The impact of A firm's intelligent manufacturing level on operational risk: empirical evidence from China's A-share manufacturing firms

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Abstract. Intelligent manufacturing is an important development direction of China's manufacturing industry, is the main direction of the construction of manufacturing power, but there are some enterprises in the development of our country in the process of intelligent manufacturing transformation has not been substantive. Based on this, this paper selects China's A-share listed companies from 2006 to 2019 as the research sample, and empirically tests the impact of intelligent manufacturing level on enterprise business risk. It is found that the level of intelligent manufacturing will significantly reduce the business risk of enterprises. Mechanism analysis shows that the level of enterprise intelligent manufacturing will affect enterprise operating risk through two paths: improving enterprise innovation level and alleviating enterprise agency conflict. The extended research finds that the inhibitory effect of manufacturing level on enterprise operating risk is more obvious in enterprises with greater external competition, stronger profitability and larger scale. The conclusion of this paper provides a new reference and basis for accelerating the construction of China's manufacturing power, promoting the establishment of modern industrial system and consolidating the foundation of the real economy.

Keywords: Intelligent Manufacturing; Enterprise Management Risk; Agency Conflict; Level of Innovation.

1. Introduction

At present, with the acceleration of the new generation of scientific and technological revolution and industrial transformation, intelligent manufacturing has become an important development direction of China's manufacturing industry. "The 14th Five-Year Plan for the development of intelligent Manufacturing", for the next five years, the development of intelligent manufacturing has formulated a roadmap and task book, mentioned that intelligent manufacturing is the main direction of the construction of manufacturing power, to consolidate the foundation of the real economy, build a modern industrial system, to achieve new industrialization has an important role. The 20th CPC National Congress Report proposed to accelerate the development of intelligent manufacturing, which is not only helpful to consolidate and strengthen the foundation of the real economy, but also related to the global status of China's future manufacturing industry. Based on the new stage of development, only by maintaining strategic focus and deeply implementing intelligent manufacturing projects can we provide stronger support for promoting the high-quality development of manufacturing industry and building new advantages in international competition. In recent years, the transformation of enterprise intelligent manufacturing has attracted extensive attention in the academia. Many studies have carried out the analysis of the economic effect of enterprise intelligent manufacturing transformation from the perspective of total factor development rate (Shen Kunrong, 2024), green technology innovation (Zhang Bing, 2023) and so on. In fact, for the long-term development of enterprises, under the background of the current downward pressure on the macro economy, how to balance the relationship between considerable benefits and potential risks is particularly important. Enterprise business risk has gradually become an important content of enterprise management and steady development. The role of enterprise intelligent manufacturing

transformation is not only reflected in the creation of economic value, but also should include the management and control of business risk. However, there are still few studies on this aspect. Therefore, this paper focuses on examining the impact of enterprise intelligent manufacturing level on empirical risk. The marginal contribution of this paper is to deeply analyze the process of the role of enterprise intelligent manufacturing level and business risk, and provide empirical evidence and theoretical basis for better understanding the impact of enterprise intelligent manufacturing level on empirical risk. On the one hand, this paper theoretically expands the research field of the economic consequences of enterprise intelligent manufacturing level. Through empirical analysis, this paper reveals the important impact of intelligent manufacturing on enterprise innovation level and agency conflict, which provides strong theoretical support and practical guidance for enterprises to make intelligent manufacturing decisions. On the other hand, this paper also makes a contribution to the research on the influencing factors of enterprise business risk. Through in-depth analysis of the mechanism of intelligent manufacturing on enterprise business risk, this paper reveals the positive role of intelligent manufacturing in reducing business risk and improving business stability, and provides new ideas and methods for enterprise risk management and strategy formulation.

2. Literature review and theoretical analysis

Due to the influence of factors such as the uncertainty of external environment, poor internal management and decision-making errors, the main business of enterprises will face great negative impact, and the resulting operational risks will become an adverse factor affecting the healthy development of enterprises. Enterprise risk not only affects the enterprise's own profitability and market value, but also relates to the risk level and fluctuation of the overall economy. Excessive corporate risk will inevitably endanger the sustainable profitability of enterprises, and may even cause systemic financial risks. For enterprises promoting intelligent manufacturing transformation, intelligent manufacturing transformation can improve the company's tolerance in an uncertain environment. By sorting out relevant theories, this paper believes that the transformation of intelligent manufacturing has an impact on reducing the operating risks of enterprises from the following two aspects:

The first is to reduce the operating risk of enterprises by improving the level of enterprise innovation. With the improvement of the level of intelligent manufacturing, the innovation cycle of enterprises is becoming shorter, the speed of product upgrading is faster, the homogeneity of related products is becoming more and more obvious, and the competition between enterprises is becoming more and more exciting. In order to cope with the fierce external market competition environment, enterprises will actively adopt innovation strategy, increase innovation research and development investment, occupy the commanding heights of technology and products, so as to reduce the business risks brought by market competition. Some studies have shown that innovation activities can create differentiated development opportunities for enterprises, improve their operating efficiency, and reduce their operating risks.

The second is to reduce enterprise risk by alleviating agency conflict. Intelligent manufacturing transformation can enable enterprise management to obtain timely operation and management information, effectively improve their operation and management level, and improve the efficiency of resource allocation. When the business volume increases, enterprises can use intelligent technology to coordinate enterprise resources, which is conducive to expanding the production scale and improving the production efficiency of enterprises. When the business volume decreases, the enterprise can use intelligent technology to deal with redundant resources, promote the utilization of enterprise resources, and reduce the adjustment cost. In addition, the transformation of intelligent manufacturing can make information transmission more efficient, information more transparent, and the connection between the principal and the agent of the enterprise is more convenient. The principal

is not only easier to grasp the enterprise management information, but also easier to supervise the behavior of the agent, which can alleviate the enterprise agency conflict and reduce the enterprise management risk.

Based on the above analysis, this paper puts forward the following research hypotheses:

H1: If other factors are limited, the level of intelligent manufacturing is negatively correlated with the level of enterprise operating risk, that is, the higher the level of intelligent manufacturing is, the lower the enterprise operating risk is.

In the practice process of intelligent manufacturing transformation, enterprises often face many obstacles. The basic technology of many enterprises is not enough to support the "digital transformation", and the high cost input makes enterprises "dare not transform". In fact, the transformation of intelligent manufacturing is a highly complex process, and the transformation and updating of related technical equipment and daily operation and maintenance are accompanied by a large amount of investment in personnel, technology and capital and other resources. If the organizational system of the enterprise is not adapted to the intelligent manufacturing, the organizational change caused by the intelligent manufacturing transformation will increase the cost of the enterprise. At the same time, many enterprises are also facing the dual dilemma of low profit level and financing constraints, which makes the transformation of intelligent manufacturing in a low level state. This situation is more obvious in small and medium-sized enterprises and enterprises with weak profitability. This paper holds that in China's economic transition period, enterprise size and profitability determine the endowment of supporting resources required by enterprise intelligent manufacturing transformation to a certain extent, and thus lead to significant differences in the economic effects of intelligent manufacturing transformation of enterprises with different sizes and profitability levels. To this end, this paper proposes the following research hypotheses:

Due to the influence of geographical location, natural resource conditions and economic policies, the external competitive environment of Chinese enterprises is quite different. Therefore, it is particularly important to investigate the moderating effect of external competition environment on the relationship between intelligent manufacturing transformation and enterprise operating risk, so as to grasp the internal logic of the large differences in enterprise intelligent manufacturing transformation and economic effect under different external competition environments. Therefore, this paper puts forward the following research hypotheses:

H2: Compared with smaller enterprises, the negative correlation between intelligent manufacturing transformation and enterprise operating risk level is stronger in larger enterprises.

H3: Compared with enterprises with weak profitability, enterprises with strong profitability have a stronger negative correlation between intelligent manufacturing transformation and the level of business risk.

H4: Compared with enterprises with weak external competitive environment, enterprises with strong external competitive environment have stronger negative correlation between intelligent manufacturing transformation and enterprise operating risk level.

3. Research design

3.1 Data source and sample selection

This paper selects China's A-share listed companies from 2006 to 2019 as the initial research sample, and processes the original data as follows: (1) excluding financial enterprises; (2) Eliminating ST and *ST enterprises in the sample; (3) Eliminating the enterprises with missing and abnormal indicators. In order to control the influence of extreme values, all continuous variables are winsorized at the level of 1%. After the above processing, the final number of observed data is 16439. Among

them, the intelligent manufacturing data are obtained by manual collation (Guo et al., 2020), and the rest of the data are from the CSMAR database and Wind database.

(2) Variable setting

3.2 Explained variable -- business Risk (Risk)

Enterprise operating risk will affect the profitability and market value of enterprises, and also relate to the risk level and fluctuation of the whole economy. The expression method of enterprise operating risk adopted in this paper is as follows:

$$Risk = 1.2 \times X_1 + 1.4 \times X_2 + 3.3 \times X_3 + 0.6 \times X_4 + 0.999 \times X_5$$

Where X_1 is the ratio of working capital to total assets, X_2 is the ratio of retained earnings to total assets, X_3 is the ratio of eBIT to total assets, X_4 is the ratio of book value of owners' equity to total liabilities, and X5 is the ratio of operating income to total assets.

4. Explanatory variable -- Intelligent manufacturing level *(SmMa)*

Intelligent manufacturing makes production digital and intelligent. The existing literature mainly uses the word frequency of the theme keywords of "intelligent manufacturing" (refer to Table 1) to measure intelligent manufacturing. The theme keywords of "intelligent manufacturing" can effectively reflect the importance of enterprises to the level of intelligent manufacturing. This paper refers to Guo Lei's text data (2020), and uses the word frequency of "intelligent manufacturing" theme keywords and the proportion of intelligent manufacturing to measure the level of intelligent manufacturing in each enterprise. The higher the word frequency of "intelligent manufacturing" theme keywords, the higher the level of intelligent manufacturing.

Table 1: "Intelligent manufacturing" theme keywords

Categories	Keywords
Macro policy	Made in China 2025; Industry 4.0; Internet +
Paradigm features	Automation; Information, information management, information application; Digitalization; Networking, integration, virtualization; intelligence
Enabling technology	Internet of things; Virtual reality; 3D printing; Artificial intelligence, biometrics, pattern recognition, neural networks; Cloud computing, cloud platform, cloud service, cloud technology; Big data, massive data, data center, data storage, data analysis, data mining; Internet, mobile Internet, interconnection
Key equipment and tools Radiation field	Robots, industrial robots; CNC machine tools; Numerical control system; sensor Intelligent logistics; Intelligent service; Intelligent terminal; Green manufacturing; High-end equipment manufacturing; Civil-military integration; Smart grid; Energy Internet, smart energy; Smart home; Smart city, smart transportation, smart medical care, smart community, e-commerce; New energy vehicles, electric vehicles, electric vehicles, power batteries, charging piles

5. Control variables.

This paper selects enterprise Size (Size), years of listing (Age), asset-liability ratio (Det), cash flow (Cashf), growth ability (Tobing), ownership concentration (Top), proportion of independent directors (Indep), current ratio (CR) and profitability (Roa). At the same time, Year variable (Year) and industry variable (Inds) are used as control variables to participate in the regression. See Table 2 for the definition and description of variables.

Table 2: Definition and meaning of variables

Types of variables	Variable name	Variable symbol	Variable definition
Explained variable	Business risk	Risk	Risk=1.2×X1+1.4×X2+3.3×X3+0.6×X4+0.999×X5. Where, X1 is the ratio of working capital to total assets, X2 is the ratio of retained earnings to total assets, X3 is the ratio of eBIT to total assets, X4 is the ratio of book value of owners' equity to total liabilities, and X5 is the ratio of operating income to total assets.
Explanatory variables	Level of intelligent manufacturing	SmMa	Proportion of intelligent manufacturing
Control variables	Enterprise size	Size	Ln (total assets +1)
	Years on the market	Age	Reporting year - year of listing
	Asset-liability ratio	Det	Total liabilities/total assets
	Cash flow	Cashf	Net cash flow from operating activities/total assets
	Ability to GROW	Tobing	Total company market capitalization/total assets
	Ownership concentration	Top	Shareholding ratio of the largest shareholder
	Proportion of independent directors	Indep	Number of independent directors/total number of board members
	Current ratio	CR	Current assets/current liabilities
	Profitability	Roa	Company EBIT/total assets
Dummy variable	Year	Year	Control for year factors
	Industry	Inds	Control for industry factors

5.1 Construction of benchmark regression model

In order to test the hypothesis and explore the relationship between the level of intelligent manufacturing and the business risk of enterprises, the following regression model is constructed:

$$Risk_{i,t} = \alpha_0 + \alpha_1 SmMa_{i,t} + \alpha_2 Controls_{i,t} + \Sigma Year + \Sigma Inds + \varepsilon_{i,t} \quad (1)$$

In Model (1), *i represents* the enterprise and *t represents* the time. $Risk_{i,t}$Is the business risk of the enterprise, is the proxy variable of the intelligent manufacturing level of the enterprise, is the control variable, $SmMa_{i,t}Controls_{i,t}$ *Year* and *Inds* are the fixed effects of year and industry respectively, is the residual term. $\varepsilon_{i,t}$According to H_1, this paper focuses on the coefficient. α_1If the

coefficient is significantly negative, it indicates that the level of enterprise intelligent manufacturing will reduce the business risk of enterprises.

6. Empirical analysis

(1) Descriptive statistical analysis

According to the statistical results in Table 3, the maximum value of Risk is 8.527, the minimum value is -0.251, and the standard deviation is 1.555. This shows that there are great differences in business risks among different enterprises. The minimum value of the explanatory variable SmMa is 0, and the maximum value is 0.966, indicating that the level of intelligent manufacturing owned by the sample enterprises varies greatly. Some enterprises have been on the right track or even in a more cutting-edge position, while some enterprises have not taken intelligent manufacturing transformation measures. The descriptive statistical results of the control variables are reasonably distributed on the whole, which is similar to the existing literature, and will not be described here.

Table 3 Descriptive statistical results of variables

Variables	Number of samples	Mean	Standard deviation	Median	Minimum value	Maximum
SmMa	16439	0.131	0.178	0.062	0.000	0.966
risk	16439	2.345	1.555	1.979	0.251	8.527
Det	16439	0.390	0.197	0.379	0.050	0.866
Age	16439	8.092	6.712	7.000	0.000	29.000
Cashf	16439	0.049	0.066	0.047	0.138	0.232
Tobing	16439	0.002	0.002	0.002	0.000	0.010
Top	16439	34.885	14.244	33.300	9.120	74.020
Indep	16439	3.153	0.539	3.000	2.000	5.000
CR	16439	2.806	2.990	1.793	0.434	18.992
Roa	16439	0.042	0.072	0.042	1.648	0.590
Size	16439	21.890	1.147	21.736	19.903	25.357

Benchmark regression

This paper first uses Model (1) to test whether H1 is valid, that is, the impact of the company's intelligent manufacturing level on the business risk of the enterprise. The regression results are shown in Table 4, and columns (1) - (3) in the table are the regression results with explanatory variables, control variables, control year and industry fixed effects respectively. From the regression results, no matter whether control variables or fixed effects of control year and industry are added, the *coefficients of intelligent manufacturing level (SmMa)* on enterprise operating Risk (Risk) are significantly negative at the level of 1%, indicating that intelligent manufacturing level will have a significant consistent effect on enterprise operating risk, which proves H1. For *every one* standard deviation (0.178) *increase* of intelligent manufacturing level (SmMa), the enterprise's operating Risk (Risk) *de*creases by 3.35% (0.178×0.188×100%). This is equivalent to 1.417% (0.0335/2.345×100%) of the sample *mean* of enterprise operating Risk.

Table 4 Benchmark regression results

	(1)	(2)	(3)
	Risk	Risk	Risk
SmMa	-0.623***	-0.322***	-0.188***
	(-11.013)	(-16.553)	(-8.763)
Det		-2.358***	-2.386***
		(-52.980)	(-52.523)
Age		0.008***	0.008***

		(8.902)	(9.548)
Cashf		1.106***	1.121***
		(13.501)	(13.379)
Tobing		-22.261***	-14.302***
		(-6.352)	(-3.551)
Top		0.003***	0.003***
		(10.665)	(10.007)
Indep		0.016*	-0.004
		(1.897)	(-0.499)
CR		0.327***	0.326***
		(89.892)	(88.264)
Roa		5.420***	5.199***
		(49.008)	(46.893)
Size		-0.002	0.018***
		(-0.419)	(2.872)
Year	No	No	Yes
Industry	No	No	Yes
N	16439	16439	16439
Adj.R2	0.005	0.872	0.875

Note: The figures in parentheses are the robust standard errors of industry-level clustering; ***, ** and * indicate significance at the levels of 1%, 5% and 10%, respectively; the figures in parentheses are t values, the same below.

(3) Robustness test

1. Change the explained variable

In the benchmark regression, this paper mainly uses the Z-value method modified by Altman (2000) to measure the operating risk of enterprises.

$Z = 1.2\times X1+1.4\times X2+3.3\times X3+0.6\times X4+0.999\times X5$

Where X1 is the ratio of working capital to total assets, X2 is the ratio of retained earnings to total assets, X3 is the ratio of eBIT to total assets, X4 is the ratio of book value of owners' equity to total liabilities, and X5 is the ratio of operating income to total assets.

However, the total market value of Chinese listed companies before the stock reform only represents part of the current stock market value, which only accounts for a small proportion of the company's shares, which leads to the bias of the empirical results. Based on this, this paper adopts the Z value suitable for developing countries (Altman and Haldeman, 1995; Fan et al., 2013).

$Z' = 0.717\times X1+0.846\times X2+3.107\times X3+0.420\times X4+0.998\times X5$

Where, X1 is the ratio of working capital to total assets, X2 is the ratio of retained earnings to total assets, X3 is the ratio of eBIT to total assets, X4 is book value, and X5 is the ratio of operating income to total assets.

Table 5 shows the regression results of replacing the core explanatory variables. It can be found that after replacing the enterprise operating risk index, the enterprise operating risk decreases significantly with the increase of the enterprise intelligent manufacturing level, and the results are consistent with the benchmark regression results.

Table 5 Robustness test: Changing the measurement method of variables

	(1)	(2)	(3)
	Risk	Risk	Risk
SmMa	-0.641***	-0.335***	-0.191***
	(-10.950)	(-16.954)	(-8.780)
Det		-2.179***	-2.198***

		(-47.118)	(-46.539)
Age		0.008***	0.009***
		(9.377)	(9.884)
Cashf		1.181***	1.180***
		(14.198)	(13.863)
Tobing		-24.115***	-16.267***
		(-6.668)	(-3.918)
Top		0.003***	0.003***
		(9.705)	(9.114)
Indep		0.012	-0.008
		(1.432)	(-0.890)
CR		0.358***	0.358***
		(88.174)	(87.018)
Roa		5.418***	5.199***
		(47.067)	(44.959)
Size		-0.001	0.019***
		(-0.178)	(2.905)
Year	No	No	Yes
Industry	No	No	Yes
N	16439	16439	16439
Adj.R2	0.005	0.875	0.878

2 Change the sample

Considering that the 2008-2009 financial crisis and the 2015 stock market crash will have an impact on the regression results, this paper eliminates the two time periods and runs the regression again. It can be seen that after the change of samples, the business risk of enterprises decreases significantly with the increase of intelligent manufacturing level, and the results are consistent with the benchmark regression results.

Table 6 Robustness test: Changing samples

	(1)	(2)
	Excluding financial crisis years: 2008, 2009	Excluding year of stock crash: 2015
	Risk	Risk
SmMa	-0.183***	-0.190***
	(-8.418)	(-8.333)
Control	Yes	Yes
Year	Yes	Yes
Industry	Yes	Yes
N	15556	14981
Adj.R2	0.876	0.873

(IV) Mechanism analysis

The previous research shows that the level of intelligent manufacturing will inhibit the business risk of enterprises, and the coefficient of the two is significantly negative at the level of 1%. On the basis of H1, this paper further explores the mechanism of action between the level of intelligent manufacturing and enterprise operating risk, and tests whether the level of intelligent manufacturing can reduce enterprise operating risk through the two intermediary channels of improving enterprise innovation level and reducing enterprise agency cost (the specific results are shown in Table 5).

Table 7 Results of mechanism analysis

	(1)	(2)
	Inno	Turnover
SmMa	1.528***	-0.133***
	(17.013)	(-9.620)
Control	Yes	Yes
Year	Yes	Yes
Industry	Yes	Yes
N	16439	16439
Adj.R2	0.287	0.197

6.1 Mediating effect of enterprise innovation level in the relationship between intelligent manufacturing level and enterprise operating risk

Column (1) of Table 5 shows the regression results of "intelligent manufacturing level → enterprise innovation level". The coefficient of intelligent manufacturing level (SmMa) in Column (1) is significantly positive at the level of 1%, indicating that for every percentage point increase in intelligent manufacturing level, the innovation level (Inno) of enterprises increases significantly by 1.53%; Referring to the research of Lu Xuebo et al. (2023), the innovation capability of enterprises can significantly reduce the business risk of enterprises. Based on the above analysis, it can be seen that the level of intelligent manufacturing will lead to the reduction of business risks by improving the level of enterprise innovation.

6.2 Mediating effect of agency conflict in the relationship between intelligent manufacturing level and enterprise operating risk

Column (2) of Table 5 shows the regression results of "intelligent manufacturing level → enterprise agency conflict." The coefficient of intelligent manufacturing level (SmMa) in Column (2) is significantly negative at the level of 1%, indicating that for every percentage point increase in intelligent manufacturing level, the agency cost (Trunover) of enterprises is significantly reduced by 0.13%, thus significantly alleviating the agency conflict of enterprises; Through the agency cost effect, alleviating the agency conflict can also effectively reduce the business risk of enterprises. Based on the above analysis, it can be seen that the level of intelligent manufacturing will reduce the operational risk of enterprises by alleviating the agency conflict.

Combined with the above analysis, the level of enterprise intelligent manufacturing may reduce the business risk of enterprises by affecting the degree of enterprise innovation and alleviating the agency conflict. On the one hand, intelligent transformation can improve the internal communication efficiency of enterprises, help improve the management ability of enterprises, and flatten the organizational structure of enterprises; Optimizing corporate governance structure, improving corporate governance mechanism and improving corporate governance efficiency can alleviate agency conflicts to a certain extent. It can reduce the possibility that the management will take radical measures to satisfy the self-interest motive, so as to reduce the operation risk. On the other hand, the promotion of intelligent manufacturing significantly improves the level of enterprise innovation and provides new impetus for the high-quality development of enterprises. (Yin Hongying et al., 2022) and then profoundly reform the production mode and industrial form (Xu Xiqing, 2021), which has a positive impact on productivity and product quality (Tang Yihong, 2022), thus reducing the business risks of enterprises.

Based on the above analysis, H2 is established in this paper.

7. Extended research

The previous study confirms that the level of enterprise intelligent manufacturing has a significant inhibitory effect on enterprise operating risk, and the level of enterprise innovation and enterprise agency conflict play a partial mediating role in it. What is worth paying attention to is that the above effects may differ in different scenarios. Based on this, this paper conducts further research from three aspects: the degree of external competition, corporate profitability and corporate size.

(1) Heterogeneity analysis based on external competition degree

This paper uses the Herfindahl-Hirschman index (HHI) to measure the degree of external competition. The index ranges from (0,1), with higher value indicating lower degree of external competition. In this paper, the median of the degree of external competition is taken as the grouping standard, and the one less than the median is defined as the group with high degree of external competition, and the other is the group with low degree of external competition. The regression results according to the degree of external competition of enterprises are shown in Table 7.

In Column (1) and column (2) of Table 7, the regression coefficients of intelligent manufacturing level (SmMa) are -3.04 and -0.022 respectively in the group with high degree of external competition and the group with low degree of external competition, which are significant and insignificant at the level of 1% respectively, and there is a significant difference between the two groups. This shows that compared with enterprises with low degree of external competition, enterprise intelligent manufacturing level has a greater inhibitory effect on the operating risk of enterprises with high degree of external competition.

(2) Heterogeneity analysis based on enterprise profitability

According to the profitability of enterprises, this paper uses the method of introducing dummy variables to divide the samples. If the industry median of enterprise profitability is higher than the enterprise profitability, it is set as 1, and if the industry median of enterprise profitability is lower than the enterprise profitability, it is set as 0. The grouped regression results according to the strength of corporate profitability are shown in Table 7.

In Column (3) and column (4) of Table 7, the regression coefficients of intelligent manufacturing level (SmMa) are − 0.274 and − 0.097 respectively in the group with strong enterprise profitability and the group with weak enterprise profitability, both of which are significant at the level of 1%, and there are differences between the two groups. This shows that compared with enterprises with weak profitability, the level of intelligent manufacturing has a greater inhibitory effect on the operating risk of enterprises with strong profitability.

(3) Heterogeneity analysis based on enterprise size

According to the enterprise size, this paper uses the method of introducing dummy variables to divide the sample. If the enterprise size is higher than the industry median, it is set as 1, and if the enterprise size is lower than the industry median, it is set as 0. The regression results by group according to enterprise size are shown in Table 7.

In Column (5) and column (6) of Table 7, the regression coefficients of intelligent manufacturing level (SmMa) are − 0.263 and − 0.089 respectively in the large enterprise size group and the small enterprise size group, both of which are significant at the level of 1%, and there are differences between the two groups. This shows that compared with small and medium-sized enterprises, intelligent manufacturing level has a greater inhibitory effect on the operational risk of large scale enterprises.

Table 8 Results of heterogeneity analysis

	High HHI	Lower HHI	ROA is higher	Lower ROA	Higher Size	Lower Size
	(1)	(2)	(3)	(4)	(5)	(6)
	Risk	Risk	Risk	Risk	Risk	Risk

SmMa	-0.304*** (-10.064)	-0.022 (-0.712)	-0.274*** (-8.002)	-0.097*** (-3.635)	-0.263*** (-8.561)	-0.089*** （-3.188）
Control	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
N	8195	8195	8195	8195	8195	8195
Adj.R2	0.841	0.901	0.864	0.820	0.782	0.912

8. Research conclusions and policy recommendations

This paper theoretically analyzes the impact of intelligent manufacturing level on enterprise operating risk and its mechanism, and selects the relevant data of A-share listed companies in China from 20 to 2019 for empirical test. The results show that: (1) the level of intelligent manufacturing has a significant inhibitory effect on the operating risk of enterprises. (2) From the perspective of influence mechanism, intelligent manufacturing level mainly acts on enterprise operating risk through two paths: improving enterprise innovation level and alleviating enterprise agency conflict. (3) The mediating effect of enterprise innovation level and enterprise agency conflict will vary according to the degree of external competition, enterprise profitability and enterprise size. Therefore, the inhibitory effect of intelligent manufacturing level on enterprise operating risk is more obvious in enterprises with strong external competition, strong enterprise profitability and large scale.

The following policy recommendations are obtained from this study:

Firstly, for enterprises; Enterprises need to evaluate, plan and promote the transformation of intelligent manufacturing based on their own actual situation and future development expectations, so as to improve the core competitiveness of enterprises and reduce business risks by improving the level of intelligent manufacturing. Among them, for enterprises with weak innovation foundation and economic strength, it is necessary to focus on evaluating the feasibility of intelligent manufacturing transformation, and blindly promoting intelligent manufacturing transformation may lead to enterprises' gains and losses. Secondly, for the government; The government should strengthen policy support to help enterprises lay a solid foundation for transformation.

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