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Article

Sales innovation and synergy strategy of Chinese pharmaceutical enterprises in the context of digital transformation: A perspective from the affordance theory

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Abstract: In the rapidly evolving landscape of China's pharmaceutical industry, this study investigates how pharmaceutical enterprises can achieve profitable sales innovation amid the process of digital transformation. Grounded in the Affordance theory, it posits that the positive impact of digital transformation on sales innovation is driven by the affordance afforded by digital technology and ubiquity. The research focuses on A-share pharmaceutical companies in China, utilizing data from 2012 to 2022 and employing multiple regression analysis to examine the influence of digital transformation on corporate sales innovation. The results demonstrate a significant positive effect of digital transformation on sales innovation. The study further categorizes digital transformation into technological affordance and ubiquity affordance, separately validating their roles in promoting sales innovation. Moreover, by considering synergistic effects, the research unveils the intricate relationship between digital transformation and corporate innovation performance. The findings provide a fresh perspective on understanding how digital technology propels sales innovation and offer concrete guidance for the digital transformation practices in the pharmaceutical industry.

Keywords: affordance theory; digital transformation; Synergy; sales innovation

1. Introduction

The 2022 Guidelines for the Digital Transformation of Small and Medium-Sized Enterprises position digital technology as a core driver of disruptive innovation that significantly enhances enterprise performance. Externally, Chinese pharmaceutical companies, characterized by high investment, high risk, and high returns, face increasingly fierce market competition and an urgent need to leverage new technologies to unlock unrealized business potential. Digital transformation has become an industry-wide trend, enabling companies to restructure value chains and reshape business models. In the healthcare industry, digital transformation is now regarded as critical to achieving competitive advantage. Digital innovation is defined as "changes or creations in products and innovation processes resulting from new combinations of digital and physical components driven by digital technology" (Liu et al., 2023). However, scholars argue that digital transformation focuses on extracting latent value from existing operations rather than creating entirely new value (Teece, 1986; Zobel, 2017).

Internally, the level of digitalization in Chinese pharmaceutical companies remains relatively low, with more than half of these companies primarily in isolated stages of information nalization and exhibiting limited digital integration (Gu and Zhuang, 2023). The factors contributing to this gap include misunderstandings of

digital transformation, lack of comprehensive planning, inefficiencies in decision-making processes, talent shortages, and insufficient funding (Li and Ye, 2021; Li et al., 2023). The digitalization of the pharmaceutical industry has distinctive characteristics, heavily reliant on the digitalization of GMP (Good Manufacturing Practice) systems, which involve real-time collection and analysis of production status, equipment conditions, energy usage, and quality control data. This increases transparency, reduces production costs, and improves drug quality, giving companies a competitive advantage in cost and quality management. Furthermore, the industry's reliance on precise but limited data points underscores the need for targeted digital strategies.

This study analyzes digital transformation technology capabilities from external and internal perspectives. External digital transformation technology capabilities primarily involve acquiring external resources and responding to market demands, while internal capabilities focus on resource integration, organizational structure optimization, and technology upgrades (Mikalef and Pateli, 2017). Digital transformation is interpreted as the evolution of information technology, encompassing changes in business processes and entering new markets or exiting old ones (Chanias et al., 2021). Collaborating with research institutions and other companies enhances innovation capabilities through absorptive capacity, fostering product innovation (Najafi et al., 2022). Therefore, understanding how digital transformation is intrinsically linked to sales innovation and synergy in the current landscape becomes a primary focus of this study.

The essence of digital transformation lies in the strategic shift and deep integration of digital technology with strategy. Digital transformation requires companies to fundamentally change their business models and corporate culture, ultimately leading to increased sales revenue (Bughin et al., 2017). It is suggested that companies should increase their investment in digital technology, accelerate the process of digital transformation, and believe that digitalization can sustain long-term profits and foster healthy development, enhancing the company's market competitiveness. Digital transformation is viewed as utilizing digital technology to eliminate data barriers among industry levels, enhancing operational efficiency between enterprises at its core, fundamentally improving overall performance (García et al., 2021). From the resource-based view, studies have found a positive impact of digital transformation on corporate performance (Nwankpa et al., 2016). The unique differences in scholars' research highlight that how digital transformation truly affects sales innovation and synergy remains a less-explored research area.

Focusing on digital transformation in the pharmaceutical industry, traditional retailers gain a competitive advantage in price amid the digital transformation backdrop. Digital transformation can improve and facilitate synergy between pharmaceutical companies and retailers, achieving coordinated development (Cordon et al., 2016). Scholars, using the Bertrand and Stackelberg price competition model, have examined the pricing game between traditional sales channels and digital platforms of healthcare enterprises post-digital transformation (Mao et al., 2014). The research indicates that pharmaceutical companies can encourage traditional retailers to accept digital platform channels by reducing wholesale prices, ultimately achieving coordinated dual-channel development (Klimanov et al., 2021). In the coordinated

dialogue of the dual-channel sales chain of healthcare enterprises post-digital transformation, quantity discount contracts are easy to implement, achieving a coordinated effect (Suhner, 2024).

To address the opacity of its theory, some scholars have employed affordance theory to explain the mechanism and conditions from a visibility perspective, confirming the relationship between the adoption of digital transformation and sales innovation (Gibson, 1997; Volkoff and Strong, 2017). Studies based on affordance theory indicate that the value realization in the process of digital transformation depends on organizational actions and innovativeness. This is considered a rational perspective for studying the relationship between digital transformation and sales innovation (Chatterjee et al., 2020; Trocin et al., 2021; Volkoff and Strong, 2013).

Through this rational perspective, it becomes evident that for pharmaceutical enterprises, digital transformation itself originates from innovation and synergy scope. This allows for a further analysis of how Chinese pharmaceutical companies achieve additional profits through digital transformation activities. Utilizing affordance theory, it is not difficult to analyze that, given the relatively imperfect institutional environment of emerging markets, the illuminative nature of digital innovation aids in overcoming institutional limitations to pursue growth, which is crucial for pharmaceutical enterprises.

Based on affordance theory, it is evident that the value realization of digital transformation depends on organizational actions and context. This is considered an appropriate theoretical perspective for studying the relationship between the adoption of digital innovation and performance (Chatterjee et al., 2020; Trocin et al., 2021; Volkoff and Strong, 2013). According to the above literature, the analysis reveals that the support of digital transformation is beneficial for the integration of business processes between upstream and downstream enterprises. On one hand, it reduces integration costs, and on the other hand, it promotes the efficiency of related product improvements or creations, effectively controlling the benefits of innovation, driving companies to obtain additional financial profits, and enhancing internal operational efficiency. Therefore, I will focus on researching the contributions of relevant scholars in these two aspects. Digital transformation is an innovation in the use of digital technology by companies, covering both technological and strategic aspects. It requires the reconstruction of strategies, organizational structures, and business processes to adapt to the ever-changing economic environment (Mooney et al., 1996). In this process, synergy with relevant external partners is inevitably required to achieve value co-creation and enhance sales innovation (Romero and Molina, 2009).

In pharmaceutical enterprises, digital transformation provides a range of new technological “affordances”, such as cloud computing, big data analytics, artificial intelligence, and more. These technologies enable companies to process large amounts of data, optimize decision-making processes, and enhance operational efficiency. The technological foundation provided by digital transformation facilitates synergy both internally within the enterprise and externally. The processes of digitization and synergy support sales innovation both technically and strategically. Digital transformation offers the “affordance” of new technologies to pharmaceutical enterprises, promoting synergy both internally and externally, and this synergy further drives the innovation and optimization of sales strategies.

Existing literature explores the concept and effects of technological affordances, providing theoretical references for this study. First, regarding the concept of technological affordances, technological affordances are defined as the potential for various outcomes resulting from the interaction between an actor and a technological entity in different contexts (Xie et al., 2024). Second, concerning the role of technological affordances, research based on the theoretical concept of technological affordances finds that technological affordances have a positive impact on the media industry (Chen et al., 2022). Third, regarding the effects of digital technological affordances, leveraging the definition of technological affordances, the concept of digital technological affordances further introduce d, categorizing it into cumulative affordances and variable affordances. It is suggested that both contribute to the expansion of the scope of enterprise digital innovation value (Li et al., 2022). Focusing on the impact of digital technological affordances on enterprise business model innovation, it is argued that cumulative affordances significantly promote both incremental and disruptive changes in business models, while variable affordances drive the development of disruptive business models (De Luca et al., 2021).

Combining the analysis from the previous literature, it is inevitable that the affordance of digital technology will have an impact on the development of sales innovation in enterprises. Therefore, can the technological affordance of digital transformation enhance sales innovation in enterprises, and what is the mechanism between the two? Based on validated evidence from listed companies, this paper empirically examines the impact mechanism of digital technology transformation on corporate innovation performance. The potential contributions of this paper may include:

(1) Existing literature mostly focuses on the exploration of technological affordance in digital technology transformation, with limited empirical research. This paper incorporates the affordance of digital technology transformation into the research framework, contributing to the enrichment of related field studies.

(2) Current research predominantly concentrates on the impact of technological affordance in digital technology transformation on sales innovation, without analyzing its influence on corporate innovation performance from a micro perspective. This paper explores the relationship between digital technology affordance and corporate sales innovation from a fresh perspective, addressing a gap in the existing academic field.

(3) To further explore whether there is a mechanism between the two, an attempt is made to use a mediation model to investigate the internal mechanism of how digital technology affordance affects corporate innovation performance, providing a new direction for driving sales innovation in enterprises.

2. Theoretical foundation and research hypotheses

2.1. The process of digital transformation under affordance theory

The concept of affordance was introduced by Gibson and initially appeared in the field of ecological psychology (Gibson, 1997). Technological affordance theory integrates two opposing views, technological determinism and social constructivism (Liu et al., 2024; Robey et al., 2013). Affordance theory provides a theoretical

foundation for further analyzing how digital transformation acquires effective value and interacts with innovation actors (Carte et al., 2015; Nambisan et al., 2019). Affordance can be used to understand how the materiality of digital technology promotes or restricts its potential uses in an organizational environment (Zammuto et al., 2007). Additionally, the goals of the acting entity shape the characteristics of technology (Markus and Silver, 2008).

From the perspective of affordance, digital transformation can be defined as "a potential for action, that is, what individuals or organizations can do with technology or information systems for specific purposes" (Majchrzak and Markus, 2013). Simultaneously, digital technology accumulation affordance enables enterprises to establish innovation element-sharing platforms, providing support for paradigm innovation in product development, process improvement, and equipment maintenance, thus promoting the quality and efficiency of innovation activities and enhancing corporate innovation performance. On the other hand, digital technology variation affordance facilitates breakthrough innovation by restructuring the combination of digital technologies.

Building on affordance theory, the value of digital transformation itself depends not only on the technology itself but also on the relatively imperfect overall market environment, leading to the question of whether the affordance of digital technology is helpful in overcoming institutional constraints for growth (Autio et al., 2018; Nambisan et al., 2019; Van, 2011).

Digital affordance under digital transformation can be divided into accumulation affordance and variation affordance, both of which contribute to the elevation of enterprise innovation performance. On the one hand, digital technology accumulation affordance helps enterprises establish an innovation element-sharing platform, providing resource support for innovation activities in product development, process improvement, and equipment maintenance, thereby promoting innovation activities' quality and efficiency and assisting in enhancing corporate innovation performance. On the other hand, digital technology variation affordance aids enterprises in implementing breakthrough innovation by restructuring the combination of digital technologies, achieving innovation in sales (Kafouros et al., 2015; Zysman and Newman, 2006).

To further verify the potential mechanisms mentioned above, this study will use affordance theory to reveal the mechanisms behind the relationship between digital transformation innovation and corporate performance.

Affordances can be used to understand how the materiality of digital technology promotes or limits its various potential uses in an organizational environment (Zammuto et al., 2007). Simultaneously, the goals of actors also shape the characteristics of technology (Markus and Silver, 2008). This theoretical perspective emphasizes the relationship between the goal orientation of actors, expected goals, and the dynamic feedback of actual behavior, as illustrated in **Figure 1**. Leveraging this theoretical perspective effectively analyzes the underlying mechanisms of value creation in socialized network marketing enterprises, revealing the process of value creation in the context of industrial big data. It also provides a new perspective for understanding the impact of digital technology on digital innovation and its impact on enterprise performance.

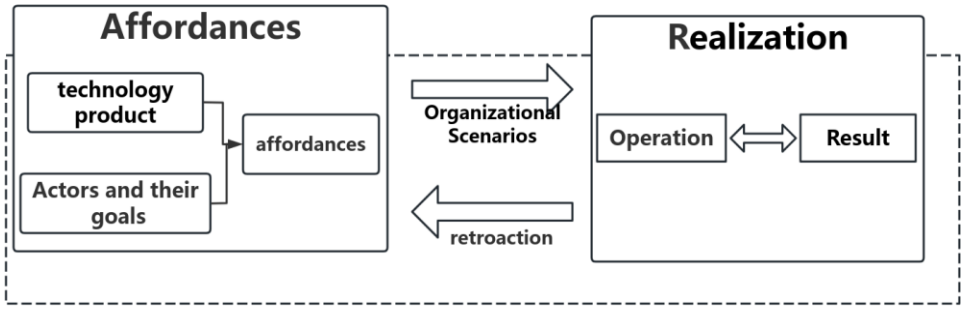

Figure 1. Affordance theory framework.

The process of achieving digital innovation involves enterprises, guided by the goal of innovation, applying digital technology on the foundation of adjusting the organizational environment to support the implementation of digital transformation, ultimately aiming to generate innovation and enhance performance. In this context, the organizational environment possesses subjectivity and serves as a prerequisite condition for affordance realization. Digital technology, with its functional characteristics, forms the material foundation for affordance realization. Digital transformation embodies interactive relationships, representing the perception and utilization of technological objects by the acting entity. The ultimate innovation outcomes signify the realization of affordances. Based on this, the theoretical framework depicted in **Figure 2** can be established, serving as the foundation for constructing corresponding empirical models.

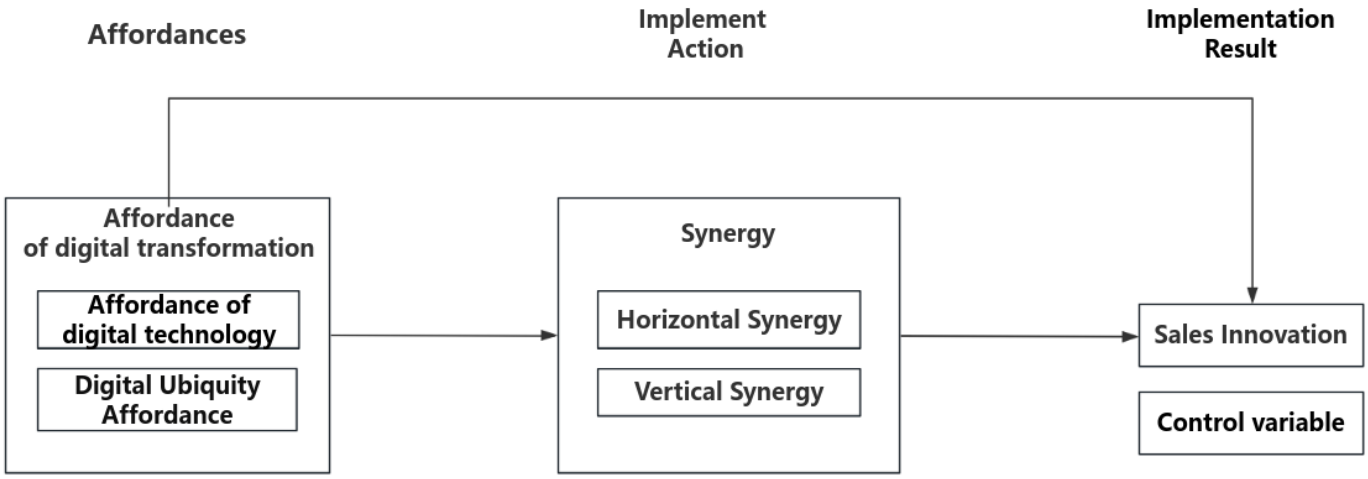

Figure 2. Digital transformation framework based on affordance theory.

2.2. Theoretical hypotheses

Enterprise digital transformation management capability is developed on the basis of traditional management capabilities. With the advancement and expansion of the digital economy era, the rational application of digital technology can drive sales innovation, disrupting enterprise management structures and organizational capabilities. This, in turn, better enables enterprises to set strategic goals, adapt flexibly to market changes, and gain a sales innovation advantage. The characteristics of enterprise digital transformation are not only reflected in technology investment

and talent acquisition but also in the restructuring of the existing organizational structure. The transition from a "pyramid" to a "flattened" organizational structure not only accelerates the flow of information but also speeds up the issuance of enterprise instructions and the implementation of overall strategies (Markides and Williamson, 1996). The alignment between "digital thinking" and the digital transformation capability of enterprise management is crucial. When enterprises engage in digital transformation to empower their development, a restructuring of the organizational structure and strategic decision-making processes occurs (Huang et al., 2020). The intelligent development of enterprises brings new changes to management. Based on the reconfiguration of traditional management concepts and methods, the overall framework of enterprises has been upgraded and restructured, bringing new flexibility and strategies. This is also conducive to sales innovation (Jing et al., 2023).

Digital transformation poses severe challenges to organizational management within enterprises. The increased cost of decision-making thresholds due to digital technology adds complexity to organizational management, completely overturns existing ideologies, and challenges organizational inertia (Qian, 2019). However, it also brings new opportunities. Through digital transformation, enterprises achieve organizational structural transformations, optimize the flexibility of technological production, effectively promote adaptability and flexibility to internal and external environments, ultimately enhancing sales and sales innovation, and gaining a competitive advantage in the market (He, 2023).

Therefore, the following hypotheses are proposed:

H1: Digital transformation has a positive impact on sales innovation.

H1a: The technological affordance of digital transformation has a positive impact on sales innovation.

H1b: The ubiquity affordance of digital transformation has a positive impact on sales innovation.

Digital transformation is an innovation in enterprise use of digital technology, covering both technological and strategic aspects. It requires the reconstruction of strategies, organizational structures, and business processes to adapt to the constantly changing digital economy (Mooney et al., 1996). Business operations are closely related to social networks, and through cooperation with suppliers, customers, etc., digital technology can be shared, enhancing creativity (Bharadwaj and Mitra, 2016). The development of digital technology changes the way enterprises think, providing new avenues for creating, delivering value, and gaining profits, driving organizational and strategic changes. The concept of "synergy," i.e., entities synergistically creating value through resource sharing, is introduced. Based on synergistic innovation theory, the concept of synergistic innovation is proposed to explain the resource sharing and division of labor synergy that enterprises engage in to achieve innovation (Boer et al., 2006). Synergy can help enterprises break through boundaries and resource constraints, promote innovation, reduce innovation risks, and facilitate knowledge spillover. Research on synergistic innovation mainly involves paths, models, and the relationship with sales innovation (Lee et al., 2019). To achieve value co-creation and enhance sales innovation, synergistic cooperation among various innovation entities is required (Romero and Molina, 2009). Cooperation with research institutions and

other enterprises can enhance innovation capabilities, promote product innovation through absorptive capacity (Najafi-Tavani et al., 2018).

H2: Digital transformation has a positive impact on synergy.

H2a: Digital transformation has a positive impact on horizontal synergy.

H2b: Digital transformation has a positive impact on vertical synergy.

Synergy is an important feature of enterprise networks. Network synergy refers to the connection of external information, relationships, technological resources, and the entire lifecycle of products. In the fiercely competitive context of the digital economy era, both horizontal and vertical network synergy methods have an impact on sales innovation (Lopez et al., 2019). Horizontal synergy has a positive impact on sales innovation. With the interconnection of digital technologies, enterprises connect different entities to form a horizontal, intertwined relationship network, acquiring resources such as technology, research and development, and marketing. By integrating these resources to complement their shortcomings, enterprises can better achieve common goals. For example, synergy between enterprises and universities, research institutes create an innovation platform for industry, linking intermediary consulting agencies to obtain first-hand market information, and connecting with the government to obtain funding and policy support. Through synergy with peers and partners in other industries, companies fill in their technological gaps. Through process innovation, production costs are reduced, production efficiency is increased, allowing the company to maintain high-profit margins while providing consumers with higher quality and more cost-effective products. At the same time, there is greater space for resource allocation in new product development. For instance, TSMC has established an open synergistic relationship with partners. Sharing data in the information pool on aspects such as research and development, production, quality standards, and after-sales service helps both parties improve product/service quality synergistically, achieving a win-win situation (Rowley, 2002). Synergy with research institutions such as universities, establishing a rapid technology iteration system, can help companies create diversified and differentiated products at a lower cost and risk through the flow of external innovation resources, addressing the disadvantages of a single product and potentially creating market demand, helping companies gain a larger market share. By sharing marketing resources (brand image), relationship resources (customer channels), and other marketing resources, companies can enhance their ability to identify target customers and efficiently convey product value to them. Synergistic marketing channels help customers perceive the novelty of new products, enhancing the competitiveness of incremental products. Vertical synergy has a positive impact on sales innovation (Lahiri and Narayanan, 2013). Enterprises engage in value creation activities by connecting various members of the value chain through vertical synergy, achieving product and service innovation reflected in strategic synergy, operational synergy, and customer synergy.

H3: Synergy effects have a positive impact on sales innovation.

H3a: Horizontal synergy has a positive impact on sales innovation.

H3b: Vertical synergy has a positive impact on sales innovation.

Digital transformation is a necessary initiative for enterprises seeking innovation and gaining sustained competitive advantage. Its essence lies in leveraging digital technology to alter the connections and collaborations between businesses and other

partners, thereby influencing business processes and bringing about a transformation in the way value is created. It is not an isolated activity but rather an ongoing interaction between the enterprise, partners, customers, and other entities to acquire innovative resources. This, in turn, revolves around creating new products and services based on value propositions, transforming digital resources into a process of differentiated value creation. Therefore, digital transformation is a strategic imperative for enterprises to adapt to the demands of a new business environment, and network synergy serves as a strategically driven action deployment, playing an intermediary role in the processes of digital transformation and innovation performance. Therefore, this study posits:

H4: Synergy plays a mediating role in the relationship between digital transformation and sales innovation.

3. Research design

3.1. Sample and data collection

The financial and patent data used in this study were sourced from the Guotai CSMAR database. The CSMAR database is one of the most authoritative and widely used research databases in China's financial market, providing high-quality time-series data specifically for academic researchers and financial practitioners. To obtain the necessary financial and patent data for A-share pharmaceutical companies, I utilized the database's search system and set specific filtering criteria, including company type as "pharmaceutical companies", market as "A-share", and the time range from 2012 to 2022. During this process, financial indicators such as the asset-liability ratio, net profit, total asset growth rate, as well as the number of patent applications and grants, were retrieved from the "Company Financial Data" and "Patent Data" modules within the CSMAR database.

To ensure the completeness and consistency of the data, I utilized the batch download function provided by the CSMAR database and further verified the downloaded data to ensure no critical variables were omitted. Additionally, after collecting the data, I performed an initial cleaning process to check for and remove any potential missing values and outliers. The extensive coverage and precise data provided by the CSMAR database enabled me to efficiently and comprehensively gather the sample data required for this study.

This study selected A-share pharmaceutical companies as the research subjects, utilizing statistical data spanning ten consecutive years from 2012 to 2022 for empirical research. To ensure the robustness of the research results, the following screening and processing steps were applied to the data:

1) Companies in ST status were excluded.
2) Companies that were delisted due to abnormal financial conditions were excluded.
3) Companies listed after 2014, with shorter listing periods, were not included.

In addition, to minimize the impact of outliers, Winsorization was applied to continuous variables, excluding the top and bottom 1%. This process resulted in a total of 63 listed companies and 8710 balanced panel sample observations. Financial indicators and patent data were sourced from the Guotai CSMAR database. Data

processing was carried out using Python and Excel 2010, while data analysis utilized SPSSAU.

3.2. Indicator construction

3.2.1. Explained variable/dependent variable

Enterprise Sales Innovation (ESI) is primarily measured by the ratio of sales innovation input to sales innovation output. Referring to the method of Young (2016), the entropy weight method is used to construct the sales innovation input and output systems separately. The main measurement indicators for sales innovation input include the company's investment in sales activities and funds allocated for the development of new products and innovative technologies. Meanwhile, the key indicators for sales innovation output include new product sales revenue, corporate profit, and market share.

3.2.2. Explanatory variable/independent variable

Enterprise Digital Transformation (EDT): The digital transformation indicator is measured by the proportion of digital resources established in fixed and intangible assets. It is derived from the details of fixed and intangible assets in the notes to the balance sheet (Tang et al., 2022). Considering the affordance of data, this paper uses the proportion of digital assets (hardware and software) in total assets to express the digital transformation of enterprises, which is described as follows: First, the affordance of digital technology: digital fixed asset investment is taken as the measurement standard. For example, "electronic equipment", "office equipment", "management equipment", "test equipment" and so on in fixed assets. The second is digital ubiquity: measured by investment in digital intangible assets. Such as intangible assets in the "management system", "e-commerce", "cloud platform", "ERP software", "management information system", "wechat public number" and so on.

3.2.3. Mediating variable

Synergy (Sy): Synergy is a crucial feature of enterprise networks, representing the connection of external information, relationships, technical resources, and the entire product life cycle. Based on the previous descriptions, further configuration will be made based on horizontal and vertical synergy.

3.2.4. Control variables

Enterprise size, total asset growth rate, asset-liability ratio, major shareholder ownership ratio, board independence, operating cash flow, sales cost, year and industry were set as control variables.

As key control variables:

(1) Enterprise Size (Size): The natural logarithm of total assets represents the size of the company. Larger-sized listed companies have more funds for innovation activities, which is favorable for improving the company's innovation performance. So, the expected sign is positive.

(2) Total Asset Growth Rate (Growth): The total asset growth rate is expressed as the difference between year-end assets and initial assets divided by initial assets. I t indicates the development prospect of the enterprise. A higher growth rate

implies better development prospects for the company. Therefore, this paper predicts that the total assets growth rate is positively correlated with enterprise performance, which is a positive sign.

(3) Asset-Liability Ratio (Level): The asset-liability ratio is the ratio of the company's year-end total liabilities to year-end total assets. It indicates the company's ability to carry out business activities with the help of creditor funds. A lower asset-liability ratio and financial leverage indicates less external pressure on the company, reflecting stronger operational capabilities. Therefore, this paper predicts that the asset-liability ratio will have a negative impact on corporate performance and it is a negative sign.

(4) Major Shareholder Ownership Ratio (Ownership): The ownership ratio of the major shareholder refers to the proportion of the first major shareholder's holdings to the total share capital. Studies have shown that a higher ownership ratio positively influences company performance. Therefore, this paper predicts that the ownership ratio will have a positive impact on corporate performance and it is a positive sign.

(5) Board Independence (Independence): Board independence is reflected in the proportion of independent directors to the total number of directors. In the operation efficiency of the board of directors, the independence of the board of directors plays an extremely important role. Previous studies have shown that the higher the proportion of independent directors, the lower the efficiency of the board. Therefore, this paper predicts that the independence of the board of directors will have a negative impact on corporate performance, and it is a negative sign.

(6) Operating Cash Flow (Ocf): Operating cash flow is measured by the net operating cash flow of an enterprise. Business activities affect the net profit of enterprises, accounting profit needs sufficient cash flow support from business activities to achieve good business performance. Therefore, this paper predicts that operational cash flow has a positive impact on enterprise performance and it is a positive sign.

(7) Sales Cost (Cos): Sales cost is expressed as the ratio of operating costs to operating income, reflects the expenses required for each unit of sales income. A higher sales cost ratio indicates lower profitability. Therefore, this paper predicts that the cost of sales is negatively correlated with enterprise performance, and it is represented by a negative sign.

Refer to **Table 1** for specific variable definitions and explanations.

Table 1. Definition of empirical test variables.

Variable Types	**Variables and Symbols**	
Explained Variable	Enterprise Sales Innovation (ESI)	
Explanatory Variables	Enterprise Digital Transformation (EDT)	Digital Transformation Technology (DTT)
		Digital Transformation Management (DTM)
Mediating Variable	Synergy (Sy)	Horizontal Synergy Capability (HCV)
		Vertical Synergy Capability (VCC)

Table 1. (*Continued*).

Variable Types	Variables and Symbols
	Enterprise Size (Size)
	Total Asset Growth Rate (Growth)
	Asset-Liability Ratio (Level)
Control Variables	Major Shareholder Ownership Ratio (Ownership)
	Board Independence (Independence)
	Operating Cash Flow (Ocf)
	Sales Cost (Cos)

3.3. Model construction

To study the impact of digital transformation on sales innovation, this research establishes a panel data model to test Hypothesis 1 (H1). The model is as follows:

H1: $ESI_{i,t} = \eta_1 + \eta_2 EDT_{,it} + \eta_k Control_{i,t} + \sum \text{Year} + \sum industry + \varepsilon_{i,t}$

H1a: $ESI_{i,t} = \eta_1 + \eta_2 DTT_{i,t} + \eta_k Control_{i,t} + \sum \text{Year} + \sum industry + \varepsilon_{i,t}$

H1b: $ESI_{i,t} = \eta_1 + \eta_2 DTM_{i,t} + \eta_k Control_{i,t} + \sum \text{Year} + \sum industry + \varepsilon_{i,t}$

The dependent variable is enterprise sales innovation, denoted by ESI. The independent variable is enterprise digital transformation, denoted by EDT. The independent variable digital transformation technology is denoted by DTT, and the independent variable digital transformation management is denoted by DTM. The control variable is denoted by Control. ∑Year represents time fixed effects, ∑industry represents industry fixed effects, and $\varepsilon_{i,t}$ represents the random disturbance term. The subscript i represents the enterprise, and t represents the year.

H2: $Sy_{i,t} = \eta_1 + \eta_2 EDT_{i,t} + \eta_k Control_{i,t} + \sum Year + \sum industry + \varepsilon_{i,t}$

H2a: $HCV_{i,t} = \eta_1 + \eta_2 EDT_{i,t} + \eta_k Control_{i,t} + \sum Year + \sum industry + \varepsilon_{i,t}$

H2b: $VCC_{i,t} = \eta_1 + \eta_2 EDT_{i,t} + \eta_k Control_{i,t} + \sum Year + \sum industry + \varepsilon_{i,t}$

The dependent variable is synergy, denoted as Sy, horizontal synergy capability, denoted as HCV, vertical synergy capability, denoted as VCC, independent variable enterprise digital transformation, denoted as EDT, independent variable digital transformation technology, denoted as DTT, independent variable digital transformation management, denoted as DTM, control variable denoted as Control, ∑Year for time fixed effects, ∑industry for industry fixed effects, $\varepsilon_{i,t}$representing random disturbance term, subscript i represents enterprise, and t represents year.

The impact of collaboration on sales innovation can be studied using the following regression model:

H3: $ESI_{i,t} = \eta_1 + \eta_2 Sy_{i,t} + \eta_k Control_{i,t} + \sum Year + \sum industry + \varepsilon_{i,t}$

H3a: $ESI_{i,t} = \eta_1 + \eta_2 HCV_{i,t} + \eta_k Control_{i,t} + \sum Year + \sum industry + \varepsilon_{i,t}$

H3b: $ESI_{i,t} = \eta_1 + \eta_2 VCC_{i,t} + \eta_k Control_{i,t} + \sum Year + \sum industry + \varepsilon_{i,t}$

The dependent variable is enterprise sales innovation, denoted as ESI. The independent variable is collaboration, denoted as Sy. Horizontal synergy capability is denoted as HCV, and vertical collaboration capability is denoted as VCC. Control variables are denoted as Control. ∑Year represents time fixed effects, ∑industry represents industry fixed effects, and $\varepsilon_{i,t}$ denotes the random disturbance term. Subscript *i* represents the enterprise, and t represents the year.

To examine how digital transformation affects enterprise sales innovation and whether the influence path exists, this paper conducts an empirical analysis based on affordance theory, using collaboration as a mediating variable. Referring to the research by Wen et al. (2014), the stepwise regression method is used to test the mediation effect.

H4: $Mediator_{i,t} = \eta_1 + \eta_2 Szfix_{i,t} + \eta_k Control_{i,t} + \sum \text{Year} + \sum industry + \varepsilon_{i,t}$

$$ESI_{\text{i,t}} = \eta_1 + \eta_2 EDT_{\ i,t} + \eta_k Control_{i,t} + \sum \text{Year} + \sum industry + \varepsilon_{i,t}$$

Among them, the mediator variable (Mediator) is collaboration (Sy), $\varepsilon_{\text{i,t}}$ representing the random disturbance term.

4. Results and discussion

The data of listed companies selected in this study from 2012 to 2022 not only exhibit individual differences among different companies but are also influenced by changes over time. Therefore, compared to mixed effects and random effects, using a two-way fixed effects model for empirical testing is more reasonable, but relevant tests are still required. See **Table 2**.

According to the regression model test results in **Table 2**, the fixed effects model is the best choice for this study. First, the F-test results show that the *P*-value is 0.0000, which significantly rejects the null hypothesis, indicating that the true model is a mixed regression model. This means that the mixed regression model is insufficient to explain the individual effects in the data, and therefore, a choice must be made between the fixed effects and random effects models. Secondly, the LM test results also reject the null hypothesis of the mixed regression model with a *P*-value of 0.0000, indicating that the random effects model theoretically has better explanatory power compared to the mixed regression model. However, the most critical is the Hausman test, whose *P*-value is also 0.0000, significantly rejecting the null hypothesis of the random effects model, indicating a correlation between individual effects and independent variables. Therefore, it can be seen that the fixed effects model can more effectively control unobserved individual characteristics than the random effects model, thus more accurately reflecting the dynamic changes within enterprises and their impact on the dependent variable. In summary, based on the comprehensive results of the F-test, LM test, and Hausman test, the fixed effects model should be preferred for data analysis in this study.

In this study, correlation and collinearity analyses were conducted for each variable, and the results are shown in the table below.

Table 2. Regression model test results.

	Null hypothesis	**Statistic**	***P*-value**	**Result**
F Test	The true model is a mixed regression model	13.12	0.0000	Reject the null hypothesis and adopt the fixed effects model
LM test	The true model is a mixed regression model	1252.45	0.0000	Reject the null hypothesis and adopt the random effects model
Hausman test	The true model is the random effects model	252.74	0.0000	Reject the null hypothesis and adopt the fixed effects model

According to the collinearity analysis results in **Table 3**, sales innovation (ESI) has a significant positive correlation with the independent variables of enterprise digital transformation (EDT), synergy effect (Sy), and enterprise scale (Size), and these correlations are highly significant statistically ($p < 0.001$). According to the analysis results of the VIF values, the issue of multicollinearity in the model is not severe, and the interdependence of the variables remains within an acceptable range, which will not significantly affect the regression results of the model. Therefore, it can be concluded that the collinearity issue in this study does not pose a substantial threat to the robustness of the results.

Table 3. Collinearity analysis.

	1	2	3	4	5	6	7	8	9	10	11	VIF
ESI	1											1.026
EDT	0.088***	1										1.571
Sy	0.064***	0.012***	1									2.509
Size	0.084***	0.953***	0.066***	1								3.351
Growth	0.096***	0.181***	0.165***	0.051**	1							1.666
Level	−0.025	0.072***	0.074***	0.085***	−0.088***	1						1.032
Ownership	0.008	−0.151***	−0.15***	−0.042***	0.173***	0.090***	1					1.068
Independence	−0.002	−0.292***	−0.27***	−0.104***	−0.124***	−0.058***	−0.016	1				9.180
Ocf	−0.002	−0.183**	−0.172***	−0.095***	−0.147***	−0.035*	−0.013	0.295***	1			1.557
Size	−0.008	−0.123***	−0.125**	−0.023*	−0.159***	−0.045**	−0.069***	0.009***	0.123***	1		8.820
Cos	−0.033*	−0.151***	−0.093***	−0.193***	−0.148***	−0.031	−0.005	0.43***	0.132***	0.249***	1	1.924

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The benchmark regression results in **Table 4** support research hypothesis H1, indicating that digital transformation has a positive impact on enterprise sales innovation. The regression results show that digital transformation (EDT) has a significant positive effect on sales innovation (ESI), with a regression coefficient of 0.007, a *t*-value of 5.763, and a significance level of $p < 0.001$. This result validates hypothesis H1, indicating that digital transformation overall has a positive impact on sales innovation.

The regression results for hypotheses H1a and H1b further support this conclusion. The technological affordance of digital transformation (DTT) has a significant positive effect on sales innovation, with a regression coefficient of 0.006, a *t*-value of 4.715, and a significance level of $p < 0.001$. This indicates that the affordance of digital technology has significantly promoted sales innovation in enterprises, validating hypothesis H1a. Similarly, the general affordance of digital transformation (DTM) also has a significant positive impact on sales innovation, with a regression coefficient of 0.005, a *t*-value of 5.452, and a significance level of $p < 0.001$, validating hypothesis H1b. This indicates that the widespread application of digital resources can significantly enhance the sales innovation performance of enterprises.

Table 4. Benchmark regression.

	H1	**H1a**	**H1b**
Constant	1.323*** (16.586)	1.313*** (16.184)	1.307*** (15.995)
EDT	0.007*** (5.763)		
DTT		0.006*** (4.715)	
DTM			0.005*** (5.452)
Size	0.071 (1.333)	0.003 (0.052)	0.090 (1.563)
Growth	0.134 (1.938)	0.144* (2.146)	0.189* (2.448)
Level	0.145* (2.170)	0.176** (2.803)	0.309** (4.513)
Ownership	0.151** (2.737)	0.083 (1.525)	0.163** (2.658)
Independence	−0.024 (−0.489)	−0.048 (−1.000)	−0.017 (−0.314)
Ocf	0.071 (1.333)	0.003 (0.052)	0.090 (1.563)
Industry	Control	Control	Control
Year	Control	Control	Control
Sample Size	8578	8578	8578
R2	0.009	0.009	0.009

Dependent variable: ESI *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, t-values in parentheses

The benchmark regression results in **Table 5** validate research hypothesis H2, indicating that digital transformation has a positive impact on the collaborative capability of enterprises.

Table 5. Benchmark regression.

	H2 (Sy)	**H2a (HCV)**	**H2b (VCC)**
Constant	3.106*** (3.473)	2.563** (2.807)	2.951*** (3.294)
EDT	0.051** (5.232)	0.045** (5.552)	0.015 (1.241)
Size	0.119 (1.553)	0.117 (1.567)	0.116 (1.436)
Growth	0.179* (2.427)	0.125 (1.682)	0.195* (2.558)
Level	0.127 (1.271)	0.123 (1.263)	0.16 (1.580)
Ownership	−0.076 (−0.788)	−0.082 (−0.902)	0.019 (0.213)
Independence	0.210** (2.635)	0.156 (1.972)	0.216** (2.657)
Ocf	−0.016 (−0.219)	−0.036 (−0.522)	−0.009 (−0.124)

Table 5. (*Continued*).

	H2 (Sy)	H2a (HCV)	H2b (VCC)
Industry	Control	Control	Control
Year	Control	Control	Control
Sample Size	8578	8578	8578
R2	0.012	0.007	0.012

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, *t*-values in parentheses.

The regression coefficient of digital transformation (EDT) on collaborative capability (Sy) is 0.051, with a *t*-value of 5.232 and a significance level of $p < 0.01$, indicating that digital transformation has a significant positive impact on collaborative capability. This validates hypothesis H2, suggesting that digital transformation helps improve the overall collaborative capability of enterprises. Further analysis of the results for H2a and H2b shows that digital transformation also has a significant positive impact on horizontal synergy capability (HCV). The regression coefficient is 0.045, the *t*-value is 5.552, and the significance level is $p < 0.01$, indicating that digital transformation can significantly enhance the horizontal collaboration capability at the same level, thus verifying hypothesis H2a. The improvement in horizontal collaboration capability may be attributed to the promotion of digital technology in information sharing, resource integration, and internal collaboration.

In hypothesis H2b, although digital transformation also has a positive effect on vertical collaboration capability (VCC), its regression coefficient is 0.015, the *t*-value is 1.241, which does not reach the significance level, thus hypothesis H2b is not yet verified.

According to the benchmark regression results in **Table 6**, research hypothesis H3, which posits that collaboration positively impacts sales innovation, has been validated. The regression coefficient of collaboration (Sy) on sales innovation (ESI) is 0.003, with a *t*-value of 5.597 and a significance level of $p < 0.001$, indicating that the synergy effect has a significant positive impact on sales innovation. This validates hypothesis H3, indicating that a company's collaborative capability can effectively promote the enhancement of sales innovation.

Table 6. Benchmark regression.

	H3	H3a	H3b
Constant	1.312*** (15.953)	2.156* (2.326)	2.187* (2.369)
Sy	0.003*** (5.597)		
HCV		−0.004 (0.627)	
VCC			0.002*** (6.227)
Size	0.002 (0.398)	0.002* (2.225)	0.002* (0.045)
Growth	0.001*** (−5.096)	0.002** (2.912)	0.004* (2.094)

Table 6. (*Continued*).

	H3	H3a	H3b
Level	0.004* (0.110)	0.005** (0.197)	0.006* (0.578)
Ownership	0.016* (1.991)	0.011** (1.358)	0.015* (1.792)
Independence	0.707* (0.301)	1.191* (0.496)	0.439* (0.186)
Ocf	0.106*** (0.473)	0.563** (0.807)	0.951*** (0.294)
Industry	Control	Control	Control
Year	Control	Control	Control
Sample Size	8578	8578	8578
R2	0.011	0.012	0.017

Dependent variable: ESI *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, t-values in parentheses

For hypothesis H3a, horizontal synergy capability (HCV) did not show a significant impact. The regression coefficient is −0.004, the t-value is 0.627, and it does not reach statistical significance. This indicates that in the sample of this study, horizontal collaboration does not have a significant positive effect on sales innovation, thus hypothesis H3a is not supported. For hypothesis H3b, the impact of vertical collaboration capability (VCC) on sales innovation is significant and positive. The regression coefficient is 0.002, the t-value is 6.227, and the significance level is $p < 0.001$, which supports hypothesis H3b. This indicates that vertical collaboration capability, i.e., the collaboration between upstream and downstream in the supply chain, has a significant positive effect on sales innovation. By collaborating with upstream and downstream partners in the supply chain and integrating technological resources, enterprises can effectively enhance their sales innovation performance.

According to the mediation effect model test results in **Table 7**, research hypothesis H4, which posits that the synergy effect mediates the relationship between digital transformation and sales innovation, is confirmed.

Table 7. Mediation effect model testing.

	EDT	Sy	EDT
Constant	0.723** (2.803)	0.871** (3.953)	0.707** (2.620)
Size	0.081 (1.127)	−0.035 (−0.581)	0.081 (1.133)
ESI	0.352** (5.981)	0.562** (6.437)	0.026** 6.245)
Sy			0.52** (3.521)
Growth	0.144* (2.097)	0.033 (0.561)	0.143* (2.081)
Level	0.057 (0.606)	0.067 (0.839)	0.055 (0.590)
Sharehoder	−0.148 (−1.691)	0.278** (3.720)	−0.153 (−1.682)

Table 7. (*Continued*).

	EDT	Sy	EDT
Independence	0.128 (1.703)	−0.055 (−0.855)	0.129 (1.709)
Ocf	−0.002 (−0.030)	0.042 (0.741)	−0.003 (−0.042)
R2	0.312	0.321	0.322
Industry	Control	Control	Control
Year	Control	Control	Control

*$p < 0.05$,**$p < 0.01$, the *t*-value is in parentheses

Digital transformation (EDT) has a significant positive impact on the synergy effect (Sy), with a regression coefficient of 0.352, a *t*-value of 5.981, and a significance level of $p < 0.01$. This indicates that digital transformation significantly promotes the enhancement of the synergy effect, providing a basis for the existence of the mediation effect. The synergy effect (Sy) also shows a significant positive impact on sales innovation (ESI), with a regression coefficient of 0.652, a *t*-value of 3.521, and a significance level of $p < 0.01$. This indicates that the synergy effect can significantly promote the improvement of sales innovation, further supporting the existence of the mediation effect.

Meanwhile, the direct impact of digital transformation (EDT) on sales innovation remains significant, but after introducing the synergy effect (Sy), the regression coefficient drops from 0.352 to 0.026, indicating that the synergy effect plays a partial mediation role between digital transformation and sales innovation. Although the direct impact of digital transformation on sales innovation still exists, the synergy effect enhances this relationship through a mediating pathway. Furthermore, the control variables in the model (such as enterprise scale, total asset growth rate, debt-to-asset ratio, etc.) do not significantly interfere with the results, further validating the robustness of the mediation effect model.

Therefore, the test results of the mediation effect model validate hypothesis H4, indicating that the synergy effect indeed plays a significant mediating role between digital transformation and sales innovation. Digital transformation promotes the realization of sales innovation by enhancing the collaborative capability of enterprises.

Based on the above analysis, the following conclusions can be drawn, as shown in **Table 8**:

Table 8. Summary of hypothesis testing results.

Hypothesis	Result
H1	Supported
H1a	Supported
H1b	Supported
H2	Supported
H2a	Supported
H2b	Not Supported
H3	Supported

Table 8. (*Continued*).

Hypothesis	Result
H3a	Not Supported
H3b	Supported
H4	Supported

The digital transformation of Fosun Pharma provides a successful case supporting the main hypothesis of this study. By applying advanced technologies such as big data and artificial intelligence, Fosun Pharma has optimized its operational model in areas such as supply chain management, marketing, and customer relations, significantly enhancing the company's sales innovation capabilities. This case illustrates the positive impact of digital transformation on sales innovation. Through its technological affordances, Fosun Pharma has integrated big data platforms and artificial intelligence technologies to automate and enhance intelligence the drug production and sales processes, thereby improving production efficiency and customer responsiveness. This further proves the critical role of technological affordance in driving corporate innovation. In addition, Fosun Pharma's managerial affordance has been validated, as the company optimized resource allocation and management processes, deeply applied digital technology in decision-making, and strengthened collaboration with upstream and downstream supply chain partners. This has facilitated the effective implementation of its innovation strategy and enhanced its competitive advantage in the market. Moreover, Fosun Pharma's vertical synergy effect is particularly notable. The company has established close cooperation with raw material suppliers and distributors within the supply chain, not only improving production and logistics efficiency but also enhancing its ability to respond quickly to market demands, further driving sales innovation. This pricing company's case clearly demonstrates the critical role of digital transformation and vertical collaboration in driving corporate innovation.

5. Discussion

5.1. Result and discussion

Based on affordance theory, this study focuses on analyzing the impact of the affordance of digital technology during the process of digital transformation on sales innovation. By separately considering the accumulation affordance and variation affordance of digital technology, the research reveals how these factors drive the improvement of innovation performance in enterprises. Empirical evidence based on data from Chinese A-share pharmaceutical companies validates the proposed hypotheses. The results indicate a significant positive impact of digital transformation (including both technological and managerial capabilities) on sales innovation. This enriches the literature in the field of digital transformation and provides profound insights into the practical operations of enterprises, especially in the pharmaceutical industry. These findings contribute to understanding how to effectively leverage digital technology to enhance innovation performance and competitiveness.

From a theoretical standpoint, this study demonstrates that affordance theory extends beyond the concept of technological potential, encompassing the roles of accumulation and variation affordances, each exerting distinct influences on the innovation processes within organizations. This discovery not only deepens the theoretical understanding of the role of digital technologies in enterprise transformation but also provides new insights for the application of affordance theory across various contexts. By illustrating the complementary nature of digital technologies and managerial strategies, this research addresses a gap in the extant literature concerning the relationship between digital transformation and innovation performance, offering valuable contributions toward the development of a more comprehensive framework for digital transformation.

In terms of practical application, the study offers substantial guidance for enterprise managers, particularly within the pharmaceutical industry. The findings indicate that the success of digital transformation is contingent not solely on the adoption of new technologies but also on the enhancement of managerial capabilities that align technological advancements with the organization's innovation objectives. This insight is of considerable practical relevance, especially in highly competitive markets where firms must emphasize internal resource integration and external collaboration to fully exploit the potential of digital technologies. By doing so, companies can bolster sales innovation and strengthen market competitiveness. The study provides concrete recommendations on how to enhance the effectiveness of digital transformation through internal collaboration and partnerships, equipping enterprises to more effectively respond to the challenges posed by the digital economy.

In future studies, the author intends to explore digital transformation's applicability and effects in different enterprise environments, considering varying scales and types of companies. Further research on the impact of digital transformation on various internal departments (e.g., human resources, finance, operations) and how these departments synergize to drive overall innovation performance would be valuable. Qualitative research methods, such as case studies or in-depth interviews, could provide a deeper understanding of human behavior, attitudes, and perceptions during the process of digital transformation.

In conclusion, the research has provided valuable insights into how digital transformation affects the innovation performance of enterprises, offering meaningful guidance for both practitioners and academics. Simultaneously, highlighting the limitations of the study and suggesting future research directions is crucial for advancing the field further. Despite China being a leading emerging market globally, the singular national geographic focus of this research restricts the generalizability of our findings to other emerging markets.

The research indicates that digital transformation, by providing new technological possibilities and modes of market engagement, changes firms' business models and value creation processes. Technological affordance offers a technological basis for firms to develop new products, optimize services, and improve production processes, while universal affordance expands firms' market coverage and customer engagement by enhancing the interaction and connection between enterprises and consumers. Additionally, this study underscores the role of synergistic effects in the digital transformation process, showing that enterprises can further enhance the impact

of sales innovation through internal resource integration and collaboration with external partners.

This study provides insights for pharmaceutical companies on how to effectively leverage digital technologies to promote sales innovation and offers a theoretical basis for managers to formulate digital transformation strategies. The findings emphasize that in the era of the digital economy, pharmaceutical enterprises need to take proactive digital transformation measures, not only investing in the development and application of new technologies but also by fostering internal and external collaborative efforts to fully realize the potential value of these technologies.

5.2. Research suggestion

Pharmaceutical companies must increase their investment in technology when advancing digital transformation. Specifically, companies should adopt systematic internal resource integration measures during this process. This includes restructuring the organizational framework to accommodate technological changes, breaking down traditional departmental silos, and fostering the flow of information and cross-departmental collaboration. By establishing cross-functional teams and innovation project management mechanisms, companies can quickly respond to changes in various business areas, while also stimulating the innovative potential of different departments. Additionally, external collaboration is a critical element. Companies should actively seek partnerships with research institutions, universities, technology suppliers, and other innovative enterprises to promote product development and technological innovation through technology sharing and joint research and development. Such collaborative efforts not only allow companies to access cutting-edge technological advancements but also provide the necessary external resources and knowledge to support their innovation activities. In rapidly changing market environments, external collaboration offers sustained innovation momentum that helps companies maintain a competitive edge.

Moreover, the vertical synergy effect has a more significant impact on promoting sales innovation. In addition to horizontal innovation collaborations, companies should also strengthen cooperation with upstream and downstream partners in the supply chain. By collaborating with suppliers, distributors, and other downstream entities, pharmaceutical companies can achieve effective resource integration, optimizing production and logistics processes, thus improving overall operational efficiency and innovation capabilities. For instance, working with upstream raw material suppliers can provide greater flexibility in procurement and quality control, while collaboration with downstream distributors and retailers allows companies to respond more quickly to customer demands in the end market, enhancing the effectiveness of sales innovation. Through such vertical synergy within the supply chain, companies can optimize the entire value chain and achieve stronger competitive advantages in the market.

To support the digitalization process in the pharmaceutical industry, the government could establish dedicated innovation funds to assist companies in investing in digital technology adoption and application, talent development, and research and development efforts, thereby reducing the financial burden during the

early stages of transformation. Such incentive policies would motivate companies to accelerate digital transformation and leverage technological innovation to enhance their core competitiveness. Additionally, the government should strengthen industry regulation and policy guidance to ensure that companies can effectively respond to market and technological changes during the digital transformation process. For example, the government could establish relevant industry standards and regulations to ensure that companies follow best practices when adopting new technologies, thereby avoiding risks associated with improper use or misuse of digital technologies during the transformation process.

Furthermore, the government should focus on building digital infrastructure, particularly in remote areas and among small and medium-sized enterprises (SMEs), to enhance the accessibility and efficiency of digital infrastructure, thereby laying the foundation for the digital transformation of the entire pharmaceutical industry. More importantly, the research results suggest that policymakers should pay attention to different types of synergy effects, particularly the role of vertical synergy in improving corporate innovation performance. The government could provide policy guidance to encourage pharmaceutical companies to engage in more collaborative innovation across the supply chain, thereby enhancing the overall competitiveness of the industry. Specifically, the government could establish public platforms for collaborative innovation, facilitating closer cooperation between pharmaceutical companies and their upstream and downstream partners, research institutions, and industry associations. This would promote the sharing of technology, information, and resources, driving innovation across the entire industry. Such policy support not only helps individual companies enhance their innovation capabilities but also amplifies the overall innovation outcomes of the industry through synergy effects, thereby providing strong support for improving national competitiveness.

5.3. Research limitations

This study has several limitations. The sample primarily consists of Chinese A-share pharmaceutical companies, which may limit the generalizability of the research findings. The pharmaceutical industry is characterized by high capital intensity, long product development cycles, and stringent regulatory frameworks, which may differ significantly from other industries, thus constraining the applicability of the conclusions across different operational and regulatory environments. Future research should consider expanding the sample to include companies from various industries and regions, particularly those with different levels of digital maturity, to enhance the universality and external validity of the findings.

Additionally, the study employs a multiple regression model for empirical analysis, which, while appropriate for examining relationships between variables, may not fully capture the dynamic complexity of digital transformation. Other statistical or econometric methods, such as panel data analysis, could offer deeper insights into how the effects of digital transformation evolve over time. Time-series analysis, for example, could help identify trends, cycles, and potential long-term effects that may not be observable in cross-sectional data. Future research using such methods could

provide a more nuanced understanding of the temporal characteristics of digital transformation and its impact on innovation.

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