Leverage Ratio, Property Rights and Electronic Enterprise Innovation

Empirical Research Based on Hansen's Threshold Regression Model

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Abstract. Considering the current background of China's efforts to strengthen deleveraging and the strategy of innovation-driven development, this paper focuses on electronic enterprises, and studies the relation between leverage ratio and innovation, considering the influence of property rights heterogeneity. Based on the samples of electronic enterprises from China Industry Business Performance Database during 2005 to 2007, this paper uses Hansen's Threshold Regression Model to give the accurate relationship between R&D Investment and total leverage ratio/short-term leverage ratio/long-term leverage ratio. The research has found that the total leverage ratio has a positive impact on R&D investment when it is lower than 83.04%, and the optimal total leverage ratio is about 54.45%–55.47%, the optimal short-term leverage ratio is about 54.47%–55.45%. Besides, the long-term leverage ratio has a negative impact on R&D investment when it is over 22.27%. According to the property rights heterogeneity analysis, as for state-owned enterprises, R&D investment is restrained when total leverage ratio is lower than 49.67%, and boosted when long-term leverage is not higher than 25.10%. As for non-state-owned enterprises, on the contrary, R&D investment is boosted when total leverage ratio is lower than 83.04%, and restrained when long-term leverage ratio is lower than 26.75%. This paper has not only enriched the studies on influence of leverage on innovation considering the property rights heterogeneity, but also brought reference for China to defuse debt risks of enterprises and enhance the spur China's electronic enterprises to promote innovation.

Keywords: Innovation · R&D Investment · Leverage Ratio · Property Rights · TR Model · Electronic Industry

1 Introduction

The 14th Five-Year Plan for National Economic and Social Development, with the headline "Adhere to the Strategy of Innovation-driven Strategy and Create New Development Advantages in an all-round way", has asked to improve the innovation capability of enterprises and strengthen the dominant role of enterprises in innovation. Meanwhile, China has emphasized on the urgency of solving key posers in the field of semiconductor industry and other electronic industry, which means China's electronic enterprises are in great need of innovation.

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Enterprise innovation always requires a great deal of R&D investments, which in most cases can only be supplied by means of leverage. Yet with the leverage whose ratio is too high the enterprises' financial risks and debt burden will be increased, and the enterprises will be forced to cut down high-risk investments like R&D. On the other hand, with the leverage whose ratio is too low the enterprises might be in a shortage of funds or a deficiency of funding liquidity, which also will reduce the R&D investments of enterprises. Taking in to account all these factors, it is of great value to find out the optimal leverage ratio for innovation of electronic enterprises, especially in the background that the Report to the 19th National Congress of CPC continues emphasizing on the importance of deleveraging.

Unfortunately, existing research on the relation between leverage and enterprise innovation mostly have too extensive scope, generally their objects of studies are listed enterprises without being distinguished or selected by their industrial peculiarity or property rights. Therefore, to make up for such pity, this paper focuses its research scope on China's electronic enterprises which manufactures telecommunication equipment, computers and other electronic equipment, studies the relation between leverage and innovation of these enterprises, and find out the optimal leverage level to spur the innovation. Moreover, on account of the property rights heterogeneity, state enterprises and non-state enterprises have different debt pressure, investment allocation and the relation among each other, that is why this paper makes a property rights heterogeneity analysis, that is to study the influence of leverage on innovations of state enterprises and non-state enterprises separately.

The rest of this paper has a structure as follow: the second part is the literature review, which is to summarize and review the references about innovations, the factors influencing innovations, the relation between leverage and innovation, the influence of property rights, etc. The third part is the research design, which is to introduce the data source, the illustration of variables and the modeling. The fourth part is the empirical analysis, which is to give the descriptive analysis, the results of threshold effect and the property rights heterogeneity analysis. The fifth part is conclusion and suggestion.

2 Literature Review

2.1 Innovation

Joseph Schumpeter (1912) has defined innovation as an economic object in his masterpiece Theory of Economic Development for the first time, and identified 5 types of innovation: the introduction of a new product or new product quality, the introduction of a new production process, the opening up of a new market, the securing of a new source of raw materials or other inputs, the creation and application of a new organizational structure in an industrial sector [35].

Traditional research defines product innovation as producing new functions to increase the differentiation of products [16], the definition has been improved as follow: product innovation is increasing the differentiation of products to reduce the substitutability of products. The methods of product innovation are internal R&D (including but not limited to internal innovation, reverse engineering, commissioned innovation

and joint innovation) and external acquirement (including but not limited to introducing innovation, M&A, purchase of authorization) [8, 27], Lambertini (2009) suggests that product innovation is endowed with the goals of market-share-first strategy, market follower strategy, low-cost strategy and low-risk strategy [17, 18].

In terms of technological innovation, generally it is considered as developing new technology or extending and improving the existing technology in order to reduce the cost of existing products and service and increase the efficiency in production [5], this kind of innovation can reduce marginal cost and might bring about product innovation [8, 27, 31]. The representatives of technological innovation theory----Kamien and Schawartz (1982) suggests that technological innovation is mainly influenced by the size of enterprise, the condition of market competition and monopoly power of enterprise [16].

Besides product innovation and technological innovation, there is organizational innovation inside the enterprises, Damanpour (1991), DiMaggio PJ & Powell WW (1983) have studied this kind of innovation, and defined it as: new organizational structure interiorly adopted by the enterprises, including but not limited to the innovation of functional structure, the innovation of management system, the innovation of institutional settings, the innovation of horizontal coordination, the innovation of operational mechanism, the innovation of organizational communication across enterprises [4, 6].

Enterprises need not only the unprecedented and radical innovation, but also the innovation which can develop its existing business model to ensure stable income [7], in other words, ambidextrous innovation is what they need. Ambidextrous innovation means doing the activities of conducting the exploratory innovation which is high-input, high-risk, high-return, and the applied innovation which is low-input, low-risk, low-return at the very same time. Tushman & O' Relly (1996) propounded structural ambidextrous innovation which is spatially separated [37], Gibson & Birkinshaw (2004) propounded the contextual ambidextrous innovation [9].

2.2 Determinants of Innovation

In the field of economics and management, the research on the external determinants of innovation has already been relatively mature. Neoclassical economics is a traditional method to analyze enterprise innovation, it regards technology as a static parameter of production function, which tends to be evenly distributed among enterprises and promotes public interest. Schumpeter (1934) paid further attention to innovation and propounded 2 direct determinants of innovation: scale and market concentration, which are often impacted by market attention, social resources, business environment, industrial policy and government regulation [35]. Another viewpoint enriches the external analysis methods of innovation, Williamson (1975) with his Transaction Cost Economics (TCE) pointed out the defects of innovation activities such as specificity, uncertainty and information asymmetry, which hindered the impact of market mechanism on innovation [39]. Jensen & Meckling (1976) with their Agency Theory have explained the impact of interest-divergence among enterprises as economic subjects [13]. Nelson (1982) analyzed the process of innovation, then pointed out recessiveness, systematicness, information accumulation, irreversibility of technological path of the process, and emphasized the huge technical differences among enterprises [29].

Whether it is for policy incentives or public incentives, it is essential to know the impact of external determinants of innovation. Yet the internal factors also determine the innovation, after all, in most cases the innovation process is carried out within the enterprise. Among the internal determinants of innovation, some are intangible, including human resources to form R&D teams, business resources to determine user requirements and corporate identity, organizational resources to coordinate R&D-marketing relationship and internal management, informational resources based on technology and market research [27]. In addition, there are studies also on the impact of enterprise diversification on innovation, [3] and the impact of enterprise internationalization on innovation [28]. Others of internal determinants are tangible, including enterprise scale, leverage level, extent of monopolizing, etc. Schumpeter (1934) put forward the great influence of enterprise scale on innovation very early. Subsequent economists discussed its influence effect through various methods [35]. In terms of the facilitation of innovation, some scholars preferred large enterprises with larger economic scale, larger market, larger funding possibility and smaller risks, [12] other scholars preferred small/medium enterprises which are more flexible, easier to communicate or argue, and more likely to be specialized rather than market-oriented, [23] as well as the enterprises with characteristics of both scales [33]. Another tangible determinant is the liabilities, Williamson's Transaction Cost Economics (1957) analyzes the high specificity and unpredictability of technical R&D, which increases the transaction cost and blocks debt financing [39]. Jensen's and Meckling's agency theory (1976) also believes that the high risk and information asymmetry of innovation activities will cause debt financing problems, the pressure of debt financing might also hinder innovation [13]. Scherer (1965) thinks that debt financing endows enterprises with the capital to start new R&D, and promotes innovation to some extent [34].

2.3 Leverage and Innovation

As a direct reflection of the debt level of enterprises, leverage directly determines the investment decisions of enterprises. The relationship between leverage ratio and innovation is by no means simply linear. In fact, the effect of leverage on innovation includes both promotion and inhibition, specific what kind of effect dominates, often depends on the leverage ratio, as well as the enterprise's financial capability and risk tolerance.

2.3.1 Promotional Effect of Moderate Leverage on Innovation

A large amount of R&D investment is required in the process of innovation, which is usually difficult to maintain merely relying on internal financing. Therefore, it is necessary to use external financing and moderately increase the leverage ratio to meet the funding needs of high R&D investments. Through debt financing, enterprises can utilize their own assets to control larger assets and cash flow, so that they can increase R&D expenditure [5]. Together with capital, debt brings about creditors' supervision mechanism and debt control effect. Under the supervision of external creditors and investors, enterprises must improve their operation and management, and make decisions which tend to do the optimized and efficient innovation projects [32]. Jensen (1976) has pointed out the positive impact of leverage on innovation: while creditors receive

principal and fixed interest, investors receive dividends from the excess earnings of the enterprise. Under the circumstances of high leverage ratio and high debt pressure, only R&D projects with high risks but high returns can still bring excess earnings after the debt is settled, that is why the attitude of investors at this time tends to promote innovation [14]. According to Ross's Signal Incentive Model (1977), the increase in leverage ratio is accompanied by the increase in the risk of bankruptcy, the high cost of debt financing releases a positive signal to the market that the enterprise is seeking to improve itself rather than doing nothing [32]. Jensen's Free Cash Flow Theory (1977) pointed out that when the leverage ratio is too low, the enterprise has a rich free cash flow which leads to haphazard investment and over-investment, which will also inhibit innovation [14]. Balakrishnan (1993) believes that innovation brings intangible assets with strong market competitiveness to enterprises, enabling enterprises to gain continuous support from creditors and investors [2]. In addition to promoting innovation, appropriate leverage ratio is also beneficial to the enterprise's operation with a "tax shield" effect, i.e., the interest generated from debt is treated as financial expenses but not included in pretax profit, so as to achieve the purpose of tax avoidance. From an empirical point of view, M. Ayyagari (2011) has taken data from 47 developing countries as samples, and found that the leverage ratio and R&D investment of enterprises show a positive correlation within a certain range [1].

2.3.2 Inhibitory Effect of Excessive Leverage on Innovation

The process of innovation is always long-periodic and high-risk. Debt financing increases the financial risk, bankruptcy cost and agent cost. When the leverage ratio reaches a certain height, the enterprise will be forced to reduce high-risk investments under operating pressure, and innovation activities will be suppressed accordingly.

First, excessive leverage brings financial risks. Enterprises need to pay debt interest regularly, resulting in an increase in financial costs, besides, debt financing needs stable support of cash flow and risk rating. The high-input and high-risk innovation activities will have to be reduced when the leverage ratio is too high, the enterprise will veto new R&D proposals, reduce the fund of existing R&D projects, or even directly suspend R&D investments [26]. High leverage also means bankruptcy risks. When the leverage ratio is heightened, the financial stability of the enterprise is damaged, and the risk of financial crisis or bankruptcy is heightened, which increases the financial uncertainty and managing uncertainty within the enterprise. The increase of bankruptcy risk also affects the financing credit and reputation of the enterprise. Investors reduce their investment due to the fear of bankruptcy, so that the enterprise lose more opportunity costs [3].

Furthermore, leverage aggravates the principal-agent problem of enterprises. The interests of investors and managers diverge, as the investors are concerned about the long-term development of the enterprise while the managers are concerned about the income during their short term of office. Since R&D process is destined to be long-term and uncertain, the managers usually have little interest in innovation [5]. Meanwhile, with a high leverage, managers need to pay more attention to the risk management and the safety of cash flow currently, and the risk of innovation will be enlarged to an unbearable level because the enterprise will face huge difficulties to pay off debts and

the managers will also face the possibility of losing their jobs once the R&D results are not as good as expected [13].

2.4 Property Rights and Innovation

The internal operation efficiency, management mode, incentive mechanism of enterprises and their impact on innovation are different due to the property rights. Compared with non-state-owned enterprises, state-owned enterprises have more advantages in resource endowment, which is reflected in the regulatory role of government grants. In China, there are problems of soft budget constraint within state-owned enterprises, that is to say, when facing financial losses, state-owned enterprises will derive financial assistance and tax incentives from local or central government [21]. In addition, there is a large funding gap in state-owned enterprises. State-owned enterprises do not just take profit as their purpose, but have the responsibility to implement regulatory policies. In order to not disperse the control of state-owned shares, in most cases state-owned enterprises choose to raise funds by means of debt, and with government guarantee they are more likely to get financial support from banks than non-state-owned enterprises. Therefore, state-owned enterprises need and can maintain normal operation and R&D process with a high leverage ratio [15]. However, the problems of resource redundancy and resource waste within state-owned enterprises also occur from time to time, which weaken the risk-taking of state-owned enterprises and prevent them from carrying out more innovation activities [10].

2.5 Related Empirical Research

In recent years, a number of scholars have made empirical studies on the relationship between leverage ratio and innovation. Liu Shengqiang et al. (2011) have used the panel data of listed enterprises in manufacturing industry and high-tech industry from 2004 to 2008 to test the impact of debt on R&D investment with different growth opportunities by using the fixed effects model [22]. Luo Nengsheng et al. (2018) have selected the panel data of A-share listed companies from 2010 to 2015 to study the relationship between leverage ratio and innovation of different scales through threshold regression model [25]. Wang Yuze, Luo Nengsheng et al. (2019) have conducted an empirical study on what leverage is conducive to innovation within enterprises based on samples of A-share listed companies from 2010 to 2015, and found that there is an "inverted-U" relationship between leverage ratio and innovation input/output [25]. Ma Yadong (2019) used data envelopment analysis (DEA) to study the impact of leverage on the innovation efficiency of listed manufacturing enterprises [26]. Li Peiwen & Yan Yan (2020) have used quadratic regression analysis to examine the relationship between leverage and innovation input/output based on the data of A-share listed non-financial companies from 2010 to 2015. The results show that there is also an "inverted-U" relationship between leverage ratio and innovation input/output [20].

It is basically determined that the relationship between the leverage ratio and the innovation of an enterprise presents an "inverted-U" shape similar to a concave function. Considering that the index of innovation changes significantly after the leverage ratio increases to a certain point, it is significant for Luo Nengsheng et al. (2018), Li

Gaoya et al. (2021) to use threshold regression model to study the relationship between leverage and innovation [19, 25]. What's more, the result of quadratic regression model or other polynomial regression model may not reflect the actual situation, but when using Hansen's threshold regression model (2000) it no longer need to give any hypothesized non-linear equation, and can make the result closer to the actual situation [11].

Due to the difference in debt capacity between state-owned enterprises and non-state-owned enterprises, the leverage ratio has different effect on innovation. Therefore, enterprises with different property rights should be distinguished when studied. The enterprises studied in this paper are mainly in the field of electronic products manufacturing, and if we simply take the data of A-share listed companies as samples, some new and developing electronic enterprises that have not yet been listed will be neglected, that is the reason why we picked out the samples of electronic enterprises from China Industry Business Performance Data during 2005–2007.

3 Research Design

3.1 Data Source

This paper mainly uses the enterprises data of "Database of All China's State-owned and Non-state-owned Industrial Enterprises" (hereinafter referred to as "China Industry Business Performance Database") in 2004–2007 for empirical research. The database has the following advantages: (1) The sample size is large enough. During the selected period, each year there are about 20,000 enterprises as samples, which can reduce sampling error. (2) The database well distinguishes enterprises from their industries, and completely covers listed enterprises and unlisted enterprises in electronic industry. (3) The database includes the R&D expenses, total liabilities, current liabilities, total assets, fixed assets, net profit, operating income, main business income, age and other indicators of the enterprise, which meets the requirements of the empirical model.

According to the purpose of the research, this paper selects the samples of enterprises which belong to "computer, communication equipment and other electronic equipment manufacturing industry" in "China Industry Business Performance Database".

In the data processing, the invalid value such as negative R&D expenses, non-positive operating income, negative total liabilities, negative current liabilities, non-positive long-term liabilities, non-positive total assets, non-positive current assets, non-positive fixed assets and non-positive main business income are eliminated. Then, the panel data are balanced to obtain 15,888 valid samples. According to the business structure of enterprise registration, state-owned enterprises, enterprises solely fund by the state, state-controlled enterprises are all regarded as state-owned enterprises, while the others are all regarded as non-state-owned enterprises, and there are 365 valid samples of state-owned enterprises and 15,523 valid samples of non-state-owned enterprises.

3.2 Variable Selection

3.2.1 Dependent Variable

This paper selects R&D investments as an indicator to measure the innovation of enterprises. Some research that also study the relationship between leverage ratio and innovation take patent counts, innovation output, innovation performance or other achievements in innovation as the measurement [30]. However, the achievements of innovation are often random, not directly controlled by the capital management of enterprises, and have a week correlation with the leverage ratio which measures the debt level of enterprises. R&D investments and development expenses have the strongest correlation with leverage ratio, which also reflects the attitude of enterprises towards innovation. While further affecting innovation achievements, it is also affected by the feedback effect of innovation achievements. In other words, enterprises receiving returns will increase their R&D investments, so the impact of innovation achievements is covered to a certain extent. Therefore, the ratio of total R&D expenses to operating income is selected as the measure of innovation.

3.2.2 Independent Variables

Refer to Luo Nengsheng's (2018, 2019) and Ma Yadong's (2019) research, total leverage ratio, short-term leverage ratio, long-term leverage ratio are selected as independent variables in this paper.

1. Total leverage ratio = total liabilities/total assets, it reflects the overall debt level, overall solvency and overall debt risk of the enterprise [25].
2. Short-term leverage ratio = current liabilities/total assets, it reflects the level of liabilities with a repayment period of one year or more than one year in an operating cycle, and shows the short-term solvency and short-term liquidity of the enterprise [25].
3. Long-term leverage ratio = long-term liabilities/total assets, it reflect the level of liabilities with repayment period of more than one year or more than one operating cycle, and shows the long-term solvency, long-term liquidity, long-term operation and capital structure of the enterprise. Note: generally short-term solvency is the basis of long-term solvency [25].

3.2.3 Grouping Variables

Property rights: according to the business structure of enterprise registration, state-owned enterprises, enterprises solely fund by the state, state-controlled enterprises are classified as "state-owned enterprises", and other enterprises are classified as "non-state-owned enterprises".

3.2.4 Control Variables

Refer to Luo Nengsheng's (2018), Li Peiwen's (2020), P. Wang's (2020), Li Gaoya's (2021) research, this paper selects scale, solvency, profitability, growth capability, operating capability, fixed assets ratio, age as the control variables.

1. Scale: the larger the scale, the stronger the risk tolerance of the enterprise. In order to strengthen the monopoly in the field, the decisions usually tend to invest in innovative R&D projects within large enterprises, and that is why there is a certain positive correlation between the scale and the R&D investments. (Balakrishnan, 1993) This paper selects the total assets of enterprises to measure the scale, and reduces the range of it by adding 1 and then taking the logarithm.
2. Solvency: the solvency of an enterprise determines the difficulty of getting credit and the investing strategy of the enterprise, which in turn influences the R&D investment. This paper selects current ratio to measure the solvency, which is the ratio of current assets to current liabilities [25].
3. Profitability: when it comes to the decision-making of innovation, enterprises always consider their own profitability to determine whether to take risks to improve returns. This paper selects net profit growth rate to measure the profitability, which is the ratio of net profit growth to net profit of last year [20].
4. Growth capability: in most cases the growth of an enterprise influences the top brass's view on the development needs of the enterprise, and indirectly influences R&D investment within the enterprise. This paper selects total assets growth rate to measure the growth capability, which is the ratio of total assets growth to total assets of last year [20].
5. Operating capability: the operation of an enterprise reflects the inventory turnover, which determines the needs of new products or new production technique. This paper selects current assets turnover to measure the operating capability, which is the ratio of main business income to average current assets [20].
6. Fixed assets ratio: fixed assets reflects the basic capital and the bankruptcy cost of an enterprise, and the fixed assets ratio, which is the ratio of fixed assets to total assets, shows the capital structure of an enterprise which determines its risk tolerance and risk decisions [19].
7. Age: established time shows the historical background of an enterprise, which shows the maturity of its operation structure, production, marketing, and thus might influences its motivation for innovation. This paper calculate the age of enterprises by subtracting the year of establishment from the current year of database and then adding 1 (Table 1).

3.3 Modeling

In order to study the impact of various leverage ratios on innovation, this paper uses Hansen's threshold regression model (2000) [11]. In the different intervals of threshold variable, the coefficients of the dependent variable concerned are set to different values:

$$y_{it} = u_i + \beta_1' x_{it}(q_{it} \leq \gamma) + \beta_2' x_{it}(q_{it} \succ \gamma) + \varepsilon_{it} \quad (1)$$

In the above formula, q it are the threshold variables, γ is the threshold value, x it are the explanatory variables. The test of threshold effect is mainly in 2 aspects: one is to test whether the threshold effect exists, and the null hypothesis is β 1 = β 2, which means the threshold effect does not exist, when the null hypothesis is rejected significantly, the threshold effect exists. The other is to test how accurate the estimation of threshold

Table 1. Variable Declaration

Variable	Symbol	Definition
Dependent Symbol		
R&D Investments	Ini	R&D Expenses/Operating Income
Independent Variables		
Total Leverage Ratio	lev	Total Liabilities/Total Assets
Short-term Leverage Ratio	levs	Current Liabilities/Total Assets
Long-term Leverage Ratio	levl	Long-term Liabilities/Total Assets
Grouping Variables		
Property Rights	state	Classified as "state-owned enterprises" and "non-state-owned enterprises"
Control Variables		
Scale (Size)	Size	ln (Total Assets + 1)
Solvency	Cur	Current Ratio = Current Assets/Current Liabilities
Profitability	Pro	Net Profit Growth Rate = (Current Net Profit-Net Profit Last Year)/Net Profit Last Year
Growth Capability	Gro	Total Assets Growth Rate = (Current Total Assets-Total Assets Last Year)/Total Assets Last Year
Operating Capability	Ope	Current Assets Turnover = Main Business Income/Average Current Assets
Fixed Assets Ratio	Fix	Fixed Assets/Total Assets
Age	Year	Current Year of the Database-the Year of Establishment + 1

value is. In terms of the test of threshold effect, Hansen (2000) gives the statistics LR for Likelihood-ratio test:

$$LR \equiv [SSR * -SSR(\hat{\gamma})]/\hat{\sigma}^2 \tag{2}$$

Among the formula, $\sigma^2 \equiv \frac{SSR(\hat{\lambda})}{\mathrm{n}(T-1)}$ is the consistent estimator of error variance. By using the Bootstrap Method it can simulate the asymptotic distribution of the statistics and the P value to judge whether to reject the null hypothesis. If the null hypothesis is rejected, then the threshold effect exists, and the test of threshold value is the next one to do. The statistics LR for likelihood-ratio test is defined as follow:

$$LR(\gamma) \equiv [SSR(\gamma) - SSR(\hat{\gamma})]/\hat{\sigma}^2 \tag{3}$$

The asymptotic distribution of LR is non-standard with the cumulative distribution function which is $\left(1 - e^{-\frac{x}{2}}\right)/2$, and the confidence interval of γ can be calculate from this.

When there are multiple threshold values, such as 2 threshold variables, the threshold regression model is set as follow:

$$\begin{aligned} y_{it} &= u_i + \beta_1' x_{it}(q_{it} \le \gamma_1) + \beta_2' x_{it}(\gamma_1 \prec q_{it} \le \gamma_2) \\ &+ \beta_3' x_{it}(q_{it} \succ \gamma_2) + \varepsilon_{it} \end{aligned} \tag{4}$$

Among the formula, $\gamma 1 < \gamma 2$. The same procedure may be easily adapted to obtain the threshold regression model with three or more threshold values.

Based on the model of the impact of leverage ratio on innovation, this paper establishes the threshold regression model as follow:

$$\begin{aligned} Ini_{it} &= u_i + \beta_1 \ln(lev_{it})(lev_{it} \le \gamma) + \\ &\beta 2 \ln(lev_{it}) \ln(lev_{it} > \gamma) + controls + \varepsilon_{it} \end{aligned} \tag{5}$$

Ini_{it} are the explanatory variables impacted by the threshold variables, lev_{it} are the threshold variables, γ is the threshold value, α is the constants, $\varepsilon_{it} \sim iid(0, \sigma^2)$ are the error terms (random distribution terms).

4 Empirical Analysis

4.1 Descriptive Analysis

The mean of R&D investment is 0.009452, the standard deviation is 0.040003, the minimum value is 0, and the maximum value is 2.352000, which indicates that the proportion of R&D expenses relative to operating income of most electronic enterprises is low, and there are some differences among different enterprises.

The mean of the total leverage ratio is 0.568101, the standard deviation is 0.298125, the minimum value is 0.002225, and the maximum value is 8.223014, which indicates that the leverage ratio of most of the electronic enterprises is maintained at a high level, and the difference between different enterprises is large. Among the components of leverage, the short-term leverage accounts for the largest proportion, ranging from 0.000,002 to 6.591969 with an average of 0.533068 and a standard deviation of 0.285157, while the proportion of long-term leverage is low, with an average of 0.029296 and a standard deviation of 0.112670, ranging from 0 to 7.223366. This shows that most of the electronic enterprises in China have limitations in their loan capability, and the repayment period is basically less than one year or one business cycle, which is detrimental for the enterprises to adopt long-term and aggressive investment strategies. Therefore, in general, these enterprises might be relatively cautious about innovative R&D, and it is anticipated that the investment of these enterprise is likely to be focused on short-term and low-risk R&D projects (Table 2).

Table 2. Descriptive Statistics

Variable	Symbol	Mean	Standard Derivation	Minimum Value	Maximum Value
Dependent Variable					
R&D Investment	Ini	0.009452	0.040003	0	2.352000
Independent Variable					
Total Leverage Ratio	lev	0.568101	0.298125	0.002225	8.223014
Short-term Leverage Ratio	levs	0.533068	0.285157	0.000002	6.591969
Long-term Leverage Ratio	levl	0.029296	0.112670	0	7.223366
Control Variable					
Scale (Size)	Size	10.74258	1.640973	6.070738	18.14097
Solvency	Cur	110.932	5316.653	0.016104	444910
Probability	Pro	117.8166	5822.279	−174314.3	436389.3
Growth Capability	Gro	19.48718	172.3563	−1	11455.08
Operating Capability	Ope	0.648914	0.817127	−7.261091	4.917954
Fixed Assets Rate	Fix	0.260429	0.198809	0.000039	4.050747
Age	Year	9.624245	7.102655	1	76

4.2 Benchmark Regression

4.2.1 Test of Threshold Effect

This paper first tests the threshold effect of all enterprise samples and finds out the number of thresholds and threshold value which are shown in Table 3.

From the test results, the double threshold effect of total leverage ratio on R&D investment is most significant, the significance level is 5%, and the F value is 21.31, so the double threshold model is the optimum one for regression on total leverage ratio. The double threshold effect of short-term leverage ratio on R&D investment is most significant, the significance level is 1% and the F value is 45.15, so the double threshold model is the optimum one for regression on short-term leverage ratio. Meanwhile, the double threshold effect of long-term leverage ratio on R&D investment is also most significant, the significance level is 5% and the F value is 26.15, thus, this paper chooses double threshold model for regression on long-term leverage ratio.

Table 3. Threshold effect test results

Threshold Variable	Threshold	F	P	Critical Value		
				10%	5%	1%
lev	Single threshold test	11.18	0.4500	22.5964	31.1326	41.2622
	Double threshold test	21.31**	0.0500	15.7526	15.9695	101.4108
	Triple threshold test	10.84	0.3500	16.9122	21.8478	25.2664
levs	Single threshold test	19.21	0.1000	15.6962	25.0981	70.1516
	Double threshold test	45.15***	0.0000	16.4606	18.6047	21.7402
	Triple threshold test	17.91	0.2500	22.2432	25.0943	25.4232
levl	Single threshold test	5.66	0.3000	8.7616	8.9402	9.4836
	Double threshold test	26.15**	0.0500	5.8492	8.1759	38.0645
	Triple threshold test	2.04	0.7000	9.5782	10.2005	12.3681

Note. $**$, $**$, and $*$ respectively represent passing hypothesis tests with significance levels of 1%, 5%, and 10%

Table 4. Threshold estimation results

Threshold Variable		Estimated Value	95% Confidence Interval
Lev	Threshold 1	0.5445	[0.5405, 0.5638]
	Threshold 2	0.5547	[0.5520, 0.5570]
levs	Threshold 1 Threshold 2	0.5447 0.5545	[0.5420, 0.5649] [0.2717, 0.5571]
Levl	Threshold 1 Threshold 2	0.2355 0.2640	[0.2162, 0.2640] [0.2476, 0.2808]

4.2.2 Results of Threshold Regression

According to Table 4, as for all the samples of electronic enterprises, the estimated threshold value of total leverage ratio are 0.5445 and 0.5547, the estimated threshold value of short-term leverage ratio are 0.5447 and 0.5545, the estimated threshold value of long-term leverage ratio are 0.2355 and 0.2640. The threshold effect shows that the impact of total leverage ratio, short-term leverage ratio and long-term leverage ratio on R&D investment are non-linear.

According to Table 5, in the interval $(0, 0.5445]$, the coefficient of total leverage ratio is 0.004993, in the interval $(0.5445, 0.5547]$, the coefficient of total leverage ratio is 0.026412, in the interval $(0.5547, 0.8325]$, the coefficient of total leverage ratio is 0.002838. It is obvious that the total leverage basically has a positive impact on R&D investment, and it has the most significant positive impact on R&D investment in the range of $(0.5445, 0.5547]$ with a significance level of 1%.

Table 5. Parameter estimation results of threshold model

Independent Variables	Coefficient	Coefficient	Coefficient
Size	−0.001417	−0.001492	−0.001428
Cur	−1.04e-08	−2.82e-09	−1.38e-08
Pro	2.15e-08	1.85e-08	1.73e-08
Gro	1.44e-06	1.23e-06	1.46e-06
Ope	−0.006751***	−0.006712***	−0.006630***
Fix	0.002602	0.002640	0.002599
Year	0.000316*	0.000332	0.000320
lev ∈ (0, 0.5445]	0.004993		
lev ∈ (0.5445, 0.5547]	0.026412***		
lev ∈ (0.5547, 0.8325]	0.002838		
levs ∈ (0, 0.5447]		0.008557	
levs ∈ (0.5447, 0.5545]		0.039352***	
levs ∈ (0.5545, 0.8304]		0.006250	
levl ∈ (0, 0.2228]			−0.001069
levl ∈ (0.2228, 0.2355]			−0.004094
levl ∈ (0.2355, 0.2640]			−0.030851***
R^2	0.0242	0.0216	0.0194
F Value	9.35	11.6	8.77

Note. * * *, * *, and * respectively represent passing hypothesis tests with significance levels of 1%, 5%, and 10%

In the interval (0, 0.5447], the coefficient of short-term leverage ratio is 0.008557, in the interval (0.5447, 0.5545], the coefficient of short-term leverage ratio is 0.039352, in the interval (0.5545, 0.8304], the coefficient of short-term leverage ratio is 0.006250. It can be seen that the short-term leverage ratio also has a positive impact on R&D investment basically, and it has the most significant positive impact on R&D investment in the range of (0.5447, 0.5545] with a significance level of 1%.

In the interval (0, 0.2228], the coefficient of long-term leverage ratio is −0.001069, in the interval (0.2228, 0.2355], the coefficient of long-term leverage ratio is −0.004094, in the interval 0.2355, 0.2640, the coefficient of long-term leverage ratio is −0.030851. It is obvious that the long-term leverage ratio basically has a negative impact on R&D investment and it has the most significant negative impact on R&D investment in the range of (0.2355, 0.2640] with a significance level of 1%.

4.3 Heterogeneity Analysis

According to the heterogeneity of enterprise property rights, the threshold regression analysis is carried out respectively for state-owned enterprises and non-state-owned enterprises, and the following results are obtained.

4.3.1 State-Owned Enterprises

4.3.1.1 Test of Threshold Effect

This paper tests the threshold effect of state-owned enterprise samples and finds out the number of thresholds and threshold value which are shown in Table 6.

From the test results, the double threshold effect of total leverage ratio on R&D investment is most significant with a significance level of 10% and F value of 33.21, so the double threshold model is the optimum one for regression on total leverage ratio as for state-owned enterprises. All kinds of threshold effect of short-term leverage ratio on R&D investment is not significant enough as for state-owned enterprises, so the discussion about short-term leverage ratio is omitted. Besides, the double threshold effect of long-term leverage ratio on R&D investment is most significant with a significance level of 1% and a F value of 124.60, thus the double threshold model is chosen for regression on long-term leverage ratio.

4.3.1.2 Results of Threshold Effect

According to Table 7, as for samples of state-owned electronic enterprises, the estimated threshold value of total leverage ratio are 0.4881 and 0.4632, the estimated threshold value of long-term leverage ratio are 0.0107and 0.0044. The threshold effect shows that the impact of total leverage ratio and long-term leverage ratio on R&D investment are non-linear.

According to Table 8, as for state-owned enterprises, in the interval $(0, 0.4632]$, the coefficient of total leverage ratio is -0.222409 with a significance level of 5%, in the interval $(0.4632, 0.4881]$, the coefficient of total leverage ratio is -0.439144 with a significance level of 1%. In the interval $(0.4881, 0.4967]$, the coefficient of total leverage ratio is -0.177405 with a significance level of 5%. It is obvious that the total leverage ratio has a significant negative impact on R&D investment when it comes to state-owned enterprises.

In the interval $(0, 0.0044]$, the coefficient of long-term leverage ratio is 2.461135 with a significant level of 1%, in the interval $(0.0044, 0.0107]$, the coefficient of long-term leverage ratio is 1.113289 with a significance level of 1%, in the interval $(0.0107, 0.2510]$, the coefficient of long-term leverage ratio is 0.014290 with a significance level of 10%. Approximately, the long-term leverage ratio has a positive impact on R&D investment when it is not more than 0.2510.

4.3.2 Non-state-Owned Enterprise

4.3.2.1 Test of Threshold Effect

Lastly this paper tests the threshold effect of non-state-owned enterprise samples and finds out the number of thresholds and threshold value which are shown in Table 9.

Table 6. Threshold effect test results

Threshold Variable	Threshold	F	P	Critical Value		
				10%	5%	1%
lev	Single threshold test	31.84	0.2000	45.8522	48.0283	119.0059
	Double threshold test	33.31*	0.1000	31.1419	37.0236	94.1908
	Triple threshold test	8.10	0.7000	72.5528	74.3239	118.9532
levs	Single threshold test	19.08	0.1500	20.7892	22.4420	29.0297
	Double threshold test	15.34	0.3500	56.0766	63.1761	67.6570
	Triple threshold test	6.62	0.6000	21.0632	21.6491	31.6115
levl	Single threshold test	34.95*	0.1000	20.9124	36.7831	134.1238
	Double threshold test	124.60***	0.0000	22.8129	55.8411	63.2742
	Triple threshold test	1.39	1.0000	90.4543	124.8390	862.9267

Note. ∗ ∗ ∗, ∗ ∗, and ∗ respectively represent passing hypothesis tests with significance levels of 1%, 5%, and 10%

Table 7. Threshold estimation results

Threshold Variable		Estimated Value	95% Confidence Interval
lev	Threshold 1	0.4881	[0.4844, 0.4967]
	Threshold 2	0.4632	[0.4460, 0.4824]
levs	Threshold 1 Threshold 2	N/A N/A	N/A N/A
levl	Threshold 1 Threshold 2	0.0107 0.0044	[0.0092, 0.0115] [0.0019, 0.0052]

From the test results, the double threshold effect of total leverage ratio on R&D investment is most significant with a significance level of 10% and a F value of 23.96, so the double threshold model is the optimum one for regression on total leverage ratio as for non-state-owned enterprises. All kinds of threshold effect of short-term leverage ratio on R&D investment is not significant enough as for non-state-owned enterprises, so the discussion about short-term leverage ratio is omitted. Besides, the double threshold effect

Table 8. Parameter estimation results of threshold model

Independent Variable	Coefficient	Coefficient
Size	−0.017903	−0.025732
Cur	0.004040	0.000816
Pro	1.97e-06	−0.000027***
Gro	5.57e-06	0.000032***
Ope	0.019443	0.011708
Fix	−0.083364	−0.014084
Year	0.000401	0.001470
lev ∈ (0, 0.4632]	−0.222409***	
lev ∈ (0.4632, 0.4881]	−0.439144***	
lev ∈ (0.4881, 0.4967]	−0.177405***	
levl ∈ (0, 0.0044]		2.461135***
levl ∈ (0.0044, 0.0107]		1.133289***
levl ∈ (0.0107, 0.2510]		0.014290
R^2	0.0238	0.0238
F Value	11.03	11.03

Note. ∗ ∗ ∗, ∗ ∗, and ∗ respectively represent passing hypothesis tests with significance levels of 1%, 5%, and 10%

of long-term leverage ratio on R&D investment is most significant with a significance level of 5% and a F value of 27.78, thus the double threshold model is chosen for regression on long-term leverage ratio.

4.3.2.2 Results of Threshold Effect

According to Table 10, as for samples of non-state-owned electronic enterprises, the estimated threshold value of total leverage ratio are 0.5443 and 0.5547, the estimated threshold value of long-term leverage ratio are 0.2356 and 0.2675. The threshold effect shows that the impact of total leverage ratio and long-term leverage ratio on R&D investment are non-linear.

According to Table 10, as for non-state-owned enterprises, in the interval (0, 0.5443], the coefficient of total leverage ratio is 0.006152, in the interval (0.5443, 0.5547], the coefficient of total leverage ratio is 0.026164 with a significance level of 1%. In the interval (0.5547, 0.8304], the coefficient of total leverage ratio is 0.002267. It is obvious that the total leverage ratio basically has a positive impact on R&D investment when it comes to state-owned enterprises.

Table 9. Threshold effect test results

Threshold Variable	Threshold	F	P	Critical value		
				10%	5%	1%
lev	Single threshold test	12.33	0.3500	17.2921	17.4937	20.9700
	Double threshold test	23.96*	0.1000	14.4181	28.5878	32.8621
	Triple threshold test	12.22	0.3500	17.6027	21.3499	63.5051
levs	Single threshold test	20.07	0.1500	20.9475	21.8406	38.1742
	Double threshold test	10.99	0.4500	27.6503	44.7184	54.8745
	Triple threshold test	6.17	1.0000	16.9570	17.2811	31.7170
levl	Single threshold test	9.54	0.1500	12.1876	20.5409	54.4998
	Double threshold test	27.78**	0.0500	17.5037	18.4821	92.9741
	Triple threshold test	2.15	0.7000	26.3564	47.7291	120.7146

Note. ∗ ∗ ∗, ∗ ∗, and ∗ respectively represent passing hypothesis tests with significance levels of 1%, 5%, and 10%

Table 10. Threshold estimation results

Threshold Variable		Estimated Value	95% Confidence Interval
lev	Threshold 1	0.5443	[0.5403, 0.5635]
	Threshold 2	0.5547	[0.5508, 0.5569]
levs	Threshold 1 Threshold 2	N/A N/A	N/A N/A
levl	Threshold 1 Threshold 2	0.2356 0.2675	[0.2158, 0.2675] [0.2500, 0.2852]

In the interval (0, 0.0517], the coefficient of long-term leverage ratio is −0.002283, in the interval (0.0517, 0.2227], the coefficient of long-term leverage ratio is −0.005410 with a significance level of 5%, in the interval (0.2227, 0.2356], the coefficient of long-term leverage ratio is −0.033887 with a significance level of 1%, in the interval (0.2356, 0.2675], the coefficient of long-term leverage ratio is −0.005882 with a significance level of 5%. From these results, it is obvious that the long-term leverage significantly has a negative impact on R&D investment of non-state-owned enterprises (Table 11).

Table 11. Parameter estimation results of threshold model

Independent Variable	Coefficient	Coefficient
Size	−0.001583	−0.001624*
Cur	−9.12e-09	−1.29e-08
Pro	1.97e-08	1.52e-08
Gro	1.55e-06	1.65e-06
Ope	−0.007294***	−0.007178***
Fix	0.003341	0.003362
Year	0.000411**	0.000403**
lev ∈ (0, 0.5443]	0.006152	
lev ∈ (0.5443, 0.5547]	0.026164***	
lev ∈ (0.5547, 0.8304]	0.002267	
levl ∈ (0, 0.0517]		−0.002283
levl ∈ (0.0517, 0.2227]		−0.005410**
levl ∈ (0.2227, 0.2356]		−0.033887***
levl ∈ (0.2356, 0.2675]		−0.005882**
R^2	0.0238	0.0198
F Value	11.03	10.49

Note. ∗ ∗ ∗, ∗ ∗, and ∗ respectively represent passing hypothesis tests with significance levels of 1%, 5%, and 10%

5 Conclusions and Suggestions

5.1 Research Conclusions

Firstly, taking all the samples of electronic enterprises as the research object, when the total leverage ratio of enterprises is not more than 83.25%, the total liabilities have a positive impact on innovation, especially when the total leverage ratio is about 55.45%–55.47%, the effect of promoting R&D investment in electronic enterprises is the most significant. In terms of current liabilities, when the short-term leverage ratio is not more than 83.04%, the current liabilities have a positive impact on innovation, especially when the short-term leverage ratio is about 54.47%–55.45%, the effect of promoting R&D investment in electronic enterprises is the most significant. However, the long-term liabilities have a slight negative impact on R&D investment. In order to promote the innovation of electronic enterprises, it would be better to reduce the long-term leverage ratio to a level of not more than 22.28%. In summary, to promote R&D investment of electronic enterprises, the total leverage and the short-term leverage are appropriate when the former is less than 83.25% and the latter is less than 83.04%, the long-term leverage need to be cut down by a big margin.

Secondly, based on the property rights of electronic enterprises, this paper makes a heterogeneity analysis on state-owned enterprises and non-state-owned enterprises,

and finds that the R&D investment of state-owned enterprises is negatively affected by the total leverage, which is most significant when the total leverage ratio is between 46.32% and 48.81%, thus the total leverage ratio shall be reduced to less than 46.32% to promote innovation. Nevertheless, virtually the long-term leverage promotes R&D investment in state-owned enterprises when it is not more than 25.10%, and the optimal range of long-term leverage ratio is 0.44% to 25.10%. Besides, as for non-state-owned enterprises, when the total leverage ratio is not more than 83.04%, the R&D investment is positively impacted by the total leverage ratio within non-state-owned enterprises, and the optimal total leverage ratio is about 54.43%–55.47% to promote innovation. On the contrary, the long-term leverage ratio negatively affect the innovation within non-state-owned enterprises, and the R&D investment is significantly restrained when the long-term leverage ratio is about 22.27%–26.75%, thus the long-term leverage ratio of non-state-owned enterprises would better be reduced to no more than 22.27%. In summary, substantially the total leverage has a positive effect on the innovation of non-state-owned electronic enterprises, and yet not on the innovation of state-owned electronic enterprises, and the situation of long-term leverage just the opposite.

5.2 Suggestions

First of all, the components of leverage should be distinguished, the level of deleveraging should be defined according to the total leverage ratio, short-term leverage ratio and long-term leverage ratio respectively. Secondly, the optimal ratio of state-owned enterprises is obviously different from that of non-state-owned enterprises, since the heterogeneity of property rights is an important factor that impacts the relationship between leverage ratio and innovation. Thus, the uniformity should not be imposed on the implementation of deleveraging, which means there should be not one-size-fits-all debt level ceiling but different deleveraging strategies adopted for electronic enterprises with different property rights. According to the scientific basis of the relationship between leverage ratio and innovation of electronic enterprises, the government can build an asset-liability constraint mechanism based upon various leverage structure and property rights of enterprises, so as to prevent and resolve major risks and consolidate the foundation for promoting innovation of electronic enterprises. Meanwhile, enterprises should make full use of the positive effort of leverage on innovation, optimize their leverage structure, their internal financial decision-making and their R&D investment strategy to ensure their long-term and high-quality development.

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