

The Impact of Supplier Concentration on Innovation in Manufacturing Firms: Moderating Effects Based on Digital Transformation

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Abstract:

Innovation is an important driving force for China to move from a manufacturing power to a manufacturing power, and adjusting the supplier strategy to promote corporate innovation is an important initiative to stimulate corporate vitality in a highly competitive environment, and is also a necessary guarantee to promote the effective transformation of the economy and achieve high-quality development. In order to study the effect of supplier concentration on corporate innovation, the statistical data of A-share listed manufacturing companies from 2009 to 2022 are taken as samples, and regression method is used to conduct empirical analyses. The results show that supplier concentration has an inhibitory effect on innovation inputs and innovation outputs, and the study also finds that digital transformation will significantly weaken the inhibitory effect of supplier concentration on corporate innovation. This study not only contributes to the literature on the relationship between supplier concentration and firm innovation, but also provides practical guidance for firms to engage in innovation activities according to their own circumstances under the conditions of digital transformation.

Keywords:

Supplier Concentration, Innovation Inputs, Innovation Outputs, Digital Transformation

1. Introduction

The report of the 20th Party Congress puts forward the idea of “promoting the economy to achieve effective qualitative improvement and reasonable quantitative growth”, which points out the way forward for the high-quality development of China’s economy. Manufacturing industry is the main body of the real economy, and it is of great significance to promote the innovation and development of manufacturing industry to promote the high-quality development of China’s real economy. Although the total patent applications of manufacturing enterprises above the scale in China have grown at an average annual rate of more than 16% in recent

years, the proportion of invention patents among them decreased from 40.1% in 2016 to 37.6% in 2019. In addition, in terms of key parts, components and key materials, our technological dependence is above 50%. Compared with the technological level of developed countries such as the United States and Japan, there is still a big gap in our innovative technology level. At present, China's manufacturing innovation as a whole shows "quality and efficiency of both low" situation, has seriously affected China's key core technologies in the "neck" problem breakthrough. Since the 18th National Congress, China has paid great attention to the importance of manufacturing industry in international competition and national development, and put forward the idea of transforming the manufacturing industry by applying the new generation of information technology. Since the 19th National Congress, our government has repeatedly stressed the need to accelerate the digital transformation of the real economy represented by the manufacturing industry, and has elevated the data element to the same level of importance as traditional economic factors such as land, labour and capital. Enterprises are not only the main body of the market economy, but also the main carrier of innovation activities, and enterprise innovation has always been a hot spot in academic research. Existing studies have conducted many explorations on the factors affecting enterprise innovation mainly from the macro [1] [2,3] and micro [4,5] levels, but it is not yet clear how supplier concentration affects enterprise innovation. In summary, this paper takes A-share listed manufacturing enterprises as a research sample and investigates the impact of supplier concentration on corporate innovation inputs as well as innovation outputs. Further, this paper pays special attention to the moderating effect of "digital transformation" on the relationship between the two. The contribution of this paper is twofold: first, it provides empirical evidence that higher supplier concentration inhibits firms' innovation, and second, from the perspective of digital transformation, it investigates the impact of the degree of digital transformation of manufacturing firms on the relationship between supplier concentration and firms' innovation, and expands the empirical research on supplier concentration and firms' innovative behaviours by associating firms with digitalisation. Finally, this paper puts forward some conclusions and recommendations to help enterprises better cope with the impact of supplier concentration on corporate innovation, and thus improve their innovation capability and competitiveness.

2. Theoretical Analysis and Research Hypothesis

2.1. Supplier concentration and corporate innovation

Suppliers provide essential raw materials and services for enterprise production, and their impact on enterprise inventory management and inventory turnover tends to run through the entire production and operation activities of the enterprise. Resource base theory suggests that firms are composed of heterogeneous resources, which confer different competitive capabilities on firms, while market competition inadvertently improves firms' resource integration capabilities [6]. Firstly, higher supplier concentration restricts firms' access to the latest technology and innovation resources [7], which may lead to firms being in an information asymmetry position in the market, which in turn has a certain inhibitory effect on firms' innovative behaviours. There are certain differences in the resource channels and marketing methods, etc., owned by different enterprises, which will have an impact on their innovation methods. Enterprises form a high degree of co-operation with some suppliers, which is equivalent to an invisible contract embedded in the transaction, at which time the

enterprise will form an over-dependence on the supplier, and once this relationship is terminated, the enterprise will bring risks to the production operation due to the shortage of raw materials [8]. Secondly, as most of the firms have higher bargaining power in the market due to their high dependence on suppliers, which leads to suppliers being able to make higher profits by raising prices, this may limit the firms' investment and development in innovation. Moreover, high supplier concentration limits competition in the market to a certain extent, leading to a lack of incentives for suppliers to innovate and improve product quality, thus limiting firms' choices and development in terms of innovation. Again, due to the temporary change of suppliers also increases the opportunity cost of the firms, which reduces the innovation capability of the firms. Changes in supply chain relationships also affect the efficiency of information exchange and transfer between members of the supply chain, making it difficult for suppliers to help enterprises maximise their benefits, thus hindering enterprise innovation [9]. Finally, as supplier concentration increases, the risk of leakage of a firm's innovations, knowledge, resources and technology increases, and also negatively affects the firm's innovative behaviour due to the sunk costs of innovation itself [10]. Based on the above analyses, this paper proposes the following hypotheses.

Hypothesis 1: Other things being equal, higher supplier concentration significantly dampens innovation investment.

Hypothesis 2" Other things being equal, higher supplier concentration significantly dampens innovation output.

2.2. Moderating effects of digital transformation

In recent years, industries and relevant government departments in major industrial countries around the world have been strongly advocating digital transformation, that is, the use of a new generation of information technology to promote industrial change, thereby enhancing the overall operational efficiency of the industry and building a new digital economic system. In the wave of digitisation, how to improve the independent innovation ability of enterprises is an urgent problem to be solved. In this context, how supplier concentration affects enterprise innovation is one of the key issues to be studied in this paper. First of all, with the increase in the level of digital transformation, enterprises are increasingly inclined to use artificial intelligence technology, blockchain technology, cloud computing technology big data technology, digital technology, etc. in the whole process of production and operation to improve the performance of production and operation of the enterprise, accurately analyse the market positioning and customer demand, expand a wider supply chain network, and eliminate the problems faced in the supply chain through digital technology. In this context, the expansion of the supplier network can alleviate the procurement path dependence formed by enterprises due to supply chain concentration and reduce the bargaining power of suppliers [11]. Secondly, digital transformation provides more opportunities and possibilities for collaboration between enterprises and suppliers, as enhanced communication and exchange between the two parties can help both parties better adapt to market changes and thus improve the innovation and competitiveness of enterprises. Once again, digital transformation can also increase market transparency and information symmetry, making it easier for purchasers to understand the various suppliers and products in the market, thus reducing the degree of supplier monopoly. Finally, digital transformation can increase the efficiency and productivity of firms, making it easier for firms to develop and produce products on their own and

reduce their dependence on suppliers, thus reducing the market share and influence of suppliers. Based on the above analyses, this paper proposes the following hypotheses.

Hypothesis 3: As digital transformation deepens, the negative impact of supplier concentration on firms' investment in innovation is weakened.

Hypothesis 4: As digital transformation deepens, the negative impact of supplier concentration on firms' innovation output is weakened.

The model diagram for this study is shown in Figure 1.

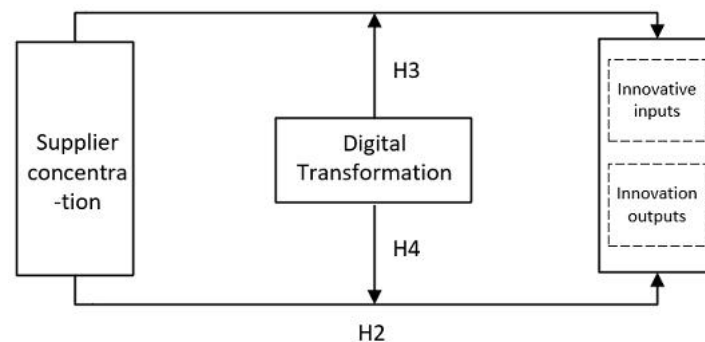


Figure 1. Research Modelling Diagram.

3. Research Design

3.1. Sample selection and data sources

This paper takes the manufacturing enterprises listed on China's A-share market from 2009 to 2022 as the research sample, and the relevant data come from CSMAR database and Wind database. In order to improve the data quality and ensure the credibility of the research results, this paper has processed the original sample data as follows: firstly, ST and *ST enterprises during the period of 2009-2022 are deleted; secondly, enterprises with serious missing data are excluded; finally, in order to reduce the impact of outliers on the data, we have performed the shrinking treatment of 1% and 99% for all continuous variables. After the above operations, 15698 valid observations were finally identified.

3.2. Variable Definition and Measurement

(1) Explained variable: enterprise innovation. Enterprise innovation is a comprehensive manifestation of the efficiency of resource input and use, referring to the study of Lin Ling et al [12], this paper measures enterprise innovation by innovation input (RD) and innovation output (Patent). Among them, innovation input is measured by the ratio of R&D investment to operating revenue as its proxy variable, and innovation output is mostly measured by the number of patents of enterprises. Under the patent system, it can be divided into the number of patent applications and the number of patents granted. In addition, based on the technical heterogeneity of patent connotation, the number of enterprise patent applications can be distinguished into three types: the number of invention patents, utility model patents and design patent applications. Considering that the patent application indicator has the advantages of universality and consistency, and the patent authorisation is easily affected by bureaucratic factors [13], this paper adopts the total number of enterprise patent applications (Patent) as the proxy variable for innovation output.

(2) Explanatory variable: supplier concentration (SC). Referring to the study of Ren Lili et al [14], this paper measures the supplier concentration of the year by the proportion of the purchase amount of the top five suppliers in each year.

(3) Moderator variable: digital transformation (Dig). Referring to the study of Wu Fei et al [15], this paper extracts the keywords of digital transformation in the annual reports of enterprises based on text analysis and uses the number of occurrences of the keywords to portray the degree of digital transformation of enterprises. In particular, the higher the frequency of the word “digital transformation”, the higher the relative degree of digital transformation of the enterprise. In order to reduce the interference of heteroskedasticity on the empirical results, this paper carries out natural logarithmic processing on the basis of adding 1 to the number of word frequencies.

(4) Control variables: there are many factors affecting corporate innovation, both in terms of macro policy and micro aspects such as the enterprise itself, in order to accurately examine the impact of supplier concentration on corporate innovation, this paper selected the following control variables: enterprise size (Size), gearing ratio (Lev), the company’s years of existence (FirmAge), two jobs in one (Dual), Shareholding ratio of the first largest shareholder (Top1), Cashflow ratio (Cashflow). The specific variables and definitions are shown in Table 1.

Table 1. Main variables and their definitions.

Variable Type	Variable Name	Variable Symbol	Variable Definition
Explained Variables	Innovation inputs	RD	R&D investment as a percentage of operating income
	Innovation outputs	Patent	Logarithm of the total number of invention, utility model and design patent applications plus 1
Explanatory variables	Supplier concentration	SC	Ratio of purchases from top 5 suppliers to total annual purchases
Moderating Variables	Digital transformation	Dig	Logarithm of word frequency statistics based on text analysis plus 1
Control Variables	Firm size	Size	Natural logarithm of annual total assets
	Gearing ratio	Lev	Ratio of year-end total liabilities to year-end total assets
	Years in business	FirmAge	$\ln(\text{current year} - \text{company establishment year} + 1)$
	Two positions in one	Dual	Chairman and general manager is the same person for 1, otherwise 0
	Shareholding ratio of the first largest shareholder	Top1	Number of shares held by the first largest shareholder/total number of shares
	Cashflow Ratio	Cashflow	Net cash flow from operating activities/total assets

4. Empirical Results

4.1. Descriptive statistics

Table 2 presents the descriptive statistics of the main variables. In terms of the explanatory variables, the mean value of innovation output (Patent) is 3.3, the standard deviation is 1.498, the minimum value is 0, and the maximum value is 6.676,

with the maximum value, minimum value, mean value, and standard deviation being relatively similar, which indicates that the innovation outputs of the enterprises are relatively similar, and that there is not much difference between the enterprises; the mean value of innovation investment (RD) is 4.821, the minimum value is 0.07. The mean value of innovation input (RD) is 4.821, the minimum value is 0.07, the maximum value is 23.32, and the difference between the maximum value and the minimum value is large, indicating that the innovation input of each enterprise is uneven; for the explanatory variables, the mean value of supplier concentration (SC) is 33.15, the standard deviation is 17.84, the minimum value is 0.33, and the maximum value is 99.9, and in terms of the mean value, the phenomenon that the supplier concentration of most enterprises exists relatively high, and the standard deviation is 17.84, indicating that different enterprises within the manufacturing industry have similar innovative outputs. 17.84, indicating that the degree of reliance on suppliers of different enterprises within the manufacturing industry also has a great difference. Meanwhile, in terms of the maximum and minimum values, the gap between the two is too large, indicating that there are large differences in supplier concentration between different enterprises; for the moderating variable (Dig), the mean is 1.358, the standard deviation is 1.291, the minimum value is 0, and the maximum value is 4.7, indicating that there is a significant difference between different enterprises in the degree of digital transformation. In addition, the maximum value, minimum value and standard deviation of each control variable are all within a reasonable range, indicating that the samples in the selected area have a certain degree of reasonableness.

Table 2. Descriptive statistics for key variables.

Variable	Sample size	Mean	Standard deviation	Minimum value	Maximum value
RD	15698	4.821	3.870	0.070	23.32
Patent	15698	3.300	1.498	0	6.676
SC	15698	33.15	17.84	0.330	99.90
Dig	15698	1.358	1.291	0	4.700
Size	15698	22.08	1.162	17.81	27.55
Lev	15698	0.386	0.185	0.058	0.858
FirmAge	15698	2.900	0.314	1.792	3.497
Dual	15698	0.323	0.467	0	1
Top1	15698	33.15	13.93	8.087	75.78
Cashflow	15698	0.053	0.0647	-0.199	0.283

4.2. Correlation analysis

In order to test whether the design of variables is reasonable, this paper carried out correlation analysis on each variable, and the results are shown in Table 3. From the values in the table, it can be seen that the correlation coefficient between innovation input (RD) and innovation output (Patent) is 0.15 and significant at the 1% level, which reflects the reasonableness of the two indicators to measure enterprise innovation. The correlation coefficient between Supplier Concentration (SC) and Innovation Input (RD) is -0.033 and significant at 1% level, and the relationship between Supplier Concentration (SC) and Innovation Output (Patent) is also significant at 1% level, with a correlation coefficient of -0.273. The above data suggests that when firms face a higher degree of Supplier Concentration, their innovation behaviours may be negatively affected, and will have a certain impact on innovation. The above data suggests that when enterprises face a higher degree of

supplier concentration, their innovation behaviour may be adversely affected, which will be manifested in the decline of innovation output and the reduction of innovation input of enterprises. In addition, as shown in Table 3, the correlation coefficients between the variables are less than 0.6, and according to the statistical experience, we can basically judge that there is no multicollinearity between the variables selected in this paper.

Table 3. Correlation analysis of key variables.

	RD	Patent	SC	Dig	Size	Lev	Top1	Cashflow	Dual	FirmAge
RD	1									
Patent	0.150***	1								
SC	-0.033***	-0.273***	1							
Dig	0.228***	0.296***	-0.134***	1						
Size	-0.178***	0.502***	-0.222***	0.129***	1					
Lev	-0.232***	0.276***	-0.167***	0.036***	0.492***	1				
Top1	-0.113***	-0.003	-0.004	-0.051***	0.091***	-0.011	1			
Cashflow	-0.072***	0.023***	-0.017**	-0.026***	0.085***	-0.169***	0.099**	1		
Dual	0.124***	-0.049***	0.018**	0.068***	-0.153***	-0.098***	-0.004	-0.007	1	
FirmAge	-0.087***	0.087***	-0.031***	0.058***	0.193***	0.123***	-0.074**	0.045***	-0.085**	1

4.3. Regression analysis

(a) Supplier concentration and firm innovation

Table 4. Main regression results.

	(1)	(2)
Variable	RD	Patent
SC	-0.019*** (-10.96)	-0.014*** (-24.11)
Size	-0.152*** (-4.96)	0.600*** (56.78)
Lev	-4.730*** (-25.02)	0.169*** (2.59)
Top1	-0.029*** (-13.69)	-0.005*** (-6.64)
Cashflow	-5.666*** (-12.02)	-0.254 (-1.56)
Dual	0.751***	0.084***

	(11.80)	(3.81)
FirmAge	-0.600***	-0.055*
	(-6.25)	(-1.65)
Constant	13.385***	-9.239***
	(19.93)	(-39.88)
Observations	15,698	15,698
R-squared	0.097	0.283

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4 reports the results of the core test of the “supplier concentration - firm innovation” relationship. Column (1) shows the regression results of customer concentration (SC) and innovation investment (RD). From the analytical results of column (1), it can be seen that after gradually adding a series of control variables such as firm size, gearing ratio (Lev), etc., there is a significant negative correlation between supplier concentration (SC) and innovation investment (RD) (regression coefficient -0.019, t-value -10.96), indicating that supplier concentration has a significant inhibitory effect on innovation investment of firms. 10.96), indicating that supplier concentration has a significant inhibitory effect on firms’ innovation input. The higher the supplier concentration, on the one hand, suppliers have greater bargaining power, which can affect the business performance of the enterprise by increasing the price of the product and reducing the quality of the product; on the other hand, the increase in supplier concentration will produce a certain lock-in effect, and the enterprise will increase the cost of the transaction to change the supplier [16], in addition, the change of the supplier will also cause the leakage of technological knowledge, which will bring about greater economic losses, all of which will have a significant inhibitory effect on the innovation investment of the enterprise. In addition, changing suppliers can lead to leakage of technical knowledge, which can lead to greater economic losses, all of which can have a negative impact on firm innovation, thus Hypothesis 1 is verified. Column (2) shows the regression results of customer concentration (SC) and innovation output (Patent), after controlling other factors, customer concentration (SC) and innovation output (Patent) are always significantly negatively correlated at 1% level (regression coefficient is -0.014, t-value is -24.11), which suggests that supplier concentration has a significant inhibitory effect on firms’ innovation output. This suggests that when firms are overly dependent on their main suppliers for items such as raw materials, this can limit their access to diversified supply and innovation resources, thus affecting their innovation output. Hypothesis 2 is thus verified.

(b) Moderating effects of digital transformation

Table 5. Moderated effects regression results.

	(1)	(2)
Variable	RD	Patent
SC	-0.024***	-0.014***
	(-10.64)	(-17.52)
Dig	0.392***	0.210***
	(8.37)	(13.05)
Dig×SC	0.009***	0.001***
	(7.20)	(3.11)
Size	-0.264***	0.558***
	(-8.81)	(54.20)

Lev	-4.420***	0.279***
	(-24.06)	(4.42)
Top1	-0.026***	-0.004***
	(-12.28)	(-4.94)
Cashflow	-5.029***	-0.021
	(-10.98)	(-0.13)
Dual	0.586***	0.021
	(9.44)	(1.01)
FirmAge	-0.691***	-0.093***
	(-7.41)	(-2.89)
Constant	15.171***	-8.643***
	(23.18)	(-38.39)
Observations	15,698	15,698
R-squared	0.150	0.329

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The moderating effect of digital transformation is presented in Table 5. This paper introduces the cross-multiplier term of digital transformation and supplier concentration (Dig×SC) to test the moderating effect of digital transformation on the relationship between supplier concentration (SC) and firm innovation (RD, Patent). The results show that the regression coefficients of Dig×SC are 0.009 and 0.001 (*t*-values of 7.2 and 3.11), respectively, and both are significant at the 1% level, which suggests that digital transformation has a significant negative impact on the inhibitory effect of customer concentration on innovation inputs (RD) as well as innovation outputs (Patent). This means that with the continuous strengthening and deepening of digital transformation, enterprises can use more means and ways to obtain supplier information to find more suitable supplier partners, and effectively reduce the transaction costs formed when adjusting supplier relationships, thus weakening the inhibitory effect of supplier concentration on enterprise innovation [17]. Therefore, the empirical results support hypotheses 3 and 4.

4.4. Robustness Tests

In this paper, the regression results are validated using robustness tests.

(a) Replacement of explanatory variables. The share of R&D expenditure in total assets is used to indicate the innovation input of enterprises, the total number of applications for invention-type patents, utility model patents and design patents is taken as logarithm after adding 1, and the weights of the three types of patents are taken according to 3:2:1 to indicate the innovation output of enterprises. The results of robust regression are shown in Table 6, from column (1) and column (2), it can be seen that supplier concentration (SC) and innovation input (LRD) are significantly negatively correlated at 1% level, and the regression coefficient is -0.006, i.e., supplier concentration has a significant inhibitory effect on enterprise innovation input, and Hypothesis 1 passed the test; supplier concentration (SC) and innovation output (LPatent) are significantly negatively correlated at 1% level, and the weights of three kinds of patents are taken according to 3:2:1 to indicate the innovation output. The regression coefficient of supplier concentration (SC) and innovation output (LPatent) are significantly negatively correlated at 1% level, and the regression coefficient is -0.014, which again verifies hypothesis 2. The regression coefficients of

the interaction term (Dig×SC) in columns (3) and (4) are positive and both are significant at 1% level, which further verifies hypotheses 3 and 4.

Table 6. Robustness test results.

	(1)	(2)	(3)	(4)
Variable	LRD	LPatent	LRD	LPatent
SC	-0.006*** (-5.89)	-0.014*** (-22.28)	-0.009*** (-7.25)	-0.015*** (-17.20)
Dig			0.198*** (7.56)	0.187*** (10.46)
Dig×SC			0.005*** (7.67)	0.002*** (4.41)
size	-0.117*** (-6.83)	0.643*** (55.09)	-0.178*** (-10.62)	0.601*** (52.54)
Lev	-0.439*** (-4.15)	0.151** (2.09)	-0.268*** (-2.61)	0.263*** (3.76)
Top1	-0.003*** (-2.86)	-0.006*** (-7.69)	-0.001 (-1.18)	-0.005*** (-6.15)
Cashflow	2.196*** (8.34)	-0.393** (-2.19)	2.543*** (9.93)	-0.157 (-0.90)
Dual	0.299*** (8.41)	0.077*** (3.19)	0.209*** (6.03)	0.015 (0.64)
FirmAge	-0.075 (-1.40)	-0.065* (-1.79)	-0.122** (-2.35)	-0.102*** (-2.87)
Constant	5.607*** (14.95)	-9.339*** (-36.51)	6.597*** (18.01)	-8.714*** (-34.87)
Observations	15,662	15,698	15,662	15,698
R-squared	0.021	0.266	0.076	0.306

t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

(b) Robustness test based on manufacturing industry. The characteristics of suppliers vary greatly from industry to industry. In view of the representativeness of the manufacturing industry and the importance of suppliers in manufacturing enterprises, a representative sample of the manufacturing industry is selected to re-conduct the multiple regression analyses of the above hypotheses, in order to attenuate the potential impact of industry characteristics on the above empirical research, and the regression results continue to be consistent.

5. Conclusions and Recommendations

Taking supplier concentration as an entry point, this paper examines the impact of supplier concentration on firm innovation by selecting A-share listed manufacturing firms from 2009 to 2022 as the research sample. The results show that higher supplier concentration hinders firms' innovation input and output, and the effect of supplier concentration on firms' innovation is weakened with the deepening of digital transformation, and the above results remain robust after a series of tests.

The research in this paper helps enterprises and government departments to have a more comprehensive understanding of the impact of supplier concentration on firms' innovation behaviours, and provides important insights into how firms manage their supply chain relationships and make decisions about their innovation behaviours. Firstly, enterprises should pay attention to supplier management, try to avoid over-

concentration of suppliers, and do not put “eggs” in one basket, so as to reduce the dependence on individual suppliers and improve the flexible response ability in emergencies, such as supply chain crises. Secondly, enterprises should make reasonable use of digital transformation opportunities to expand more supplier resources and reduce the degree of dependence on a particular supplier, so as to alleviate the inhibiting effect of supplier concentration on enterprise innovation. Enterprises can use digital technology to find new suppliers, establish more cooperative relationships, and achieve supply chain diversification. In addition, digital transformation can also help enterprises achieve transparent and intelligent management of the supply chain and improve the efficiency and flexibility of the supply chain, so as to better adapt to market changes and innovation needs. Finally, in the process of enterprise development, it is important to focus on the choice of innovation methods. Synergistic development is important, but it is also necessary to highlight the focus of development so that enterprises can maximise their benefits. Enterprises can, according to their own situation and development plan, choose the innovation route with optimal efficiency and maximum benefit to ensure the long-term development of the enterprise when their own capacity is sufficient.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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