Digital Transformation and Enterprise Innovation— Empirical Evidence from Listed Companies in China

Liu Hongfu

College of Economics, Guangxi University, Nanning, Guangxi, China
1497978551@qq.com

Abstract: Under the tide of digital economy, digital transformation has become the only way for enterprises to develop with high quality. At the same time, as China's economic development mode gradually changes from resource-driven to technology-driven, the improvement of technological innovation capability of enterprises has become urgent. Can the digital transformation of enterprises promote the innovation of enterprises? Based on the text analysis of the annual reports of listed companies in China from 2011 to 2020, the panel fixed effect model and other methods are used to study and find that the digital transformation of listed companies significantly promotes enterprise innovation. The conclusion is still valid after a series of robustness tests. The conclusion can provide reference for enterprises to make decisions on digital transformation, the government to issue relevant guiding policies on digital transformation, and to deepen the research on the impact of enterprise innovation factors.

1. Introduction

Since the new era, China's attention to the development of digital economy has stepped to a new level, and the development of digital economy has entered a new stage. In September 2016, the general secretary emphasized the digital economy at the G20 summit in Hangzhou. At the end of the year, China's digital economy added value reached 22.58 trillion yuan, accounting for 30.1% of GDP. The 2017 government work report, the 19th national congress report and the 19th national congress put forward the concepts and strategies of "digital economy" development, "digital development, digital integration development" and "promoting the deep integration of internet, big data, artificial intelligence and real economy". According to China Internet Development Report 2022, the outcome document of the world internet conference Wuzhen Summit in 2022, China's digital economy accounted for 39.8% of GDP in 2021, up 9.7 percentage points from 30.1% five years ago, reaching 45.5 trillion yuan.

Digital economy mainly includes digital industrialization and industry digitalization, which are closely connected and complement each other.[1] Digital industrialization is the process of industrialization of digital technology, and industrial digitalization is the process by which an enterprise integrates advanced digital technology with its business development, and then uses digital technology to improve the production efficiency of the company; The digital transformation of traditional industries has become the main battlefield for the development of digital economy, and it

is one of the important tasks for China's economy to turn to a high-quality stage of development. [2] Enterprise is the most representative micro-body in the economic system and the backbone of the construction of digital China. In the global digital wave, digital transformation is the only way for enterprises to achieve their own high-quality development. Since the 18th National Congress of the CPC, the Chinese government has issued special planning and guidance on promoting industrial digitalization in many official documents and major conferences, guiding our enterprises to carry out digital transformation.

With the deepening of digital transformation research, new research results are emerging in this field. Zhao Chen Yu et al. [3] and Tang Tao et al. [4] found that digital transformation can significantly improve the total factor productivity and labor productivity of enterprises; Huang Dayu and others[5] and Yi Lulu and others[6] pointed out that digital transformation has a significant effect on corporate value and corporate performance by analyzing and studying the annual reports of listed companies. At the same time, some scholars found that[7], the development of the Internet can directly and indirectly promote the efficiency and level of regional innovation. Other scholars pointed out that financial science and technology can promote corporate innovation by easing corporate financing constraints and improving the innovative effect of tax rebates[8], and this promoting effect is more obvious under reasonable financial supervision[9]. So will digital transformation affect enterprise innovation? The possible marginal contribution of this paper is to directly link the digital transformation with the enterprise innovation, to verify the promotion effect of the digital transformation on the enterprise innovation, and to further point out its impact path; It enriches the research in relevant fields, and provides references for enterprises to make decisions on digital transformation, the government to issue relevant guiding policies on digital transformation, and to deepen the research on the impact of enterprise innovation factors.

2. Literature Review and Research Hypothesis

2.1 Literature Review

2.1.1 The concept of enterprise digital transformation and its micro impact on the enterprise research review

In various documents, the definition of digital transformation is not uniform. Vial[10] points out that the definition of digital transformation should include the following four parts: target entity, transformation method, transformation scope and expected results. It then defines digital transformation as the process by which an entity triggers significant changes and improves the entity by combining information, computing, communication, and connectivity technologies. It can be seen that the upgrading of digital equipment and the simple combination and application of technology cannot be equated with the digital transformation. In the digital economy, data has become the same important elements as labor, capital and land, which are written into the production function together and become the driving force of the innovative output of enterprises[11].

At present, there are many literatures on the micro-impact of digital transformation on enterprises. One is to point out the positive impact of digital transformation on enterprises. Wu Changqi et al [12] empirically tested how the digital transformation of an enterprise helps the enterprise to achieve high-quality development by influencing the selection of competitive strategies by analyzing the data of listed companies in Shanghai and Shenzhen stock markets from 2010 to 2019; Wu Fei et al [13] verified through empirical analysis that corporate digital transformation can significantly improve the liquidity of listed companies' shares. Wang Jingyong et al [14] pointed out that digital transformation can significantly ease corporate financing constraints. The other is to point out the possible negative consequences of digitalization of enterprises. Qi Yudong et al. [15] found that, as digital transformation

is not only a simple technological upgrade for most enterprises, but also an adjustment of the organization system, if the enterprise's ability to manage the organization system lags behind the advanced technological structure of digital transformation, the positive benefits brought by digital transformation will be offset by the same increase in management costs brought by it; Yujiang county and others [16] also pointed out that the improvement of the digitalization level of enterprises will cost a lot of money. In order to adapt to the improvement of the digitalization level, the internal learning cost of enterprises is also huge. It can be seen that at present, most of the academic circles hold a positive attitude towards the digital transformation of enterprises, but at the same time, they also point out the possible adverse effects.

2.1.2 Review of the research on the influencing factors of enterprise innovation

The research on the influencing factors of enterprise innovation is endless. These studies can be roughly divided into internal and external aspects. External factors of the enterprise. From the perspective of industrial policy, Yu Minggui et al [17] verified the significant encouraging effect of industrial policy on the invention patents of enterprises by studying the patent data of listed companies and their subsidiaries from 2001 to 2011; Considering the business environment, He Lingyun et al. [18] conducted an empirical analysis based on the survey data of the World Bank, indicating that the better the government's integrity, service efficiency and the market environment in which the enterprises are located, the higher the research and development investment of the enterprises; Internal factors of the enterprise. Zhang Jinfan and others[19] found that enterprises can promote enterprise innovation through IPO in the stock market, because the listing of enterprises greatly eases their financing constraints and promotes the construction of innovative talents team of enterprises; Lang Xiang Xiang and others[20] found that Digital inclusive finance significantly promoted enterprise innovation by easing the financing constraints of small and medium-sized enterprises and reducing financing costs; Li Chuntao and others[21] found that the CEO compensation incentive can promote the interests of managers and shareholders to be consistent, so that they can consider more about the long-term development of the enterprise, expand the scale of innovation investment and create more innovation results; Yang Daoguang et al. [22] Empirical analysis found that the improvement of internal control level of enterprises promoted the improvement of innovation efficiency. It can be found that there are many literatures that analyze the influencing factors of enterprise innovation from the internal and external aspects of the enterprise, but few literatures study its impact on enterprise innovation from the perspective of digital transformation.

2.1.3 A review of the research on the relationship between digital transformation and enterprise innovation

Enterprise innovation belongs to the micro-behavior of enterprises. In the existing literature, the factors that affect enterprise innovation from the digital perspective are mostly abstracted from the macro-level of some digital features, and then the impact of enterprise innovation (macro→micro) is studied. For example, Han Xianfeng and others[7] have studied the impact of internet development level on innovation, Li Chuntao and others[8] have studied the impact of technology development level on innovation, and few literatures have studied the impact factors of innovation from the same perspective (micro→micro); The digital transformation of enterprises is precisely such a micro perspective. Existing researches have found that the digital transformation of enterprises has a wide range of impacts on enterprises, such as its impact on the enterprise's factor productivity[4], operating efficiency, internal control, etc. However, there is less literature on the impact of digital transformation on enterprise innovation. Based on the micro perspective of enterprise digital transformation, this paper enriches the research on micro factors that affect innovation.

2.2 Research hypothesis

The impact of digital transformation on enterprises is all-round and innovation is an important aspect. From the perspective of transformation mode, the application of digital technologies such as artificial intelligence, block chain, cloud computing, big data and mobile internet involved in enterprise digitalization can promote innovation. For example, the improvement of digital technology can ease the information constraint of enterprises, improve the information asymmetry between markets, accelerate the interconnection among enterprises and weaken the innovation barriers; Digital application can ease the resource constraints of enterprises and realize the ecology of the Internet of Things, so that different innovation subjects can participate in the innovation process at the same time; From the perspective of transformation scope, the emergence and development of new models and formats such as "sharing economy" and "cloud data" enable enterprises in the supply chain to improve the efficiency of resource utilization, reduce the cost of learning and information collection, and improve the efficiency of innovation by sharing equipment and services. From the perspective of the expected purpose of transformation, the way for enterprises to obtain value is not only to support the existing value proposition, but also to create new value, and this value-creating process is a process of innovation. Therefore, the improvement of innovation level is one of the important purposes of enterprises' digital transformation.

Based on the above analysis, the following assumptions are proposed:

Hypothesis H1: Digital transformation can significantly promote enterprise innovation.

3. Empirical Design

3.1. Data sources and data samples

The research object of this paper is listed companies in China, and the data from 2011 to 2020 is used as the research sample. The digital transformation index uses the "Digital Transformation Index of Listed Companies in China" published by Guangdong Institute of Finance the data in the documents, the patent application data are from the CNRDS database, and the data of other companies are all from the CSMAR database. Referring to the existing research, all data are processed as follows: 1) Remove the ST and ST enterprise samples (if ST and ST occur in a certain year, remove all annual samples of the company); 2) Excluding the sample of financial enterprises (including real estate enterprises because of their heavy financial attributes); 3) Remove the samples with missing main variables; 4) Considering the stationarity of the data, only samples of companies with 5 consecutive years or more are retained; 5) Shrink the data of other variables except for virtual variables at the upper and lower 1% levels. After treatment, a total of 22,036 observations from 2,496 companies were obtained.

3.2. Model design

In order to study the impact of digital transformation on enterprise innovation, this paper constructs multiple regression model (1) as follows:

$$Innovation = \beta_0 + \beta_1 Digital + \beta_2 Controls + Firm + Year + \varepsilon \qquad (1)$$

Among them, enterprise Innovation is the dependent variable of the model, enterprise Digital transformation digital is the independent variable, the set of control variables is represented by Controls, and the fixed effects of Firm and Year are added to absorb the individual differences that do not change with time and the differences that do not change with individuals but change with time, thus overcoming the problem of missing variables to a certain extent and relieving the endogeneity

of the model; ε is a random perturbation term, and the coefficient concerned in this paper is β_1, if it is significantly positive, it means that hypothesis H1 is verified.

3.3. Identification strategies

3.3.1 Interpreted variables

Innovation. Referring to the existing research[23], this paper selects the total number of three types of innovation patents (i.e. invention patents, utility model patents and design patents) independently applied by listed companies in the research interval as the proxy index of enterprise innovation. And it is digitized, i.e. the natural logarithm is taken after adding one to the total number of patents.

3.3.2 Core explanatory variables

Digital enterprise transformation. This paper uses the research of Wu Fei [13] and others for reference, and uses the frequency of the words related to "digital transformation" in the annual reports of listed companies as an agent index to measure the degree of enterprise digital transformation. In order to make the data more stable, the number of words related to "digital transformation" is processed by adding one to the word frequency and then taking the natural logarithm.

The index constructs a "digital transformation" word spectrum by referring to relevant research and policy documents such as "digital economy" and "digital transformation", and uses Python technology to count the frequency of words matching the "digital transformation" word spectrum in the annual report of listed companies. The higher the frequency of such words, the higher the degree of digital transformation of the enterprise. The digital transformation lexicon consists of "application of bottom-level technologies" and "application of technology in practice". The application of bottom-level technologies includes artificial intelligence, block chain, cloud computing and big data technology. The specific vocabulary included in the lexicon is shown in the document "Digital Transformation Index of Listed Companies in China" published by Guangdong Institute of Finance.

3.3.3 Interpreted variables

Table 1: Definition of Indicators

Variable symbol	Variable name	Variable meaning
Innovation	Enterprise innovation	Apply the total number of innovative patent applications plus one and take the natural logarithm.
Digital	Digital Transformation of Enterprises	Use digital transformation related word frequency, add one and then take natural logarithm
Size	Company size	The data of total assets of the enterprise are taken as natural logarithm.
Age	Company age	The number of years of establishment of the enterprise is adopted, and the natural logarithm is taken after adding one.
Top1	Ownership concentration	Adopting the shareholding ratio of the largest shareholder of the enterprise
Lev	Asset-liability ratio	Equal to total liabilities/total assets
Cash	Proportion of cash assets	Equal to the balance of cash and cash equivalents/total assets at the end of the period
PPE	Percentage of fixed assets	Equal to net fixed assets/total assets
Roa	Return on assets	Equal to net profit/total assets

Referring to the relevant research[24-26], this paper determines the Size of the company, Age of the company, rate of return on assets (Roa), asset-liability ratio (Lev), Cash asset ratio (Cash), fixed asset ratio (PPE) and equity concentration ratio (Top1) as the control variables of the model. The specific variable definitions are shown in Table 1.

4. Empirical analysis

4.1 Descriptive statistics of variables

As shown in Table 2, from the data of Innovation, the minimum value is 0, the average value is 1.658, and the maximum value is 6.133, indicating that there is a large difference in innovation level between listed companies, with the median value of 1.609, slightly less than the average value of 1.658, showing a "left-leaning" feature; The minimum value of the explanatory variable Digital is 0, the average value is 2.755, and the maximum value is 5.864, which indicates that there is a great disparity in the degree of digital transformation of each enterprise, with the median value of 2.708, which is less than the average value of 2.755, showing a slight "left-leaning" characteristic. In addition, the difference between the median value and the mean value of all variables is small. It can be considered that the distribution of each variable tends to normal distribution, which well meets the basic assumptions of regression analysis.Science and technology of insurance companies

Table 2: Descriptive Statistics

Variable name	sample number	minimum value	average value	median	maximum	standard deviation
Innovation	22036	0	1.658	1.609	6.133	1.643
Digital	22036	0	2.755	2.708	5.864	1.341
Age	22036	1.648	2.812	2.864	3.469	0.355
Lev	22036	0.0505	0.405	0.399	0.843	0.196
Roa	22036	-0.224	0.0413	0.0394	0.192	0.0561
Size	22036	19.95	22.17	22.00	26.14	1.270
Top1	22036	0.0854	0.346	0.327	0.746	0.148
Cash	22036	0.0118	0.168	0.129	0.643	0.132
PPE	22036	0.00467	0.216	0.183	0.695	0.156

4.2 Benchmark Regression

Table 3: Enterprise Digital Transformation and Enterprise Innovation–Benchmark Regression

VARIABLES	(1)	(2)
	Innovation	Innovation
Digital	0.048***	0.043***
	(3.58)	(3.22)
Lev		-0.386***
		(-3.42)
Roa		0.220
		(1.11)
Size		0.058*
		(1.70)
Top1		-0.383*
		(-1.85)
Cash		-0.164
		(-1.60)
PPE		0.195
		(1.39)
Age		-0.110
		(-0.58)
Constant	1.347***	0.659
	(37.09)	(0.75)
N	22,036	22,036
Firm FE	YES	YES
Year FE	YES	YES
Adj.R^2	0.0182	0.0206

Note: *, * *, * * * are significant at 10%, 5% and 1%, respectively. The value of T statistic is shown in brackets, and robust standard error (White, 1980) is used for estimation, the same below.

Table 3 is the benchmark regression results for Model (I). Columns (1) and (2) are the regression

coefficients after the addition of no control variable and a series of control variables respectively (both regressions have added the fixed effect of company and year). It can be seen that the coefficients β_1 in both columns are positive, and the value of T statistic is 3.58 and 3.22 respectively, which indicates that the original assumption can be rejected at least at 1% statistical level, thus verifying the assumption in this paper that H1: digital transformation can significantly improve enterprise innovation.

4.3 The robustness test

4.3.1 Replace explanatory variables

The enterprise digital transformation index (Digital2) provided by CSMAR database is used as an alternative to the original digital transformation index. The index system is established from six aspects: strategic guidance, technology-driven, organizational empowerment, environmental support, digital results and digital application. The index system is used to score listed enterprises in China, and the digital transformation index of each enterprise is obtained after standardization. After using this indicator, the regression results are shown in column (1) of Table 4, with coefficient value of 0.299 and statistical value of T of 3.66, indicating that the coefficient β_1 is significantly positive at the level of 1%, which verifies the assumption in this paper that H1: digital transformation can significantly improve enterprise innovation.

4.3.2 Replace the interpreted variable

Table 4: Robustness Test-Alternate Variables

VARIABLES	(1)	(2)
	Innovation	Innovation2
Digital2	0.299***	
	(3.66)	
Digital		0.032***
		(2.97)
Lev	-0.386***	-0.257***
	(-3.42)	(-3.05)
Roa	0.243	0.241
	(1.23)	(1.54)
Size	0.056*	0.085***
	(1.65)	(3.35)
Top1	-0.362*	-0.202
	(-1.75)	(-1.37)
Cash	-0.150	-0.171**
	(-1.46)	(-2.08)
PPE	0.201	0.159
	(1.43)	(1.47)
Age	-0.125	-0.088
	(-0.66)	(-0.58)
Constant	-0.216	-0.615
	(-0.24)	(-0.92)
N	22036	22036
Firm FE	YES	YES
Year FE	YES	YES
Adj.R^2	0.0210	0.0208

Referring to the research of Li Wenjing and others [24], among the three types of patents applied by enterprises, invention patents can best directly show the achievements of key technologies of enterprises, and the increase in their number can better reflect the improvement of innovation ability of enterprises, which is a "qualitative change" of enterprise innovation; Compared with this, the increase in the number of applications for the other two types of patents reflects the "quantitative

change" of enterprise innovation, which is more in order to obtain government support and cater to the policies and regulations, and reflects the weak function of improving the innovation ability of enterprises. Therefore, this paper uses the number of applications for invention patents (Innovation2) of listed enterprises as an alternative index of the original enterprise innovation index (which is also subjected to mathematical treatment), and uses model (1) again for regression. The regression results are shown in column (2) of Table 4, with coefficient β_1 value of 0.032 and statistical value of T of 2.97, indicating that the coefficient is significantly positive at the level of 1%, which verifies the assumption in this paper that H1: digital transformation can significantly improve enterprise innovation.

5. Conclusion

This paper takes the listed companies in China as the research object, based on the text analysis of the listed companies' annual reports from 2011 to 2020, to study the impact of the digital transformation of enterprises on enterprise innovation under the digital wave. This study found that digital transformation can significantly improve enterprise innovation, and this conclusion still holds after a series of robustness tests. The conclusions of this paper can provide a reference for enterprises to make digital transformation decisions, the government to issue relevant guiding policies for digital transformation, and to deepen the research on the impact of enterprise innovation factors.

References

[1] Qi Huaijin, Cao Xiuqin, Liu Yanxia. The Impact of Digital Economy on Corporate Governance: Based on Information Asymmetry and Managers' Irrational Behavior [J]. Reform, 2020(04):50-64.

[2] Qi Yudong, Xiao Xu. Enterprise Management Reform in the Digital Economy Era [J]. Management World, 2020, 36(06): 135-152.

[3] Zhao Chenyu, Wang Wenchun, Li Xuesong. How Digital Transformation Affects Total Factor Productivity of Enterprises [J]. Finance and Trade Economics, 2021, 42(7):114-129.

[4] Tang Tao, Li Fangjing, Xia Lun. The Impact of Enterprise Digitization on Labor Productivity: Empirical Evidence from Private Enterprises in China [J]. Journal of China University of Geosciences (Social Science Edition), 2022, 22(06): 112-124.

[5] Huang Dayu, Xie Huobao, Meng Xiangyu, et al. Digital Transformation and Enterprise Value: Empirical Evidence Based on Text Analysis Method [J]. Economist, 2021(12):41-51.

[6] Yi Luxia, Wu Fei, Chang Xi. The Process of Digital Transformation of Enterprises and Performance of Main Businesses: Empirical Evidence from Text Recognition of Annual Reports of Listed Enterprises in China [J]. Modern Finance (Journal of Tianjin University of Finance and Economics), 2021, 41(10):24-38.

[7] Han Xianfeng, Song Wenfei, Li Boxin. Can the Internet Become a New Kinetic Energy to Enhance Regional Innovation Efficiency in China [J]. China Industrial Economy, 2019(07):119-136.

[8] Li Chuntao, Yan Xuwen, Song Min, et al. Financial Technology and Enterprise Innovation: Evidence from New Third Board Listed Companies [J]. China Industrial Economy, 2020(01):81-98.

[9] Tang Song, Wu Xuchuan, Zhu Jia. Digital Finance and Enterprise Technology Innovation: Structural Characteristics, Mechanism Identification and Effect Differences under Financial Supervision [J]. Management World, 2020,36(05):52-66.

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

[11] He Fan, Liu Hongxia. Evaluation of Performance Enhancement Effect of Entity Enterprise Digital Transformation from the Perspective of Digital Economy [J]. Reform, 2019(4):137-148.

[12] Wu Changqi, Zhang Kunxian, Zhou Xinyu, et al. Digital Transformation, Competitive Strategy Selection and High-quality Enterprise Development: Evidence Based on Machine Learning and Text Analysis [J]. Economic Management, 2022, 44(04):5-22.

[13] Wu Fei, Hu Huizhi, Lin Huiyan, et al. corporate digital transformation and capital market performance-empirical evidence from stock liquidity [J]. Management world, 2021, 37(07):130-144.

[14] Wang Jingyong, Sun Tong, Li Pei, et al. Digital Transformation and Corporate Financing Constraints: Empirical Evidence from Listed SMEs [J]. Scientific Decision-Making, 2022(11):1-23.

[15] Qi Yudong, Cai Chengwei. Study on the Multiple Effects of Digitalization on the Performance of Manufacturing Enterprises and Its Mechanism [J]. Learning and Exploration, 2020(07):108-119.

[16] Yu Jiang, Meng Qingshi, Zhang Yue, et al. Digital Innovation: Exploration and Enlightenment of New Perspective of Innovation Research [J]. Scientific Research, 2017, 35(07):1103-1111.

[17] Yu Minggui, Fan Rui, Zhong Huijie. Industrial Policy and Enterprise Technology Innovation in China [J]. China Industrial Economy, 2016(12):5-22.

[18] He Lingyun, Tao Dongjie. Will the Business Environment Affect Enterprise R&D Investment? —Empirical analysis based on the survey data of the World Bank [J]. Journal of Jiangxi University of Finance and Economics, 2018(03):50-57.

[19] Zhang Jinfan, Li Hanya, He Hui. Enterprise Listing and Enterprise Innovation: Research Based on Enterprise Patent Application in China [J]. Financial Research, 2017(05):160-175.

[20] Lang Xiangxiang, Zhang Meng, Wang Jianing. Digital inclusive finance, Financing Constraints and Innovation of Small and Medium-sized Enterprises: A Study Based on the Data of New Third Board Enterprises [J]. Southern Finance, 2021(11):13-25.

[21] Li Chuntao, Song Min. Innovative Activities of Manufacturing Enterprises in China: Ownership and the Role of CEO Incentives [J]. Economic Research, 2010, 45(05):55-67.

[22] Yang Daoguang, Wang Jiani, and Chen Lirong. "Overcoming the Right Deviation" or "Reasonable Control"? —The role of internal control in enterprise innovation [J]. Economic Management, 2019, 41(08):113-129.

[23] Zhou Xuan, Cheng Liru, Wang Hao. Is the higher the level of technological innovation, the better the financial performance of enterprises? —An empirical study based on 16 years of patent application data of pharmaceutical listed companies in China [J]. Financial Research, 2012(8):166-179.

[24] Li Wenjing, Zheng Manni. Substantive innovation or strategic innovation? —The impact of macro-industrial policies on micro-enterprise innovation [J]. Economic Research, 2016, 51(04):60-73.

[25] Pan Hongbo, Gao Jinhui. Digital Transformation and Enterprise Innovation: Empirical Evidence Based on the Annual Reports of Listed Companies in China [J]. Journal of Central South University (Social Science Edition), 2022, 28(05): 107-121.

[26] Fan Hongzhong, Wang Ziyue, Tao Shuang. Digital Transformation and Enterprise Innovation: Empirical Evidence Based on Text Analysis Method [J]. Technology Economy, 2022, 41(10):34-44.