Balancing Supply Chain Concentration and Efficiency: An Empirical Study of the Medical Manufacturing Industry

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Abstract: With the continuous exploration of the methods of cost reduction and efficiency improvement in supply chain, the potential influence of supply chain structure has been paid more and more attention. This study focus on one structural aspect - supply chain concentration, investigating its impact on supply chain efficiency and exploring the moderating role of supply chain transparency. A highly regulated and innovation - intensive industry - medical manufacturing industry is selected as the research industry in this study. The panel data from 366 medical manufacturing industry firms with 2,300 firm-year observations over the period 2014-2023 is used as the longitudinal dataset in this study. The results shows that supply chain concentration has a significantly negative impact in supply chain efficiency in medical manufacturing industry; supply chain transparency has a negative moderator effect, that is, firms in medical manufacturing industry with higher supply chain transparency obtain less supply chain efficiency. The findings provide valuable insights for both academic research and managerial practice by indicating the importance of balancing supply chain concentration and transparency in improving supply chain efficiency.

1 INTRODUCTION

In an era of increasing complexity and globalization, supply chain structure has become a critical determinant of organizational performance. Supply chain concentration is one structural element that has received increased attention because of its effects on risk exposure and operational efficiency. A concentrated supply chain might have advantages like lower coordination costs and better partnerships, but it can also make a company more susceptible to interruptions and less flexible in terms of operations (Choi & Krause, 2006). Over-reliance on a small number of suppliers or purchasers can increase the risks, especially in highly regulated and innovative industries like medical manufacturing (Gereffi, 2019).

Supply chain efficiency is one of the most important parts to estimate the performance of a supply chain. Increased supply chain concentration may impair efficiency by decreasing a firm's flexibility and negotiating power, according to previous study (Tang & Tomlin, 2008). However, the moderating role of supply chain transparency has not been thoroughly explored in this context. Thus, the research object is to investigate the relationship between supply chain concentration and supply chain efficiency and further examines the moderating effect of supply chain transparency. Panel data of 2,300 firm-observations in the medical manufacturing industry over the 2014-2023 period is used to do the regression analysis.

2 BACKGROUND AND HYPOTHESIS DEVELOPMENT

2.1 Supply Chain Concentration

Supply chain concentration refers to a firm's dependency on a small number of suppliers and customers, suggesting interconnectedness between upstream and downstream supply chain participants (Lanier et al., 2010), or a company's supplier and customer mix density in relation to the significance of its main suppliers and customers (Ak and Patatoukas, 2016; Tang and Rai, 2012).

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The number of suppliers that supply a company with raw materials and the amount of purchases are both considered aspects of supplier concentration. A high degree of supplier concentration reflects limited interaction with suppliers and with a large portion of purchases coming from primary suppliers (Kahkonen et al., 2015).

Resource dependency theory states that organizations depend on outside parties for essential resources such labor, funds, information, and materials. This interdependence produces unpredictability and power imbalances, causing firms to pursue strategies like creating alliances, mergers or political ties to manage and decrease dependence and ensure resource access (Pfeffer and Salancik,1978). In supply chains, a high level of concentration can lead to more robust relationships with suppliers, which can enhance risk management and improve coordination. However, the concentration also means that the failure of just a few key suppliers can significantly disrupt the entire chain, making it more vulnerable to interruptions (Hendricks and Singhal, 2014).

2.2 Supply Chain Efficiency

Researchers have explored supply chain efficiency from diverse perspectives, each emphasizing different key elements that contribute to overall performance. An efficient supply chain relies on strategic and operational factors such as resource optimization, cost control, faster deliveries, high quality and increased profitability (Negi,2020).

In order to maintain low supply chain costs and achieve high profitability, businesses must ensure strong performance both within the organization and across the supply network. Internal performance refers to factors such as production efficiency and lead times, while external performance covers aspects like delivery reliability, responsiveness, customer support, and pricing. Competing successfully in a connected global market requires attention not only to internal operations but also to the broader management of the supply network. As noted by Christopher (1998), to stay competitive in a rapidly changing global market, companies need to constantly find new strategies to reduce costs while improving service quality. As a result, the role of a high-performing supply chain becomes increasingly vital to long-term success.

The core challenge for a company lies in striking the right balance between cost efficiency and operational performance. This means maximizing the use of facilities and minimizing capital expenditure, while also ensuring quick and accurate deliveries, high customer satisfaction, reduced lead times, and lean inventory levels. Achieving this balance is essential for optimizing overall outcomes. Ultimately, effective supply chain management plays a crucial role in boosting profitability and gaining a competitive edge in the market (Schary and Skjøtt-Larsen, 2001).

Earlier research suggests that efficiency can be evaluated through both quantitative and qualitative lenses. Quantitative assessments typically focus on factors like profitability, cost control, productivity, and responsiveness to customer needs. In contrast, qualitative measures emphasize areas such as customer satisfaction, strong supplier relationships and effective risk management (Negi,2020).

Since highly concentrated supply chain always have limited supplier with large amount of critical resources, supply chain may be more fragile and easy to disruptions and causing the decrease in supply chain efficiency. Thus, hypothesis 1 is developed as follow.

Hypothesis 1: Supply chain concentration has a negative impact on supply chain efficiency.

2.3 The Role of Supply Chain Transparency

Supply chain transparency involves openly sharing precise and comprehensive information about various aspects of a company's operations and products. As noted by Bai and Sarkis (2020), supply chain transparency involves sharing comprehensive information related to sourcing, manufacturing, cost structures and logistics. In previous researches, terms like visibility, traceability, openness and disclosure are frequently used to convey similar ideas, reflecting the multifaceted nature of transparency in supply chains. Transparency initiatives in supply chains play a crucial role in shaping how organizations share information. These strategies not only help define suitable levels of disclosure but also promote a culture of accountability and build stakeholder trust by reinforcing a sense of openness throughout the supply network (Montecchi,et al., 2021).

Mechanisms through which supply chain transparency influences supply chain efficiency are from different aspects. On the one hand, it helps bridge information gaps among partners, fosters trust, and enhances coordination across the network (Montecchi,et al., 2021). On the other hand, transparency also carries risks by making internal operations more visible, it may expose vulnerabilities or sensitive financial data, potentially giving

competitors a strategic advantage (Årdal, et al., 2021). Firms may adopt conservative strategies such as increasing safety stock to mitigate competitive disadvantages, which will affect supply chain efficiency in some degree. In certain highly regulated industries, maintaining transparency is crucial for meeting legal and regulatory requirements (Christopher, 2016). Stricter compliance requirements could increase tracking and scrutiny, potentially affecting the efficiency with which resources move through the supply chain. Thus, hypothesis 2 is developed as follow.

Hypothesis 2: The positive impact of supply chain concentration on supply chain efficiency is reinforced with high supply chain transparency.

3 METHODOLOGY

3.1 Sample and Data

The research selects 366 listed firms in China of medical manufacturing industry from 2014 to 2023 as research samples to test the hypothesis based on the following reasons. First, the supply chain of medical care has already been identified as a field with great potential for improved efficiency (Ebel, et al., 2013). Given the context of this industry, it is valuable to examine how both supply chain concentration and transparency influence overall operations and performance. Second, the supply chain of medical industry is complicated. The production of active pharmaceutical ingredients (APIs), critical components of all medicines, is concentrated in just a handful of countries, making it highly dependent on these regions (Årdal, et al., 2021). In this context, it is critical to understand how supply chain concentration affects efficiency. Third, the medical manufacturing industry can be significantly impacted by global supply chain disruptions, highlighting the fragility of the supply chain (Årdal, et al., 2021). It is necessary to study supply chain concentration and transparency to develop strategies to improve resilience and efficiency.

All data comes from GTA-China Stock Market and Accounting Research Database, which is the largest and most accurate financial database in line with China's national conditions, providing reliable, comprehensive and effective data for this research.

Industry classification code is used in this research to combine the financial data with the sample. Finally, for hypothesis 1 and hypothesis 2, a longitudinal dataset of 366 firms with 2300 firm-year observations is obtained.

3.2 Measurements

Dependent Variable. The measurement of supply chain efficiency referred to the method proposed by Zhang and Duan (2023). The inventory turnover days is a measure of how many days it takes an average business to sell out its inventory, calculated as a ratio of 365 to inventory turnover. It is worth noting that the larger the inventory turnover days is, the lower the supply chain efficiency will be. Thus, the research takes the reciprocal of inventory turnover days as a measurement for supply chain efficiency. The larger the reciprocal of inventory turnover days is, the higher the supply chain efficiency will be.

Independent Variable. Supply chain concentration is measured by calculating the average ratio of purchases and sales from the five largest suppliers and customers. This indicator is available directly from the CSMAR database.

Moderator Variable. Referring to the method of Gong, et al. (2022), supply chain transparency is measured by the proportion of the transaction volume of the major suppliers and customers whose names are explicitly disclosed in the total transaction volume of the top five suppliers and customers. The larger the value, the higher the transparency of the firm's supply chain.

Control Variables. The selection of control variables refers to relevant literature, and the control variable group is composed of firm size, firm age, firm solvency and firm corporate profitability. Firm size (Size) is calculated as the natural logarithm of the firm's total assets. Firm age (Age) is determined by the natural logarithm of its years of establishment. Firm solvency is assessed through the leverage ratio (Lev), which compares total liabilities to total assets. Corporate profitability is expressed as return on assets (ROA).

3.3 Model Specification

Considering that the data set is vertical, ordinary multiple linear regression is conducted in this research for analysis.

Model 1:

$$SCE = \beta_0 + \beta_1(SCC)_i + \beta_2(Size)_i + \beta_3(Lev)_i + \beta_4(ROA)_i + \beta_5(Age)_i + \varepsilon_i \quad (1)$$

Model 2:

$$SCE = \beta_0 + \beta_1(SCC)_i + \beta_2(Size)_i + \beta_3(Lev)_i + \beta_4(ROA)_i + \beta_5(Age)_i + \beta_6(SCT)_i + \beta_7(SCC * SCT)_i + \varepsilon_i \quad (2)$$

4 RESULTS

4.1 Correlation and Descriptive Statistics

The correlation matrix and descriptive statistics of the variables are showed in Table 1. The correlation coefficients suggest a moderate and satisfactory level of discriminant validity among the variables.

Table 1: This caption has one line so it is centered.

Variable	Age	Size	Lev	ROA	SCC	SCT
Age	1					
Size	0.276**	1				
Lev	0.151**	0.212**	1			
ROA	0.079**	0.089**	-0.350**	1		
SCC	-0.246**	-0.464**	-0.175**	-0.090**	1	
SCT	-0.055*	-0.190**	0.001	-0.046*	0.260**	1
Mean	3.264	21.981	0.299	0.053	30.449	0.047
Standard deviation	0.218	1.043	0.172	0.110	14.909	0.110

4.2 Regression Analysis

Table 2 shows the results of linear regression analysis for supply chain efficiency.

Table 2: This caption has one line so it is centered.

Variables	Model 1	Model 2
Intercept	0.261***	0.256***
	(14.149)	(13.713)
Age	-0.007***	-0.006**
	(-2.579)	(-2.527)
Size	-0.002***	-0.002***
	(-2.719)	(-2.525)
Lev	0.030***	0.030***
	(6.286)	(6.336)
ROA	0.061***	0.061***
	(8.724)	(8.733)
SCC	-0.0002***	-
	(-3.681)	0.000154**
		(-2.628)
SCT		0.035*
		(1.946)
SCC*SCT		-0.001**
		(-2.269)
R^2	0.048	0.050
Adjusted R^2	0.046	0.047
F-statistics	22.142***	16.600***

Notes:
1.*p < 0.1, **p < 0.05 and ***p < 0.01.
2.t-statistics in parentheses.

According to Model 1, the coefficient of supply chain concentration is negative (β =-0.0002, p<0.01), indicating that supply chain concentration has a significantly negative impact in supply chain efficiency in medical manufacturing industry. Therefore, Hypothesis 1 is supported.

In model 2, the interaction between the supply chain concentration and supply chain transparency displays a significantly negative effect on supply chain efficiency (β =-0.001, p<0.05), indicating that firms in medical manufacturing industry with higher supply chain transparency obtain less supply chain efficiency. Thus, Hypothesis 2 is supported.

5 DISCUSSION

The research provides evidence that supply chain concentration has a negative impact on supply chain efficiency in medical manufacturing industry. Here are some possible reasons to explain it.

First, highly centralized supply chains tend to be more vulnerable to disruptions (Hendricks and Singhal, 2014), making it necessary to maintain larger inventory buffers as a safeguard against potential supply-related risks (Guo et, al., 2016). Medical manufacturing industry is a industry with strong bargaining power of suppliers, key ingredients such as active pharmaceutical ingredients (API) and specialty excipients are often supplied by a small number of suppliers (Årdal, et al., 2021). Therefore, firms with a high concentration of supply chains tend to require longer inventory holding periods to prevent shortages of raw materials.

Second, the highly regulated environment and dependence on suppliers in the medical manufacturing industry leads to high supplier replacement costs (National Academies of Sciences, Engineering, and Medicine, 2022), and companies

with a highly concentrated supply chain often need to hold more inventory to avoid production disruptions.

Third, demand fluctuates greatly in medical manufacturing industry, especially in seasonality or public health emergencies. For example, during COVID-19, global medical supply chain is under enormous pressure. Medicine shortages are common in the run-up to 2020 and exacerbated by increased demand, blockades, border closures and hoarding (Årdal, et al., 2021). In high-concentration supply chains, firms often require higher inventory levels in response to demand fluctuations in these emergencies, reducing supply chain efficiency in some degree.

Supply chain transparency has a negative moderate effect on supply chain efficiency in medical manufacturing industry. First, supply chain transparency is often accompanied by stricter compliance requirements. These regulations require firms to keep detailed track of the flow of medicine. Additional investment in this aspect may result in lower turnover efficiency and higher demand for safe stocks. Second, greater transparency may inadvertently reveal sensitive business information, such as supplier relationships and production capacities (Årdal, et al., 2021). To mitigate potential competitive disadvantages, firms might adopt conservative strategies, including maintaining higher inventory levels, which can reduce efficiency.

6 CONCLUSIONS

The study views supply chain concentration. It examined the relationship between supply chain concentration and supply chain efficiency, investigated the impacts supply chain transparency on the relationship between supply chain concentration and supply chain efficiency. By analyzing the data about 366 listed firms in medical manufacturing industry in China, the study reveals that supply chain concentration decreases the supply chain efficiency. In addition, supply chain transparency can influence the main relationship between supply chain concentration and supply chain efficiency.

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