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An Empirical Analysis of the Relationship Between Supply Chain Complexity and Firm Performance

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Abstract

Companies have become increasingly complex as industries have advanced. In turn, supply chains have also become more complex, with businesses responding to environmental changes by forming strategic alliances or outsourcing to enter new markets and launch new products. Therefore, supply chain complexity has received much scholarly attention. However, earlier studies have not reached a consensus on the components involved in measuring supply chain complexity. Therefore, this study aims to identify the criteria for measuring supply chain complexity. This study classifies and measures complexity based on its form. Form is divided into organization, product, and process. The results of this study show that supply chain complexity has an inverted U-shaped relationship with firm performance. The maximum value found in the inverted U-shaped relationships indicates the specific point at which firm performance no longer increases, but begins decreasing, with an increase in supply chain complexity. This study offers several implications. First, it conducts a detailed examination of the individual variables used to measure supply chain complexity. Second, a new perspective is presented for investigating the effect of supply chain complexity on firm performance. Although some components of supply chain complexity are found to have a negative effect on firm performance, thereby confirming prior studies, other components are found to have a positive effect on firm performance up to a certain point; beyond that point, a negative effect is observed.

Keywords: supply chain complexity; organizational complexity; product complexity; process complexity.

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1. Introduction

A supply chain is a network of various organizations that create value in transforming raw materials into a final product that is delivered to consumers [1]. As businesses respond to environmental changes by forming strategic alliances or outsourcing to enter new markets and launch new products, the supply chain becomes more complex [2-3]. Accordingly, supply chain complexity has received much scholarly attention [4].

However, previous studies have several limitations. First, earlier studies have not reached a consensus on the components for measuring supply chain complexity [5]. The organization, products, and processes are crucial components of corporate strategy [6], and they may be factored in to measure company complexity. In order to fill the lacuna, this study classifies and measures complexity based on its form. Form is divided into organization, product, and process. Delineating the components that comprise supply chain complexity in this way enables identifying the key factors that organizations should focus on managing.

Second, most prior studies focused on elucidating the negative impact of supply chain complexity on firm performance [7]. Perona and his colleagues [8] found that high-performing firms had less complex supply chains compared to the industry average. Among firm performance measures, Reference [7] focused on delivery and argued that supply chain complexity has a significantly negative impact on delivery performance. Recent studies, however, have explored both the positive and negative impacts of supply chain complexity on firm performance. Rigby [9] emphasized that when a firm grows its international business division or local business, it can more accurately identify customer needs and benefit from its scale. He also stressed that adding new products intensifies firm complexity but offering novelty to customers can rally sales.

While companies cannot always control the growing complexity of the supply chain, they should identify the appropriate means for effectively managing it. Otherwise, firm performance may be undermined. Therefore, this study aims to identify the criteria for measuring supply chain complexity and to examine how supply chain complexity affects firm performance.

2. Literature Review

Supply Chain Management (SCM) systematically and strategically integrates traditional management functions and tactics within an individual organization and all the organizations in its supply chain to improve long-term performance for both the individual organization and its partners [10]. Reference [7] defined supply chain complexity as numerousness, interconnectivity, and system unpredictability. They sorted supply chain complexity into technology and information processing. Technology was further divided into structure and infrastructure, wherein structure branches out into product and process while infrastructure is classified as the management system. Lastly, information processing is divided into complicatedness and uncertainty.

Supply chain complexity can be divided into organizational complexity, product complexity, and process complexity [9, 11]. Organizational complexity comprises the various facilities, groups, and systems that operate a company’s processes. Product complexity refers to the diversity of products offered to customers. Finally, process complexity refers to the range of business processes and business contact points utilized in providing a

product and its support.

2.1 Organizational Complexity and Firm Performance

Most scholars examining the relationship between organizational complexity and firm performance have argued that complexity negatively affects firm performance [7]. The number of suppliers, a major component of organizational complexity [12], potentially has a negative effect on organizational performance [13]. Other components of organizational complexity, including a geographical span of suppliers and the number of echelons in the supply chain, are also found to have a negative effect on firm performance [14].

The ensuing debate implies that a certain amount of organizational complexity has a positive impact on firm performance, but that too much complexity has a negative impact. According to Trent and Monczka [15], having many suppliers is a way of mitigating supply risk, including costs and reliability. However, when the number of suppliers is excessive, organizations face roadblocks in forging close partnerships. Based on the study of Geringer and his colleagues [16], therefore, they proposed that international market diversification, categorized under organizational complexity, has an inverted U-shaped relationship with firm performance.

Overall, prior studies have claimed that organizational complexity, composed of the number of suppliers, departmental interactions, and geographical span of customers, negatively affects firm performance. However, SCM studies have neither systematically classified organizational complexity nor empirically analyzed the relationship between organizational complexity and firm performance.

2.2 Product Complexity and Firm Performance

There are conflicting arguments among researchers on the relationship between product complexity and firm performance. First, most studies examining the relationship between product complexity and firm performance have argued that increasingly complex products lead to challenges in development, manufacturing, and delivery that have a negative effect on firm performance [17]. MacDuffy and his colleagues [18] claimed that diversity in product portfolio may negatively influence the supply chain. Growing product diversity raises complexity levels in production systems as well as forecasting [19], sales [20], and production scheduling [21], and, in the end, it negatively impacts delivery [22].

In contrast, some studies have proposed that a certain amount of product complexity is beneficial to an organization. These studies have claimed that increased product diversity improves sales by satisfying customer demands through differentiation. Reference [23] noted that managerial influence leads companies to implement line extension as a marketing strategy, as managers consider line extension a low-cost, low-risk approach to meeting customer demands. In addition, Reference [9] emphasized that although adding new products increases organizational complexity, it also enables a company to become an industry leader. In particular, this type of product complexity can improve company sales during economic recession.

This debate implies that a certain amount of product complexity is useful because it strengthens sales, but past that point, product complexity fails to create customer value and increases costs [24-25]. Geringer and his

colleagues [16] also proposed that product diversification, categorized under product complexity, has an inverted U-shaped relationship with firm performance.

In summary, prior studies have highlighted that it is crucial for firms to attain an appropriate level of product complexity. However, SCM studies that systematically classify product complexity and empirically test the relationship between product diversity and firm performance largely remain missing.

2.3 Process Complexity and Firm Performance

There Process complexity refers to levels of mechanization, predictability or uncertainty, and systemization [26]. The degree of mechanization is related to the point of contact between labor and equipment; processes become more complex as the degree of mechanization rises. The level of predictability is closely related to interactions among tasks or steps within the processes. As more interactions occur within a system, it becomes challenging to predict the consequences of the small variations in those interactions. Finally, systemization levels are determined by standardization and formal control.

Most scholars who examined the relationship between process complexity and firm performance contended that processes negatively affect firm performance as they become more complicated. Reference [11] regarded process complexity as the number of contact points and task steps required for producing and supporting products. They argued that although a certain level of process complexity has value-added effects, any complexity beyond that level has non-value-added effects. They also noted that factors such as overseas market entry and outsourcing can further increase process complexity. Identifying and eliminating such process complexities yield an immediate and direct improvement in cash flow. Therefore, they argued that strengthening firm performance entails transforming the organization as well as the products with regard to process complexity.

On the other hand, Reference [9] argued that although companies that manage complexity typically begin with process management, efforts to reduce process complexity should be taken as the final step. The rationale is that product variety and inadequate organizational structure generate intricate processes. Thus, to maximize performance, product complexity should be addressed first, followed by organizational complexity, and finally process complexity. Streamlining the organization first and increasing its efficiency afterward enable faster and more appropriate decision-making as well as tighter cost control. Lastly, companies should identify areas of excessive spending through process complexity management and make an effort to improve performance.

In conclusion, despite their differing opinions, most of the previous studies agree that process complexity has value-added effects and, therefore, positively influences firm performance.

However, when process complexity crosses a certain threshold, non-value-added effects are produced, which negatively influence firm performance. Although production management studies often examined process complexity, many focused on specific production methods such as lean production. Therefore, this study systematically classifies process complexity and empirically analyzes the relationship between process complexity and firm performance.

3. Research Methodology

3.1 Hypotheses

Most previous research examining the relationship between supply chain complexity and firm performance has focused on their negative relationship. Bozarth and his colleagues [27] suggested, in detail, the negative impact of supply chain complexity on firm performance. Perona and his colleagues [8] empirically analyzed that high-performing firms had less complex supply chains than the industry average. Reference [7] focused on delivery and argued that supply chain complexity had a significantly negative impact on delivery.

Recent studies, however, have explored both the positive and negative impacts of supply chain complexity on firm performance. Rigby [9] emphasized that when a firm grows its international business division or local business, it can more accurately understand customer needs and, thus, benefit from its scale. He also stressed that although adding new products intensifies firm complexity, offering novelty to customers can rally sales. Reference [11] contended that process complexity up to a certain level produces added value, but surpassing that threshold results in non-value-added effects.

Based on studies by Geringer and his colleagues [16], they empirically demonstrated that international market diversification and product diversification strengthen firm performance more when they are at the intermediate rather than the lower or higher level. Following the argument that supply chain complexity positively influences firm performance but has a negative influence once passing a certain threshold, this study sets the following hypotheses.

H1: Organizational complexity and firm performance will have an inverted U-shaped relationship.

H2: Product complexity and firm performance will have an inverted U-shaped relationship.

H3: Process complexity and firm performance will have an inverted U-shaped relationship.

3.2 Data

Data were collected from domestic manufacturers of various sizes in a wide range of industries. One survey response was collected per organization. If a firm had an SCM department, then its administrator was designated as the respondent. Otherwise, the respondent was an administrator responsible for supply chain strategies in the planning, purchasing, production, or sales department.

Managers in the SCM department or departments well-informed of the production site were contacted through telephone calls for study participation consent. A professional research firm mailed the questionnaire, along with a cover letter explaining the research objectives, terms of confidentiality and potential contribution. Follow-up telephone calls and mailings were used to improve the response rate. Analysis was carried out based on the remaining 172 responses.

4. Result and Discussion

To test the research model, SPSS 18.0 was used to run multiple regression analysis. This analysis is appropriate for hypothesis testing studies that determine the relative effect of the independent variables. When there is high multi-collinearity, the explanatory power of an independent variable may appear to be low, even if its explanatory power on the dependent variable is high [28]. Therefore, multi-collinearity between independent variables was tested using VIF (Variance Inflation Factor) index. As a result, the VIF index among the independent variables was 1.416~1.731, which was less than 10, indicating that there was no multi-collinearity.

After testing for linearity and nonlinearity in the relationships between supply chain complexity and firm performance, including cost, delivery, quality, and flexibility, the impact of supply chain complexity on firm performance was analyzed. Table 1 shows the analysis results for the linear and the nonlinear model for the effect of supply chain complexity on firm performance. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was a difference in the R^2 values of the two models. Moreover, the scatter plots showed that the second model was more appropriate than the first model. Therefore, supply chain complexity and firm performance were found to have a nonlinear relationship.

Table 1: Model statistics and parameter estimates for research model

Equation	Model statistics				
	R^2	F	df1	df2	p
Linear model	.776	194.216	3	168	.000
Nonlinear model	.915	296.422	6	165	.000

Table 2 shows the multiple regression analysis results for the effect of supply chain complexity on firm performance. First, with regard to the effect of organizational complexity on firm performance, organizational complexity had a negative effect (β = -0.096, $p<0.05$), and organizational complexity squared had a negative effect (β = −1.624, $p<0.01$) on firm performance. These results indicate an inverted U-shaped relationship between upstream complexity and quality.

Second, the inverted U-shaped relationship between product complexity and firm performance was tested. Product complexity had a negative effect (β = -0.751, $p<0.01$), and product complexity squared had a negative effect (β = −2.629, $p<0.01$) on firm performance. The first model and the second model were both statistically significant at the 99% confidence level. However, the difference between the R^2 values of the two models was not small; the R^2 value for the second model was greater than the determination coefficient of 0.13, as suggested by Cohen and his colleagues [29] for social sciences research. This indicates an inverted U-shaped relationship between product complexity and firm performance.

Third, process complexity had a positive effect on firm performance (β = -0.140, $p<0.01$), whereas process complexity squared had a negative effect (β = −0.482, $p<0.05$). These results indicate an inverted U-shaped

relationship between process complexity and firm performance.

Table 2: Effect of supply chain uncertainty on firm performance

Variable	Model I	Model II
Organizational complexity	-.096*	-1.525**
Product complexity	-.751**	-1.670**
Process complexity	-.140**	-.510*
Organizational complexity²		-1.624**
Product complexity²		-2.629**
Process complexity²		-.482*

* $p<0.05$, **$p<0.01$

5. Conclusion

Companies must manage supply chain complexity. However, the impact of supply chain complexity on firm performance has not yet been clearly identified. Moreover, most studies have focused on elucidating the negative effects of supply chain complexity on firm performance, overlooking that a certain level of supply chain complexity is inherent. This study aimed to fill this lacuna in existing supply chain complexity research. Addressing the lack of consensus on supply chain complexity measurement criteria, this study carefully categorized measurement items based on perspectives from strategic management, distribution, marketing, and organizational behavior. Their impact on firm performance was also investigated. In addition, this study verified that supply chain complexity has not only negative effects but also positive effects on firm performance.

This study offers implications. First, supply chain complexity measurement items were classified and systematically analyzed based on the form of the complexity. Prior studies took different analytical approaches to examining supply chain complexity measurement items and, thus, presented interesting results with regard to impacts on firm performance. This study conducted a detailed examination of various individual variables used to measure supply chain complexity. Therefore, this study contributes to the supply chain literature by systematically organizing the supply chain complexity measurement variables that have previously been proposed by studies on supply chain complexity.

Second, this study took a new perspective on investigating the effects of supply chain complexity on firm performance. Most previous research focused largely on the negative effects of supply chain complexity on firm performance, such as increased costs and lengthened lead time. However, recent studies argued that supply chain complexity may have positive effects, such as when customers demand customized products regardless of increased costs and longer delivery times. Thus, this study expanded the scope of previous studies by investigating both the positive and negative effects of supply chain complexity. In other words, components of supply chain complexity were found to have a positive effect on firm performance up to a certain point. However, when complexity moved beyond that point, a negative effect was observed. This revealed an inverted U-shaped relationship, thus presenting a perspective that previous studies have not offered.

This research has limitations and future studies are needed to supplement it. This study focuses on the impact of supply chain complexity on firm performance, but fails to suggest how companies should manage supply chain complexity. As companies move into new markets or launch new products, supply chain complexity will inevitably increase. Therefore, it is expected that further research will be done to suggest ways that companies can utilize in management activities.

6. Recommendations

According to the results of this study, supply chain complexity has a positive impact on firm performance up to some extent, however, negative effect after that level. Therefore, it is recommended that the managers of companies should maintain the supply chain complexity to the appropriate level for improving firm performance, rather than considering it as negative.

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