Dealing with Complexities in Digital Supply Chain

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Summary:

Using a four-dimension analysis, this capstone explores how supply chain complexities and buyer-supplier relationships as a complex adaptive system interact with an integrated and enacted external environment and drive the key supply chain performance of the company. Methodologies in this paper provide cornerstones for implementing data-driven decision making in supply chain management.

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KEY INSIGHTS

1. Reducing supply chain complexities improves service level but will have adverse impact on sales.
2. Buyer-supplier relationships as a complex adaptive system interact with supply chain complexities and the external environment, driving the key supply chain performance of the suppliers.
3. Company size, revenues, and years in the industry moderates the relationship of supply chain performance with supply chain complexities and buyer-supplier relationships

Introduction

The explosive growth of computing services led to heavy capital expenditures mostly related to data-center. This surge in demand has been favorable to data-center infrastructure suppliers in terms of revenues. However, suppliers are now facing great difficulties due to the advent of “hyperscalers,” the rapidly-growing and highly-innovative cloud service providers such as Google, Microsoft, and Amazon. As a result, data center suppliers are challenged by volatile product volumes, short product turnaround cycles, and complex requirements for high-level customization, among others.

Research Context

One of the major contributors to this complex supply chain system is the “**buyer-supplier relationship**,” causing subsequent collateral complexities. This relationship plays a unique role in changing the dynamics of the whole supply chain, and may be the key to high performance for the suppliers in the long run.

The complex and adaptive dynamics of the buyer-supplier relationship in a supply chain can be better understood in the framework of a **complex adaptive system (CAS)** in Figure 1. This capstone explored how buyer-supplier relationships as a complex adaptive system interact with **supply chain complexities** and the **external environment** and drive the **key supply chain performance** of the

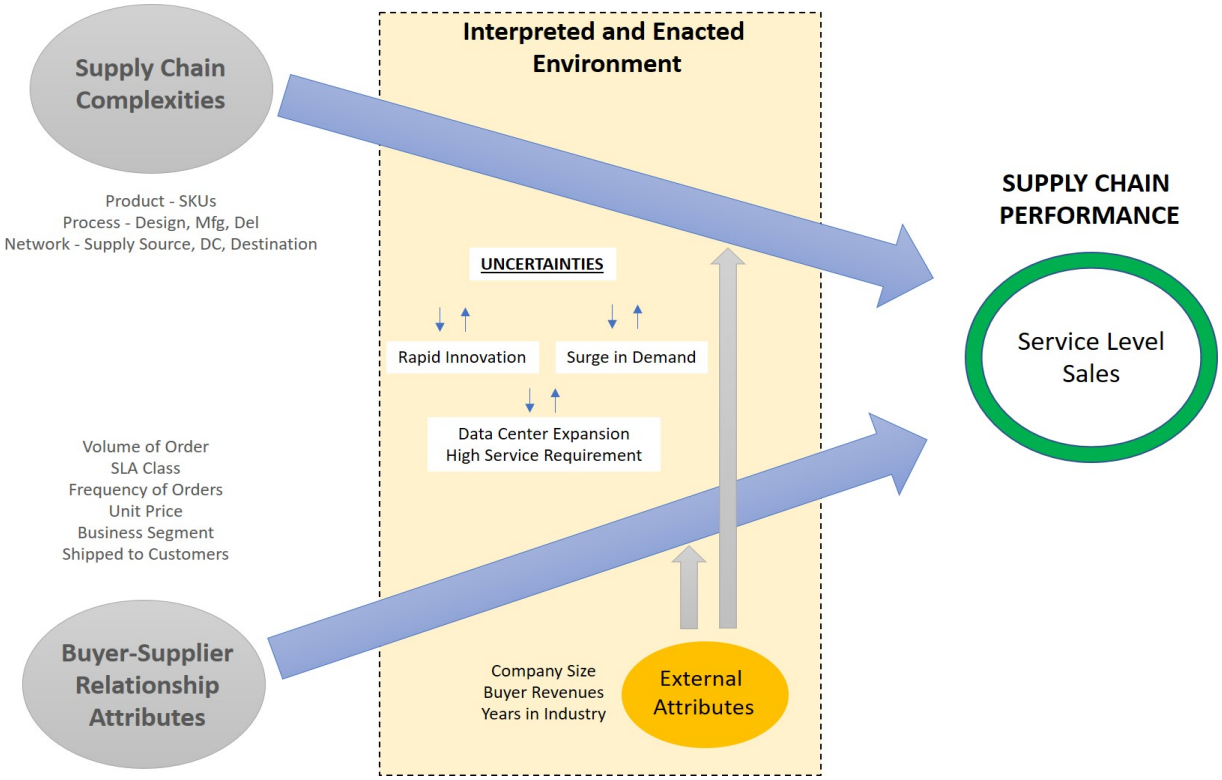

Figure 1: Digital Supply Chain as a Complex Adaptive System

suppliers. This method brings new insights to companies seeking to **digitally transform** their management analytical ability by making effective use of their digital data assets.

With this motivation, the following 10 hypotheses were set up:

H1a: High supply chain complexity leads to low service level and lower sales

H1b Higher values of buyer-supplier attributes lead to high service level and higher sales

H2a: Service level influence the sales in the same time period, which will subsequently influence service level in the following time period.

H2b: Over time, service level and sales will be more strongly associated with their immediately preceding levels than their initial levels;

H3a: External attributes of the buyer-supplier relationship moderates the impact of agents on the service level.

H3b: External attributes of the buyer-supplier relationship moderates the impact of agents on the sales amount.

H4a: High innovation level of customer causes higher supply chain complexity and leads to lower service level

H4b: High demand in end-users causes higher supply chain complexity and leads to lower service level

H4c: Rapid data center expansion of buyers causes higher supply chain complexity and leads to lower service level

H4d: High service level requested by buyers causes higher supply chain complexity and leads to lower service level.

Methodology

This project was conducted in three main phases shown as shown in Figure 2. The 10 hypotheses were, first, tested by econometric models, namely panel data analysis and seeming unrelated regression (SUR). Panel data analysis is an adequate

tool to analyze longitudinal data, capturing time-series attributes of the data. SUR analysis brings deeper insight in terms of exploring dynamic correlations between variables, reflecting complex and adaptive nature of supply chain.

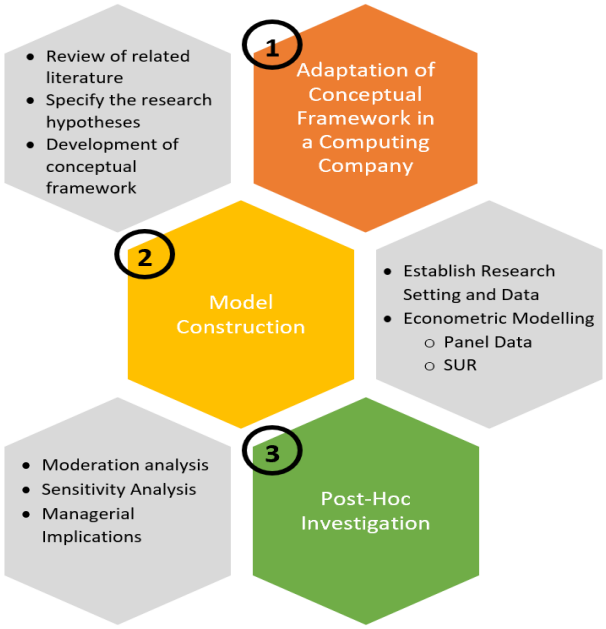

Figure 2: Overview of the Methodology

Then, post-hoc investigation was conducted through moderation analysis and sensitivity analysis, which are simulation-based methods, exploring changes in the dynamics of the system under a number of scenarios.

Finally, managerial implications are provided to extract insights from the results of the analyses conducted.

The data provided by the company comprise 54 features for 3 years describing 7,677 buyer-supplier relationships and 989 products. The unit of analysis is combination of buyer and products. In addition, complementary features of the 3,300 buyers' characteristics were gathered from external databases historical revenue, company size, and years in the industry for moderation analysis.

The dependent variables are order delays and sales. Independent variables are attributes under the supply chain complexities and buyer-supplier attributes, as summarized in Figure 1.

Additionally, external data were gathered on 3,300 buyers' characteristics including historical revenue, company size, and years in the industry, were also utilized to measure how these features impact the system as moderators.

Results & Discussions

Fixed-effects Panel Data

Fixed-effects panel data analysis was conducted to explore the relationship of order delays and sales amount between supply chain complexities and buyer-supplier relationship attributes.

Results show that on the average, higher supply chain complexity lead to lower service level but higher sales only **partially support H1a**. Reducing supply chain complexities improves service level but will have adverse impact to sales. However, one has to differentiate between the link to demand and link to supply in improving service level and sales

On the other hand, higher values of buyer-supplier relationship attributes have different effects to both service level and sales. This suggest that only some of the **attributes supports H1b**. As such, each attribute of buyer-supplier relationship should be looked into more detail as it has various impact to supply chain performance.

Seemingly Unrelated Regression

SUR analysis was chosen as it is useful in exploring mutually adaptive attributes of variables as it allows modelling "cyclical" linkage between variables through multiple time periods as depicted in Figure 3.

The analysis focuses on 8 independent variables (*design lead-time, manufacturing and delivery lead-time, source of supply, distribution center, SLA, business segment and shipped to customer*) that were selected based on their high significance ($p<0.05$) in fixed-effects panel data analysis.

Following this, equations were created to quantify the correlations between dependent variables in different time frame from year 1 to year 3. Selected independent variables were included as control variables. 6 equations were created and applied in the SUR analysis.

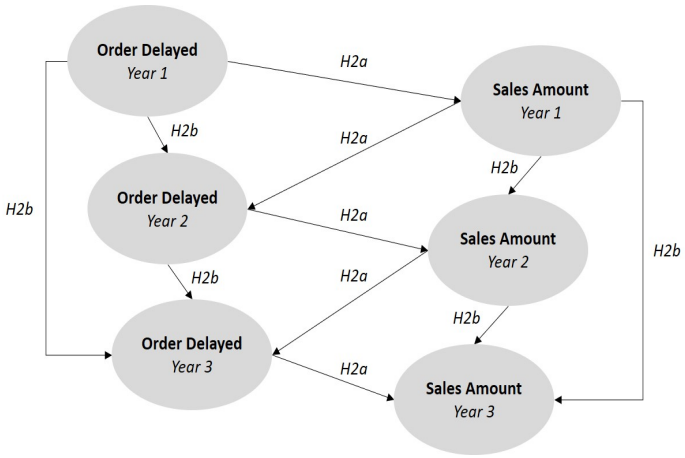

Figure 3: Conceptual Scheme for SUR

The results **fully supported** hypothesis **H2a** and **partially supported** hypothesis **H2b**. The order delayed period in year 1 significantly influenced sales amount in year 1, which, in turn, impacted order delay in year 2. Moreover, the order delay showed high significance in correlation with the outcome of the following year and the year after, although the most immediate outcome had higher correlations than the one with 2 years gap. However, sales amount did not show such correlations. This would be due to the fact that sales amount is outcome derived from interactions with various factors which prevent them from being directly affected by each other.

Moderation analysis

Moderation analysis was conducted to determine how external buyer attributes moderates in the impact of supply chain complexities and buyer-supplier relationships on the supply chain performance.

In response to **H3a**, all external buyer attributes namely company size, company revenue, and years industry moderates the impact of agents on the service level, **fully supporting** the hypothesis. The company size, company revenue, and years in the industry moderates using various low to high settings, the impact of supply chain complexities and buyer-supplier attributes on order delays.

Hypothesis **H3b** is also **fully supported**, as company size and company revenue have an almost similar moderating impact on the relationship between sales amount and the agents.

Sensitivity analysis

Next, a sensitivity analysis was conducted to determine the impact of the uncertainties namely rapid innovation, surge of demand, data center expansion, and higher service level requirements.

Results partially supported 4 hypotheses, as changes in supply chain complexity (**H4a** and **H4d**) led to lower service level while others led to higher service level. Moreover, sales amount was not reactive to changes in supply chain complexities. However, changes in buyer-supplier relationship attributes (**H4b** and **H4c**) did impact both service level and sales. Yet, the way coefficients reacted differed by variables and years the change was applied to.

Conclusions

Understanding the complex adaptive system of digital supply chain requires focus in 3 main areas: agents, interpreted and enacted environment and emergent system properties. After breaking this down, the dynamics within each part were observed using several analytical methods.

Supply chain complexities and buyer-supplier relationships have different impact on service level and sales that changes through time. Consequently, the findings derived from the data analyses will be useful guidelines for supply managers as well as the management to pinpoint the factors which have most critical impact on their performance.

The methodology and framework presented in the paper would provide a great starting point for Digital Transformation process. Quantifying the complexities underlying the supply chain would help pinpoint the areas which are impacting the performance of the company most, bringing efficiency in terms of lead-time as well as resource utilization.