

Structural Characteristics of Leverage Ratio of China's Non-Financial Enterprises during COVID-19

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Abstract

This paper investigates the structural characteristics of the financial leverage ratios of non-financial enterprises in China during the COVID-19 period using 2296 A-share listed companies from 2016q1 to 2022q4. It finds that the leverage ratio of non-financial enterprises increased significantly during the pandemic, and the leverage growth shows heterogeneity across industries, firm sizes, and profitability levels: Most industries' leverage ratios exhibited significant growth, while the real estate remained stable and the comprehensive industry experienced a leverage decline, which may be caused by the combined effects of the characteristics of the epidemic impact, internal decision-making of enterprises, and external policy intervention; The smaller the enterprise size, the faster its leverage grows, which leads to a convergence trend between different size groups; The leverage of firms in the lowest ROA group increased more rapidly compared to the other three groups. These findings provide empirical evidence for understanding the heterogeneous impact of exogenous shocks on corporate capital structure, and offer policy implications for targeted deleveraging and financial risk prevention in the post-pandemic era.

Keywords

Capital Structure, Leverage Heterogeneity, COVID-19, Non-Financial Enterprises

1. Introduction

According to existing literature, the factors determining a company's financial leverage ratio can be broadly categorized into three levels: enterprise, industry, and macro environment. At the firm level, prior studies have established a relationship between financial leverage and firm-specific characteristics, including

company size, ownership structure, tangibility, profitability (Frank & Goyal, 2009; Prime & Qi, 2013), cash flow risk (Rehman et al., 2023), the cost of financial distress (Zhou et al., 2016; Xie, 2026), and financing costs (Strebulaev, 2007). At the industry level, the influence factors of corporate leverage ratios include such indicators as the average or median value of industry leverage, industry sensitivity to policy changes, industry growth potential, and industry concentration and so on (Zhong et al., 2016). At the macro level, the economic and political environment significantly shapes enterprise capital structure adjustments, including monetary policy (Alter & Elekdag, 2020), economic policy uncertainty (Wang et al., 2018), financial cycles (Choi & Pyun, 2026), and even sudden large-scale epidemic shocks (Rehman et al., 2024; Vo et al., 2022). It is widely acknowledged that the COVID-19 pandemic not only poses a threat to human health and life safety but also exerts a profound negative impact on the global economy (Zhang et al., 2020). During the pandemic, companies' operations and business activities were severely disrupted, and various financial performance was inevitably affected (Zhang et al., 2020; Aljughaiman et al., 2023), including capital structure decisions (Fahlenbrach et al., 2021; Vo et al., 2022; Xie, 2025, 2026), financial distress (Leng & Sun, 2024) and corporate earning management (Aljughaiman et al., 2023). The study results of Frank & Goyal (2009), Kayo and Kimura (2011), and Wang et al. (2018) show that different industries exhibit distinct company attributes, and firms' response speed, financing needs and capital structure decisions differ when confronting sudden large-scale shocks or policy changes. To the best of our knowledge, prior studies about the interactions between leverage choices and COVID-19 pandemic mainly focus on leverage adjustment speed and leverage responses of firms with different financial conditions. Vo et al. (2022) explored the impact of COVID-19 economic crisis on the speed of leverage adjustment using an international sample. Rehman et al. (2024) investigate the relationship between COVID-19 exposure and corporate leverage adjustment using 3260 US-listed companies and a novel measure of COVID-19 exposure. Xie (2025) and Xie (2026) examines the heterogeneous impacts of the COVID-19 on corporate leverage decisions for companies with different financing constraints and financial distress risk level during the COVID-19 pandemic period using Chinese listed firm data, respectively. However, there is almost no literature to investigate the structural characteristics of micro leverage ratios following the outbreak of the COVID-19 epidemic. In this study, we aim to fill this gap.

As is known to all, the leverage ratio of enterprise departments is generally divided into macro leverage ratio and micro leverage ratio. Macro leverage ratio is a core indicator for measuring the size of a country's debt, which refers to the ratio of the total debt of the government, non-financial enterprises, and residents to the total economic output (GDP). Micro leverage ratio mainly measures the size of a company's debt, referring to the ratio of a company's total debt to total assets. In China, the macro leverage ratio of non-financial enterprise department rapidly increased from 97.7% in 2008 to 146.9% in 2015, far exceeding the threshold of

90% for OECD countries. At the end of 2015, China began to “deleveraging”. With the whole society vigorously deleveraging, the leverage growth of non-financial corporate sector slowed down in 2016, and declined in 2017 and 2018. However, the COVID-19 broke out in December 2019. Its uncertainty and destructive impact on the economy led to a rapid growth in the leverage ratio of non-financial enterprises, as shown in **Figure 1**. Nevertheless, the macro leverage ratio cannot fully capture the structural issues in the micro leverage ratio of enterprise sectors, and there are significant differences in the micro leverage levels for different types of enterprises, which exhibit clear structural characteristics (Wang et al., 2018; Gong et al., 2019; Tan et al., 2020). Gong et al. (2019) described the structural characteristics of leverage ratio of non-financial listed companies from five aspects: term structure, region, ownership, scale, and industry from 2002 to 2016. Tan et al. found that the highly leveraged enterprises after the financial crisis are mostly large scale firms and state-owned enterprises, located in the real estate, construction, electricity, heat, gas, and water production and supply industries, transportation, warehousing, postal services, and manufacturing industries. During the COVID-19, some industries in China centered around “home necessities”, “digital substitution”, and “health protection”, such as pharmaceutical manufacturing, online education, gaming and digital entertainment, and live streaming economy, experienced counter trend growth, while some traditional industries, such as tourism, offline catering, and cinemas, suffered overall setbacks. Moreover, the central and local governments have introduced a series of targeted credit support policies for different enterprises. Against this backdrop, it is worth paying attention to exploring the structural characteristics of leverage ratio of micro enterprises in China during the epidemic period. In this paper, our

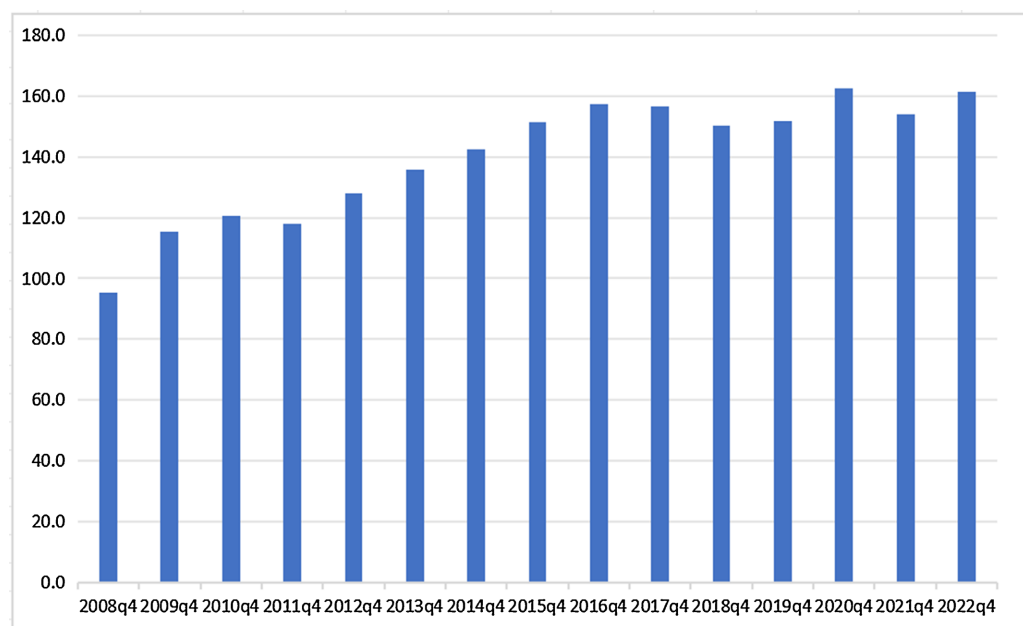


Figure 1. The macro leverage ratios of China's non-financial enterprises department from 2008q4 to 2022q4. Data Source: Center for National Balance Sheets (CNBS) in China.

goal is to explore the structural characteristics of the leverage ratio growth among Chinese non-financial enterprises during the COVID-19 period, analyze the underlying causes, and offer suggestions for deleveraging policies in the post-pandemic era.

2. Date and Sample Selection

In this paper, we choose A-share listed companies on the Shanghai and Shenzhen Stock Exchanges in China as our sample. All data are obtained from the CSMAR database. The COVID-19 epidemic broke out in China at the end of December 2019 and officially ended on December 7, 2022. To study the impact of the pandemic on corporate financial leverage, we use the pre-pandemic period of 2016-2019 as a benchmark, thus the sample period spans from the first quarter of 2016 to the fourth quarter of 2022. We remove all financial enterprises, ST and *ST companies, as well as firms with fewer than 28 observations. After these selection procedures, we obtain a final sample of 2296 distinct firms and 64,288 firm-quarter observations. In addition, to mitigate the impact of outliers, all variables are winsorized at the 1st and 99th percentiles. The specific variable definitions are provided in **Table 1**.

Table 1. Definitions of main variables.

Variables	Symbol	Variable definitions
Total debt	Totaldebt	The total of various liability items; it equals the sum of short-term and long-term liabilities.
Short-term debt	Shortdebt	Total of short-term liabilities
Long-term debt	Longdebt	The total long-term liabilities
Total assets	Totalassets	Total book assets
Total leverage ratio	Totallev	The ratio of total debt to total assets
Short-term leverage	Shortlev	Short-term debt/Total assets
Long-term leverage	Longlev	The ratio of long-term debt to total assets; it equals the difference between the total leverage ratio and short-term leverage ratio.
Return on assets	ROA	The ratio of after tax net profit to total assets.

According to the “Classification and Codes of Industry Statistics for Listed Companies” (JR/T 0020-2024) issued by the China Securities Regulatory Commission, our sample firms are distributed across 17 industries, with industry codes and names listed in **Table 2**. **Table 3** lists the numbers of enterprises in each industry in the entire sample. As shown in **Table 3**, the industry distribution is uneven. The manufacturing industry comprises 1431 firms, accounting for roughly two-thirds of the whole sample. Other industries with relatively large numbers of firms include information transmission, software, and technology services (139 firms), wholesale and retail (124 firms), and real estate (101 firms).

Table 2. Industry codes and names.

Industry code	Industry name
A	Agriculture, forestry, animal husbandry, and fishery
B	Mining industry
C	Manufacturing industry
D	Electricity, heat, gas and water production and supply
E	Construction industry
F	Wholesale and retail
G	Transportation, storage and postal services
H	Accommodation and catering
I	Information transmission, software and information technology services
K	Real estate
L	Leasing and business services
M	Scientific research and technology services
N	Water conservancy, environment and public facilities management
P	Education
Q	Health and social work
R	Culture, sports and entertainment
S	Comprehensive industry

Table 3. The industry distribution of sample enterprises.

Industry	Firm Number	Industry	Firm Number	Industry	Firm Number
A	32	G	77	N	28
B	53	H	27	P	20
C	1431	I	139	Q	25
D	80	K	101	R	31
E	68	L	22	S	17
F	124	M	21		

In contrast, industries with relatively few firms include comprehensive industry (17 firms), education (20 firms), scientific research and technology services (21 firms), and leasing and business services (22 firms).

3. Empirical Results Analysis

3.1. Descriptive Statistics

Table 4 represents the descriptive statistics of variables before and during COVID-19. From **Table 4**, we can see that the mean and median values of total debts, short-term debts, long-term debts, total assets, total leverage, short-term

Table 4. Summary statistic.

	Obs	Before COVID-19			Obs	During COVID-19			
		Mean (1)	Median (2)	Std. dev. (3)		Mean (4)	Median (5)	Std. dev. (6)	Diff (4)-(1)
Totaldebt	36,736	0.999	0.176	3.040	27,552	1.380	0.263	3.700	0.381***
Shortdebt	36,736	0.676	0.144	1.960	27,552	0.928	0.206	2.380	0.252***
Longdebt	36,736	0.309	0.021	1.150	27,552	0.421	0.040	1.350	0.122***
Totalasset	36,736	1.680	0.475	4.370	27,552	2.310	0.645	5.390	0.630***
Totallev	36,736	0.416	0.409	0.197	27,552	0.448	0.446	0.194	0.033***
Shortlev	36,736	0.326	0.311	0.163	27,552	0.346	0.335	0.165	0.020***
Longlev	36,736	0.089	0.049	0.104	27,552	0.101	0.067	0.103	0.012***
ROA	36,736	0.025	0.018	0.045	27,552	0.020	0.015	0.055	-0.005***

Note: Totaldebts, Shortdebts, Longdebts, Totalassets are the values in the table multiplied by 10 billion. *** represents significance at the 1% level.

leverage, long-term leverage all present a significant increase while ROA experiences a great decrease during COVID-19 period. As mentioned earlier, China has implemented a deleveraging policy since 2015, and the leverage ratio has started to decline in 2017. Therefore, we can preliminarily draw a simple conclusion that the production and business activities of the enterprise have been badly disrupted, and the enterprise suffered severe loss of yield and have to increase the leverage to survive the crisis during the pandemic period. It is worth noting that before the epidemic, the mean value of total leverage (total debts) is 0.416 (0.999 billion yuan) and the short-term leverage (debts) is 0.326 (0.676 billion yuan), while the mean value of long-term leverage (debts) is only 0.089 (0.309 billion yuan). This indicates that short-term debts is the main component of the external borrowing of non-financial enterprises in China. Next we explore the structural characteristics of leverage growth from three perspectives of industry, firm size and profitability level.

3.2. Structural Characteristics of Leverage Ratio during COVID-19 Period

3.2.1. Structural Characteristics in Industry

Figure 2 describes the average total leverage ratios in pre- and during-COVID period for all industries in the whole sample. **Figure 3** depicts the mean values of leverage ratio¹ from the fourth quarter of 2016 to the fourth quarter of 2022 for all sample industries. From **Figure 2** and **Figure 3**, we can obtain that the leverage ratio during the pandemic increased significantly for most industries. Only the real estate industry (K) and the scientific research and technology services industry (M) experienced almost no increase², while the comprehensive industry (S)

¹In the next content, leverage (ratio) refers to the total leverage (ratio).

²The mean leverage ratio increased about 0.003 and 0.005 in K and M industry during COVID period, respectively.

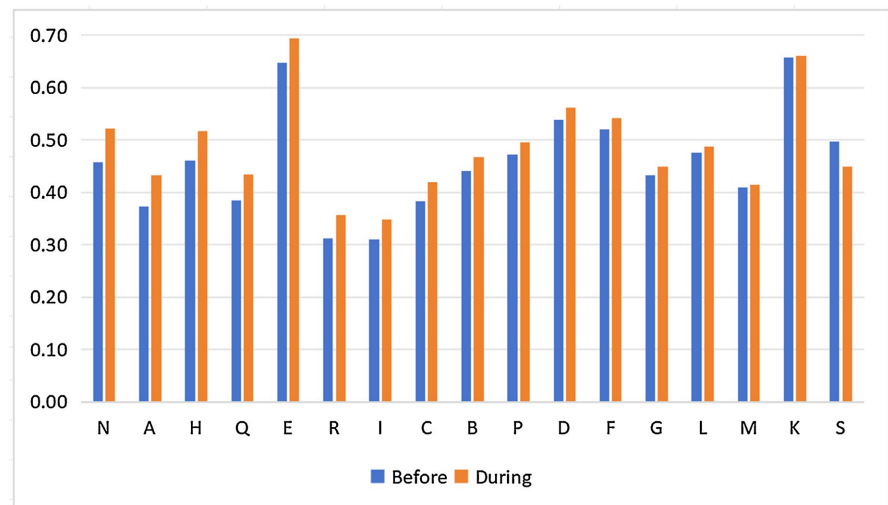


Figure 2. The average leverage ratios before and during COVID-19 for each industry.

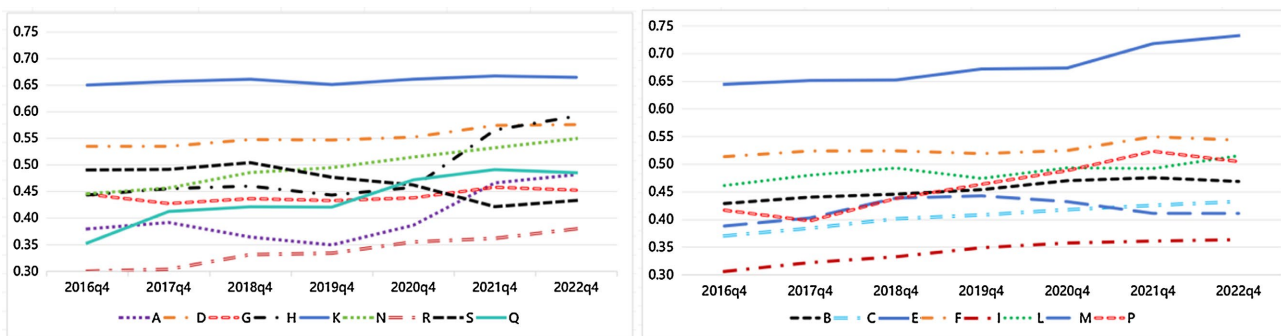


Figure 3. Leverage ratios of 17 industries from 2016q4 to 2022q4.

saw a great decline in financial leverage. This indicates that the growth of leverage ratio for China's non-financial enterprises exhibits clear industry heterogeneity during the pandemic period, which may be caused by the combined effects of the characteristics of the epidemic impact, internal decision-making of enterprises, and external policy intervention.

During the epidemic, the government introduced stable growth policies and increased investment in public services such as environmental protection, education, healthcare, and public facilities. Enterprises in environment and public facilities management (N), education (P) and health and social work (Q) industry were easier to obtain low-interest loans, which encouraged them to proactively expand debt financing projects and showing an active increase in leverage ratio.

Business activities of companies in the industries of accommodation and catering (H), transportation, storage and postal services (G), and culture, sports and entertainment (R), as offline gathering industries, were restricted after the outbreak of COVID-19, resulting in a cliff-like drop in revenues, while rigid operating costs such as rent, personnel salaries, and equipment depreciation still had to be paid. These companies faced a serious cash flow shortage in maintaining basic operations. In response, the Chinese government introduced anti-epidemic credit

support policies, such as prohibiting financial institutions from blindly withdrawing, cutting off, or suppressing loans, and allowing extensions or renewals for enterprises facing difficulty in repaying maturing loans. In addition, the leverage ratios of the three industries were below the warning line of 0.5, indicating a moderate-to-low level with controllable short-term debt pressure. As a result, enterprises in these industries had to rely on extending existing debts and/or borrowing new loans to survive the pandemic, leading to a passive significant increase in leverage ratios.

More than 70% of enterprises in the mining industry (B) and electricity, heat, gas and water production and supply (D) are large state-owned enterprises, and the leverage level in pre-COVID was below the warning line 0.6, possessing strong debt paying ability. More importantly, they have better access to gain bank loans based on their good credit and relationship with bank, making the leverage ratios stable with an upward trend during the pandemic.

As the industry with the highest leverage ratio, real estate companies (K) had long been in a state of high debt, and their development had entered a turning point before COVID. After the outbreak of the pandemic, national policies did not relax financing constraints on them. Instead, in August 2020, relevant regulatory authorities introduced the “three red lines” to directly limit the leverage of real estate companies. In December, “loan concentration” management was implemented, prompting real estate companies to shift from “ensuring cash flow” to “reducing leverage.” As a result, the real estate industry was actually in a state of deleveraging during the COVID period. However, as a highly leveraged sector, the construction industry (E) saw its leverage ratio continue to rise during the pandemic. The reasons may be as follows: on the one hand, output value and profits declined while epidemic prevention costs increased, leading to a rapid shrinkage of assets. On the other hand, operating cash flow income decreased, and in order to ensure the resumption of work and the continuation of strategic projects, enterprises actively issued new bonds or add new loans to maintain operations. More importantly, the expansion of special debt, such as special epidemic treasury bonds and local special debt, indirectly supported the financing availability of construction enterprises. Moreover, over 80% of construction companies are large enterprises that maintain good relationships with government departments. These factors resulted in a significant increase in the absolute value of debt.

Unlike the industries mentioned earlier, the industry of information transmission, software, and information technology services (I) was a sector that benefited from the COVID-19 pandemic and experienced a rapid decrease in leverage. During this period, demand for online office, online education, remote healthcare, e-commerce live streaming, and similar services surged, which directly boosted the industry’s business volume and revenue, thereby improving its cash flow. However, new infrastructure initiatives such as computing power, big data, and artificial intelligence require substantial upfront investment on research and development. For an industry with 73.3% private small and medium-sized firms, it was a good opportunity to expand market share and layout new tracks. Thus, it was of-

ten necessary to expand investment. Beyond their own funds, debt financing also serves as a vital source, which directly increased leverage.

Contrary to most industries, the comprehensive industry (S) is the only industry with a decrease in leverage ratio during the COVID period. **Figure 4** describes the short-term and long-term leverage ratios and ROAs of the S industry from 2016q4 to 2022q4. As shown, the ROA declined in 2020q4, but sharply increased in 2021q4. Accordingly, the short-term leverage increased in 2020, but it immediately decreased in 2021. This may be related to the wide range of businesses involved, covering multiple industries. In this way, the industry has greater risk resilience, and is better able to withstand sudden exogenous shocks and quickly recovers profits.

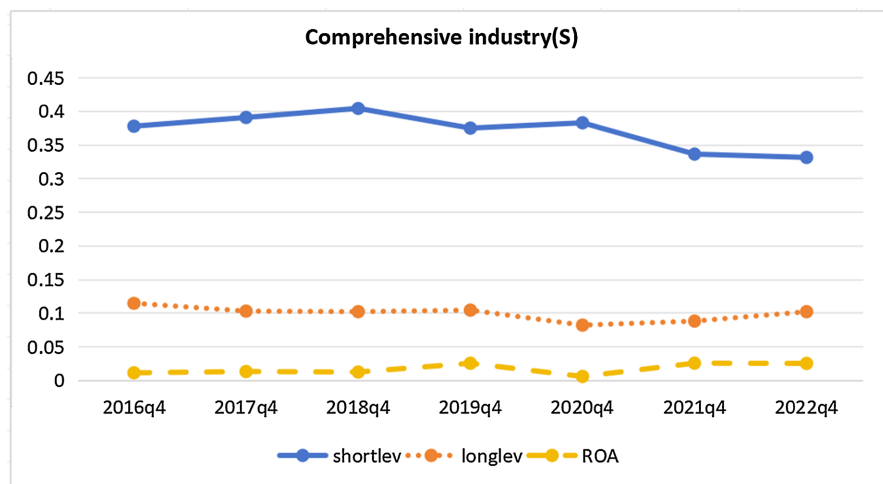


Figure 4. Leverage ratios and ROA of comprehensive industry from 2016q4 to 2022q.

3.2.2. Structural Characteristics in Company Size

In this section, we analyze the structural characteristics of the capital structure of micro non-financial enterprises from the perspective of company size. We first calculate the mean value of each company's size before the COVID period, then sort all sample companies in ascending order of company size and evenly divide them into four groups, and finally calculate the average leverage ratio of each group in each quarter. The smallest companies are classified into the 0% - 25% group, whereas the largest companies are classified into the 75% - 100% group. The results are reported in **Figure 5**.

As shown in **Figure 5**, the larger the company size, the higher the leverage ratio. Interestingly, a clear stratification pattern emerges: the difference in leverage ratios between the 75% - 100% and 50% - 75% groups exceeds 0.1, whereas the difference between the 50% - 75% and 25% - 50% groups is relatively smaller, slightly below 0.1. Moreover, the difference between the 0% - 25% and 25% - 50% groups narrows further to less than 0.06.

We can also observe that the financial leverage of the four groups of companies experiences significant growth throughout the entire sample period. It is worth noting that leverage ratios begin to increase at a faster pace after the outbreak of

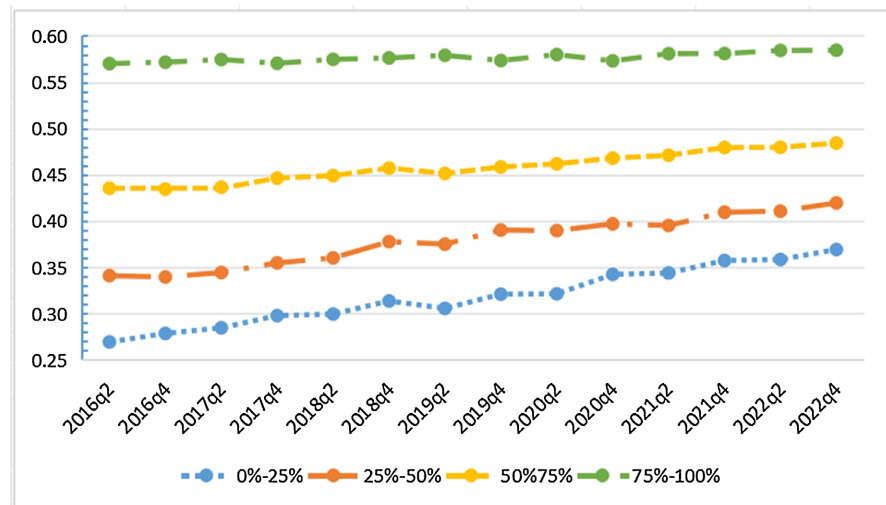


Figure 5. Leverage ratios grouped by enterprise size from 2016q2 to 2022q4.

the COVID-19 pandemic, and the smaller the company size, the more rapidly its leverage ratio rises, which leads to a central tendency. That is to say, the gap between groups becomes increasingly narrower over time.

The enterprises in the top two groups were high-leverage companies³ before the epidemic, with weak long-term solvency and heavy debt repayment pressure. If they had taken on too much additional debt during the epidemic, they would have faced the risk of bankruptcy. In addition, in the top group, 60.63% of companies are state-owned firms, as shown in **Table 5**. High-leverage state-owned companies have been the key targets of the deleveraging policy since 2017. Therefore, the leverage of the top group barely grew during the COVID period. In the bottom two groups, over 64% are small and medium-sized private enterprises with relatively low leverage levels, and they are not subject to deleveraging pressure. Furthermore, the Chinese government has implemented a series of financial support policies to help small and medium-sized enterprises overcome difficulties caused by losses during the pandemic. Thus, enterprises in the bottom two groups

Table 5. Distribution of enterprises with different ownership structures (group by company size).

Group	Ownership						Total
	State	Proportion	Private	Proportion	Other	Proportion	
0% - 25%	114	19.86%	399	69.51%	61	10.63%	574
25%-50%	169	29.44%	367	63.94%	38	6.62%	574
50% - 75%	212	36.93%	305	53.14%	57	9.93%	574
75% - 100%	348	60.63%	177	30.84%	49	8.54%	574
Total	843	36.72%	1248	54.36%	205	8.93%	2296

³The leverage ratio in the group of 75% - 100% is over 0.55, and that in the 50% - 75% group ranges from 0.43 to 0.48.

had to obtain more external loans to increase cash flow, and their leverage ratios exhibited significant growth.

3.2.3. Structural Characteristics in Corporate Profitability

In this section we explore the structural characteristics of the micro leverage ratio for non-financial enterprises from the perspective of ROA⁴. First, the average ROA of each company is calculated using a method similar to that in Section 3.2. All sample enterprises are then sorted in ascending order by ROA and equally divided into four groups, after which the leverage ratio is calculated for each group. Companies with the lowest ROA are assigned to the group of 0% - 25%, while those with the highest ROA are placed in the group of 75% - 100%. **Figure 6** illustrates the leverage ratios grouped by ROA from 2016q2 to 2022q4.

From **Figure 6**, it is evident that the lower a group's ROA, the higher its average leverage ratio, with noticeable differentiation across groups. The leverage ratios in the top two groups show a slight upward trend from 2016q2 to 2022q4, yet they remain nearly parallel, indicating that COVID-19 had almost no effect on their leverage. In contrast, the bottom two groups—the 0% - 25% and 25% - 50% groups—begin to diverge from the second quarter of 2016. Our focus is on the observation that the pace of differentiation accelerated more rapidly during the COVID-19 period than in the pre-COVID period. This suggests that companies with the lowest ROA⁵ and highest leverage in the bottom group experienced a rapid rise in leverage during the pandemic. Generally speaking, the weaker a firm's profitability, the less capacity it has to actively increase leverage during the epidemic. The rise in leverage may be attributed to the following reasons: affected by the pandemic, their profits deteriorated sharply, compounded by excessive

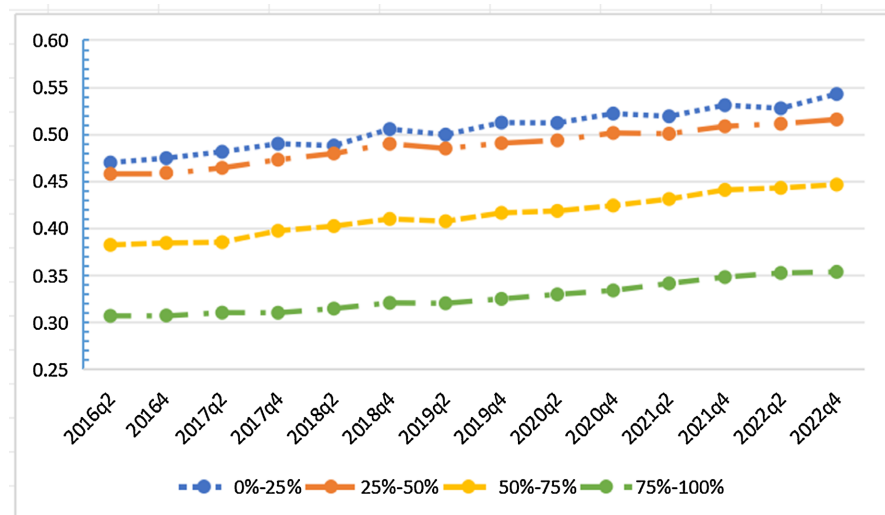


Figure 6. Leverage ratios grouped by ROA from 2016q2 to 2022q4.

⁴ROA is the abbreviation of return on assets, referring to the ratio of after tax net profit to total assets. The smaller the value, the lower the profitability.

⁵According to our sample, the average ROA in the bottom group is -0.11%. other three group are 1.33%, 2.63% and 5.40%.

debt accumulated before the outbreak. For large enterprises, financing channels narrowed, maturing debts defaulted, and assets shrank, leading to a passive increase in leverage. For small and medium-sized enterprises, they had to rely on targeted credit support from the government and financial institutions to survive, which likewise contributed to a passive rise in loans and leverage during the COVID-19 period.

4. Conclusion and Policy Suggestions

In this paper, we explore the structural characteristics of the financial leverage ratio of non-financial enterprises in China during the COVID-19 period from the perspective of industry, firm size and profitability, using data from 2296 China-listed firms spanning from the first quarter of 2016 to the fourth quarter of 2022 as the sample. The empirical results show that the leverage ratio experiences a significant growth during the COVID pandemic period compared to the pre-pandemic period, and that leverage growth shows heterogeneity across industries, firm sizes, and profitability levels.

At the industry level, the micro leverage ratio exhibited an increase for most industries, but the real estate industry and the scientific research and technology services industry experienced almost no increase, while the comprehensive industry saw a decline in financial leverage. This result may be attributed to the combined effects of the characteristics of the epidemic impact, internal decision-making of enterprises, and external policy intervention. From the perspective of firm size, the smaller the corporate size, the faster its leverage grows, which leads to a convergence trend between different size groups, because most small-sized companies are lowly leveraged private enterprises that mainly relied on policy-supported loans, while large-size companies are highly leveraged state-owned firms that had been the targets of the deleveraging policy since 2017. In terms of profitability, the leverage of firms in the lowest ROA group increased more rapidly compared to the other three groups, as most of them are small and medium-sized enterprises (SMEs) that relied heavily on policy-supported credit to maintain operations amid profit declines.

Based on these findings above, there are some important policy implications for the post-pandemic era.

First, according to the heterogeneity of industry leverage, it is necessary to implement differentiated regulatory and support policies: for the industries most impacted by COVID-19, such as accommodation and catering, culture, sports and entertainment, targeted tax and fee reduction policies and credit support should be continued to help enterprises resolve debt risks accumulated during the pandemic; for the real estate industry, we should adhere to the principle of “houses are for living in, not for speculation”, maintain the continuity and stability of deleveraging policies, and prevent systemic financial risks caused by excessive leverage; for the information technology and other emerging industries that benefited from the pandemic, we should guide enterprises to make good use of leverage

to expand investment in R&D and enhance their international competitiveness.

Second, in view of the fact that SMEs have increased leverage significantly during the pandemic, it is important to further improve the inclusive financial system, unblock the financing channels for small and micro firms, appropriately extend the repayment period of policy-supported loans, and reduce their financing cost, so as to avoid large-scale debt defaults after the epidemic. For large firms with high leverage, it is necessary and vital to continue to insist on the deleveraging policy.

Third, for enterprises with low profitability and high leverage, we should establish a dynamic monitoring mechanism for debt risks, guide enterprises to optimize their debt structure, and encourage enterprises to resolve stock debts through market-oriented methods such as debt-to-equity swaps and asset restructuring, so as to prevent the passive rise of leverage from triggering liquidity risks. In the long run, we should further promote the market-oriented reform of the financial system, improve the multi-level capital market, expand the proportion of direct financing of enterprises, and guide enterprises to form a reasonable capital structure, so as to better cope with the impact of future exogenous shocks.

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Author Contributions

Conceptualization, Xie Lixu; methodology, Xie Lixu; validation, Xie Lixu, Wang Junjie; formal analysis, Xie Lixu; investigation, Xie Lixu; resources, Xie Lixu; data curation, Xie Lixu, Wang Junjie; writing—original draft preparation, Xie Lixu; writing—review and editing, Xie Lixu, Wang Junjie; visualization, Xie Lixu, Wang Junjie; supervision, Xie Lixu; project administration, Xie Lixu. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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