RESEARCH ARTICLE

The Impact of Intelligent Supply Chain Development on Firms' Cost of Debt

Yaru Wang[1], Kewen Li[1], Fan Chen[1], Rong Hu[1] & Kai Tang[1,*]

[1] Taizhou University, China

Abstract: This study investigates the impact of intelligent supply chain development on the cost of debt. We find that the development of intelligent supply chains reduces information asymmetry and enhances firm value, thereby lowering the firms' cost of debt. That is, intelligent supply chain development has a negative effect on firm's cost of debt. Our study contributes to encouraging more firms to engage in intelligent supply chain initiatives and promotes the broader development of intelligent supply chains by revealing the relationship between intelligent supply chain development and the cost of debt.

Keywords: intelligent supply chain, cost of debt, information asymmetry, firm value

1. Introduction

An intelligent supply chain refers to the construction of supply chains supported by the internet and information technology, incorporating digital, automated, visual, and intelligent technologies. Compared with traditional supply chains, intelligent supply chains significantly enhance overall supply chain efficiency (Feng & Ye, 2021). Hence, China has been actively promoting intelligent supply chain development since 2018.

Against this backdrop, to encourage firms to participate in intelligent supply chain initiatives and foster the development of intelligent supply chains, prior studies have extensively explored the broader impacts of intelligent supply chains beyond the supply chain itself. For example, Shi et al. (2023) found that intelligent supply chain development improves firm performance. Ahn et al. (2016) found that intelligent supply chains improve operational efficiency and productivity, thereby promoting operational sustainability. However, prior research has not yet addressed the role of intelligent supply chains in helping firms access heterogeneous resources. Given that capital shortages are a major constraint to corporate development and that Chinese firms predominantly rely on debt financing, this study investigates the impact of intelligent supply chain development on firms' cost of debt.

We perform an empirical analysis using a sample of firms listed on China's A-share market from 2009 to 2024. The results show that intelligent supply chain development reduces information asymmetry and enhances firm value, thereby lowering the cost of debt. That is, intelligent supply chain development negatively affects the cost of debt.

The main contributions of our study are as follows. First, while prior research explores the broader impacts of intelligent supply chain development beyond the supply chain itself to promote enterprise participation, it has largely overlooked the role of intelligent supply chains in helping firms access heterogeneous resources. By revealing that intelligent supply chain development reduces the cost of debt, our study offers new insights that can further motivate firms to engage in intelligent supply chain construction and foster the development of intelligent supply chains.

Second, a firm's cost of debt directly affects its

Corresponding Author: Kai Tang
Taizhou University, China

innovation capacity, operational efficiency, and sustainable development (Yao et al., 2022). Hence, prior studies have extensively examined the determinants of firms' cost of debt from both internal and external perspectives. However, prior studies have paid insufficient attention to supply chain-related factors. By empirically examining the impact of intelligent supply chain development—an important feature of modern supply chain advancement—on firms' cost of debt, this study provides practical guidance for reducing corporate financing costs.

The remainder of this study is organized as follows. Section 2 describes the institutional background and develops the hypotheses. Section 3 explains the sample and model. Section 4 reports the empirical results and robustness tests. Section 5 offers conclusions.

2. Institutional Background and Hypothesis Development

2.1. Intelligent supply chain in China

An intelligent supply chain is a modern supply chain system that leverages the internet and information technology to connect various segments across the entire supply chain. Prior studies suggest that competition among modern enterprises has evolved into competition among supply chains (Liu et al., 2024). Therefore, building intelligent and efficient supply chains has become a key strategy for firms to gain a competitive edge in the market.

To encourage corporate participation in intelligent supply chain construction and promote its development, prior research has widely focused on the economic consequences of intelligent supply chain development at the level of internal operations. Shi et al. (2023) found that intelligent supply chain development improves supply chain efficiency, thereby reducing operational costs, enhancing liquidity, and boosting innovation, and in turn leading to better firm performance. Dujak and Sajter (2019), and Huang et al. (2022) found that intelligent supply chain development enhances inter-firm information sharing efficiency, thereby contributing

to industrial upgrading. Ahn et al. (2016) found that intelligent supply chains improve operational efficiency and productivity, which supports sustainable business operations.

However, the prior research has not yet addressed the impact of intelligent supply chain development on firms' debt financing capacity. Debt financing is the most important source of capital for Chinese firms, and the cost of debt financing has significant implications for firm operations. By examining the impact of intelligent supply chain development on firms' cost of debt, this study helps to further promote firm participation in intelligent supply chain initiatives and supports the advancement of intelligent supply chain systems.

2.2. The cost of debt

The cost of debt refers to the expenses incurred by a firm to obtain external loans or financing. Compared with equity financing, debt financing is the main external financing channel for Chinese enterprises. Therefore, a firm's cost of debt directly affects its innovation capacity, operational efficiency, and sustainable development (Yao et al., 2022).

Prior research has extensively examined both internal and external factors that influence cost of debt. From an internal perspective, Bo et al. (2025) found that digital transformation reduces a firm's cost of debt by improving its ESG performance. Yao et al. (2022) found that corporate social responsibility and innovation exert significant impacts on the cost of debt. Nagarajan et al. (2023) found that business diversification reduces the cost of debt by enhancing financial synergies and strengthening internal capital markets. From an external perspective, Geng and Zhang (2024) found that capital market liberalization lowers firms' cost of debt by intensifying market competition and improving the information environment. Li and She (2024) found that tax credit ratings reduce information asymmetry between firms and banks, thereby decreasing firms' cost of debt.

However, prior research has not sufficiently explored the role of supply chain-level factors in determining firms' cost of debt. This study fills that gap by empirically examining the impact of

intelligent supply chain development—an essential feature of supply chain advancement—on the cost of debt.

2.3. Hypothesis development

The cost of debt is the effective interest rate a company pays on its outstanding debt, like loans and bonds. Due to the imperfections of the capital market and the financial frictions, Chinese firms generally face higher debt costs. Among these, financial frictions caused by information asymmetry are a key reason for the elevated cost of debt. Intelligent supply chains help firms monitor inventory levels, environmental conditions, and the status of products, as well as provide effective information and data to all parties within the supply chain, thereby reducing information asymmetry between firms and external stakeholders (Huang et al., 2022; Turjo et al., 2021). Therefore, the development of intelligent supply chains may lower firms' cost of debt by mitigating information asymmetry.

In addition, firm value is another important factor affecting the cost of debt. With the advancement of intelligent supply chains, firms can reduce operating costs, improve liquidity, and promote technological innovation, thereby enhancing their firm value (Liu et al., 2024; Xu, 2024). Therefore, the development of intelligent supply chains may also reduce the cost of debt by increasing firm value.

In summary, the development of intelligent supply chains may reduce information asymmetry and enhance firm value, lowering the firms' cost of debt.

Accordingly, we propose the following hypothesis:

Hypothesis: *The development of intelligent supply chains reduces firms' cost of debt.*

3. Methodology

3.1. Sample selection

We focus on Chinese A-share listed companies, with all of the data being sourced from the China Stock Market and Accounting Research (CSMAR) database. The original sample data were screened for validity as follows: 1) Delete the finance company samples; 2) Delete the ST (special treatment) and PT (particular transfer) company samples; 3) Delete all samples with missing values.

To control for the impact of the 2008 financial crisis on corporate financing, we select 2009 as the starting year of the sample period. Thus, we obtain 36,812 firm-year observations between 2009 and 2024. To mitigate the influence of outliers, we winsorize all of the continuous variables at the 1 % and 99 % levels.

3.2. The measurement of the cost of debt

Following Shi et al. (2024), we use the proportion of the sum of interest expenses, handling fee expenses and other financial expenses to the total liabilities (*COD*) to measure the cost of debt.

3.3. The measurement of intelligent supply chain development

We use *Treat×Post* to capture the shock from intelligent supply chain development. *Treat* is a dummy variable that equals 1 if firm i is located in a pilot city for intelligent supply chain construction, and 0 otherwise. *Post* equals 0 before 2018 and 1 for all other years.

3.4. Control variables

Following Shi et al. (2024), the control variables include the natural logarithm of total assets (*LnSize*), the total liabilities divided by total assets (*Lev*), net profit divided by total assets (*ROA*), a dummy variable that equals 1 if firm i is a state-owned enterprise and 0 otherwise (*SOE*), the natural logarithm of firm age (*Age*), and the net value of fixed assets divided by total assets (*Fa*). In addition, we include firm, year, and city fixed effects in the model.

3.5. Model

To test the hypothesis, we establish the multiple regression model below:

$$COD_{i,t} = \beta_0 + \beta_1 Treat \times Post_{i,t} + \beta_2 LnSize_{i,t} + \beta_3 Lev_{i,t} + \beta_4 ROE_{i,t} + \beta_5 SOE_{i,t} + \beta_6 Age_{i,t} + \beta_7 FA_{i,t}$$
$$+ Firm\ Dummies + Year\ Dummies + City\ Dummies + \varepsilon_{i,t}$$

4. Empirical Results

4.1. Descriptive statistics

Table 1. Descriptive statistics

Variables	N	Mean	S. D.	Min	P25	Median	P75	Max
COD	36,812	0.013	0.023	-0.066	-0.001	0.013	0.029	0.069
Treat	36,812	0.193	0.394	0.000	0.000	0.000	0.000	1.000
Post	36,812	0.526	0.499	0.000	0.000	1.000	1.000	1.000
LnSize	36,812	22.131	1.340	19.527	21.177	21.935	22.897	26.244
Lev	36,812	0.424	0.215	0.051	0.250	0.412	0.581	0.960
ROA	36,812	0.053	0.162	-0.948	0.027	0.069	0.115	0.439
SOE	36,812	0.375	0.484	0.000	0.000	0.000	1.000	1.000
Age	36,812	2.908	0.346	1.792	2.708	2.944	3.178	3.555
FA	36,812	0.206	0.160	0.002	0.081	0.170	0.294	0.698

Table 1 presents the descriptive statistics of the main variables. The results show that the mean and standard deviation of *COD* are 0.013 and 0.023, respectively, indicating considerable variation in debt costs across firms. The mean of *Treat* is 0.193, suggesting that approximately 19.3% of the firms in our sample are located in pilot cities for intelligent supply chain development.

4.2. Baseline regression results

Table 2. Baseline regression

Variables	(1) COD	(2) COD
Treat×Post	-0.003***	-0.003***
	(-8.424)	(-5.098)
LnSize	-0.000**	-0.000
	(-2.226)	(-1.316)
Lev	0.023***	0.023***
	(26.173)	(15.728)
ROA	-0.007***	-0.007***
	(-11.211)	(-9.433)
SOE	-0.001	-0.001
	(-1.116)	(-0.672)
Age	-0.006***	-0.006**
	(-4.028)	(-2.257)
FA	0.025***	0.025***
	(20.342)	(12.135)
Constant	0.029***	0.029***
	(4.524)	(2.645)
Firm FE	Yes	Yes
Year FE	Yes	Yes
City FE	Yes	Yes
Adj_R-square	0.4714	0.4714
F	234.25***	97.10***
Cluster by firm	No	Yes
Observations	36,812	36,812

Note: ***,**, and * indicate significance at the 1 %, 5 %, and 10 % levels, respectively, or better.

Columns 1 and 2 of Table 2 present the estimation results of the DID model without and with firm-level clustered robust standard errors, respectively. The results show that the coefficient of *Treat×Post* is -0.003 and significant at the 1% level, suggesting that the development of intelligent supply chains has a significant negative effect on firms' cost of debt.

The results in Table 2 reveal that intelligent supply chain development reduces information asymmetry and enhances firm value, thereby lowering firms' cost of debt.

4.3. Robustness tests

4.3.1. Parallel trends test

Table 3. Parallel trends test

Variables	(1) COD
Pre _2	0.001
	(0.900)
Pre _1	-0.002
	(-1.513)
Current	-0.006***
	(-6.910)
Post_1	-0.004***
	(-4.819)
Post_2	-0.002**
	(-2.279)
Post_3	-0.001**
	(-2.060)
Post_4	-0.005***
	(-4.266)
Post_5	-0.003**
	(-2.344)
Control variables	Yes
Constant	0.029***
	(2.691)
Firm FE	Yes
Year FE	Yes
City FE	Yes
Adj_R-square	0.4896
F	52.03***
Cluster by firm	Yes
Observations	36,812

Note: ***,**, and * indicate significance at the 1 %, 5 %, and 10 % levels, respectively, or better.

The key identifying assumption underlying the DID model is that the parallel trend assumption is satisfied. In our setting, the parallel trends assumption means that before the development of intelligent supply chains, a consistent time trend is observed in the debt costs of firms in pilot cities and non-pilot cities, and this parallel trend is broken after the development of intelligent supply chains. Table 3 presents the estimated coefficients of the interaction terms in the years before and after the development of intelligent supply chains. The results show that the estimated difference between the debt costs of firms in pilot cities and non-pilot cities is not significant in the pretreatment period; however, after the development of intelligent supply chains, the debt costs of firms in pilot cities significantly decreased. In summary, the parallel trend assumption of the DID model is validated.

4.3.2. Other robustness tests

In this section, as robustness checks, we perform placebo tests and the PSM-DID approach. In addition, we re-examine the hypothesis by changing the sample period and the measures of the cost of debt.

Table 4. Other robustness tests

Variables	(1) Placebo test COD	(2) PSM-DID COD	(3) Changing the sample periods COD	(4) Alternative measures of the cost of debt COD_2
Treat×Post	-0.001	-0.003**	-0.003***	-0.002**
	(-0.642)	(-2.506)	(-5.572)	(-2.178)
Constant	0.014	0.034	0.046***	0.007
	(1.002)	(1.440)	(2.882)	(0.132)
Control Variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Adj_R-square	0.4912	0.5344	0.5420	0.1637
F	79.29***	44.03***	75.22***	10.47***
Cluster by firm	Yes	Yes	Yes	Yes
Observations	28,145	10,504	23,989	36,812

Note: ***,**, and * indicate significance at the 1 %, 5 %, and 10 % levels, respectively, or better.

First, the unobservable inherent difference between the treatment group and the control group may also lead to differences in the cost of debt between different firms, then the findings of our study may not be caused by the development of intelligent supply chains. Hence, we lag the *Treat* by two periods and perform a placebo test. The results in column 1 of Table 4 show that after lagging *Treat* by two periods, the coefficient of Treat×Post is -0.001 and not significant. The results of placebo test indicate that the main effect is not driven by unobservable factors.

Second, the differences between the treatment and control groups may be caused by self-selection bias. Hence, we use the propensity score matching (PSM) methods to alleviate the endogeneity problem caused by self-selection bias and perform a robustness test. After we use the new sample data based on the 1:1 nearest neighbor matching method, the coefficient of *Treat×Post* is shown in Column 2 of Table 4. We find that the coefficient of *Treat×Post* is -0.003 and significant at the 5% level, confirming that after alleviating the impact of self-selection bias on the results, a significant negative correlation still exists between the development of intelligent supply chains and the cost of debt.

Third, to control for the impact of the "deleveraging" policy implemented in 2015 on corporate debt financing behavior, we re-examine the

hypothesis using data from 2016 to 2024. Column 3 of Table 4 shows that when the regression is conducted using data from 2016 to 2024, the development of intelligent supply chains remain significantly reduces the firms' cost of debt.

Fourth, we also use interest expenses divided by total liabilities (*COD_2*) to measure the cost of debt and re-examine the hypothesis. The results presented in column 4 of Table 4 show that when the cost of debt is measured using *COD_2*, the coefficient of *Treat×Post* is -0.002 and significant at the 5% level, further supporting our conclusion.

5. Conclusions

This study investigates the impact of intelligent supply chain development on the cost of debt. We find that the development of intelligent supply chains reduces information asymmetry and enhances firm value, thereby lowering the firms' cost of debt. That is, intelligent supply chain development has a negative effect on firm's cost of debt. Our study contributes to encouraging more firms to engage in intelligent supply chain initiatives and promotes the broader development of intelligent supply chains by revealing the relationship between intelligent supply chain development and the cost of debt.

Although this study provides a comprehensive analysis of the influence of intelligent supply chain development on the cost of debt and obtains robust

and reliable results, there are still limitations in this study, which open avenues for future research. Due to China only began developing intelligent supply chains in 2018, our study includes data from the most recent seven years since the initiation of intelligent supply chain development. In the future, we will extend our sample period to further validate our conclusions.

Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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