The impact of Digital Transformation on the Innovation Performance of Manufacturing Enterprises from the Perspective of Cloud Manufacturing

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ABSTRACT
Cloud manufacturing describes a model in which enterprises use the Internet of Things to connect equipment and share manufacturing resources, which greatly promotes technological innovation in enterprises and industries. This paper conducts a textual and quantitative analysis of the digital transformation disclosed by listed manufacturing enterprises from 2016 to 2019, analyzes the degree of digital transformation, and then analyzes its impact on the innovation performance of manufacturing enterprises. The research results show that digital transformation significantly improves the innovation performance of enterprises, especially the high-level of innovation performance. Government subsidy is a negative moderator of this effect, while enterprises with a medium-level of total asset scale, net profit margin, R&D investment scale, and R&D personnel ratio have a stronger positive effect of digital transformation on innovation performance.

Keywords: *Cloud Manufacturing; Digital Transformation; Innovation Performance; Textual Analysis; Manufacturing*

1. INTRODUCTION

Cloud manufacturing describes a manufacturing model that forms information sharing through extensive network resource support based on the existing resources of the manufacturing industry. Based on the existing equipment and materials, cloud manufacturing requires manufacturing enterprises to seek digital transformation to make full use of resources, and use cloud computing, Internet of Things, blockchain, and additive manufacturing to form high value-added production models[1]. Information technology support enables cloud manufacturing to promote manufacturers to access the business ecological environment for small-scale and high-frequency effective cooperation[2]. The good cooperation foundation further supports the diversification of cloud manufacturing services[3-6].

The researchers analyzed the impact of digital transformation on factors such as corporate profitability, organizational restructuring, operational efficiency, environmental performance, and reputation, while the analysis in the direction of innovation was insufficient[7-9]. Cloud manufacturing is closely related to enterprise innovation. Existing research supports its model, which is conducive to the rapid iteration of enterprises to promote innovation[10]. However, the research on cloud manufacturing and innovation performance is mainly based on questionnaire surveys, but lacks empirical analysis. Based on this, this paper uses quantitative analysis to quantify the digital transformation indicators of manufacturing enterprises to analyze their impact on innovation performance.

2. DATA SOURCES AND DATA PROCESSING

The independent variable used in this paper is digital transformation, and the indicator is obtained by text analysis. The data of China's A-share listed enterprises are screened, and the annual reports from 2016 to 2019 of manufacturing companies classified as C13-C43 by the China Securities Regulatory Commission in 2012 are collated. A total of 51 words in three categories such as digital-related artificial intelligence, cloud computing, and big data technology were selected for text word frequency analysis to form three types of vocabulary word frequencies. Factor analysis was performed on this data after 1% winsorization at both ends, as follows:

Table 1. Factor Analysis of Independent Variables

Title	Principal Component 1	Composite Score Coefficient	KMO
Eigen Value	1.932		
% of Variance	64.39%		
Artificial Intelligence Technology	0.578	0.578	0.64
Cloud Computing Technology	0.531	0.531	
Big data Technology	0.62	0.62	

As shown in the table above, this paper uses principal component analysis to perform factor analysis on the above three indicators and then reduces the dimension to form a single indicator, which is used as an indicator of the degree of digital transformation of the independent variable for subsequent analysis. The dependent variable used in this paper is enterprise innovation performance, which is obtained by collating financial data. The difference between the current increase minus the current decrease and the original value of the goodwill, software, patents, proprietary technology, non-patented technology and technology investment, etc. in the intangible assets of the above-mentioned enterprises in the current year is used as the dependent variable for analysis, and the original value is used for the robustness test.

The indicators used in this paper are as follows:

Table 2. Selection of Indicators

Indicator Type	Indicator	Indicator Code
Independent Variable	Degree of Digital Transformation	DT
Dependent Variable	Intangible Assets Added Value	IA
Dependent Variable（For Robustness Test）	Original Value of Intangible Assets	OIA
Control Variable	Shareholders' Equity Turnover	SET
	Working Capital Turnover	WCT
	Cash and Cash Equivalents Turnover	CET
	Non-current Asset Turnover	NCT
	Expense Rate During The Sales Period	ERS
	Net Profit Margin of Total Assets	NPA
Threshold Variable	Proportion of R&D Personnel	PP
	R&D Investment as a Proportion of Operating Income	PI
	Total Asset	TA
Coordinate Variable	Total Amount of Government Subsidy in The Current Period	TGS

All indicators fill the missing value with the median, and perform 1% winsorization at both ends.

The sample data characteristics of the above data are collated as follows:

Table 3. Descriptive Statistic

Title	N	Min.	Max.	Mean	S.D.	Median
DT	8460	-0.412	10.238	0	1	-0.328
IA	8460	0	8.673	6.123	1.244	6.239
OIA	8460	4.266	9.493	7.226	0.866	7.283
SET	8460	0.082	10.45	1.22	1.205	0.906
WCT	8460	0.216	149.192	4.776	13.353	1.948
CET	8460	0.306	74.773	7.359	9.202	4.619
NCT	8460	0.091	14.609	1.899	1.927	1.356
ERS	8460	0.02	1.087	0.2	0.144	0.162
NPA	8460	-0.633	0.226	0.033	0.092	0.039
PP	8460	0.203	67.747	15.224	11.274	12.64
PI	8460	0.05	26.753	4.721	3.876	3.885
TA	8460	8.546	11.312	9.6	0.522	9.543
TGS	8460	0	9.043	6.755	1.615	7.053

3. COORDINATION EFFECT ANALYSIS

Introduce government subsidy behavior to verify the existence of the coordination effect and conduct data analysis, including:

Table 4. Analysis of coordination effect under the condition that current net added value of intangible assets and original value are used as dependent variables respectively

Model	IA			OIA		
	1	2	3	1	2	3
Constant	6.107*** -214.958	6.106*** -215.269	6.107*** -215.299	7.186*** -365.959	7.185*** -367.215	7.186*** -367.268
WCT	0.003*** -2.807	0.003*** -2.884	0.003*** -2.88	0.002*** -2.585	0.002*** -2.7	0.002*** -2.696
CET	-0.005*** (-2.889)	-0.005*** (-2.891)	-0.005*** (-2.858)	-0.004*** (-3.943)	-0.004*** (-3.954)	-0.004*** (-3.916)
SET	0.080*** -5.883	0.079*** -5.788	0.079*** -5.797	0.108*** -11.476	0.107*** -11.362	0.107*** -11.373
ERS	0.188** -2.016	0.191** -2.052	0.191** -2.052	0.133** -2.057	0.136** -2.112	0.136** -2.113
NCT	-0.052*** (-6.680)	-0.051*** (-6.577)	-0.051*** (-6.604)	-0.050*** (-9.322)	-0.049*** (-9.186)	-0.049*** (-9.218)
DT	0.128*** -9.536	0.125*** -9.314	0.129*** -9.496	0.103*** -11.072	0.099*** -10.765	0.103*** -10.969
TGS		0.044*** -5.325	0.045*** -5.386		0.045*** -7.854	0.045*** -7.923
DT*TGS			-0.015* (-1.853)			-0.012** (-2.102)
R^2	0.019	0.023	0.023	0.035	0.042	0.042
Adjusted R Square	0.019	0.022	0.022	0.034	0.041	0.041
F	F (6,8453)=27.737	F (7,8452)=27.902	F (8,8451)=24.851	F (6,8453)=50.607	F (7,8452)=52.501	F (8,8451)=46.509
p	0.000	0.000	0.000	0.000	0.000	0.000

* p<0.1 ** p<0.05 *** p<0.01

As shown in the table above, both the independent variable and the control variable are related to the dependent variable. After the coordinating variable was introduced, both the coordinating variable and the independent variable formed a significant positive correlation with the dependent variable at the 99% confidence interval, and the coefficient of the independent variable decreased. After considering the coordination effect, this coefficient rises to the original level, and the influence of the coordination variable also increases. The coordination effect formed by the superposition of the two is significant at the 99% confidence interval, indicating that the coordination effect exists, and government subsidies inhibit the positive effect of the degree of digital transformation on the innovation performance of enterprises, forming a negative coordination effect. On the one hand, this negative coordination effect may come from the screening of corporate innovation activities by government subsidies, which makes it difficult for enterprises seeking to develop in areas such as digital transformation to obtain such direct subsidies. On the other hand, it may indicate that the government's involvement in selection and support may have a certain preference for industry structure guidance. Such subsidy review and distribution activities affect the resource coordination and cooperation behavior of enterprises seeking marketization, and there is a certain conflict between the two. The results of the robustness test using the original value are the same, the coefficient of the coordination effect is weakened, and the significance is enhanced.

4. THRESHOLD EFFECT ANALYSIS

Use threshold models to verify the role of financial and innovation conditions in digital transformation. The data collated for this threshold effect are shown in the table below:

Table 5. Threshold Effect Test

Threshold Variable	TA	NPA	PI	PP
WCT	0.002786***	0.0028954***	0.0027977***	0.00286815***
CET	-0.0046765***	-0.0046038***	-0.0044665***	-0.00473425***
SET	0.0806755***	0.080752***	0.0795114***	0.08056345***

NCT	-0.0519641***	-0.0519586***	-0.0510894***	-0.05154015***
ERS	0.2135795*	0.1927412**	0.1843461**	0.18760665**
Threshold 1	0.1899724***	0.1218957***	0.0312719	0.09962935***
Constant	6.039602***	6.121625***	6.132675***	6.0949585***
Threshold 2	2.174294***	0.4932793	0.1360267***	0.26564415***
Constant	5.82835***	5.974855***	6.096609***	5.9752565***
Threshold 3	-0.1967861	0.9735703**	-0.0632691	0.23104755***
Constant	6.708815***	5.001325***	5.685985***	6.1023985***
Threshold 4	-0.1003699	0.1830529***	0.0471082	0.4896945***
Constant	5.796076***	6.037165***	6.719172***	5.2153395***
Threshold 5	0.1133487***	0.0119096	0.1822341***	0.2263108
Constant	6.117187***	6.142695***	6.16605***	6.5685***
Threshold 6	-	0.193676***	-	0.13991645***
Constant	-	6.052555***	-	6.1527235***

As shown in the table above, different indicators significantly affect the impact of enterprise digital transformation on innovation performance.

For the total asset scale, it has formed a positive effect-strong positive effect-negative effect-negative effect-positive effect with the increase of the asset scale, forming a strong N-shape on the left as a whole. Digital transformation can still lead to significant improvements in corporate innovation performance under the condition of a higher level of total asset scale. However, this positive effect is weaker, while the moderately strong level has a more negative effect. The positive effect of digital transformation on innovation performance is stronger only under the medium and weak asset scale (about 1.4 billion yuan), while the positive effect of digital transformation under the lower asset scale is weaker. On the whole, the effect of digital transformation on enterprise innovation activities is positive when the total asset scale is low, negative when the total asset scale is high, and at very high levels of total assets, the weaker positive effect is restored. This characteristic may come from the fact that the digital transformation cost of enterprises with high asset scale is high, and the overall transformation is difficult to integrate into the cloud manufacturing environment and other scenarios, so that the improvement of their innovation performance is not significant.

For the net profit margin indicator, it forms a change of positive effect - strong positive effect - moderate positive effect - strong positive effect - strong positive effect - strong positive effect with the increase in net margin. The overall form is N-shaped, with a stronger left side and smoother right side. Similar to the threshold effect of the total asset scale data, the net profit margin indicator at both higher and lower levels makes the positive effect of digital transformation on innovation performance weaker. Under the condition of moderate net profit margin (7.24%-7.28%), the digital transformation of enterprises has a significant positive effect on innovation performance. The net profit margin significantly affects the impact of digital transformation on the innovation performance of enterprises, indicating that under the conditions of lower profit margin level and other conditions, enterprises may be more trapped in the fierce market competition, and it is difficult to form stable capital flow and other resources to support digital transformation and its achievements. For enterprises with a high level of net profit margin, the good business operation and development status of the enterprise may have formed a certain level of innovation performance, so that the positive impact of digital innovation on it is not significant. In particular, combined with the high net profit margin under the condition of high net profit margin, the digital transformation of enterprises has a positive effect on enterprise innovation. This characteristic also shows that the net profit margin can further strengthen the positive effect of digital transformation at a high level, and further indicates that such indicators may be closely related to the intensity and efficiency of digital transformation, and its environmental support for innovation activities.

For the R&D investment indicator, it forms a positive effect-strong positive effect-negative effect-positive effect-strong positive effect with the rise of R&D investment, forming an N-shaped structure. Both moderately low and high levels of R&D investment make digital transformation have a positive effect on enterprise innovation performance output, while low and moderately high levels of R&D investment weaken this positive effect or even form a negative effect. Among them, the most significant effect is the threshold value of the lowest level (11.7 yuan), and the value is extremely low, indicating that whether the enterprise has R&D investment forms the first threshold, and the positive effect of digital transformation on enterprise innovation performance is significantly enhanced for enterprises with R&D investment. However, with the increase in the scale of R&D investment of enterprises, this impact has declined until the digital transformation has a significant positive effect on the innovation performance output of

enterprises under the condition of a high level of R&D investment (>400 million yuan), and the optimal R&D investment scale is at the level of about 130 million yuan.

As for the indicator of the proportion of R&D personnel, it has changed with the increase of the proportion of R&D personnel, which is positive effect-moderate positive effect-moderate positive effect-strong positive effect-moderate positive effect-positive effect, forming an M-shaped structure with a stronger right side. Similar to the data on the R&D investment indicator, the threshold for the proportion of R&D personnel at a lower level is relatively significant. That is to say, the proportion of R&D personnel reaching a certain level (14.2%) will make the digital transformation of enterprises have a significant positive effect on the innovation performance of enterprises. The proportion of R&D personnel with a medium level (15.39%-17.58%) has a weak positive effect. Further increasing the proportion of R&D personnel (>17.96%) also has this effect. R&D personnel accounted for 17.58%-17.62%, which had a strong positive effect on the results of the digital transformation of enterprises.

5. CONCLUSION

The coordination effect analysis shows that government subsidies, as a coordination variable, inhibit the positive effect of digital transformation of enterprises on enterprise innovation performance, and this negative coordination effect still exists after the replacement of innovation performance indicators. The threshold model analysis verifies that four categories of indicators, including total asset scale, net profit margin, R&D investment scale, and R&D personnel ratio, have formed five thresholds, six thresholds, five thresholds and six thresholds models respectively. The first three exhibit an N-shaped structure, and the data perform well at medium and high levels. The characteristics of financial performance indicators indicate that smaller and stable enterprises are more suitable for digital transformation, and the positive effect of digital transformation on the innovation performance of high-performing enterprises is slightly lower than this. The scale of R&D investment has the characteristics of low threshold, and the data shows that the proportion of R&D personnel with moderately low or high levels promotes the positive effect of digital transformation on innovation performance

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