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Study on the Influencing Factors of Digital Transformation on the Resilience of Pharmaceutical Supply Chain

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Abstract. Under the background of coping with changes and crises through digital transformation in various fields in China, and by using the questionnaire data collected from employees of pharmaceutical enterprises, this study conducts multivariate logistic regression analysis on the impact of digital transformation on the resilience of pharmaceutical supply chain. The results show that the automation level of sales management, the real-time tracking level of goods, the popularity of process robots and predictive maintenance are important factors affecting the resilience level of model pharmaceutical supply chain. It is suggested that the resilience of pharmaceutical supply chain can be improved through the following ways: establishing intelligent marketing system and communication platform, realizing logistics visualization and using IOT and sensing technology to monitor goods. In addition, a fault pre-warning system should be established in the production workshop, and a detailed and feasible maintenance and optimization plan should be customized. This paper aims to provide references for the direction and measures of digital transformation, which is conducive to building a more efficient, transparent, flexible and sustainable pharmaceutical supply chain, and also helps the pharmaceutical supply chain to better cope with external changes and risks.

Keywords: Digital Transformation; Resilience of Pharmaceutical Supply Chain; Multiple Logistic Regression; Analysis of Influencing Factors.

1. Introduction

Whether in the goal of "building new advantages of digital economy" put forward in the “14th Five-Year Plan for National Economic and Social Development of People's Republic of China and the Outline of the Vision for 2035”, or in the “G20 Ministers’ Declaration for Digital Economy: Digitization Promoting Resilience, Strength, Sustainability and Inclusiveness Recovery” adopted at the G20 Ministers’ Meeting on Digital Economy [1]. Undeniably, digital transformation has become an important choice for countries to cope with changes, and it has inestimable significance in shaping the resilience of supply chain.

Digital transformation is both an opportunity and a challenge for domestic pharmaceutical supply chain. Firstly, from the perspective of risk, the application of digital technology in all links of pharmaceutical supply chain can enhance the ability of supply chain to predict, avoid and deal with internal and external environmental damage, thus increasing the flexibility and resilience of supply chain. Secondly, from the perspective of competitiveness, the digital transformation of the pharmaceutical supply chain can empower the reconstruction of the supply chain to promote the innovation of the pharmaceutical supply chain model, thus absorbing more risks and creating greater value, and then shaping the resilience of the pharmaceutical supply chain. In view of this, based on the existing research on digital transformation and resilience of supply chain, this paper further discusses the relationship between digital transformation and resilience of pharmaceutical supply chain.

The literature on digital transformation mainly focuses on its connotation, influencing factors, evaluation indicators, application scenarios and so on. Wang Jin et al. pointed out that digital transformation is at different stages of development, with a new generation of digital technology and data resources integrated in the core link to create value [2]. Chen Zanxiong et al., based on the TOE framework theory, divided the influencing factors of digital transformation of logistics enterprises into three types: technical factors, organizational factors and environmental factors [3]. Chen Tang et al. believed that the evaluation index system of digital transformation can be constructed based on its labor input, capital input, innovation platform input and environmental input [4]. Liu Sheng et al., from the perspective different from the macro-level digital transformation indicators of provinces or cities, adopted the text recognition method to construct the digital transformation indicators of enterprises [5]. Song Qihua et al. believed that the digital transformation of pharmaceutical enterprises can be specifically applied to six aspects including full-process data insight, digital innovation research and development, and digital manufacturing [6].

The literature on resilience of supply chain mainly focuses on the concept, measurement and improvement methods. Wu Anbo et al. believed that the resilience of supply chain lies in the fact that all stakeholders in the supply chain ensure the sustainable development of key nodes in the supply chain through a series of preparation, absorption, recovery and adaptation when facing risks [7]. Ponis and Koronis believed that resilience of supply chain refers to the ability to actively plan and design the supply chain network to predict unexpected destructive events, to maintain structural and functional control while responding adaptively to interruptions, and to maintain a stable operating state even after the event [8]. Shi Wangfang et al. deemed that resilience should be measured by indirect methods, which can be measured and evaluated from two aspects: survival and development and risk response [9]. However, Li Yongzhen believed that the evaluation system should be constructed from five aspects: predictive ability, reactive ability, adaptive ability, recovery ability and learning ability of pharmaceutical supply chain [10]. Yang Baoshi put forward that enterprises can improve the resilience of supply chain from four aspects: backup suppliers, rational inventory preparation, standardized production of parts and components and digital joint management and control [11].

The existing research has listed the framework of digital transformation and analysis of resilience of supply chain, and provided different measurement standards for different industries. However, there are still some limitations in the existing research, which are mainly manifested in two aspects: (1) the existing research focuses on the unilateral analysis of digital transformation or resilience of supply chain, and there is little research on the relationship between them; (2) the research on the digital transformation of manufacturing industry is more common. This paper will take the performance of the resilience of the pharmaceutical supply chain as the dependent variable and the factors of the digital transformation of the pharmaceutical supply chain as the independent variable, and analyze the influence of the digital transformation on the resilience of the pharmaceutical supply chain.

2. Research Design

2.1. Ideas of Questionnaire Design

In order to collect the opinions of medical practitioners on the impact of digital transformation on the resilience of pharmaceutical supply chain, this study followed the principles of purpose, convenience for analysis and efficiency, and designed a questionnaire named "The Impact of Digital Transformation on the Resilience of Pharmaceutical Supply Chain". This questionnaire mainly included three parts: questionnaire description, basic information of respondents and some evaluation scale questions. The questionnaire description introduced the purpose and background of this study, and requirements of filling the questionnaire. The basic information of the respondents included their job title, residence city and work unit. According to the evaluation index system of digital transformation and the evaluation system of resilience of pharmaceutical supply chain, the Likert 5-level scoring method is adopted for several scale questions. For each question, respondents need to rate the effect or degree from "extremely poor" to "excellent" according to the real situation or actual thought, with the score of 1~5.

2.2. Variable Declaration

1. Explained variable

The resilience performance of the pharmaceutical supply chain is set as the explained variable, and the corresponding variable is named Y. The 13th question "Digital transformation under the pharmaceutical supply chain is an inevitable trend, please evaluate the resilience performance of the pharmaceutical supply chain under this background" in the questionnaire “The Impact of Digital Transformation on the Resilience of Pharmaceutical Supply Chain” is taken as the measurement index of the explained variable. The options and assignment rules of this question are shown in Table 1.

Table 1. Options and assignment rules of the explained variable

Grade	Specific performance	Assignment
Extremely Poor	The existing supply chain network has undergone subversive changes and cannot offset the risks.	1
Poor	The existing supply chain network will be broken, and it is difficult to offset the risk through inventory or extra capacity.	2
Ordinary	The existing supply chain network can maintain the existing structure and offset some risks through inventory or extra capacity.	3
Good	The existing supply chain network can maintain the existing structure well, and offset some risks through inventory or extra capacity. Also, it tries to reorganize the supply chain network to absorb more risks.	4
Excellent	Under the condition that the existing supply chain network structure has not changed, most of the risks faced by the supply chain can be offset by some inventory or some extra capacity. In addition, it can absorb more risks through restructuring.	5

2. Explanatory variable

The specific situation of digital transformation in different links of pharmaceutical supply chain is taken as an explanatory variable. In this study, the pharmaceutical supply chain is divided into four stages: R&D and clinical trials, production, management and circulation, and four primary indexed and nine secondary indexes are established in turn, as shown in Table 2.

Table 2. Assignment indexes of digital transformation of pharmaceutical supply chain

Primary index	Secondary index	Assignment
R&D and clinical trials	Usage of AI drug discovery tools	1-5
	Effect of simulated clinical trial	1-5
Production link	Coverage depth of automation system	1-5
	Popularization of process robots	1-5
	The situation of predictive maintenance	1-5
Management link	The situation of intelligent service	1-5
	The situation of sales management automation	1-5
Circulation link	The situation of real-time goods tracking	1-5
	Coverage breadth of digital platform	1-5

This study divides the whole process of pharmaceutical supply chain from the beginning to the end users into four links: R&D and clinical trials, production, management and circulation, and regards them as four first-class indicators.

R&D and clinical trials include: the use of AI drug discovery tools (X_1), which is used to measure whether the process of finding and confirming potential therapeutic targets is efficient and rapid; effect of simulated clinical trial (X_2), which is used to measure the length of drug development cycle.

The production links include: the coverage depth (X_3) of the automation system, which is used to measure the automation level of the drug production workshop; popularization of process robots (X_4), which is used to measure the efficiency and accuracy of drug production workshops; the situation of predictive maintenance (X_5), which is used to measure the contribution of digital technology to reducing unnecessary expenses in maintenance.

The management links include: the situation of intelligent service (X_6), which is used to measure whether digital technology can improve the satisfaction of end users and the automation of sales management (X_7), which is used to measure whether digital technology can improve the management level of retailers in the pharmaceutical supply chain.

The circulation links include: the situation of real-time goods tracking (X_8), which is used to measure whether the digital technology can ensure the smooth and lossless circulation of goods in the pharmaceutical supply chain and always return the distribution information to the previous node; coverage depth of digital platform (X_9), which is used to measure whether digital technology can cover the entire pharmaceutical supply chain.

3. Model Construction

Logistic regression analysis can be divided into binary and multivariate Logistic regression analysis, among which multivariate Logistic regression model is suitable for studying the relationship between multivariate dependent variables and independent variables. The research on the impact of digital transformation on the resilience of pharmaceutical supply chain adopts ordered multivariate Logistic regression, and the constructed ordered multivariate Logistic regression model is as follows:

$$P_j = P(Y \leq j \mid X_i) = \frac{e^{(\alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \ldots + \alpha_i x_i)}}{1 + e^{(\alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \ldots + \alpha_i x_i)}}$$

$$Logit(P_j) = \ln\left(\frac{p_j}{1 - p_j}\right) = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 \ldots + \alpha_i X_i$$

Where j=1,2...5, i=1,2...9, $\alpha 0$ is a constant term, α_1, $\alpha_2 \ldots \alpha_i$ are regression coefficients of multivariate Logistic model. In this model, $P(Y \leq j|X_i)$ is actually the cumulative probability of the value of the outcome variable $\leq j$, that is, $P(y=1|X_i)+P(y=2|X_i)+\ldots+P(y=j|X_i)$.

4. Result Analysis

(1) Reliability and validity test

In order to ensure the reliability of the questionnaire, the reliability and validity of 207 valid sample data collected were analyzed by SPSS26.0 software. The reliability analysis of the questionnaire mainly focused on the reliability analysis of variables, and its Cronbach Alpha coefficient value is 0.898, which is close to 1, indicating that the reliability quality of the research data is high and the reliability of the questionnaire survey is good, which can be further analyzed. The validity of the questionnaire is mainly analyzed from the rationality of the questionnaire content and the rationality of the questionnaire structure. KMO and Bartlett tests are carried out on the variables, and the results show that the KMO test value is 0.919, which is close to 1. This means that the rationality of the questionnaire content and the questionnaire structure reaches the standard. In the meantime, the chi-square statistical value of Bartlett sphericity test is 950.218, and the result of p-value test is $0 < 0.05$, so it is considered that the questionnaire has passed the validity test and is effective. The reliability analysis is shown in Table 3 and the validity analysis is shown in Table 4.

Table 3. Reliability statistics table

Reliability statistics		
Cronbach Alpha	Cronbach Alpha based on standardization term	Number of terms
0.898	0.898	10

Table 4. KMO and Bartlett test table

KMO and Bartlett test		
KMO sampling suitability quantity		0.919
Bartlett sphericity test	Approximate chi-square	950.218
	Degree of freedom	45
	Significance	0.000

(2) Multivariate logistic regression model analysis

The judgement of effectiveness of the overall model will be based on the analysis of the likelihood ratio test of the model and the conclusion will be drawn. Firstly, the overall effectiveness of the model is analyzed. The original assumptions of the model test here are: whether there are independent variables or not, the quality of the model is equal in both cases. At this time, $P < 0.05$, which indicates that the original hypothesis is rejected, and it means that the addition of independent variables is effective and the model construction is meaningful. The test results of likelihood ratio are shown in Table 5.

Table 5. Likelihood ratio test results of multivariate logisctic regression model for influencing factors of resilience of pharmaceutical supply chain

Model fitting information						
	Model fitting condition			Likelihood ratio test		
Model	AIC	BIC	-2 log likelihood	Chi-square	Degree of freedom	Significance
Intercept only	620.618	633.949	612.618	-	-	-
Final result	537.692	1030.934	241.692	370.926	144	0.000

In this model, the explanatory variable X means the specific situation of digital transformation in different links of pharmaceutical supply chain, and each coefficient represents the influence of explanatory variable on the resilience of pharmaceutical supply chain. The meaning of the explained variable Y is the performance of the resilience of the pharmaceutical supply chain. After excluding the explanatory variables with less significant influence, the estimated values of parameters are shown in Table 6.

When $Y=2$, that is, when the resilience of pharmaceutical supply chain is poor, it is difficult to carry out predictive maintenance in production links ($X_5=2$), and it is difficult to track the whereabouts of goods in circulation links ($X_8=2$). Moreover, pharmaceutical enterprises can only achieve the coverage of digital platforms ($X_9=3$). These three situations passed the statistic test of significance level at the level of 0.01.

When $Y=3$, that is, the resilience of the pharmaceutical supply chain is ordinary, the production link is difficult to achieve predictive maintenance ($X_5=2$, $X_5=3$, $X_5=4$) and the sales management in the circulation link is low automation ($X_7=2$). These two situations passed the statistic test of significance level at the level of 0.01. It is difficult to track goods in real time by using process robots in production

(X_4=3) and in circulation (X_8=2), and these two situations passed statistic test of significance level at the level of 0.05.

Table 6. Parameter estimation table of multivariate logisctic model for influencing factors of resilience of pharmaceutical supply chain

Y[a]	Intercept	B	Standard error	Wald	Degree of freedom	Significance
2	[X5=2]	21.111	3.995	27.923	one	0.000
	[X8=2]	9.544	2.752	12.024	one	0.001
	[X9=3]	8.533	3.190	7.156	one	0.007
3	[X4=3]	2.787	1.094	6.487	one	0.011
	[X5=2]	11.777	1.841	40.927	one	0.000
	[X5=3]	4.002	1.215	10.855	one	0.001
	[X5=4]	3.622	1.268	8.166	one	0.004
	[X7=2]	5.738	1.503	14.577	one	0.000
	[X8=2]	5.190	2.203	5.549	one	0.018
4	[X5=3]	1.378	0.661	4.350	one	0.037
	[X5=4]	1.576	0.743	4.498	one	0.034

When Y=4, that is, the pharmaceutical supply chain shows good resilience, the production link can better predict the situation of maintenance (X_5=3, X_5=4) and it passed statistic test of significance level at the level of 0.05.

Therefore, the results show that the predictive maintenance of production links always has a significant impact on the resilience of pharmaceutical supply chain, no matter whether its performance is good or bad. When the resilience performance of pharmaceutical supply chain is upgraded from poor to ordinary, the influence of goods tracking in circulation links is slightly reduced, but it cannot be ignored. Meanwhile, the automation level of sales management is the most significant factor under this resilience level. When the resilience performance of pharmaceutical supply chain is poor, the low coverage of digital platform in circulation has a great influence on it, so it is considered that the coverage of digital platform has a significant influence on the resilience performance level of pharmaceutical supply chain.

5. Conclusion and Suggestions

In this study, through a personal questionnaire survey of employees of pharmaceutical companies, a multivariate ordered Logistic regression model is established to analyze the impact of digital transformation of pharmaceutical supply chain on the resilience of pharmaceutical supply chain. The research results provide references for the direction and measures of digital transformation, so as to improve the ability of pharmaceutical supply chain to cope with risks and recover itself. It is found that the real-time tracking level of goods in the circulation link of pharmaceutical supply chain and the popularity of process robots in the production link have made outstanding contributions to maintaining and improving the resilience of pharmaceutical supply chain. Predictive maintenance of production links and sales management automation of circulation links in pharmaceutical supply chain has the most significant impact on the resilience of pharmaceutical supply chain. Based on the above conclusions, the following suggestions are put forward:

Pharmaceutical enterprises should establish intelligent marketing system and communication platform. Adopting advanced sales management system and automatic order processing system can not only track and manage sales orders, inventory and delivery, but it can also speed up order processing, reduce human errors and provide real-time order status updates. The establishment of communication platform requires providing personalized customized services, and timely obtaining feedback data from doctors and patients to provide support for product and service optimization and enhance user stickiness.

Pharmaceutical enterprises should realize logistics visualization and use IOT and sensing technology to monitor goods. They not only need to use logistics tracking and monitoring technology to realize real-time monitoring and visualization of goods transportation, storage and distribution process, also, it is necessary for them to use the IOT and sensing technology to obtain key information such as the location, temperature and humidity of goods in real time.

Pharmaceutical enterprises should establish a fault pre-warning system in the production workshop, customize detailed and feasible maintenance and optimization plans, and improve and strengthen the exception handling rules and early warning functions of process robots. First of all, based on the results of equipment data analysis, a fault pre-warning system can be established to find equipment faults and supply chain risks in advance. Then, in the process of equipment operation, by monitoring the changes of equipment operation parameters, predefined failure modes and early warning signals of key indicators in the supply chain, potential problems can be found as early as possible, and corresponding preventive measures can be taken to avoid the impact of sudden failures on the supply chain. Secondly, based on the previous maintenance results, make a reliable maintenance plan and optimize the maintenance cycle and time of equipment. Through reasonable planning and optimized resource allocation, equipment downtime and production interruption are minimized, maintenance costs are reduced, and production efficiency is improved.

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