

An Empirical Analysis of the Relationship Between Digital Transformation and Supply Chain Centralization

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Abstract. The study delves into the repercussions of enterprise digital transformation on supply chains, particularly scrutinizing how the international experiences of enterprise top management teams (TMTs) shape these effects. Drawing upon data spanning from 2007 to 2020 from Chinese listed companies, the research unveils that the digital metamorphosis of enterprises substantially diminishes the concentration within their supply chains. Interestingly, TMTs' overseas experiences exhibit a mitigating effect on this phenomenon, indicating that such experiences significantly foster the reduction of supply chain concentration propelled by enterprise digital transformation. Moreover, they facilitate the diversification of supply chains. Further analysis underscores that this influence is more pronounced in non-high-tech sectors and privately-owned enterprises. This investigation highlights a noteworthy trend: as Chinese enterprises embrace digitalization, their supply chain configurations tend towards greater diversification rather than centralized structures. These findings underscore the pivotal role of TMTs' international exposure in shaping the dynamics of supply chain evolution amidst the digital transformation landscape.

Keywords: Digital Transformation, Supply Chain Centralization, Chinese-Listed Companies.

1. Introduction

1.1. Digital Transformation and Supply Chain Concentration

With the changes of the world, many firms face challenges in the technology revolution at present. Two challenges, which are extremely urgent, is how firm can be alive in the digital transformation and how firm can get advantages in the technology revolution. Moreover, both many advantages and disadvantages of digitalized application of firms are expressed in firms' data [1, 2]. Therefore, whether a firm need to digitalize its operation, how a firm accomplish its digital transformation will be two tough questions to all the firms.

Supply chain, which is one of the most significant part of enterprise operation, determines enterprise's success. The effective management can also help enterprises improve their performance, gain more market share, and also improve their risk resistance. Its development direction of centralization and diversification has its own advantages and disadvantages [3].

On the one hand, centralized supply chain can help businesses achieve scale effects, increase production efficiency, and improve their ability to acquire knowledge is by facilitating information sharing inside the chain. Comparing this relationship to diversification, it is simpler and more reliable. However, there may be the problem of upstream and downstream splicing their own dominant position in the supply chain to squeeze each other to other positions. Thus, a large amount of opportunism may occur, leading to information asymmetry within the supply chain and an increase in external transaction costs due to lack of contracts [4].

On the other hand, the diversification of supply chain concentration has more advantages than centralization in enhancing the resilience of the supply chain and reducing and diversifying risks [5]. At the same time, the diversification of the supply chain can also promote the sharing of knowledge and product information, thereby helping enterprises improve their own innovation capabilities [6]. However, to a certain extent, diversification also breaks the centralized existence of production, investment, and information sharing, raises the bar for coordination and collaboration between the supply chain's upstream and downstream customers and adds to its overall complexity [7].

As a result, leaders of companies will try their best to upgrade the supply chain and guarantee their supply chain having abilities to be confronted with any risks, chances and the development directions. Applying new technologies is one of common ways to improve it. In the new technology revolution, the digital transformation of firms is one of most necessary technology that firm should use in their management and operation.

Decision-making of corporations in the supply chain, as well as the process of building the supply chain itself, is significantly impacted by their digital transformation. In the supply chain, as well as the process of building the supply chain itself, is significantly impacted by their digital transformation. First of all, digital transformation can help enterprises achieve information collection and sharing at a lower cost without excessive concentration or cooperation with other non-essential enterprises, so as to formulate relevant supply chain management strategies [8]. In addition, basing on shared information, it will also reduce the squeeze on themselves by advantageous enterprises and alleviating opportunism and internal information inequality [9]. Finally, digital transformation can also assist enterprises in the design of supply chain structure, reduce the complexity and risks of chain diversification to strengthen the connection between supply chains [5].

Basing on the argument, the first hypothesis is proposed, as follows.

H₁. The digital transformation of enterprises can significantly reduce the enterprise supply chain concentration and diversify it.

1.2. Moderation of TMTs' Oversea Experiences

Nowadays, the volatile international situation and the weakening of the diversification of the global trade pattern have deeply affected the supply chain layout and development of enterprises in various countries. At the same time, the networked and flat enterprise structure, the improvement of enterprise innovation level and enterprise performance brought about by digital transformation have improved the upstream and downstream of enterprise supply chains, chain resilience and chain concentration in cost and risks reduction field [10]. In this case, the supply chain is an obvious field of digital transformation application in reality.

Moreover, because of the huge revenue and chances in the internationalization of firms, they will choose more internationalized strategy and consider more oversea benefits than the past. With several years' internationalization, most of strategies and approaches are chosen by enterprises. Thus, the top management teams (TMTs) of the companies will be one of the most significant factors in the permutation. Who has an extraordinary oversea background will be the best choice [11]. As a result, having oversea experiences ratio of top managers will influence the enterprise's internationalization, which may help the enterprise accept innovation and digitalization [12].

An overseas schooling or employment experience lasting longer than a year away from one's home country is referred to as an overseas experience. These experiences will easily influence TMTs to use an international stance to consider the strategy and operation, which may have the promotion to the internationalization. According to studies, some scholars also find out that TMTs' oversea experiences and internationalization positively affect the innovation, especially the digital transformation [13]. The reason why overseas experiences lead to this outcome could be because foreign organizations have also attempted to digitally transform, and digital transformation has become an explosive subject in worldwide commerce.

The academic community has studied digital transformation, supply chain, and overseas experiences of corporate TMTs in tremendous detail in recent years. In addition, the research direction of digital transformation on enterprise supply chain and TMTs' oversea experiences on digital transformation are popular research in the academic community. However, there is little research on the combination of the three, especially in the section of enterprise TMTs' oversea experiences and enterprise supply chain. As a result, what effect will be caused by top managers who have more oversea experiences to the digital transformation and supply chain is the second question of this research.

Basing on the argument, the second hypothesis is proposed, as follows.

H₂. TMTs' overseas experience negatively moderates the relationship between Digital transformation of the firm and supply chain concentration.

2. Methodology

2.1. Data Collection

This study uses data on Chinese listed firms from 2008 to 2020, which are sourced from the open data of Wu Fei's digital transformation index and China Stock Market Accounting Research (CSMAR) databases [7]. All the digital transformation index comes from Wu Fei's open data. Additional data from CSMAR have been extensively used in earlier research on Chinese companies. Following is the processing of the initial samples to increase their validity and reliability. Initially, financial institutions are not included; Second, *ST, and delisted companies are eliminated; Third, redundant duplicate values were eliminated; Fourth, in order to reduce the influence of outliers, variables are processed to winsorize extreme variables cutting at 1% and 99%. Finally, the panel data of 31,836 enterprises - annual sample observations were obtained.

2.2. Variable Construction

2.2.1. Dependent variable

The dependent variable of this paper is set as the supply chain concentration of the enterprise (concentration). Its measurement mainly lies in the suppliers and customers of the enterprise, which measures separately the concentration of suppliers and customers and combines two concentrations to measure the supply chain concentration. Therefore, this paper refers to the measurement method of Wu's research, this is the mean of the total percentage of sales and purchases from the top five suppliers and clients [5]. In the robustness test, because if the largest supplier and the largest customer account for a large proportion of suppliers and customers in the enterprise, the supply chain concentration will be high, so Wu chose to use the average of the sum of the proportion of purchases and sales from the largest supplier and customer as a new measurement index to replace the original indicator [5].

2.2.2. Independent variable

The degree of digital transformation of businesses is the independent variable in this study, while the frequency of digital transformation keywords in business annual reports serves as the measurement index [7]. By using Wu Fei's numerical word frequency selection range (2021), the frequency of digital transformation words in its publicly available data is chosen to gauge the extent of digital transformation of businesses. Since this variable has the characteristics of right-bias in various studies on enterprise digital transformation, the method of taking the natural number of the total word frequency (+1) is used to further deal with it [7].

2.2.3. Moderator variable

The moderator variable of this paper is set as the overseas ratio of TMTs (oversea ratio). Basing on Chen's research, the measurement of this ratio is the proportion of TMTs with overseas experiences in the whole firms' TMTs [14].

2.2.4. Control variables

According to previous studies, the control variables of this paper are as follows: (1) enterprise size (size, enterprise total asset plus 1 taken as the natural logarithm); (2) enterprise financial leverage (leverage, the ratio of total liabilities to total assets of the enterprise); (3) age of the enterprise (age, the time of establishment of the enterprise); (4) total asset turnover ratio (Tat, the ratio of sales revenue to average total assets of the enterprise); (5) net profit margin of total assets (ROA, the ratio of net profit to total asset balance); (6) the net cash flow (cashflow, the difference between the cash inflow from operating activities and the cash outflow from operating activities).

2.3. Modelling

In order to test the impact of digital transformation on the enterprise supply chain concentration and the moderating effect of enterprise internationalization, this paper refers to the research on the moderating effect of Wen’s research, and establishes formulas (1) and (2) to test hypotheses 1 and 2 [15].

$$concentration_{it} = \beta_0 + \beta_1 digital_{it} + \gamma_i \sum_{j=6}^n Control_{jit} + \varepsilon_{it} \tag{1}$$

$$concentration_{it} = \beta_0 + \beta_1 digital_{it} + \beta_2 inter_{it} + \beta_3 digital \times oversea\ ratio_{it} + \gamma_i \sum_{j=6}^n Control_{jit} + \varepsilon_{it} \tag{2}$$

In all equations, the $concentration_{it}$ is the degree of concentration of enterprise i’s supply chain in year t, i is different enterprises, t is different time, $digital_{it}$ is the degree of digital transformation of enterprise i in year t, $oversea\ ratio_{it}$ is the TMTs’ oversea ratio of enterprise i in year t, $Control_{jit}$ is the control variable, j is a different control variable, and ε_{it} is a random perturbation term.

3. Results

3.1. Descriptive Statistics

Based on the correlation analysis and descriptive statistics of the variables in Tables 1 and 2, the mean value of supply chain concentration is 29.70, the maximum value is 83.34, the minimum value is 2.33, and the standard deviation is 17.54, indicating that the supply chain concentration difference between enterprises is huge, and there is a high degree of centralization of enterprise supply chain and a high degree of diversification of enterprise supply chain. The mean value of the degree of digital transformation is 2.50, the maximum value is 5.77, the minimum value is 0, and the standard deviation is 1.40. It means that the degree of digital transformation varies widely throughout firms, with some not having carried out any digital transformation at all. The adjustment variable TMTs’ oversea ratio has a mean value of 0.07, a maximum value of 0.44, a minimum value of 0, and a standard deviation of 0.10. These values show that there is a significant variation in the number of TMTs with overseas experience amongst enterprises, with some having more TMTs appointed than others. According to the hypothesis, there is a substantial -0.029 association between the concentration of the enterprise supply chain and the degree of digital transformation of the enterprise. Multicollinearity does not exist because the mean VIF of the variables is less than 2 and all of the variables have correlation coefficients that are less than 0.5.

Table 1. Summary statistics

Variable	N	Mean	SD	p25	p50	p75	Min	Max
concentration	31,836	29.70	17.54	16.18	27.07	40.53	2.33	83.34
digital	31,836	2.50	1.40	1.39	2.48	3.47	0.00	5.77
oversea ratio	31,836	0.07	0.10	0.00	0.06	0.11	0.00	0.44
size	31,836	21.86	1.34	20.91	21.72	22.64	18.83	25.88
leverage	31,836	0.43	0.21	0.27	0.42	0.59	0.05	0.96
age	31,836	17.77	5.76	14.00	18.00	22.00	5.00	32.00
Tat	31,836	0.16	0.13	0.07	0.12	0.20	0.01	0.77
ROA	31,836	0.01	0.05	0.00	0.01	0.02	-8.23	1.72
cashflow	31,836	0.15	0.46	0.00	0.04	0.12	-0.64	3.36

Table 2. Correlation matrix

	concentration	digital	size	leverage	age	Tat	ROA	cashflow	oversea ratio
concentration	1								
digital	-0.029***	1							
size	-0.174***	0.100***	1						
leverage	-0.105***	-0.138***	0.411***	1					
age	0.092***	0.112***	0.228***	0.124***	1				
Tat	-0.091***	-0.011*	-0.071***	0.112***	-0.113***	1			
ROA	-0.015***	0.012**	-0.045***	0.107***	-0.067***	0.175***	1		
cashflow	-0.055***	0.044***	0.333***	0.075***	0.049***	0.052***	0.034***	1	
oversea ratio	-0.001	0.126***	0.053***	0.075***	-0.036***	0.003	0.016***	0.046***	1

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

3.2. Regression Results

Table 3's first four columns provide the results of the main effect test. The results of the benchmark regression are shown in Column. The regression coefficient for the digital transformation of firms was -1.156, significant at the 1% level ($\beta=-1.156$, p-value=-7.61), with no increase in control variables other than industry and time. The results of a two-way fixed-effect benchmark regression are presented in the second column. The regression coefficient for the enterprise's digital degree was -0.730, and it was significant at the 1% level ($\beta=-0.730$, p-value=-0.512) under the two control variables of increasing the enterprise's size and financial leverage. The third column reports the two-way fixed-effect benchmark regression results under the three control variables of increasing the enterprise age, total asset turnover ratio and net profit margin of total assets. The regression coefficient was -0.734, which was significant at the 1% level ($\beta=-0.734$, p-value=-5.15). Column 4 reports the addition of the proportion of independent directors, board size, and net cash flow, and added a two-way fixed-effect baseline regression result for all control variables, and the regression coefficient for digital was -0.734, which was significant at the 1% level ($\beta=-0.734$, p-value=-5.15). The regression results show that the degree of enterprise digital transformation will significantly reduce the concentration of enterprise supply chain, which is in line with the research results of Wu Qiang (2023), and the hypothesis 1 is empirically supported. From the perspective of economic implications, when enterprises implement digital transformation, the supply chain concentration of enterprises decreases by 0.734, which is equivalent to about 2.4% of the average concentration (29.70). Table 3's Column 5 presents the results of the moderating impact test. The multiplication term's coefficient is -0.603, indicating that increasing the ratio of TMTs located overseas will worsen the negative effects of business digital transformation on supply chain concentration. This is significant at the 1% level ($\beta=-0.603$, p-value=-3.89). This paper's second hypothesis is supported by empirical data.

Table 3. Regression results

	(1)	(2)	(3)	(4)	(5)
	concentration	concentration	concentration	concentration	concentration
digital	-1.156***	-0.730***	-0.734***	-0.734***	-0.603***
	(-7.61)	(-5.12)	(-5.15)	(-5.15)	(-3.89)
digital×o r					-1.793**
					(-2.00)
size		-4.272***	-4.223***	-4.208***	-4.192***
		(-14.72)	(-13.77)	(-13.65)	(-13.59)
leverage		-0.935	-1.09	-1.075	-1.017
		(-1.03)	(-1.15)	(-1.14)	(-1.08)
age			-0.04	-0.044	-0.053
			(-0.10)	(-0.11)	(-0.13)
Tat			1.097	1.028	0.986
			(0.92)	(0.85)	(0.81)
ROA				0.986	1.001
				(1.41)	(1.42)
cashflow				-0.203	-0.2
				(-1.04)	(-1.02)
oversea ratio					5.080*
					(1.69)
constant	25.024***	115.178***	114.485***	114.245***	113.706***
	-7.04	-17.26	-13.15	-13.09	-13.05
Year fe	Yes	Yes	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes	Yes	Yes
N	31834	31834	31834	31834	31834
Adjust R ²	0.151	0.183	0.183	0.183	0.184

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The numbers in parentheses are variance-adjusted t-values.

3.3. Robustness Test

In the robustness analysis, this paper firstly chooses to replace dependent variables, which is the supply chain concentration. The essay refers to Wu Qiang's (2023) method of selecting the top three suppliers' and customers' concentration to add and average, selects the supply chain concentration of the first largest supplier and customer to sum and average, and obtains a new dependent variable concentration₁ for regression. The degree of digital transformation of firms has a regression coefficient of -0.347, which is significant at the 1% level ($\beta = -0.347$, $p\text{-value} = -3.47$), according to the regression results in column 2 of Table 4. The fact that the regression results essentially agree with the initial benchmark regression in column 1 shows the robustness the study's findings are to various approaches for measuring the variables.

The paper secondly chooses to control for reverse causality. There might be endogeneity issues in the robustness analysis of this work. Digital transformation will increase the enterprise supply chain's resilience, improve its overall environment, and lower its overall risk, all of which will encourage the enterprise supply chain to become more diversified. Businesses will need to digitalize in order to diversify their supply chains. This can be achieved through digital transformation, employing big data tools to gather and evaluate market data, and increasing their incentive to collaborate between upstream and downstream supply chain participants. Because the decisions made by the enterprise supply chain in the current period will not have an impact on the digital transformation of enterprises in the previous period, this paper decides to regress the independent variables in the first period. The results are shown in column 3 of Table 4. The research conclusion is still robust when considering the dependent variables of the lagged period, as demonstrated by Table 4, where the regression coefficient of the degree of digital transformation of enterprises is -0.602, significant at the 1% level

($\beta=-0.602$, $p\text{-value}=-4.21$). The regression results are essentially consistent with the original benchmark regression in column 1.

Table 4. Robustness test

	(1) concentration	(2) concentration1	(3) concentration
digital	-0.734*** (-5.15)	-0.347*** (-3.47)	
size	-4.208*** (-13.65)	-0.700*** (-3.26)	-4.298*** (-12.14)
leverage	-1.075 (-1.14)	3.552*** (4.9)	-0.904 (-0.84)
age	-0.044 (-0.11)	-0.001 (-0.00)	0.226 (0.45)
Tat	1.028 (0.85)	0.386 (0.42)	2.04 (0.91)
ROA	0.986 (1.41)	-2.862** (-1.98)	-0.895 (-0.14)
cashflow	-0.203 (-1.04)	-0.102 (-0.61)	-0.390* (-1.94)
L.digital			-0.602*** (-4.21)
constant	114.245*** (13.09)	15.326*** (2.68)	110.494*** (10.71)
Year fe	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes
N	31834	31834	27537
Adjust R ²	0.183	0.073	0.196

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The numbers in parentheses are variance-adjusted t-values.

3.4. Heterogeneity Analysis

This paper chooses the ownership of businesses and high-tech businesses for heterogeneity study because these factors may have an impact on the digital transformation of businesses during the process of business acquisition.

Columns 1 and 2 of Table 5 present the grouped regression's findings from the viewpoint of the enterprise ownership. State-owned enterprises' digital transformation regression coefficient is -0.524, significant at the 1% level ($\beta=-0.524$, $p\text{-value}=-3.10$), whereas private enterprises' digital transformation regression coefficient is -0.740, significant at the 1% level ($\beta=-0.740$, $p\text{-value}=-3.15$).

Group regression findings are displayed in Table 5 columns 3 and 4, as seen from the viewpoint of high-tech businesses. The digital transformation of high-tech enterprises has a regression coefficient of -0.563, which is significant at the 5% level ($\beta=-0.563$, $p\text{-value}=-2.73$), whereas the digital transformation of other enterprises has a regression coefficient of -0.764, which was significant at the 1% level ($\beta=-0.764$, $p\text{-value}=-4.30$).

Every group's regression results show consistency with the benchmark regression symbols, and every result is noteworthy. It is evident that, in comparison to private companies and other non-high-tech companies, state-owned and high-tech companies may be hesitant to implement enterprise digital transformation. This reluctance may stem from a number of factors, including enterprise size, market competition, or senior managers' decision-making.

Table 5. Heterogeneity analysis

	(1) concentration	(2) concentration	(3) concentration	(4) concentration
digital	-0.524*** (-3.10)	-0.740*** (-3.15)	-0.563*** (-2.73)	-0.764*** (-4.30)
size	-4.388*** (-12.60)	-3.955*** (-6.82)	-4.298*** (-9.47)	-4.086*** (-9.89)
leverage	-0.121 (-0.11)	-2.817 (-1.63)	-0.471 (-0.34)	-1.968 (-1.60)
age	-0.916 (-1.29)	0.608 (1.19)	0.696 (1.37)	-0.279 (-0.49)
Tat	0.416 (0.31)	2.414 (0.77)	-2.161 (-1.03)	4.340*** (2.8)
ROA	0.819 (1.44)	12.835 (0.95)	1.159 (0.17)	1.540*** (3.19)
cashflow	0.118 (0.43)	-0.426 (-1.56)	-0.319 (-1.28)	-0.05 (-0.16)
_cons	122.730*** (9.84)	102.785*** (6.85)	105.945*** (8.9)	119.678*** (9.27)
Year fe	Yes	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes	Yes
N	20032	11802	14504	17330
Adjust R ²	0.16	0.227	0.17	0.185

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The numbers in parentheses are variance-adjusted t-values.

4. Conclusion

This article investigates the relationship between enterprise supply chain concentration and enterprise digital transformation, as well as the moderator of enterprise TMTs' overseas experiences, using data from Chinese listed companies from 2007 to 2020. The essay also analyzes heterogeneity from the viewpoints of the type of firm ownership and whether or not it is a high-tech enterprise. Based on both theoretical investigation and practical examination, the following conclusions are made in this paper: First, increasing enterprise digital transformation can aid in increasing enterprise supply chain diversification and reducing enterprise supply chain concentration. Second, the enhancement of enterprise TMTs' global experiences can encourage a decrease in the impact of enterprise digitalization on the supply chain's concentration. This implies that the global experiences of enterprise TMTs have an adverse moderating effect on the effect of enterprise digital transformation on the supply chain's diversification. Third, in order to lessen the concentration of enterprise supply chains, private and other non-high-tech businesses are more likely to implement enterprise digital transformation than stated-owned and high-tech businesses.

The research contribution of this essay is as follows. First, this paper studies the relationship between enterprise digital transformation and enterprise supply chain concentration, and the moderating role of enterprise TMTs' oversea experiences in it, which fills the gap in the previous literature on the relationship between the three, especially the gap in the research on enterprise TMTs' oversea experiences and enterprise supply chain concentration. Second, this paper analyzes the heterogeneity from the perspectives of enterprise ownership and whether it is a high-tech enterprise, which is helpful for making targeted policy recommendations.

The following are the study's limitations. First off, because digital transformation data was chosen, the most recent data from 2021 to 2023 were not included in this research, which is based on

secondary data of listed firms from 2008 to 2020. Thus, there may be some deviation in the results after updating the data from 2021 to 2023. Second, the data used in this paper are Chinese listed businesses; in the future, other nations may be chosen to test the theory presented in this paper. Third, this article only examines the moderating role of enterprise TMTs' overseas experiences and the impact of enterprise digital transformation on the decline in enterprise supply chain concentration. Other relationships between the three can be studied in the future, such as whether enterprise TMTs' overseas experiences also play a mediating role in it, or replace enterprise TMTs' overseas experiences with other factors, such as entrepreneurship. Fourth, the measurement method of enterprise TMTs' overseas experiences selected in this paper is the measurement method of the proportion of TMTs with overseas experiences in the whole firms' TMTs, and the measurement method of enterprise TMTs' overseas working (educational) experiences or other measurement methods of enterprise TMTs' overseas experiences can be selected to replace the moderating variables used in this paper.

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