level of significance; corporate revenue is positively correlated at 5% level of significance; and R&D is positively and weakly correlated at 10% level of significance. This may be since biohealthcare companies are mostly research dependent and have relatively low asset requirements. In fact, total assets do not fully represent the size of the company, while corporate revenue is more representative of the overall level and strength of biohealthcare companies. Therefore, for biohealthcare companies, the higher the revenue, the bigger demand for digitalization.

Through the regression results and theoretical explanation of the above model, although only in the chemical pharmaceutical industry, R&D and digitalization show a significant positive relationship; however, in the overall sample, chemical pharmaceutical enterprises account for more than 1/3 of the total sample, driving the results of the whole sample analysis to show a significant positive relationship between digitalization and R&D. Therefore, in terms of the whole biopharmaceutical industry, R&D is still a relatively crucial factor influencing the digital transformation technology of enterprises.

Robustness Test

Replace Interpreted Variables

To ensure the robustness of the results, the regressions were conducted by replacing the Explanatory Variables, and according to the regression results shown in the table, there is a significant positive linear effect between most of the R&D and operating revenue and the Explanatory Variables, which verifies the robustness of the results.

Table 9 test analysis

VARIABLES	(1) Intelligence	(2) Digitization	(3) Informatization	(4) Digital Technology
MG	0.105	0.511	3.607	0.657***
	(0.39)	(1.46)	(0.74)	(3.61)
RD	4.084***	0.518*	0.252**	0.297**
	(7.32)	(1.76)	(2.71)	(2.46)
size	0.225*	0.061***	0.584***	0.059***
	(1.96)	(4.40)	(5.05)	(4.34)
fin1	-0.833*	-0.007	-2.130**	-0.108*
	(1.78)	(-0.09)	(2.44)	(1.94)
age	-0.025	0.039	-0.599	-0.153**
	(-0.06)	(0.94)	(-1.04)	(-2.48)
age2	0.009	-0.001	0.016	0.005**
	(0.80)	(-0.72)	(1.09)	(2.19)
ROA	-0.068**	0.008	-0.056	-0.009
	(-2.54)	(1.58)	(-0.59)	(-0.68)
ROE	0.029	-0.003	0.047	0.008
	(1.58)	(-1.15)	(0.87)	(1.02)
LEV	0.011	0.001	-0.013	0.008
	(0.71)	(0.58)	(-0.50)	(1.60)
Audit	-0.135	0.016	0.409	-0.588
	(-0.26)	(0.10)	(0.22)	(-1.10)
Constant	-24.807**	0.641	-51.907	0.396
	(-2.18)	(0.46)	(-1.53)	(0.20)
Industry effect	YES	YES	YES	YES
Time effect	YES	YES	YES	YES
Observations	672	672	672	672
R-squared	0.77	0.35	0.52	0.40

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

Endogenous Tests

In order to verify is the model whether there is an endogeneity question, i.e., it is possible that companies with a high level of digitization may have a higher R&D. We hypothesize that there is a two-way causal relationship between the level of digitization and R&D, so we set up a 2SLS model with R&D as the Explanatory Variable and estimate it with the level of digitization. Based on the regression results, it is clear the estimation of digitization level on R & D investment is not significant.

Table 10 Endogeneity test analysis

	(1)	(2)
VARIABLES	NUM1	RD
MG	-1.845	
	(-0.82)	
RD	62.497*	
	(1.79)	
SIZE	5.773***	
	(2.78)	
FIN1	-0.621***	
	(-5.27)	
age	-1.183	
	(-1.24)	
age2	0.014	
	(0.69)	
ROA	-0.578*	
	(-1.76)	
ROE	0.477**	
	(2.13)	
LEV	0.099	
	(1.29)	
Audit	-0.896	
	(-0.15)	
NUM1		-0.0006
		(-0.28)
Constant	-69.935***	0.034***
	(-2.79)	(23.39)
Observations	672	672
R-squared	0.088	0.000

*Notes: *** p<0.01, ** p<0.05, * p<0.1*

Through the empirical analysis of the factors of digital transformation in this paper, it is concluded that factors such as R&D investment and total asset will affect relatively the digital transformation of enterprises; at the same time, executive education has a general impact on the level of digital transformation in the biopharmaceutical industry. According to the above conclusions, this paper further uses actual cases to testify the analysis conclusions of this paper.

Case Analysis

In the healthcare industry, the most typical representative of digital transformation is digital therapeutics, of which the essence is to transfer traditional offline treatment to online; through operation at online APP and remote management, to achieve treatment. The emergence of digital therapeutics has also changed the circulation of many traditional medicines, benefiting many parties:

① Value to patients: Gain access to proven technologies that are accessible, easy to use, and improve health outcomes. Digital therapeutics can improve access to treatment for some diseases. Digital therapeutics products realize the migration of treatment scenarios and the transformation of intervention subjects, improve the accessibility of treatment methods for psychological and neurological diseases; can improve patients' compliance with medication or treatment plans, and drive patients to adhere to treatment in a variety of ways, so as to obtain a better therapeutic effect. These methods include gamification, online doctor-patient interaction, and incentive mechanisms; through these methods, digital therapeutics products can enable patients to have a better medical experience. For example, when receiving traditional psychotherapy, patients face

the embarrassment of revealing their privacy, or consciously conceal information to affect the doctor's judgment. Digital therapeutics products simulate the interaction between doctors and patients in digital product modules, and these problems are relatively improved.

Digital therapeutics products can help patients improve their quality of life. Digital therapeutics products help patients prevent the occurrence of some diseases by managing some of their own living habits. Digital therapeutics products can also help patients manage their own chronic diseases by providing targeted solutions to patients, which can help delay disease progression, reduce complications, and improve the quality of post-illness rehabilitation, thereby improving the quality of life for patients living with illness. For example, some digital therapeutics products for postoperative rehabilitation and side effects can relieve patients' negative emotions and reduce the fatigue of rushing to the hospital after surgery. In addition, digital therapeutics products can improve patient satisfaction. Digital therapeutics products have built-in remote interaction modules, which can remotely interact with doctors when patients are at a high-risk state, so that patients can obtain necessary and effective help in a timely manner and gain a better service experience.

② Value to healthcare service providers/Clinicians: Enhance the impact of treatment plans to improve patient health and expand access to care. Digital therapeutics products help improve work efficiency by directly intervening in the disease, improving efficiency compared with the traditional model, which must be provided by doctors. In addition, the doctor-end system helps doctors track patient condition changes and self-management compliance; besides, based on medical principles and data analysis models, it can provide auxiliary diagnosis functions and remind doctors to actively intervene in

high-risk patients in a timely manner. Digital therapeutics can also assist in the development of academic research. The information collected by digital therapeutics products include patient physiology, psychology, lifestyle, natural environment and other dimensions, such as patient basic information, disease status, medication, diet, exercise, sleep, mood, temperature, humidity and other data, which help to enrich doctor's The understanding of the evolution of chronic diseases in different situations, which in return provide more real-world data for clinical research, thereby improving doctors' professional cognition and scientific research capabilities.

③ Value for payers: Reduce overall medical costs and support value-based care initiatives. Digital therapeutics products can help insurance companies control costs. Digital therapeutics products can effectively reduce the incidence of complications, control the number of emergencies, or control the evolution of the disease, thereby helping insurance companies to achieve their demand for cost control. Mainly reflected in: (1) replacement effect, replacing doctors by software; (2) optimization effect, reducing complications and reducing the need for medical treatment; (3) precision effect, data-driven to achieve precise cost control.

④ Value for medical device companies: Collect users' personal health information, provide better service and products, increase patients' adherence, and market DTx (Digital Therapeutics Products) products with existing products to increase sales. Digital therapeutics can provide timely data feedback to help healthcare companies improve the accuracy of marketing. Digital therapeutics products combined with drugs or devices can monitor through their applications the consumption of patients' drugs and

devices, capture potential demand in time, to achieve more accurate and targeted marketing, to bind drugs to improve patient stickiness. The correct judgment of digital therapeutics on the evolution of the patient's condition and reasonable guidance on medication, exercise, and diet can ultimately enable patients to obtain good therapeutic effects and enable patients to have high loyalty to digital therapeutics and the drugs used in combination with digital therapeutics; Real-world data obtained by digital therapeutics can help drug development and evaluation. Real-world data combined with machine learning data analysis can build disease progression models, which is of great significance for new drug development.

⑤ In general, digital therapeutics has benefited many parties, and it has also broken the traditional mechanism of medical devices circulation and admission. Digital therapeutics has changed the untimely treatment that relies on traditional routes, saving the time cost and "shoes cost" spent in hospitals; online treatment through APP, links back-end product supervision, provides patients with preoperative - intraoperative - entire process of postoperative service which is relatively safe and reliable compared with surgical treatment and drug treatment. Then through R & D and large-scale clinical trials, the product has proven its effectiveness clinically. After large-scale hospital admission or TO C-end promotion, we are optimistic about its commercialization scenario. For medical products, the core requirements are clinical effectiveness and safety. Since digital therapeutics has an exclusive advantage in safety and once the product efficiency is ensured, the author of this paper is firmly optimistic about the future of digital development after the market has been educated.

⑥ Focus on products design. First, from the perspective of medical principles, which include, for various mental disorders, cognitive behavioral therapy (CBT), behavioral activation therapy, acceptance and commitment therapy. Behavioral activation therapy is one of types of cognitive behavioral therapy, for depression; acceptance and commitment therapy is the third generation of CBT, for smoking cessation. Cognitive behavioral therapy is a structured, short-term, cognitive-oriented psychotherapy developed by A.T.Beck in the 1960s. It focuses on the irrational cognitive questions of patients and changes the psychological questions by changing the patients' views and attitudes towards themselves, people, or things. Cognitive-behavioral therapy believes that the treatment goal is not only for external manifestations such as behavior and emotions, but also to analyze the patient's thinking activities and strategies for coping with reality, and to find and correct wrong cognitions. The automatic thoughts and core beliefs of people with mental illness are two important parts to be changed in cognitive behavioral therapy. Automatic thinking is the idea that comes out of the brain after encountering an event, and core beliefs are the core part that supports each automatic thinking and are the driving force that guides and drives life. Therefore, what cognitive behavior therapy should do is to identify unreasonable cognition in action, replace unreasonable cognition in action, and change core beliefs in action. It can be seen that action is a very important part. The technical difficulty of digital therapeutics products for mental diseases is to design action plans that can change patients' cognition based on behavioral cognitive therapy and supported by software. In the design, requirements are placed on the scientific accuracy of the protocol and its own attractiveness to patients. While in line with medical principles, it is also necessary to make patients willing to participate in, to produce substantive actions,

to change, and to obtain therapeutic effects. For each digital therapeutics product with the same indication, the content, form, and completion cycle of the action plan are some aspects that can achieve differentiated competition.

back to the digitalization itself, the core of product effectiveness relies on the company's efforts to improve the efficacy of products and constantly improve patient compliance through a large amount of R&D investment, investment in algorithms, clinical experiments, product design, etc. Digitalization is an emerging industry, which is different from innovative drugs, innovative therapies and innovative devices, requires a strict clinical trial - certificate - admission process; digital therapeutics itself is more inclined to APP software management, intelligent operation, etc, which can directly face to the public in providing products with therapeutic functions. Some practitioners also believe that, based on digital logic and its TO C logic, it is not required in essence strict evidence-based medicine and clinical effectiveness evidence. But for now, whether Slan Health or BestCovered, IBT Brain Intelligence Technology and other enterprises in China that have received financing more than 100 million RMB, there are tens of thousands of clinical cases behind them, as well as the results of clinical effectiveness tests, which are also based on a large number of doctor teams to capture patients related data; Then based on this, the R&D team can make relevant product development and design. Due to the complicated content involved in digital medicine, the core is to find a model that has a relationship between effective pictures or links and relevant indicators of the human body. By building this model or this path, design products, and continuously feed through data to improve the effectiveness of product treatment.

In this process, R&D personnel need clinical data, evidence-based medical evidence, algorithm design + content, image design and other designs, which will test the comprehensive strength of the team; their R&D investment involves rich content, and the measurement indicators of R&D are also diversified. However, traditional clinical R & D alone is no longer enough to support the development of digital medical enterprises, and algorithm iteration, software design, and clinical program design are also required. Therefore, in general, the design of digital healthcare requires data collection and data analysis in the early stage, to find a good model based on data analysis, to develop a corresponding APP, and then to continuously optimize the model through continuous data to improve the APP design. Its product design should follow the relevant correlation or evidence extracted from a big data, upon which to build its own core model, and the core indicator to measure the product is clinical effectiveness.

In general, digital therapeutics is medical solutions that are driven by high-quality software to prevent, manage, or cure diseases. We need to interpret the term high quality further. On the one hand, the design of software needs to be targeted at diseases or specific indications. It is first necessary to complete accurate and in-depth reading of diseases, and then create algorithms based on the interpretation of diseases and medical principles; on the other hand, digital therapeutics is used as a patient-oriented disease management or the treatment plan, the software needs to have a high level of interaction design, improve the users' experience, and enhance the users' adhesion. Therefore, at first comprehensive requirements have been put forward for the design of the software itself in terms of scientific quality and user experience. Secondly, from the perspective of the second ring of evidence, companies need to provide real and credible evidence and data for digital

therapeutics to prove the effectiveness of their digital therapeutics products in disease treatment or intervention in disease management. In this link, digital therapeutics has put forward requirements for the ability of enterprises to be verified by clinical experiments. According to the current relevant policies in China, digital therapeutics products need to obtain Secondary Level Medical Device License before being introduced to the market. There are no specific approval policies and regulations for digital therapentics products. Therefore, this requires enterprises to interpret existing relevant policies and product compliance requirements. Only when the policy interpretation is completed accurately and efficiently can market access be achieved earlier. The last link, the question of how-to bring products to the market, puts forward requirements on the commercialization capabilities of enterprises. However, what exactly is a suitable business model for digital therapy is one of the challenges the industry is currently facing. Enterprises need to choose a corresponding business model or integrate multiple business models according to product characteristics, market environment and payment methods. Finally, the marketing methods for digital therapeutics products are also one of the important helps for the products to go to market. At present, the awareness of digital therapeutics in the market is still at a relatively low level, so specialized marketing methods play a key role in the process of product marketization.

In essence, digital therapeutics is a kind of computational science that uses big data to find the logic and method of the disease itself, so as to achieve the purpose of treatment. From the perspective of medical products, whether it is online digital therapy or traditional medicine or surgical treatment, the most important thing is its clinical effectiveness. To evaluate the clinical effectiveness of a product, the first measure is the level of enterprise

R & D. The core of product effectiveness lies in the company's substantial R&D investment, through investment in algorithms or clinical trials, product design, etc., to improve the efficacy of the product, and to continuously improve patient compliance. Digitalization is an emerging industry, which is different from innovative drugs, innovative therapies, and innovative devices, which require a strict clinical trial-certification-admission process; digital therapy itself is more inclined to APP software management, intelligent operation, etc., which can directly face Popularization provides products with therapeutic functions. Some practitioners believe that based on digital logic and its TOC logic, strict evidence-based medical evidence and evidence of clinical effectiveness are essentially unnecessary.

But from the current point of view, whether it is Slan Health or companies such as Bosten and Wujiang Brain Technology that have received more than 100 million yuan in financing in China, there are tens of thousands of clinical cases and clinical effectiveness test results behind them. Support is also based on the capture of patient-related data by a large number of doctor teams; and then based on this, R&D personnel develop and design related products.

In this thesis, we think that digital therapeutics is a great representative of digital health industry. Therefore, we have selected two digital therapeutics companies as our case studies to support the conclusions of this research paper.

1. Slan Health: Clinically-validated Digital Therapeutics CDMO One-stop Service Provider

Slan Health was established in Hangzhou in 2015. Slan Health is a pioneer in China’s Digital Therapeutics industry, providing CDMO and one-stop DTx service.

Bringing together multi-disciplinary talents, targeting clinical needs, relying on Slan's proprietary technology platform and global partnerships, Slan Health develops customized clinically-validated softwares for disease diagnosis, treatment, and management for our clients. Slan delivers highly regulated and cost effective products with proven track records in the market. Our Service includes: medical proposal design, product design and R&D, pilot program, clinical trial, NMPA registration service, product marketing and opeartion, RWS, IIT and etc.

Slan's first DTx product: Shield was the first product to receive NMPA medical devices registration in China back in 2019. Shield is a DTx product that prevent mother-to-child hepatitis B intervention. Its success rate is 99.7%. So far Shield holds the largest RWS data (40000+ patients) in China.

Through the collection, management and analysis of the detection indicators, clinical manifestations and pregnancy information of pregnant women infected with hepatitis B virus, the product provides clinicians with auxiliary diagnosis and treatment suggestions, and improves patient compliance, thereby improving the success rate of hepatitis B mother-to-child blockade. There is the function of diagnosis and treatment advice, realizing the main function and intended use of the product, based on the guidelines of World Health Organization, the European Society of Liver Diseases, the Asia-Pacific Society of Liver Diseases, the China's Prevention and Treatment of Chronic Hepatitis B, and Management of Hepatitis B in Pregnancy and clinical practices. Through this product, from the beginning of pregnancy to 12 months after the birth of the baby, it can record the whole process of pregnant women and babies, tracking and reminding, popularization of hepatitis B knowledge, online communication with the attending doctor, improve patient

compliance, help clinicians provide patient management, focus on key issues, diagnosis and treatment advice, data statistics and other functions, enhance the trust of doctors and patients, improve the efficiency of disease management, and achieve the goal of zero mother-to-child transmission of hepatitis B virus transformation.

At the same time, based on its own core product Shield, the company developed full-process services for digital medical care and is committed to building a CDMO enterprise of next-generation digital medical care. Through Slan Health's own exploration of the path of digital medical care, combined with Tigermed's CRO background, the company intends to provide standardized services for the next generation of medical enterprises and digital medical enterprises, occupying the milestone of the entire digital medical care. Due to the continuous emergence of many digital therapy companies and the transformation of traditional companies at this stage, the issues such as compliance and accessibility need to be considered in product development from the design and transformation of medical solutions in the R&D stage; at the completion stage of product development, it is necessary to conduct effectiveness testing and verification, clinical experiments and registration applications; when the product comes into the market, the offline operation team will operate and sell the product. It may take 3-5 years to build the team capacity required in the entire process. Based on this, the company has made efforts on how digital therapeutics companies can improve product standardization and intelligence in the early stage, reduce the size of the operation team, and control the business capital. In fact, each of our companies should give full play to their abilities and work together to create excellent products in different fields. Professional people do professional things. Slan Health has opened the capabilities of digital therapeutics CDMO

and the entire process, helping partners to quickly develop and implement digital therapeutics, effectively improving efficiency and controlling costs.

During the construction of the two platform-type products above, the company has conducted a large number of clinical trials for the Hepatitis B mother-to-child blocking management software Shield APP, the whole-cycle management of hepatitis B mother-to-child blocking (about 2 years, from pregnancy to vaccine injection) After the serological test is completed), Shield App will collect the medical data of pregnant women and babies with hepatitis B to form electronic medical records, based on the electronic medical records and the latest domestic and abroad authoritative guidelines and expert consensus on hepatitis B mother-to-child blockade, it will provide doctors with real-time high-risk patients reminders, trustworthy intelligent diagnosis, and analysis recommendations then support doctors to carry out corresponding diagnosis and treatment activities. Shield APP treated 1008 pregnant women with hepatitis B surface antigen positive and carry out immunization prophylaxis for infants in cooperating with 10 hospitals. It is recommended that mothers with HBV-DNA level > 2,000,000 IU/mL start antiviral treatment in the third trimester of pregnancy in order to ensure immunization of infants. Based on real-world statistics, the success rate of mother-to-child blockade of hepatitis B through Shield APP has reached 99.7%. On March 30, 2019, the World Health Organization (WHO) published an article on its official website reporting China's efforts and achievements in the prevention and treatment of hepatitis B, and highly recognized "Shield" as a mobile medical tool that helps doctors to better follow up and manage pregnant women with hepatitis B, which become an important role in achieving mother-infant interruption.

使用移动医疗应用“小贝壳”对中国乙型肝炎母婴传播的真实世界前瞻性研究

A Real-world Prospective Study of Mother-to-child Transmission of HBV in China Using a Mobile Health Application (Shield 01)

文章来源：临床与转化肝病杂志 2020 年第 8 卷
Article from Journal of Clinical and Translational Hepatology 2020 vol. 8

Figure 3 Shield Clinical Experiment Paper for example

This article uses Slan Health to demonstrate that its digital medical treatment has a certain curative effect on patients, but it still takes time for pre-market promotion to increase patients' awareness. At the same time, when digital therapy is for the public and the technical barriers are low, the demand for R & D is huge and diversified, and often requiring comprehensive strength in many aspects. In general, for any healthcare company, R&D investment is necessary and long-term. Only by building its own R&D platform, building a perfect R&D system, building its own moat barriers, and balancing commercialization and R&D investment, it can maintain a stable and healthy development of an enterprise.

2. Pear Therapeutics: A digital therapeutics star company completed its listing, launching the first share of digital therapy.

Pear Therapeutics discovers, develops, and delivers clinically-validated software-based therapeutics to provide better outcomes for patients, smarter engagement and tracking tools for clinicians, and cost-effective solutions for payers. Every day, we push the boundaries of technology to transform medicine. Pear has a pipeline of products and

product candidates across therapeutic areas, including severe psychiatric and neurologic conditions.

Pear has 3 PDT products with disease treatment claims from the FDA on the market currently. First product is: reSET®, for the treatment of substance use disorder. It was the first PDT to receive marketing authorization from the FDA to treat disease. Second product is: reSET-O®, for the treatment of opioid use disorder. It was the first PDT to receive Breakthrough Designation. Third product is: Somryst® for the treatment of chronic insomnia. It was the first PDT submitted through FDA's traditional 510(k) pathway while simultaneously reviewed through FDA's Software Precertification Pilot Program.

Figure 4 Pear Therapeutics Product Pipeline Diagram

The approval of Somryst is based on the results of two randomized, controlled clinical trials involving more than 1,400 adults with chronic insomnia. In a trial of 303 patients, when the follow-up is 6 and 12 months, Somryst-treated patients compared with a control group achieved clinically significant improvements in these parameters such as insomnia severity, time required to fall asleep, and time to wake up at night. In another study of 1,149 adults with chronic insomnia and depressive symptoms, those who received

treatment for 9 weeks achieved significantly lower insomnia severity compared with the control group and persisted for 12 months. At the end of the 9-week treatment period, most of the patients randomly assigned to the Somryst treatment group no longer met the clinical criteria for insomnia patients, and their insomnia status improved significantly. Another real-world study involving 7414 patients showed that more than half of the patients could insist on completing the Six Core Courses of Somryst within the 9-week, with good patient compliance.

The products reSET and reSET-O are all based on a large number of clinical trials, obtained clinical data, confirmed by evidence-based medicine, and approved by the FDA for marketing. At present, the product has revenue of more than one million USD. On the clinical and commercial sides, digital therapeutics has been proven to have curative effects on patient products, which further shows that digitalization has broad application prospects in the medical industry.

At present, there are many digital therapeutics companies. Many companies use the concept of digital therapeutics to raise funds from VCs, but it should be vigilant that digital therapy is only a concept, of which the essence lies in an application scenario of medical digitalization. The most important thing is to find a suitable indication to verify clinical effectiveness. Through the company's capitalization and the success of its commercialization, we can also foresee that digital medical care will be the development model of a new generation of healthcare companies in the future; and in the era of a new generation of digital medical care, corporate R&D investment and product efficacy will always be the core to further verify the importance of R&D investment and other factors to the digital transformation of enterprises.

CHAPTER 5: POLICY RECOMMENDATIONS AND RESEARCH CONTRIBUTIONS

Policy Recommendations

According to the results of the empirical regression, this paper accepts Hypothesis 1 and Hypothesis 2, that enterprise R&D and operating revenue can both positively promote enterprise digital transformation; meanwhile, this paper rejects Hypothesis 3 and Hypothesis 4, that enterprise size and executive education cannot positively promote enterprise digital transformation. Then, under the conclusion, enterprise R&D and digitalization are positive circular relationship, enterprise R&D can promote digital transformation; digital transformation also has a significant positive promotion effect on the development of biomedical enterprises; the conclusion analyzed by the empirical results of this paper, operating revenue also has a better promotion effect on digital transformation. Then for the above analysis results, this paper puts forward targeted suggestions.

For the government: First, it should strengthen the popularization and education of basic disciplines and prepare talents with cross-field research capabilities. The knowledge of basic disciplines such as mathematics, physics and chemistry is a solid foundation to support industrial digitalization. Strong well-rounded talent group is the cornerstone of industrial digital development. Government should create a nurturing biomedical environment, introduce relevant laws and regulations, encourage enterprises to achieve innovation, encourage enterprises to do global innovation, support complete industrial

policies and biomedical park landing policies, create a biomedical cluster circle, and help biomedical enterprises to develop healthily.

Secondly, Increase capital investment. Healthcare is a multi-billion industry that requires continuous heavy investment. Digitization in healthcare requires massive upgrade of modern medical treatment. It is the direction for the government to make efforts for building good industrial supporting fund and a friendly investment environment.

Thirdly, supporting policies and regulations: ① establish policies and regulations to improve data security and privacy standards, while allowing digital communication and sharing in a secure environment. ② establish policies and regulations to help digital health products in clinical trials practice. Digital health products like other medical products also need to go through rigorous clinical trials to receive NMPA registration. The government should take the lead in establishing regulations to improve the standardization and commercialization of digital clinical trials.

For enterprises： First, build a team of cross-disciplinary talents to lay the foundation of building good digital products and systems.

Secondly, increase R&D investment to speed up the efficiency of digital transformation.

Thirdly, deepen understanding of sharing mechanism and actively participate in data-sharing and allocation.

Innovations

Most of the previous papers have analyzed the factors affecting the digital transformation of enterprises from different perspectives; as well as the convenience and

business scalability that digital transformation can bring to enterprises. However, there is few literatures on the analysis of the influencing factors of digital transformation in the special industry of medical care, which is seriously impacted by the pandemic, and subdivided into 6 sub-sectors for in-depth analysis of the biomedical industry; and there is also few literatures from the perspective of the pandemic, focus on the analysis of digital transformation factors in the post epidemic era. At the same time, this paper is not only limited to empirical and theoretical analysis, but also based on the author's actual experience in the medical investment industry, using actual pharmaceutical enterprise cases to testify the conclusions discussed in this article; and from the perspective of the primary market, demonstrate the practical application of the relationship between enterprise R&D and digital transformation in cutting-edge technologies. In general, this paper uses empirical, theoretical, and cutting-edge biomedical technology cases to mutually elaborate and jointly verify the conclusions of this paper, emphasizing the importance of enterprise R&D and product commercialization level for digital transformation of enterprises.

BIBLIOGRAPHY

Chen, Q. J., Wang, Y. M., & Wan, M. F. (2021). Research on peer effect of enterprise digital transformation and influencing factors. Chinese Journal of Management, 18(5), 653-663.

Chen Chunhua, Zhu Li, Zhong Hao, et al. (2019) Innovation research from the perspective of digital survival management practice of Chinese enterprises [J]. **Journal of Management Science**, 22(10): 1-8.

Cheng Enwang, Xu Linpeng, Cui Yubo. (2022) 5G industry applications help the digital transformation of the medical industry [J]. **Communication World**, 2022(01):48-49.DOI:10.13571/j.cnki.cww.01.016.

Eller R，Alford P，Kallmünzer A, et al. (2020) Antecedents，consequences，and challenges of small and medium－sized enterprise digitalization [J]. **Journal of Business Research**, 112(5):119－127.

Gurbaxani, V., & Dunkle, D. (2019). Gearing up for successful digital transformation. MIS Q. Executive, 18(3), 6.

Hanelt, A., Bohnsack, R., Marz, D., & Antunes Marante, C. (2021). A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change. **Journal of Management Studies**, 58(5), 1159-1197.

He, F., & Liu, H. X. (2019). Evaluation on the performance improvement effect of digital transformation of real enterprises from the perspective of digital economy. **Reform**, 4, 137-148.

Hu Zhaoli, Chen Jiya, Lou Xueping, Li Juhong, Cao Kun, Sang Ping, Zhao Donghui. (2022) Digital healthcare boosts refined management of DRG [J]. **China Medical Insurance**, 01, 66-69.

John L, Sally E, Vikas K, et al. (2018) Towards digital transformation: Lessons learned from traditional organizations [J]. **Strategic Change**, 27(2):101- 109.

Kane G C, Palmer D, Phillips A N, et al. (2015) Strategy, not technology, drives digitales transformation [J]. **MIT Sloan Management Review and Deloitte University Press**, (14): 1-25.

Kane.G, Palmer.D, Phillips. A.N. (2015) Is your business ready for a digital future [J]. **MIT Sloan Management Review,** (56): 37- 44

Karimi J, Walter Z. (2015) The role of dynamic capabilities in responding to digital disruption: A factor－based study of the newspaper industry [J]. **Journal of Management Information Systems**, 32(1): 39－81.

Li Xiaoxue, Lu Hongyan, Lin Meng. (2020) Research on the digital transformation mechanism of retail industry [J]. **China Circulation Economy**, 34(04): 32-40. DOI: 10.14089/j.cnki.cn11-3664/f .2020.04.004.

Liang Yimin. (2019) Research on the application of digital technology in the medical field [J]. **World Latest Medical Information Digest**, 19(55): 217+227. DOI: 10.19613/j.cnki.1671-3141.2019.55.147.

Liu Shuchun, Yan Jinchen, Zhang Sixue, Lin Hanchuan. (2021) Can digital transformation of enterprise management improve input-output efficiency? [J]. **Management World**, 37(05): 170-190+13. DOI: 10.19744/j.cnki. 11-1235/f.2021.0072.

Liu Zheng, Yao Yuxiu, Zhang Guosheng, Kuang Huishu. (2020) Enterprise Digitization, Special Knowledge and Organizational Authorization [J]. **China Industrial Economy**, (09):156-174.DOI:10.19581/j.cnki.ciejournal.2020.09.008 .

Ma Haoran, Cheng Keren, Chen Hongjie, Xia Yu, Zhu Yongkun. (2021) Analysis of the application of medical digital platform to improve medical efficiency—based on DEA model [J]. **Hebei Enterprise**, (07): 20-23.DOI:10.19885/ j.cnki.hbqy.2021.07.006.

Maria LMP, Jose M S L, Eloisa D G. (2019) Servitization and digitalization in manufacturing：the influence on firm performance [J]. **Journal of Business & Industrial Marketing**, 35(3): 564- 574.

Morton, M. S. S. (Ed.). (1991). The corporation of the 1990s: Information technology and organizational transformation (Vol. 9). **Oxford University Press on Demand**..

Nai Cunjian, Zhang Xiaoxiang, Ren Yufei, Qu Xiaohui, Hu Jianping, Meng Qun. (2015) A comparative study of digital medical technology systems in my country and typical developed countries [J]. **China Hospital Management**, 35(02): 41-43.

Qi Fei. (2021) Searching for him in the crowd and Baidu: Medical digitalization [J]. **Zhangjiang Science and Technology Review**, (04):50.

TedSaarikko, UlrikaH.Westergren, TomasBlomquist. (2020) Digitaltransformation: Five recommendations for the digitally conscious firm [J]. **Business Horizons**, 63(6): 825- 839.

Tong Yu. (2022) Research on the Influencing Factors of Digital Transformation of China's Manufacturing Industry [J]. **Research on Technological Economy and Management**, (03):124-128.

Vial G. (2019) Understanding digital transformation: A review and a research agenda [J]. **The Journal of Strategic Information Systems**, 28(2): 118－144.

Wang Chunying, Chen Hongmin. (2021) Research on digital transformation of enterprises under the background of digital economy [J]. **Management Modernization**, 41(02): 29-31. DOI: 10.19634/j.cnki.11-1403/c.2021.02 .008.

Wu Chong, He Jichun, Yang Yuanxiang, Tian Baowen. (2021) The digital transformation of the medical industry: the impact of digitalization on the roles and behaviors of patients and medical institutions [J]. **Gongxin Finance and Technology**, (01): 95-108.

Wu Ziyan. (2018) The era of big data: opportunities and challenges for the development of digital medical care [J]. **Industrial Innovation Research**, (12): 35-36.

Xiao Jinghua, Wu Xiaolong. (2021) Information Technology Drives China's Manufacturing Transformation and Upgrading: A Longitudinal Case Study of Midea's Smart Manufacturing Leapfrog Strategic Reform [J]. **Management World**, 37(3): 161-179.

Xu Han. (2021) Research on the impact of enterprise digital transformation on enterprise productivity [D]. **Zhongnan University of Economics and Law**, DOI: 10.27660/d.cnki.gzczu.2021.000885.

Wade, M. (2015). Digital business transformation: a conceptual framework. **Global Center for Digital Business Transformation**, 15, 1-15.

Yan Zichun, Li Xin, Wang Weinan. (2021) Digital Transformation Research: Evolution and Future Prospects [J]. **Scientific Research Management**, 42(04): 21-34. DOI: 10.19571/j.cnki.1000-2995.2021.04.003.

Yi Jingtao, Wang Yuehao. (2021) Research on the impact of digital transformation on the export of enterprises [J]. **China Soft Science**, (03):94-104.

Yuan, C., Xiao, T., Geng, C., & Sheng, Y. (2021). Digital transformation and division of labor between enterprises: Vertical specialization or vertical integration. **China Industrial Economics**, 9, 137-155.

Zhai Yun, Jiang Minjuan, Wang Weiling. (2021) Theoretical Explanation and Operational Mechanism of China's Digital Transformation [J]. **E-Government**, (06): 67-84. DOI: 10.16582/j.cnki.dzzw.2021.06.007.

Zhang Xin, Xu Yaoyu, Ma Liang. (2022) Research on the configuration effect of the factors influencing the digital transformation of small and medium-sized enterprises [J]. **Review of Economics and Management**, 38(01): 92-102. DOI: 10.13962/j.cnki.37 -1486/f.2022.01.007.

Zhao Feng, Cao Xueqian, Wang Linnong, Chen Lixun. (2018) Research on ophthalmology application of digital medical technology [J]. **China Digital Medicine**, 13(07):18-19+60.