Supply Chain Decentralization or Concentration: Predictive Analysis of Supply Chain Concentration and Customer Sales

Hongyu Bai*

College of Management, Shanghai University, Shanghai 200444, China

Abstract: With the development of the global economy and the intensification of market competition, supply chain management has gradually become a key factor in business success. The most common means of supply chain management is to regulate the degree of concentration of the supply chain, which can be measured by calculating the ratio of sales or purchases between a company and its suppliers to the total sales or purchases. At the same time, supply chain concentration directly affects the operational efficiency and performance of a firm. This study constructs a model to test the causal effect of supply chain concentration on firms' annual sales, and in dealing with its heterogeneity and endogeneity issues, it finds that upstream supply chain concentration is not conducive to firms' ability to improve their operational performance in the downstream segment in the current year. On the contrary, customer concentration has a positive effect on operating performance and also serves to stimulate customer sales growth when kept within reasonable limits. By conducting trend predictions of total procurement, supply chain concentration, and customer sales from 2017 to 2022, and comparing LSTM and GRU models, the results demonstrate that GRU outperforms in predictive accuracy. Considering the ongoing impact of COVID-19 on supply chain management, the study suggests that firms should shift towards a decentralized procurement strategy to mitigate operational risks and enhance performance.

Keywords: Supply Chain Concentration; Customer Sales; Predictive Models; Decentralized Procurement; Business Performance

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1 Introduction

Based on relevant theoretical foundations, this study adopts an integrated perspective on supply chain concentration, analyzing the effects of upstream supplier conditions and the firm's procurement activities on operational performance. Additionally, it stratifies operational performance by sales ranking to examine the heterogeneous impacts of supply chain concentration [1]. By addressing endogeneity issues in model construction, the study aims to identify the key factors affecting performance and, through analyzing daily collaboration between firms and their upstream and downstream partners, identify pathways that promote beneficial supply chain concentration and enhance corporate performance.

2 Literature Review

2.1 The Concept of Supply Chain Concentration

By promoting information coordination and resource sharing, supply chain integration improves the efficiency

*Corresponding author: Hongyu Bai, villy-wl20232025@foxmail.com

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of information, logistics, and capital flows, reducing operational costs and enhancing responsiveness [2]. Since supply chain relationships include both downstream customers and upstream suppliers, focusing solely on customer concentration provides an incomplete picture [3]. High concentration enhances bargaining power for both buyers and suppliers [4]. Zhu Bichao et al. proposed that supply chain concentration should involve both suppliers and customers [5], and Zhang Yong explored the relationship between supply chain concentration and debt financing [6], while Fang Hongxing examined its impact on accounting information quality [7].

2.2 The Impact of Supply Chain Concentration

The effects of supply chain concentration manifest primarily in firms' risk management and performance outcomes. Stable partnerships with suppliers promote resource sharing, strengthening innovation capacity and performance [8]. Supply chain concentration can also influence capital structure. In scenarios of financial distress or high financial leverage, firms with concentrated supply chains are better positioned to optimize capital structure by reducing liabilities to ensure operational continuity [9]. Conversely, excessive concentration poses risks, such as dependence on a few key customers or suppliers, which can expose firms to liquidity crises [10].

3 Research Design

3.1 Model Setup and Variable Selection

The study utilizes supply chain data from the CSMAR database, continuously updated from 2017 to 2022, focusing on the New Third Board (NTB) listed companies. The dataset includes key indicators such as procurement and sales information from the top five customers and suppliers of listed companies, as well as supply chain concentration metrics. It also provides essential information about upstream and downstream firms within the supply chain. The data source, the NTB, officially known as the National Equities Exchange and Quotations (NEEQ), was established in 2012 and has since become a significant platform serving small and medium-sized enterprises (SMEs) and private sectors in the capital market. By the end of 2022, the NTB had served a cumulative 13,800 listed companies, covering 87 major industries, with modern services and advanced manufacturing accounting for 71.72%.

The NTB series research database encompasses company profiles, R&D innovation, supply chain information, governance structures, and financial notes. This study specifically selects four key indicators from the supply chain subset for analysis. The latest data release as of August 2023 spans from 2017 to 2022, encompassing 11,043 stock codes. Given the significant impact of COVID-19 on supply chain concentration over the past six years, the study aims to compare empirical results across this period to analyze how supply chain concentration affects corporate economic performance.

Two regression models, OLS and Tobit, were constructed to analyze the directional impact of supply chain concentration on customer sales. After establishing the initial directional conclusions, an IV-2SLS (Instrumental Variables - Two-Stage Least Squares) model was further developed, introducing total procurement as an instrumental variable to explore its mediating role in the pathway through which supply chain concentration affects customer sales. To examine the actual impact of supply chain concentration on customer sales, the following models were constructed:

$$\ln \text{sales}_{\text{top5customer}} = \beta_0 + \beta_1 \text{concentration}_{\text{supply-chain}} + \beta_2 \text{concentration}_{\text{customer}} + \beta_3 \text{X\_con} + \varepsilon_i \quad (1)$$

All selected control variables are economically significant in influencing the dependent variable within the OLS and Tobit regression equations, and there is no multicollinearity among the explanatory variables.

$$\ln \text{sales}_{\text{top-customer}} = \beta_0 + \beta_1 \text{concentration}_{\text{supply-chain}} + \beta_2 \text{concentration}_{\text{customer}} + \beta_3 \text{X\_con} + u_i \quad (2)$$

Following practices in previous studies (e.g., (5%, 5%) or (1%, 1%) trimming), the top and bottom 1% of the sales data are replaced with the 1st and 99th percentiles.

3.2 Results Analysis

Comparing the model results, upstream supply chain concentration adversely impacts downstream operational performance, primarily due to the increased bargaining

power of suppliers as firms become more dependent on them.

Table 1 Regression Results of Supply Chain Concentration and Customer Sales

Variables	(1) Sales of Top 5 Customers	(2) Sales of Top 5 Customers	(3) Sales of Top 5 Customers
Supply Chain Concentration	-0.018***	-0.018***	-0.018***
	(-13.65)	(-14.30)	(-16.69)
Customer Concentration	0.028***	0.028***	0.028***
	(24.34)	(25.66)	(27.99)
Customer Concentration (70%)	-0.522***	-0.496***	-0.496***
	(-11.31)	(-11.22)	(-11.19)
Ratio of Largest Supplier's Procurement to Total Procurement (20-35%)	-0.045	-0.042	-0.042
	(-1.54)	(-1.51)	(-1.50)

Note: Significance levels are denoted as follows: * p < 0.1, ** p < 0.05, *** p < 0.01.

Similarly, the regression coefficients for customer concentration are also highly significant at the 1% level, showing that each unit increase in customer concentration leads to an average increase of 2.8% in the sales of the top five customers for that year. Furthermore, firms with customer concentration above 70% experience about a 50% greater inhibitory effect on the growth of the top five customer sales compared to firms with lower customer concentration, demonstrating that maintaining customer concentration within an appropriate range can stimulate sales growth. The control variable—the ratio of the largest supplier's procurement to total procurement within the 20%-35% range—does not have a significant impact on the sales of the top five customers.

Table 2 Heterogeneity Analysis of the Impact of Supply Chain Concentration on Different Categories of Customer Sales

Variables	(1) Sales of the Largest Customer	(2) Sales of the Largest Customer	(3) Sales of Other Customers	(4) Sales of Other Customers
Supply Chain Concentration	-0.018***	-0.018***	-0.020***	-0.012***
	(-13.09)	(-20.10)	(-14.41)	(-20.84)
Customer Concentration	0.034***	0.025***	0.023***	0.013***
	(28.50)	(29.99)	(19.66)	(16.36)
Customer Concentration (70%)	-0.445***	-0.388***	-0.661***	-0.611***
	(-9.22)	(-8.09)	(-13.95)	(-12.89)
Ratio of Largest Supplier's Procurement to Total Procurement (20-35%)	-0.060**	-0.062**	-0.019*	-0.020
	(-1.97)	(-2.08)	(-0.62)	(-0.68)

Note: Significance levels are denoted as follows: * p < 0.1, ** p < 0.05, *** p < 0.01.

The heterogeneity analysis decomposes the dependent variable, sales of the top five customers, into sales of the largest customer and sales of other major customers (combined sales of the second to fourth largest customers), and regressions were conducted separately with supply chain concentration as the independent variable. The results across different models consistently show that the coefficients for supply chain concentration's impact on different categories of customer sales remain highly significant at the 1% level. Specifically, for each unit increase in supply chain concentration, the sales of the largest customer and other major customers decrease by an average of 1.8% and 2%, respectively. In downstream performance, the regression coefficients for customer concentration also remain highly significant at the 1% level, indicating that each unit increase in customer concentration leads to an average increase in the top five customers' sales of 1.3% to 3.4%.

Furthermore, control variables such as customer concentration (above or below 70%) and the ratio of the largest supplier's procurement to total procurement (optimal range of 20%-35%) exhibit differential impacts on sales of the largest customer versus other major customers. Firms with a customer concentration exceeding 70% experience a stronger inhibitory effect on sales growth, with the suppression effect on other major customer sales being 20% greater than on the largest customer. This suggests that high customer concentration significantly contributes to sales stratification in the final sales stage of the supply chain, enabling firms to distinguish key customers among

the top five sales targets.

The impact of the largest supplier's procurement ratio within the 20%-35% range on the sales of the largest and other major customers varies significantly. When the ratio falls within the optimal range, it exerts a suppressive effect on sales performance, ranging from 1.9% to 6%. This indirectly reflects that the procurement ratio of the largest supplier alone does not fully represent the overall concentration of the raw materials supply chain or the entire supply chain. Enhancing operational performance requires adjustments in the procurement ratios of other categories of suppliers.

3.3 Endogeneity Issues

To address the endogeneity problem, this study employs an Instrumental Variable Two-Stage Least Squares (IV-2SLS) model. Given the suspicion of endogeneity in supply chain concentration, total procurement is used as an instrumental variable in the regression. The rationale for selecting total procurement as the instrumental variable is that it represents a key component of the firm's production and operating costs for the year [11]. Changes in total procurement force firms to adjust their supply chain management, particularly the concentration of upstream suppliers. To maximize profits, firms may increase or decrease supply chain concentration to enhance their bargaining power, thereby mitigating the impact of suppliers' strong bargaining power on firm performance. However, as sales activities occur in the downstream stage, total procurement itself does not directly affect operating sales revenue.

Table 3 IV-2SLS Regression Results with Instrumental Variable: Customer Concentration

	(Two-Stage)	**(Baseline 1)**	**(Baseline 2)**
Variables	**Sales of Top 5 Customers**	**Sales of Top 5 Customers**	**Sales of Top 5 Customers**
Supply Chain Concentration	-0.421***	-0.018***	-0.018***
	(-21.92)	(-14.30)	(-16.69)
Customer Concentration	0.263***	0.028***	0.028***
	(22.69)	(25.66)	(27.99)
Customer Concentration (70%)	0.218	-0.496***	-0.496***
	(1.34)	(-11.22)	(-11.19)
Ratio of Largest Supplier's Procurement to Total Procurement (20-35%)	2.292***	-0.042	-0.042
	(16.52)	(-1.51)	(-1.50)

Note: Significance levels are denoted as follows: * p < 0.1, ** p < 0.05, *** p < 0.01.

To assess the quality of the instrumental variable selection, a weak instrument test was conducted to determine whether total procurement could substitute for supplier concentration in influencing the model. Given that F = 532.956 > 10, we reject the null hypothesis of the presence of a weak instrument, confirming that total procurement is not a weak instrumental variable.

To further address endogeneity issues, the study adds upstream supply chain procurement characteristics, specifically the procurement amounts of the largest supplier and the top five suppliers, into the Tobit model to reduce bias from omitted variables. The results show that the regression coefficient for supply chain concentration remains significantly negative, while the coefficient for customer concentration remains significantly positive, consistent with the baseline regression results.

Notably, the inclusion of potentially omitted variables improves the model's explanatory power, indicating that incorporating upstream supply chain procurement characteristics enhances the model's overall fit. The results reveal a significant negative correlation between the largest supplier's procurement amount and the sales of the top five customers, and a significant positive correlation between the top five suppliers' procurement amounts and the sales of the top five customers. This suggests that excessive concentration of procurement in top-tier suppliers is detrimental to the enhancement of firm performance.

Table 4 Regression Results of Different Categories of Supplier Procurement and Customer Sales

Variables	**(1)**	**(2)**	**(3)**
	Sales of Top 5 Customers	**Sales of Top 5 Customers**	**Sales of Top 5 Customers**
Supplier Concentration	-0.027***	-0.026***	-0.026***
	(-30.56)	(-33.88)	(-41.28)
Customer Concentration	0.036***	0.035***	0.035***
	(48.96)	(54.34)	(66.42)

Variables	(1) Sales of Top 5 Customers	(2) Sales of Top 5 Customers	(3) Sales of Top 5 Customers
Customer Concentration (70%)	-0.363***	-0.342***	-0.342***
	(-14.61)	(-15.18)	(-15.34)
Ratio of Largest Supplier's Procurement to Total Procurement (20-35%)	-0.062***	-0.058***	-0.058***
	(-3.80)	(-4.02)	(-4.16)
Largest Supplier's Procurement Amount	-0.070***	-0.087***	-0.087***
	(-2.72)	(-4.04)	(-4.25)
Procurement Amount of Top Five Suppliers	0.784***	0.810***	0.810***
	(28.33)	(35.95)	(38.37)

4 Trend Analysis: Empirical Results of New Third Board Listed Companies from 2018 to 2022

4.1 The Role of Total Procurement in the Relationship Between Supply Chain Concentration and Customer Sales

The results discussed above are based on 2017 data. In this section, the regression analysis utilizes data from 2018 to 2022, including procurement and sales information of the top five customers and suppliers, along with supply chain concentration metrics for New Third Board listed companies. The COVID-19 pandemic, which erupted nationwide in early 2020, had a widespread impact on the supply chains of manufacturing enterprises, particularly affecting procurement processes. Regions supplying raw materials and components faced stringent pandemic controls, hindering swift resumption of production. As a result, companies reliant on single-chain procurement were severely impacted, experiencing prolonged production cycles and subsequent effects on downstream sales operations.

This section's regression results reflect the causal relationship between supply chain concentration and the sales of the top five customers, using total procurement as the instrumental variable. From the onset of COVID-19 through the post-pandemic period, the negative correlation between supply chain concentration and the sales of the top five customers remained highly significant at the 1% level. At the end of 2020, data showed that the weakening effect of supply chain concentration on the top five customers' sales had lessened, likely due to the pandemic's impact on supply chains. However, by 2021-2022, as global supply chain risk management and corporate supply chain capabilities improved, the negative impact of supply chain concentration on customer sales returned to pre-pandemic levels.

Based on previous research using instrumental variables to address endogeneity, total procurement negatively correlates with supply chain concentration. Thus, enhancing corporate performance can be achieved by expanding total procurement, particularly considering the post-pandemic market dynamics. Increasing procurement scale helps reduce overall supply chain concentration, boosting the sales of key downstream customers.

Table 5 Regression Results of Supply Chain Concentration and Customer Sales Using New Third Board Listed Company Data (2018-2022)

Variables	2018 Sales of Top 5 Customers	2019 Sales of Top 5 Customers	2020 Sales of Top 5 Customers	2021 Sales of Top 5 Customers	2022 Sales of Top 5 Customers
Supply Chain Concentration	-0.400***	-0.402***	-0.384***	-0.392***	-0.425***
	(-21.65)	(-20.78)	(-21.55)	(-20.79)	(-20.07)
Customer Concentration	0.251***	0.255***	0.248***	0.250***	0.271***
	(22.07)	(20.99)	(21.71)	(20.89)	(20.29)
Customer Concentration (70%)	0.251	0.383**	0.386**	0.482**	0.254
	(1.44)	(1.98)	(1.97)	(2.32)	(1.16)
Ratio of Largest Supplier's Procurement to Total Procurement (20-35%)	2.160***	2.123***	2.129***	2.222***	2.560***
	(15.85)	(15.10)	(15.27)	(14.65)	(14.74)

Note: Significance levels are denoted as follows: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2 Trend Forecast: 2017-2022 Total Procurement, Supply Chain Concentration, and Customer Sales

Forecasting the future trends of total procurement, supply chain concentration, and customer sales is crucial in the context of supply chain management. Predicting total procurement helps companies better plan their resources, ensuring sufficient reserves of raw materials and components to mitigate market fluctuations and supply chain uncertainties. For this analysis, one firm (stock code 430003) out of the 11,043 companies was selected as the forecasting object, and its data over six years was used for model training and testing. The data from 2000 to 2022 involve non-stationary dynamic changes, making traditional statistical models (e.g., ARIMA, regression models) insufficient for capturing nonlinear relationships in the data.

In the forecasting phase, this study experimented with two widely used variants of recurrent neural networks (RNNs): Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU). Both methods incorporate memory gating mechanisms that effectively address the gradient vanishing problem commonly seen in traditional RNNs, allowing the models to capture long-term dependencies in the data. Moreover, LSTM and GRU excel in nonlinear mapping capabilities, enabling them to recognize and learn complex patterns such as abrupt changes and nonlinear trends, which are particularly valuable for analyzing volatile and uncertain data in supply chains, customer interactions, and procurement activities.

The combined dataset from 2000 to 2022, including total procurement, supply chain concentration, and customer sales, was normalized before splitting into training and testing sets at a 9:1 ratio. Model parameters were optimized through manual tuning and simple grid searches. The optimal parameters are as follows: For the LSTM model, the customer sales were best modeled with units=10 and dropout-rate=0.3; supplier procurement was modeled with units=50 and dropout-rate=0.3; supply chain concentration was modeled with units=50 and dropout-rate=0.3. For the GRU model, customer sales used units=50 and dropout-rate=0.3; supplier procurement used units=10 and dropout-rate=0.1; supply chain concentration used units=50 and dropout-rate=0.3.

Table 6 Comparison of Forecast Indicators for Total Procurement, Supply Chain Concentration, and Customer Sales

		MSE	MAE	R^2	DM
Customer Sales	LSTM	0.1385	0.3277	-0.278	
	GRU	0.1300	0.3307	-0.1991	367.03 (p-value: 0.0)
Total Procurement	LSTM	0.0652	0.2554	0.1365	
	GRU	0.0639	0.2522	0.1537	259.07 (p-value: 0.0)
Supply Chain Concentration	LSTM	0.0528	0.1745	-1.0443	
	GRU	0.0662	0.2066	-1.5613	365.98 (p-value: 0.0)

Consequently, this study prioritizes GRU modeling for forecasting and analyzing relevant data from 2023 to 2025, as shown in Figure 1.

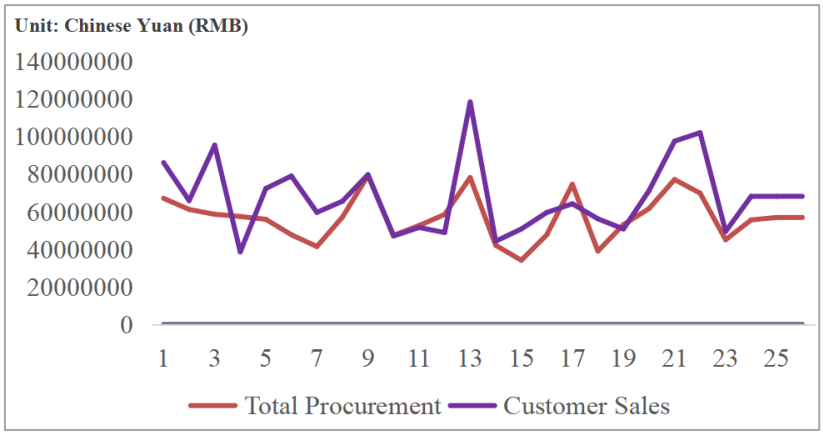

Figure 1 Forecast Results for Total Procurement and Customer Sales

5 Conclusion and Policy Implications

This study focuses on supply chain concentration by utilizing supplier and customer concentration metrics. It analyzes the impact of supply chain concentration on the sales of the top five customers, incorporating segmentation of sales targets and upstream procurement characteristics to verify the effects of various factors on corporate performance. Additionally, LSTM and GRU models were used to forecast trends in total procurement, supply chain concentration, and customer sales from 2017 to 2022, highlighting the dynamic impacts of different factors on business performance. Based on the study's findings, enhancing business performance and strengthening supply chain resilience to unexpected events can be achieved through the following approaches: Reduce Supply Chain Concentration and Build a Flexible Supply Chain. Increase Customer Concentration and Combine Decentralized with Centralized Procurement.

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