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A Study of Supply Chain Integration Initiatives' Impact on the Relationship between Supply Chain Complexity and Firm Performance

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Abstract

A Study of Supply Chain Integration Initiatives' Impact on the Relationship between Supply Chain Complexity and Firm Performance

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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.

Previous studies, however, have several limitations. First, earlier studies have not reached a consensus on the components involved in measuring supply chain complexity. Second, most studies have focused on elucidating the negative effects of supply chain complexity on firm performance while overlooking that a certain level of supply chain complexity is intrinsic. Third, research on how companies should manage supply chain complexity is lacking. Although several studies have proposed supply chain integration as a way to manage complexity, its impact has not yet been empirically tested.

Therefore, this study aims to identify the criteria for measuring supply chain complexity, and to expand on prior studies by examining not only the negative impacts of complexity on firm performance but also any positive impacts. In addition, this study aims to explicate how companies can effectively manage supply chain complexity. This study uses a 3×3 matrix to classify and measure complexity based on its origin and form. Origin is divided into upstream, internal, and downstream. Form is divided into organization, product, and process. Furthermore, supply chain integration has been presented to moderate the relationship between supply chain complexity and firm performance. The components of supply chain integration are categorized in detail and investigated. After systematically classifying and analyzing supply chain complexity and supply chain integration, this study proposes supply chain integration strategies that can be utilized by companies encountering specific problems related to supply chain complexity.

This study reviews previous literature on supply chain complexity, firm performance, and supply chain integration to inform the research model and develop hypotheses. A questionnaire was constructed based on previous studies to analyze the research model, and a professional research firm gathered questionnaire data for empirical analyses. This study collected data from 172 respondents, representing domestic manufacturers of various sizes and from a wide range of industries. Upon survey completion, Amos 18.0 and SPSS 18.0 were used to perform statistical analyses, including chi-square test, confirmatory factor analysis, and hierarchical regression analysis.

The results of this study show that supply chain complexity have an inverted U-shaped relationship with firm performance, with the exception of cost and delivery. 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. A comparison of

the maximum values by supply chain complexity type places internal complexity (5.110), downstream complexity (4.725), and upstream complexity (3.904) in that order.

Next, this study analyses the moderating effect of supply chain integration on the relationship between supply chain complexity and firm performance. In the relationship between supply chain complexity and cost, the integration in physical flows, information exchange, and collaborative activities are found to have statistically significant moderating effects. In the relationship between supply chain complexity and delivery, information exchange, collaborative activities, and long-term relationship building are found to have statistically significant moderating effects. In the relationship between supply chain complexity and quality, communication methods, and information exchange are found to have statistically significant moderating effects. In the relationship between supply chain complexity and flexibility, the integration in physical flows, communication methods, and information exchange are found to have statistically significant moderating effects.

This study offers the following theoretical implications. First, it conducts a detailed examination of the individual variables used to measure supply chain complexity. These have not been uniformly agreed on in prior studies. The present study also suggests which variables require focused attention by the firm.

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.

Third, this study proposes a supply chain integration strategy for managing the effect of supply chain complexity on firm performance. Moreover, it addresses existing claims that supply chain integration will weaken the negative relationship between supply chain complexity and firm performance. Taking a more nuanced approach, this study makes a significant contribution by identifying the appropriate combined relations among each supply chain complexity and supply chain integration component.

Practical implications of the research are as follows. First, this study proposes specific points that corporate bodies should be aware of as they manage supply chain complexities. This study identified that although firm performance increases as supply chain complexity increases up to a certain point, once crossing that threshold, increasing supply chain complexity results in decreased firm performance, thus revealing an inverted U-shaped relationship.

Second, the relational mechanisms between supply chain complexity and supply chain integration are proposed. The elucidation of these mechanisms enables companies to analyze their own supply chain complexities. Moreover, they provide a foundation for pursuing appropriate supply chain integration strategies in accordance with future organizational goals. In other words, this study presents useful strategic guidelines for introducing supply chain integration into supply chain complexity management.

Keywords: Supply chain complexity; Supply chain integration; Supply chain management; Firm performance

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I. Introduction

1. Research Purpose and Need

The globalization of business, reduced product life cycles, increased customer needs, technological advancements, and so on contribute to firm complexity (KPMG, 2011; BCG, 2006). 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 (Perona and Miragliotta, 2004; Isik, 2010). In short, globalization, customization, outsourcing, innovations, and other such trends contribute to the growing complexity of supply chains (Serdarasan, 2013).

Diversifying products to meet various customer needs increases both costs and shipment delays. Consequently, companies are confronted with choosing between cost competitiveness and product competitiveness. In most cases, companies choose product competitiveness and suffer from increased cost and reduced profitability (Wilson and Perumal, 2009). In order to achieve competitive advantage, companies must manage these internal complexities effectively and minimize their negative impact on performance.

In addition to internal complexities, companies must manage supply chain complexity (Beamon, 1998; Lambert et al., 1998; Mentzer et al., 2001). 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 (Handfield et al., 1999; Cooper and Ellram, 1993; Ferguson, 2000; Mentzer et al., 2001). Supply chains can include a complex network of organizations, each with its own objectives (Christopher, 2011; Hashemi et al., 2013).

Accordingly, supply chain complexity has received much scholarly attention (Mentzer et al., 2001; Choi and Krause, 2006). Most prior studies identified factors for measuring supply chain complexity (Sivadasan et al., 2002; Martínez-Olvera, 2008; Isik, 2010; Leeuw et al., 2013; Serdarasan, 2013) and focused on elucidating the negative impact of supply chain complexity on firm performance (Vachon and Klassen, 2002; Van der Vorst and Beulens, 2002; Hoole, 2006).

Previous studies, however, have several limitations. First, earlier studies have not reached a consensus on the components for measuring supply chain complexity (Serdarasan, 2013). Most studies primarily focused on upstream complexity, while neglecting downstream complexity (Gilbert and Ballou, 1999). In the past, only the service industry received customer participation, but now it is incorporated in all manufacturing industry processes, ranging from product planning and production to sales (Wind and Rangaswamy, 2001). From the supply chain side, customer participation enhances product quality and company productivity (Lengnick-Hall, 1996) as well as customer satisfaction (Bendapudi and Leone, 2003).

In addition, earlier studies examined only a fraction of supply chain complexities rather than systematically classifying them all (MacDuffy et al., 1996;

Closs et al., 2008; Quelch and Kenny, 1994; Nwankpa and Roumani, 2011; Childerhouse et al., 2002; Hanisch and Wald, 2014; Olhager, 2010; Liu and Lai, 2012). The organization, products, and processes are crucial components of corporate strategy (Kotha and Orne, 1989), and they may be factored in to measure company complexity. In order to fill the lacuna, this study uses a 3×3 matrix to classify and measure complexity based on its origin and form. Origin is divided into upstream for the supplier side, internal for within the organization, and downstream for the customer side. 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 previous research that examines the relationship between supply chain complexity and firm performance has focused on the negative impacts of complexity on performance. Frizelle and Woodcock (1995) argued that lead time increases and reliability decreases as supply chain complexity increases. Bozarth et al. (2009) divided supply chain complexity into upstream complexity, internal complexity, and downstream complexity. They discussed, in detail, that various supply chain measurement factors have a negative impact on firm performance. Through empirical analysis, Perona et al. (2001) found that high-performing firms had less complex supply chains compared to the industry average. Among firm performance measures, Vachon and Klassen (2002) 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 (2009) 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. Considering both the negative and positive impacts of supply chain complexity on firm performance, Narasimhan and Kim (2002) argued that supply chain complexity and firm performance have an inverted U-shaped relationship. The present study further expands on this stream of research by investigating the positive and negative effects of supply chain complexity. It also explores whether a complexity threshold exists, after which point the positive impacts of complexity on firm performance become negative.

Third, there is little research on how companies should manage supply chain complexity (Perona and Miragliotta, 2004). Although several studies (Serdarasan, 2013; Skaggs and Huffman, 2003; Perona and Miragliotta, 2004) proposed supply chain integration as a way to manage complexity, its impact has not yet been empirically tested. Thus, this study investigates the effects of supply chain integration, including supplier integration, internal integration, and customer integration (Wong et al., 2011). Testing whether supply chain integration reduces the negative impact of supply chain complexity may shed light on how companies can effectively and efficiently manage supply chain complexity.

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 (Simchi-Levi and Kaminsky, 2000; Blackhurst et al., 2004). This study aims to identify the criteria for measuring supply chain complexity and to explicate how companies can effectively manage this complexity.

In sum, the present study poses the following questions:

(1) What elements make up supply chain complexity?

(2) What is the relationship between supply chain complexity and firm performance?

(3) Which elements in supply chain integration have a significant impact on the relationship between supply chain complexity and firm performance?

2. Study Approaches

2.1. Theoretical Background

2.1.1. Resource-based Theory

The resource-based theoretical perspective maintains that firms have a sustained competitive advantage because their resources have heterogeneous and immobile qualities (Rumelt, 1984; Wernerfelt, 1984; Barney, 1991; Teece et al., 1997; Hunt and Lambe, 2000). If all companies had homogeneous resources that could be duplicated, then those companies would apply the same strategies and fail to achieve competitiveness.

Firm-specific resources include the total assets, capabilities, organizational processes, firm attributes, information, and knowledge that organizations manage in order to improve their effectiveness and efficiency (Daft, 1983). Barney (1991) argued that organizations must possess four properties to achieve sustained competitive advantage. First, resources must have value and use an organization's surrounding environment as an opportunity to offset any threat. Second, resources should remain scarce in both present and future competition. Third, resources should be inimitable to organizations. Fourth, resources should be irreplaceable.

According to resource-based theory, firms must develop new products and new technologies and build internal capability through training and communications for sustained competitive advantage. In other words, resource-based theory emphasizes internal integration.

2.1.2. Relational Theory

Relational theory asserts that resources important to an organization can be expanded beyond organizational perimeters because they are embedded in the relationship between organizations (Dyer and Singh, 1998). Relational theorists (Dyer, 1996; Powell, 1996) criticize resource-based theory for its narrow scope on intra-organizational resources and for overlooking the importance of the network in which the organization belongs.

According to relational theorists, an organization's sustained competitive advantage depends on its relationship with other organizations. Therefore, organizations must cooperate with suppliers and customers in their network. Relational theorists propose that competitive advantage stems from relationship-specific assets, knowledge-sharing channels, complementary resources and capabilities, and effective governance. Relationship-specific assets are embedded in the relationship between an organization and its corporate partner (Klein et al., 1978; Teece, 1987), and comprise site specificity, physical asset specificity, human asset specificity, and dedicated asset specificity (Williamson, 1985). Knowledge-sharing channels refer to the inter-organizational learning needed for securing competitive advantage (Levinson and Asahi, 1996; Powell et al., 1996). Complementary resources and capabilities refer to generating a synergy effect, potentially greater than the sum of its parts, from inter-organizational exchange of resources. They have been highlighted as the main benefits of corporate partnerships (Hamel, 1991; Shan et al., 1994). Lastly, effective governance refers to a governance structure that minimizes transaction costs and improves efficiency between companies (North, 1990; Williamson, 1985).

For sustainable advantage, relational theory emphasizes building a network with suppliers and customers. In short, relational theory emphasizes supplier integration and customer integration.

2.1.3. Extended Resource-based Theory

Lavie (2006) proposed an extended resource-based theory that represents a compromise between resource-based theory and relational theory. Whereas resource-based theory conventionally argues that an organization must own or have complete control over its value-creating resources, extended resource-based theory argues that access to resources, rights to use the resources, authority to enjoy the benefits associated with resources, and so forth comprise an organization's sustained competitive advantage.

According to extended resource-based theory, organizations can create a sustainable competitive advantage not only through internal integration but also through supplier integration and customer integration. In other words, extended resource-based theory contends that organizations should extend their resources by tapping into those of their suppliers and customers.

2.2. Research Perspective

Scholars in various disciplines, including strategic management, logistics, marketing, and organizational behavior, actively study supply chain management, as it has been identified as a crucial activity in sustaining competitive advantage (LaLonde, 1998; Jones, 1998; Power et al., 2001; Moberg et al., 2002; Chen and Paulraj, 2004).

The following table summarizes the key elements of supply chain management research in each discipline (Croom et al., 2000).

[Table 1] Approach to Supply Chain Management Study

Discipline	Key Elements
Strategic Management	Strategic networks Control in the supply chain Time-based strategy Strategic sourcing Vertical disintegration Make-or-buy decisions Core competencies focus Supply network design Strategic alliances Strategic supplier segmentation World-class manufacturing Strategic supplier selection Global strategy Capability development Strategic purchasing
Logistics	Integration of materials and information flows Just-in-time planning, material requirements planning, waste removal, and vendor-managed inventory Physical distribution Cross-docking Logistics postponement Capacity planning Forecast information management Distribution channel management Planning and control of materials flow
Marketing	Relationship marketing Internet supply chains Customer service management Efficient consumer response Efficient replenishment After-sales service

Organizational Behavior	Communication Human resource management Employee relationships Organizational structure Power in relationships Organizational culture Organizational learning Technology transfer Knowledge transfer

Supply chain management studies in strategic management emphasize inter-organizational benefits (Nielsen, 1988; Kanter, 1994; Dyer, 2000) over competitive advantage (Porter, 1985). Carlisle and Parker (1989) argued that companies can surpass traditionally adversarial relationships in conventional negotiations and achieve “win–win” through mutual cooperation. This paradigm enables the formation of strategic alliances among organizations and, thus, a networked supply chain management (Thorelli, 1986; Borys and Jemison, 1989; Lado et al., 1997; Ahuja, 2000).

Macbeth and Ferguson (1994) claimed that partnership sourcing is possible in supply chain management. Thackray (1986) empirically analyzed the increase in outsourcing and vertical de-integration in industries such as automotive, machinery, and industrial robotics. Moreover, Quinn (1994) highlighted the strategic importance of supply chain management and emphasized that companies should strategically outsource any pieces that fall outside of their core competence.

Strategic purchasing, on the other hand, earned attention due to the influence of the rapidly changing competition environment (Carter and Narasimhan, 1996; Carr and Pearson, 2002). Strategic purchasing is a systematic purchasing tactic that considers demand and needs requirements when selecting suppliers with the lowest total costs, inclusive of pecuniary and non-pecuniary factors. Hostile relations with a supplier can increase a firm's production costs, resulting in unreasonable prices for buyers. Therefore, buyers should seek to enhance competitiveness by building a cooperative relationship with their suppliers (Carr and Smeltzer, 1999).

Taken together, supply chain management studies in strategic management emphasize inter-organizational relations. However, the majority of empirical studies focus only on supplier–buyer relationships. Thus, there is a significant need for empirical studies that consider the entire supply chain.

In logistics, supply chain management research combines all organizational capabilities within the supply chain to emphasize enhanced efficiency in materials and information flow. In other words, effective supply chain management entails problem solving through inter-organizational cooperation and coordination within the supply.

Lee and Billington (1995) considered the supply chain as a network of functions from the purchasing of materials and transforming them through intermediary steps to creating the final product and shipping it to the consumer. They used Hewlett-Packard as a case study to propose a model that minimizes the overall inventory and costs of a supply chain and maximizes service rate. Quinn (1997) argued that supply chain management consists of delivering customer and economic value through effective planning and control of materials flow. Further, Christopher (1997) noted that supply chain management increases consumer value by minimizing the total cost of upstream–downstream relationships between suppliers, distributors, and consumers, thereby highlighting distribution channel management.

However, some have argued that the influence of supply chain management is increasingly extending beyond logistics. Giunipero and Brand (1996) argued that supply chain management improves customer satisfaction by strengthening an organization's competitive performance and profitability. Cooper (1997) noted that supply chain management includes all inter-organizational activities within the supply chain, from supplying raw materials to reaching the final consumer. Extending the scope beyond logistics, he conceptualized supply chain management as the overall process of a company.

From a relationship marketing perspective, supply chain management emphasizes the comprehensive management of various inter-organizational processes. Most marketing channel studies focused on the relationships between channel activities (Anderson and Narus, 1984; Dwyer and Oh, 1987) and contended that a variety of organizational forms exist, ranging from independent business relationships, collaborative interests, and long-term contractual relationships to ownership. However, traditional marketing channels center on downstream activities, whereas supply chain management emphasizes both downstream and upstream activities.

Supply chain management studies in marketing have primarily focused on the consumer. In regard to the shift from cost savings to creating customer value through innovative supply chain management, Tyndall (1996) recommended investigating whether each activity within the supply chain actually increases customer value. Instances of industrial implementation include the Quick Response System (QRS) in the apparel industry and Efficient Consumer Response (ECR) between manufacturers and large retailers in the food and beverage industry. QRS preleases a small amount of products into the market, analyzes consumer behavior, and goes into full-scale production based on trending market response. ECR reengineers the entire distribution process, from raw materials procurement to sales, thereby eliminating inefficiencies and excess costs. These systems increase revenue and return on assets while reducing logistics costs, such as inventory and order management expenses.

Lastly, supply chain management studies in organizational behavior have highlighted the importance of communication, organizational structure, knowledge transfer, and so on. Suppliers and buyers need to engage in bi-directional communications in order to form successful relationships (Ansari and Modarress, 1990; Newman and Rhee, 1990; Krause, 1999). Carter and Miller (1989) revealed that supplier quality performance improves when the buyers' purchasing department and the suppliers' sales department, as well as other relevant departments, have active communication lines. Supplier quality issues often stem from a lack of communication with buyers (Newman and Rhee, 1990; Lascelles and Dale, 1989). Thus, prompt feedback and reliable information exchange between organizations strengthen product quality (Dean and Bowen, 1994; Carr and Smeltzer, 1999).

Bowersox et al. (1986) called for the creation of a separate department responsible for supply chain management. Bowersox and Daugherty (1995) argued that supply chain management is critically affected by formalization, centralization, and span of control, and Droge et al. (1989) extended that list to include complexity, integration, and organizational size.

Another line of supply chain management studies in organizational behavior examines knowledge transfer for strengthening supplier capacity. Products derive their competitiveness from both organizational competence as well as supplier capacity (Modi and Mabert, 2007). Therefore, suppliers must be able to respond to customer needs and changes in technologies (Krause et al., 2007; Wisner et al., 2005). Buyers transfer their production knowledge to their suppliers (Delios and Beamish, 2001; Luo and Peng, 1999) in order to improve both product quality and buyer satisfaction (Krause et al., 2007; Modi and Mabert, 2007).

In summary, this study treats supply chain management as including all organizational processes. Moreover, to supplement existing studies that center on the buyer–supplier relationship, this study also considers customers, as they have been identified as an important component in marketing.

3. Research Method and Organization

3.1. Research Method

This study aims to provide a literature review and to conduct empirical research in the following method.

First, a research model and hypotheses were formulated to analyze the present study. In particular, this study employs a 3×3 matrix to classify the complexity measurement factors gleaned from previous studies on supply chain complexity, firm performance, and supply chain integration.

Second, a questionnaire based on previous research was constructed to analyze the research model, and a professional research firm gathered questionnaire data for empirical analyses. Experts tested the questionnaire prior to conducting the full-scale survey to improve its content validity. Based on the pre-test, general question items were specified, and complex questions were broken down and modified.

Third, upon survey completion, Amos 18.0 and SPSS 18.0 were used to perform statistical analyses, including factor analysis, reliability analysis, and hierarchical regression analysis. Collected data were tested for normality as well as construct reliability and validity at the onset. Afterwards, hypotheses related to the impact of supply chain complexity on firm performance and the moderating effect of supply chain integration were tested.

3.2. Research Subjects

The purpose of this study is to analyze the relationship between supply chain complexity and organizational performance in domestic firms and the moderating effect of supply chain integration. With this goal, consumer-goods industries, heavy machinery industries, and assembly industries within manufacturing were surveyed. The project received one survey response per organization. If a firm had a supply chain management department, then its administrator was designated as the respondent; otherwise, an administrator responsible for supply chain strategies in planning, production, or sales departments was the respondent.

To ensure questionnaire reliability, the expertise of a professional research firm was employed. The professional research firm selected questionnaire respondents through a multi-step process. First, because this study examines supply chain complexity, a list of all the companies in the consumer-goods, heavy machinery, and assembly industries was obtained. Next, a phone interview was conducted with each of the companies to request their participation in the survey. Finally, a survey was carried out with the companies that agreed to participate.

3.3. Research Organization

This study is organized into five parts, as follows:

Part I analyzes the limitations of previous studies related to supply chain complexity. It also establishes the research objectives and theoretical basis of this study. In addition, Part I briefly summarizes the study method and subjects, and outlines the overall design of the study.

Part II examines three bodies of literature. First, it explores the concept of supply chain complexity as defined by prior studies and proposes a possible approach to classifying various types of supply chain complexity. Second, the impact of each complexity type on firm performance is analyzed. Third, this section defines supply chain integration and investigates its moderating effect on the relationship between supply chain complexity and firm performance.

Part III proposes a research model that ties supply chain complexity, firm performance, and supply chain integration together. It also establishes the research model hypotheses. Moreover, operational definitions are offered for supply chain complexity, firm performance, and supply chain integration based on previous research. Measurement factors for each of the three constructs are also proposed.

Part IV discusses the empirical testing of the research model. This section covers study subjects and data collection methods. It explains the methods used to analyze the measurement model and to test the hypotheses. Hypotheses testing is primarily divided into two procedures. First, the relationship between supply chain complexity and firm performance is examined. Second, the moderating effect of supply chain integration on the relationship between supply chain complexity and firm performance is evaluated.

Part V summarizes the study results and discusses the research implications. Furthermore, this section proposes supply chain integration as a management strategy for supply chain complexity and empirically analyzes the effect, thereby offering practical insight to organizational leaders. Part V closes with study limitations and suggestions for future research.

II. Literature Review

1. Supply Chain Complexity

1.1. Definition of Supply Chain Complexity

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 (Council of Logistics Management, 2000). In other words, SCM is a comprehensive approach to planning and controlling the overall supply chain in order to offer high customer value (Oliver and Webber, 1982; Fisher, 1997; Stevens, 1990; Kalakota and Whinston, 1996; Ellram, 1990; Bhattacharya et al., 1996; Davies and Brito, 1996).

Thus, SCM is an intricate system of materials and information flow between suppliers, manufacturers, distributors, and other related organizations. Each firm participates in many supply chains and maintains its own distinct goals, thereby contributing to the dynamic and uncertain qualities of supply chains (Blackhurst et al., 2004).

Wilding (1998) first introduced the term *supply chain complexity*. He proposed the supply chain complexity triangle, composed of deterministic chaos, parallel interactions, and demand amplifications, and argued that the interactions of these three factors create supply chain uncertainty. Deterministic chaos refers to the irregular and limited dynamics stemming from deterministic systems. Parallel interactions represent interactions between different bodies within the same tier of the supply chain. Demand amplifications refer to the increase of raw material suppliers from small consumer demands over time (Forrester, 1961).

Vachon and Klassen (2002) 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.

Blecker et al. (2005) noted that previous studies could not agree on a uniform definition of supply chain complexity because those studies examined it from a variety of perspectives, including system theory and chaos theory. They applied system theory to define supply chain complexity as an attribute of a system. They treated an attribute as an innate ability to adapt to different environmental conditions.

Meanwhile, Giménez et al. (2012) examined supply chain complexity embedded within the buyer–supplier relationship. They conceived supply chain complexity as a process complexity that arises in the ordering, manufacturing, and delivery processes between the buyer and the supplier. This definition is consistent with Welker's (2004) conception of SCM.

Based on previous research, this study defines supply chain complexity as interactions between structural properties, including the number of suppliers, number of customers, product variety, and complexity elements (Vachon and Klassen, 2002; Bozarth et al., 2009).

1.2. Classification of Supply Chain Complexity

Although the existing research has classified supply chain complexity in a range of ways, studies have generally utilized one of the following three approaches.

First, supply chain complexity can be organized into upstream complexity, internal complexity, and downstream complexity (Isik, 2010; Bozarth et al., 2009). For example, Bozarth et al. (2009) classified supply chain complexity into upstream complexity, internal complexity, and downstream complexity. Upstream complexity includes the number of suppliers, long and/or unreliable supplier lead time, and globalization of the supply base. Internal complexity includes the number of products and parts, one-of-a-kind/low-volume batch production, and manufacturing schedule instability. Downstream complexity includes the number of customers, heterogeneity in customer needs, shorter product life cycles, and demand variability.

However, most studies of supply chain complexity have focused on upstream complexity, which pertains to the supplier side of the supply chain. This has left a gap with regard to studies of downstream complexity, which pertains to the customer side (Gilbert and Ballou, 1999; Li et al., 2005). Downstream complexity has not attracted scholarly attention partly because companies cannot control customer complexity. Nevertheless, variability and rapid changes in customer needs are increasingly generating complexities from the customer side that warrant investigation.

Second, supply chain complexity can be divided into organizational complexity, product complexity, and process complexity (Vachon and Klassen, 2002; Rigby, 2009; Wilson and Perumal, 2009). This incorporates elements important in manufacturing strategies into supply chain complexity. For example, Rigby (2009) argued that firm complexity largely appears in the organization, its products, and its processes. He proposed that organizations must take a comprehensive approach to managing complexity instead of addressing just one of type of complexity.

Organizations generally tend to reduce product variations in order to minimize complexity. However, Wilson and Perumal (2009) argued that although firm complexity exists in product design, production, and support processes, it also exists in the infrastructure (i.e., the organization itself) operating those processes. 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.

Based on prior studies that considered the organization as an infrastructural part of SCM and product and process as structural (Leong et al., 1990; Wheelwright, 1984), Vachon and Klassen (2002) largely divided SCM into infrastructure and structure, wherein infrastructure includes the organization and structure includes products and processes. They proposed infrastructure as the supplier's and customer's regional bases, product diversity and customization, supplier's delayed delivery, and the various supply chain echelons. Structure included tasks and sub-processes, parts and components, and an organization's processing capacity. The research, however, is limited because of its inconsistent sorting of supply chain complexity for product diversity and customization and supplier's delayed delivery as infrastructural instead of structural.

Third, supply chain complexity can be divided into static complexity and dynamic complexity (Frizelle and Woodcock. 1995; Vachon and Klassen, 2002; Bozarth et al., 2009; Serdarasan, 2013). Senge (1990), an organization scholar, sorted complexity into detail complexity and dynamic complexity. Detail complexity encompasses the set of variables within a system, and dynamic complexity represents the subtle relationship, or ambiguous interaction, between cause and effect.

Applying this concept to SCM, static complexity, akin to detail complexity, is generated from having a significant number of variables within a supply chain, whereas dynamic complexity arises from the interaction of variables within a supply chain or frequent interactions between those variables and the external environment (Frizelle and Woodcock, 1995). In static complexity, variables have clear causal relationships (Klir, 2000), but in dynamic complexity, the causal relationship between variables is nebulous (Sterman, 2000).

Focusing on this difference, Bozarth et al. (2009) and Serdarasan (2013) named static complexity as structural complexity because the former is related to the supply chain structure, its various components, and the strength of their relationships. Because dynamic complexity is related to supply chain uncertainty and the interconnectivity of its components as well as to time and randomness, this type is treated as operational complexity.

However, several studies have revealed the difficulty in categorizing supply chain complexity into static complexity and dynamic complexity. Bozarth et al. (2009) presented a set of supply chain complexity measurement items and contended that heterogeneity in customer needs, one-of-a-kind/low-volume batch production, and long and/or unreliable supplier lead times, among others, all have both static and dynamic complexities. Serdarasan (2013) explained that decision-making complexity, defined as the complexity found in decision-making processes, also has static and dynamic complexities.

This study uses a 3×3 matrix to classify complexity first by origin (i.e., upstream, internal, or downstream) and then by form (i.e., organization, product, or process). Complexity characteristics, the third criterion, are excluded because of challenges in distinguishing supply chain complexity as either static or dynamic (Bozarth et al., 2009; Serdarasan, 2013). Therefore, this criterion has been deemed an inadequate classification method for this study.

2. Supply Chain Complexity and Firm Performance

2.1. Classification by Complexity Origin

2.1.1. Upstream Complexity and Firm Performance

Suppliers that companies work with inevitably become complex over time for the following reasons. First, manufactured products require an increasingly greater variety of parts. To procure those parts, firms do business with a number of suppliers. Second, escalated competition among organizations forces cost reduction and faster launching of diverse new products, which leads to increased instances of replacing existing suppliers. Third, due to parts modularization, the role of suppliers has expanded to include responsibilities formerly held by the buyer (Hsuan, 2003). Fourth, companies expand their customized product lines with ever-increasing customer requirements. Although these product lines have great diversity (Miller, 1987; Porter, 1980), demand for them tends to be unstable (Miller, 1988).

Studies that examine the relationship between upstream complexity and firm performance produce different results depending on how complexity components are classified and which corporate performance indicator was used. Frizelle and Woodcock (1995) argued that lead time increases and reliability decreases as upstream complexities grow. Similarly, Bozarth et al. (2009) examined upstream complexity as the number of suppliers, long and/or unreliable supplier lead times, and globalization of the supply base. They analyzed the impacts on firm performance, measured as schedule attainment, unit manufacturing cost performance, customer satisfaction, and competitive performance. The study found that upstream complexity had a negative effect on all firm performance indicators except unit manufacturing cost performance. The largest negative impact was on schedule attainment.

In addition, as global sourcing increases, it becomes more difficult to control suppliers (Doig et al., 2001; Robinson et al, 2008). Concentrated supply bases enhance financial performance (Lanier et al., 2010) and reduce inventory costs (Guimaraes et al., 2002). Following this argument, Steven et al. (2014) was the first to examine the relationship between support complexity and quality performance. They claimed that monitoring the activities of globalized dispersed suppliers is difficult, and results in both large collaboration costs (Denis et al., 2002) and increased quality problems.

Based on their survey of the Italian white goods industry, Perona et al. (2001) revealed that well-performing companies have fewer upstream complexities, on average, compared to other firms in their industry. Specifically, their components standardization index was high and the average order size was large, whereas the number of suppliers and the number of intermediate products were low. They argued that low complexity reduces components' running capital costs, obsolescence costs, finished products' running capital costs, transportation costs, and administrative costs while enhancing operating profits and average yearly sales.

In sum, prior studies addressing the relationship between upstream complexity and company performance claimed that complexity makes it tricky for the buyer to control or collaborate with its suppliers, which weakens firm performance. However, earlier studies mainly focused on cost and delivery among various firm performance indicators, and fell short in exploring the influence that upstream complexity has on quality and flexibility.

2.1.2. Internal Complexity and Firm Performance

A large body of research has examined internal complexity and firm performance. First, some studies have investigated how companies reduce complexity through product modularization (Ulrich and Tung, 1991; Sanchez and Mahoney, 1996) as well as the relationship between modularization and firm performance. Study results from Das and Narasimhan (2000) showed that product modularization has a significantly positive effect on cost and prompt response to customer needs, but does not have a significant effect on quality and delivery. Prencipe (1998) also illuminated that product modularization encourages faster new product development, as separate modules are planned and built in various organizations.

Furthermore, Pimmler and Eppinger (1999) described product modularization as a technique for improving quality and reliability. Following this thought, Nepal et al. (2006) proposed minimization of modularization costs and maximization of overall product quality as the criteria for product modularization. In addition, Perona and Miragliotta (2004) demonstrated that an organization dramatically improves efficiency through modular design and asserted that maintaining complexity requires product modularization.

Second, other studies have examined internal complexity reduction through lean production (Womack et al., 1990; Schonberger, 1983) along with the relationship between lean production and firm performance. Lean production is an integrated system of producing products using minimized costs (Womack et al., 1990; Hopp and Spearman, 2004) and has received attention as a method for organizational performance. Vinodh and Joy (2012) studied various industries and found that lean production enhances manufacturing strength by eliminating wastes, variability, and inventory as well as by improving manufacturing objectives such as cost, quality, flexibility, and environment. Lean production also minimizes processes and reduces process variation and waste to promote financial performance of companies.

Recently, studies have looked at the impacts of other components of internal complexity on firm performance. For example, Bozarth et al. (2009) described internal complexity as the number of products, the number of parts, one-of-a-kind/low-volume batch production, and manufacturing schedule instability. They analyzed its impact on firm performance, including schedule attainment, unit manufacturing cost performance, customer satisfaction, and competitive performance. Empirical analysis of the results showed that internal complexity had a negative impact on all four performance measures. Moreover, manufacturing schedule instability was the only factor that had a significant effect on all four performance measures, and increasing one-of-a-kind/low-volume batch production also significantly increased unit manufacturing cost performance. The numbers of products and parts had no significant effect on firm performance.

To summarize, prior studies on internal complexity have mainly focused on product modularization, lean production, and the effects of complexity on firm performance. Although recent studies have investigated a wider range of the components comprising internal complexity, the field remains largely lacking. There is a need for research that takes a systematic approach to examining the elements of internal complexity and how they influence firm performance.

2.1.3. Downstream Complexity and Firm Performance

Although most prior studies have centered on upstream complexity and internal complexity, recent research has taken great interest in downstream complexity as well. From the customer side of SCM, complexity arises for the following reasons. First, product design and development become increasingly complex to satisfy customer needs. Second, the globalization of production and the customer base forces companies to produce competitive products at more affordable prices. As a result, the range of available products widens, and downstream complexity intensifies (Christopher, 2011). In addition, when companies produce different products to meet the needs of various local markets, the supply chain becomes complex (Sahin et al., 2005).

Most studies have argued that downstream complexity negatively affects performance in general. Bozarth et al. (2009) measured downstream complexity as the number of customers, heterogeneity in customer needs, shorter product life cycles, and demand variability. Their results showed that downstream complexity negatively affects schedule attainment, unit manufacturing cost performance, and customer satisfaction, but does not affect competitive performance. Among the components that make up customer complexity, significantly negative effects were found with heterogeneity in customer needs on unit manufacturing cost as well as with demand variability on schedule attainment, unit manufacturing cost performance, and customer satisfaction.

Vachon and Klassen (2002) classified the extent of the customer base and the geographical span of customers as management system complicatedness, and demand volatility as management system uncertainty. Their study analyzed the effect of those factors on delivery. Delivery was divided into delivery speed and delivery reliability. Delivery speed was further broken down into lead time and throughput time, whereas delivery reliability was divided into late delivery and tardiness. Study results showed that uncertainty in management systems has a significantly negative effect on delivery speed and delivery reliability, and examining the relationship among the elements showed a significantly positive influence of geographical span of customers on tardiness.

In short, existing studies have argued that downstream complexity has gradually risen, negatively affecting firm performance. However, most research has focused on upstream complexity and internal complexity, leaving the relationship between downstream complexity and firm performance largely unexamined.

2.2. Classification by Complexity Form

2.2.1. Organizational Complexity and Firm Performance

According to organizational theory, organizational complexity arises when a large organization comprises numerous subsystems (Lawrence and Lorsch, 1967). Therefore, the level of organizational complexity can be measured as the number of tiers, departmental interactions, and so on (Daft, 1995).

Most scholars examining the relationship between organizational complexity and firm performance have argued that complexity negatively affects firm performance (Simchi-Levy et al., 2000; Vachon and Klassen, 2002). The number of suppliers, a major component of organizational complexity (Beamon, 1998), potentially has a negative effect on organizational performance (De Toni and Nassimbeni, 1999). Other components of organizational complexity, including geographical span of suppliers and the number of echelons in the supply chain, are also found to have a negative effect on firm performance (Lee et al., 1997; Stock et al., 2000).

Wilson and Perumal (2009) presented four major effects of organizational complexity: (i) non-value-added costs and buried assets increase; (ii) performance falters; (iii) information communications become insufficient; and (iv) accountability declines. In contrast, other researchers proposed that organizational complexity has a positive effect on firm performance. Rigby (2009) argued that companies inevitably grow into complex matrix organizations as they expand in size and strive to remain close to their customers. He claimed that with sufficient freedom, overseas or regional business departments can play a key role in maintaining sales during economic recessions.

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 (1999), 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. Narasimhan and Kim (2002) argued that international market diversification uses economies of scales and, as a result, has a positive impact on firm performance. However, diversification leads to logistical costs, trade barriers, cultural diversity, and other high transaction costs that negatively impact firm performance. Based on the study of Geringer et al. (1989), 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.

2.2.2. 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 (MacDuffy et al., 1996; Closs et al., 2008). Stalk (1988) analyzed that reducing the variety of end items by 50% improves productivity by 30% and cuts costs by 17%. Additionally, MacDuffy et al. (1996) claimed that diversity in product portfolio may negatively influence the supply chain. Growing product diversity raises complexity levels in production system as well as forecasting (Fisher et al., 1997), sales (Kotteaku et al., 1995), and production scheduling (Van Donk and van Dam, 1995), and, in the end, it negatively impacts delivery (Brown and Vastag, 1993).

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 (Lancaster, 1979; Kekre and Srinivasan, 1990; Quelch and Kenny, 1994). Quelch and Kenny (1994) 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. Based on the study by Quelch and Kenny, Hardle and Lodish (1994) identified cases in which product extensions improved overall firm performance. In addition, Rigby (2009) 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 (Moorthy, 1984; Robertson and Ulrich, 1998; Perona and Miragliotta, 2004; Thompson et al., 2005). Narasimhan and Kim (2002) established product diversification levels and argued that performance is higher at the intermediate level than at the lower and higher levels. Referencing Itami et al. (1982) and Geringer et al. (1989), they also proposed that product diversification, categorized under product complexity, has an inverted U-shaped relationship with firm performance.

Wilson and Perumal (2009) described the difficulty in determining the right level of product diversity within real business environments. Many companies bring excessively complex products to market because they are concerned about a possible lack of competitive product selection.

Orfi et al. (2011) noted that growing product diversification resulted from organizational needs to satisfy market demands in a global market environment. Product variety refers to diversified product components, functional requirements, and production processes and is pinpointed as the main source of product complexity. While product variety improves company performance by addressing the diverse needs of customers, it has an adverse impact on product development time, productivity, costs, and so on. Consequently, an optimal variety level that maximizes the cost-to-revenue ratio must be determined.

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.

2.2.3. Process Complexity and Firm Performance

Process complexity refers to levels of mechanization, predictability or uncertainty, and systemization (Woodward, 1965; Kotha and Orne, 1989). 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 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. Wilson and Perumal (2009) 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 (e.g., redundant processes and ad hoc handling processes caused by rework) 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, Wilson and Perumal argued that strengthening firm performance entails transforming the organization as well as the products with regard to process complexity.

On the other hand, Rigby (2009) 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 costs 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. Supply Chain Integration

3.1. Definition of Supply Chain Integration

Numerous studies have analyzed the collaborative relationship between manufacturers and suppliers or customers (Mabert and Venkataramanan, 1998; Fawcett and Magnan, 2002). Recently, companies are realizing that they can secure competitive advantage through a mutual integration of partner companies within the supply chain (Horn et al., 2014).

Webster (1966) defined integration as “the unified control of a number of successive or similar economic or especially industrial processes formerly carried on independently.” Pagell (2004) argued that organizational performance weakens when integration is lacking and emphasized the importance of integration among supply chain members (Watts et al., 1992) as well as among internal functions (Watts et al., 1992). Based on the research of Kahn and Mentzer (1998) and O'Leary-Kelly and Vokurka (1998), integration is defined as an interactive and collaborative process wherein manufacturing, purchasing, and logistics work cooperatively to reach mutually acceptable outcomes.

In addition, supply chain integration is defined as the strategic collaboration of the manufacturer with its supply chain partners and the degree of collaborative management in both intra-organizational (i.e., among departments) and inter-organizational (i.e., among buyers, suppliers, and customers) processes (Flynn et al., 2010; Zhao et al., 2011). The goal of supply chain integration is to deliver maximum value to the customer (Morash and Clinton, 1998), using low costs and high speed to ensure an effective and efficient flow of products, services, information, money, and decisions.

The core constructs of supply chain integration include the following (Flynn et al., 2010): (i) strategic collaboration, (ii) intra- and inter-organizational processes that comprehensively encompass a variety of activities, and (iii) maximizing customer value.

3.2. Classification of Supply Chain Integration

3.2.1. Classification according to Dimensions

Despite a consensus among many contemporary scholars that supply chain integration consists of multiple dimensions, earlier studies offered a wide range of suggestions for how supply chain integration is constructed. Previous research has classified supply chain integration using a single dimension (Armistead and Mapes, 1993; Rosenzweig et al., 2003; Marquez et al., 2004), two dimensions (i.e., internal integration and external integration) (Stanley and Wisner, 2001; Pagell, 2004; Petersen et al., 2005; Ragatz et al., 2002), or multiple dimensions (e.g., supplier integration, internal integration, and customer integration) (Stank et al., 2001; Narasimhan and Kim, 2002; Droge et al., 2004; Campbell and Sankaran, 2005; Koufteros et al., 2005; Giménez and Ventura, 2005; Vickery et al., 2003).

First, Rosenzweig et al. (2003) based their study on Frohlich and Westbrook's (2001) research to examine the impact of supply chain integration on competitive capabilities and business performance among consumer products manufacturers. They treated supply chain intensity as a supply chain integration strategy, whereby the intensity of supply chain integration indicates the level of connections among various supply chain elements. Marquez et al. (2004) applied the system dynamics method to analyze the operational and financial effectiveness of e-collaboration in supply chain integration. Results revealed that using Internet tools for supply chain collaboration improves the level of integration. This study took a single-dimensional approach to supply chain integration and sorted it into partial integration or full integration based on demand forecast and inventory information and planning.

Second, some studies took a two-dimensional approach to supply chain integration by dividing it into internal integration and external integration. Stanley and Wisner (2001) contended that purchasing plays a crucial role in internal and external supply chain integration and is the key determinant in successfully transforming raw materials into the final product. Along this line, cooperative buyer–supplier relationships were revealed to have a positive relationship with internal service quality as well as external product and service quality. In contrast, Pagell (2004) emphasized the importance of integrating internal functions. He proposed structure and culture at the plant, reward systems, and formal and informal communication as the factors that enable the integration of key internal supply chain functions, such as purchasing, operations, and logistics.

Third, a number of studies took a three-dimensional approach, classifying supply chain integration into supplier integration, internal integration, and customer integration. According to Narasimhan and Kim (2002), supply chain integration strategy modifies the impact of product diversification and market diversification on business performance. They divided and measured supply chain integration as external integration with suppliers, internal integration across the supply chain, and external integration with customers. Study results showed that different types of supply chain integration along with product diversification and market diversification serve to improve business performance. The authors proposed that for the greatest benefit, firms should have an organizational diversification strategy as well as a supply chain integration strategy.

Campbell and Sankaran (2005) developed a framework capable of promoting supply chain integration among suppliers and resellers, most of which are small and medium enterprises (SMEs). This research defined supply chain integration as the process of developing linkages between intra-organizational bodies or between organizations and their business partners. The study treated supply chain integration as intra-organizational bodies performing independent operations aimed at either internal or external integration. External integration was sorted into backward integration (i.e., upstream supply chain integration) and forward integration (i.e., downstream supply chain integration).

The present study considers supply chain integration along three dimensions. Supply chain integration is mainly divided into internal integration and external integration, and external integration is further divided into supplier integration and customer integration (Narasimhan and Kim, 2002; Flynn et al., 2010; Zhao et al., 2011).

Internal integration represents the collaborative and cooperative intra-organizational efforts to satisfy customer needs and maintain low costs in product design, procurement, production, distribution, and sales (Follett, 1993; Morash et al., 1996). In internal integration, different functional bodies within the organization are treated as part of an integrated process rather than as independent pieces. Internal integration seeks to break down boundaries among intra-organizational bodies and facilitate real-time information exchange (Narasimhan and Carter, 1998; Wisner and Stanley, 1999).

Furthermore, external integration comprises supplier integration and customer integration. Companies form strategic partnerships with suppliers and customers and together develop strategies for responding to market opportunities (Narasimhan and Kim, 2002). Through close interactions with suppliers and customers, external integration creates relation-specific assets and reduces transaction costs to leverage core competencies (Zhao et al., 2008; Flynn et al., 2010).

Supplier integration represents strategic collaborations between an organization and its supplier through information sharing and strategic alliance (Lai et al., 2010), enabling costs reduction and profit sharing (Koufteros et al., 2005). Additionally, customer integration is a strategic action that improves visibility and makes possible joint planning by sharing company information and collaborating with customers (Fisher et al., 1994).

3.2.2. Classification according to Constructs

Although much research has been conducted in the classifications of supply chain integration based on its dimensions and consensus has been reached, research in supply chain integration classification by constructs has yet to be done.

Frohlich and Westbrook (2001) raised the problem that studies have not yet identified the forms in which manufacturers integrate with suppliers and customers. Other scholars (Ho et al., 2002; Chen and Paulraj, 2004) have also criticized that research identifying the constructs of supply chain integration remain largely missing.

Major studies on supply chain integration constructs can be described as follows. Aryee et al. (2008) primarily categorized supply chain integration measurement components into hard issues and soft issues. They presented technology as a hard issue and included Material Requirements Planning (MRP), Enterprise Resource Planning (ERP), and other similar components under this category. Soft issues consist of collaborative relationships between the buyer and the supplier, and they make up a crucial component, similarly to hard issues. Collaborative relationships include characteristics such as trust and risk sharing.

Van der Vaart and van Donk (2008) used an empirical study to classify supply chain integration measurement components as supply chain practices, supply chain patterns, and supply chain attitudes. First, supply chain practices are tangible activities or technologies that play a critical role in the collaboration between a company and its suppliers or its customers. Examples of supply chain practices include Electronic Data Interchange (EDI), integrated production planning, and Vendor Managed Inventory (VMI). Second, supply chain patterns represent the interaction patterns between a company and its suppliers or its customers. The patterns, for example, are regular visits to the supplier’s facility, frequent face-to-face communication, and periodic written evaluation of suppliers.

Lastly, supply chain attitudes refer to attitudes that buyers and suppliers have toward SCM. For example, pursuing long-term relationships with key suppliers or attitudes toward joint problem-solving when problems arise.

Based on van der Vaart and van Donk's (2008) study, Giménez et al. (2012) subdivided the supply chain integration constructs into supply chain practices, supply chain patterns, and supply chain attitudes. Supply chain practices are classified into the integration in physical flows, information exchange, and collaborative activities between the supplier and the key buyer. Integration in physical flows primarily includes activities such as automatic recognition of products shipped to key buyers and the frequency of shipments made to key buyers. Information exchange refers to sharing information including inventory levels and production plans with key buyers. Collaborative activities between a company and its key buyers refers to joint production planning with key buyers and includes activities such as establishing delivery plans together. Supply chain patterns refer to how a supplier communicates with its key buyers and include interactions such as face-to-face communication, EDI, or Internet-based direct computer-to-computer links. Lastly, supply chain attitudes refer to the attitudes with respect to the relationship with key buyers and include long-term relationship building between a supplier and its key buyers and viewing key buyers as an extension of the firm.

Although prior studies identified supply chain integration constructs, their limitations include neglecting to more specifically examining the effect of each construct after dividing supply chain integration into several constructs.

Therefore, building on the studies of van der Vaart and van Donk (2008) and Giménez et al. (2012), this study classifies supply chain integration into supply chain practices, supply chain patterns, and supply chain attitudes. Supply chain practices, again, are subdivided into the integration in physical flows, information exchange, and collaborative activities, while supply chain patterns refer to communication methods, and supply chain attitudes represent long-term relationship building. This study more closely examines the effect of each supply chain integration construct and offers practical implications to corporate leaders.

3.3. Role of Supply Chain Integration

It is becoming increasingly important for organizations to integrate suppliers in supply chain upstream activities and customers in downstream activities (Frohlich and Westbrook, 2001). Such a strategy enables firms to apply supplier knowledge and techniques (Quinn and Hilmer, 1994; Mikkola and Skjoett-Larsen, 2003; Vickery and Droge, 2010) to significantly lower costs (Vickery and Droge, 2010; Koufteros et al., 2012). Therefore, many existing studies have explored the relationship between supplier integration and firm performance (Ragatz et al., 1997; Handfield et al., 2009; Vachon et al., 2009; Wagner and Krause, 2009) or the relationship between customer integration and firm performance (Bhatnagar and Viswanathan, 2000; Heikkila, 2002; Fynes et al., 2005; Sahin and Robinson, 2005).

Study results vary depending on how supply chain integration dimensions and components and firm performance components are treated. For example, Shin et al. (2000) took a single-dimensional approach. They proposed the concept of supply management orientation, identified as long-term supplier–buyer relationships, supplier-involved product development, quality focus in selecting suppliers, and reduced supplier base. Their results showed that supplier management orientation significantly affects supplier and customer performance. Among the performance indicators, delivery and quality performance have a more significant effect than do cost and flexibility outcomes.

Next, Das et al. (2006) divided supplier integration into two dimensions: internal and external. The authors argued that optimal configuration in each dimension can maximize firm performance. This study examined both the positive and negative effects of supplier integration. Supplier integration lowers transaction costs in developing, negotiating, and monitoring and achieves economies of scale and economies of scope to improve firm performance. On the other hand, supplier integration can also reduce performance because of decreased flexibility and costs generated from coordination and compromise. As a result, the study revealed a non-linear relationship in which performance gradually drops as supplier integration efforts move farther away from the optimal point.

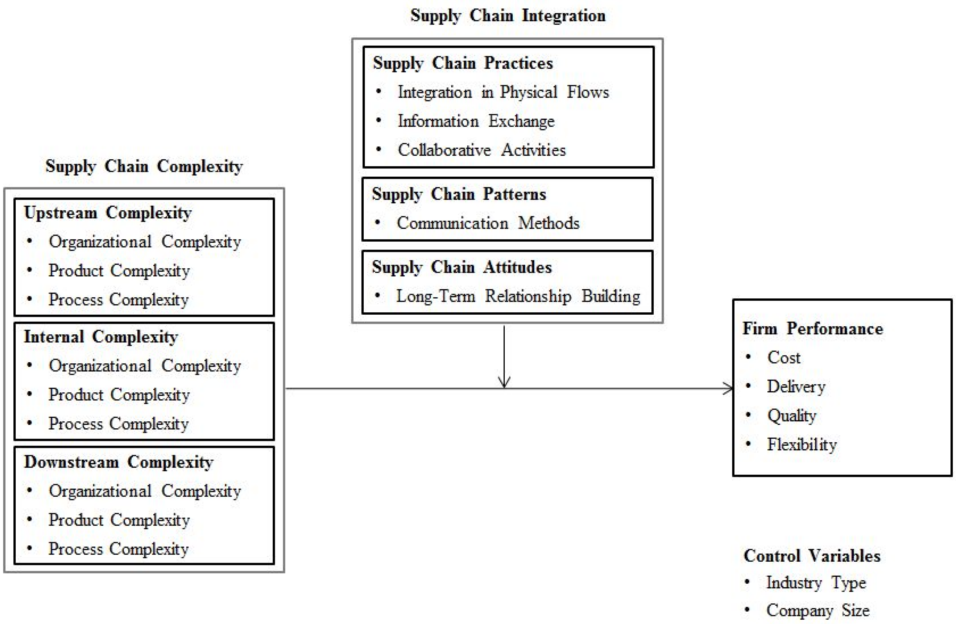
Lastly, some studies have divided supply chain integration into three dimensions and explored their relationship with firm performance. Lee et al. (2007) distinguished supply chain integration as supplier integration, internal integration, and customer integration. They empirically showed that all three integrations positively affect supply chain performance. The study revealed that internal integration has the largest impact on organizational costs containment, and that supplier integration is the best strategy for achieving reliable performance. Similarly to Lee et al. (2007), Flynn et al. (2010) divided supply chain integration into supplier integration, internal integration, and customer integration. Further, they divided performance into operational and business, wherein operational performance includes process efficiency and logistics service performance and business performance includes financial performance and market share. Study results showed that internal integration had a significantly positive effect on both operational and business performances. While customer integration strengthened operational performance, it had no significant effect on business performance. On the other hand, although supplier integration had no significant effect on any of the performance measures, the interaction between supplier integration and customer integration had a significant effect on operational performance.

However, most previous studies that examined the effect of supply chain integration on firm performance failed to account for firm-level contingencies. Sousa and Voss (2008) underscored the context of operational management and emphasized a need for a contingency theory. Ho et al. (2002) criticized that previous studies on SCM failed to take context into consideration. Although most prior studies claimed that supply chain integration has a positive effect on firm performance (Shin et al., 2000; Lee et al., 2007; Flynn et al., 2010), Das et al. (2006) argued that once supplier integration reaches a certain threshold value, it no longer has a positive effect on firm performance. These mixed conclusions may stem from earlier studies not accounting for firm-level contingencies. Germain et al. (2008) argued that in the context of internal coordination, integration is effective with high demand variability but is ineffective with low variability. They found that with low demand variability, official control (documented rules and procedures) is more appropriate than integration. Therefore, this study treats supply chain complexity as a primary contingency surrounding a firm, and investigates the relationships among supply chain complexity, supply chain integration, and firm performance.

III. Research Model and Hypotheses

1. Conceptual Research Model

The following conceptual research model has been constructed based on the discussions in earlier sections.



[Figure 1] Research Model

This study largely consists of two parts. The first part examines the impact of supply chain complexity on firm performance, and the second part analyzes the moderating effect of supply chain integration on the relationship between supply chain complexity and firm performance.

Supply chain complexity is broken down into three levels: upstream complexity, internal complexity, and downstream complexity. Each complexity level is further divided into three categories: organizational complexity, product complexity, and process complexity. Firm performance is broken down into cost, delivery, quality, and flexibility. Lastly, supply chain integration is divided into supply chain practices, supply chain patterns, and supply chain attitudes. Supply chain practices are composed of the integration in physical flows, information exchange, and collaborative activities. Supply chain patterns refer to communication methods, and supply chain attitudes refer to long-term relationship building.

2. Hypotheses

2.1. Relationship between Supply Chain Complexity and Firm Performance

Most previous research examining the relationship between supply chain complexity and firm performance has focused on their negative relationship. Frizelle and Woodcock (1995) argued that lead time increases and reliability decreases as supply chain complexity increases. Bozarth et al. (2009) suggested, in detail, the negative impact of supply chain complexity on firm performance.

Perona et al. (2001) empirically analyzed that high-performing firms had less complex supply chains than the industry average. Vachon and Klassen (2002) 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 (2009) 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. Wilson and Perumal (2009) contended that process complexity up to a certain level produces added value, but surpassing that threshold results in non-value-added effects.

Narasimhan and Kim (2002) argued that supply chain complexity and firm performance have an inverted U-shaped relationship. Although they did not use the term *supply chain complexity*, they examined international market diversification (i.e., organizational complexity) and product diversification (i.e., product complexity). Based on studies by Itami et al. (1982) and Geringer et al. (1989), 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: Supply chain complexity and firm performance will have an inverted U-shaped relationship.

H1a: Supply chain complexity and cost will have an inverted U-shaped relationship.

H1b: Supply chain complexity and delivery will have an inverted U-shaped relationship.

H1c: Supply chain complexity and quality will have an inverted U-shaped relationship.

H1d: Supply chain complexity and flexibility will have an inverted U-shaped relationship.

2.2. Moderating Effect of Supply Chain Integration

Supply chain integration improves firm performance by building a collaborative relationship between a firm and its partners within the supply chain (Fawcett and Magnan, 2002; Pagell, 2004). A company integrates with its suppliers and leverages their knowledge and skills to improve corporate performance (Quinn and Hilmet, 1994; Mikkola and Skioett-Larson, 2003; Vickery and Droge, 2010). In addition, a company integrates with its customers and shares information to enhance visibility and boost corporate performance (Bhatnagar and Viswanathan, 2000; Heikkila, 2002; Fynes et al., 2005; Sahin and Robinson, 2005).

According to a study by Shin et al. (2000), while supply chain integration positively influences firm performance, among performance factors, delivery and product were shown to have more significant impact than cost and flexibility. Das et al. (2006) argued that supply chain integration reduces development, negotiation, observation, and other transaction costs and promotes firm performance through economies of scale and economies of scope. Lee et al. (2007) showed that internal integration had a large impact on cost reduction, whereas supplier integration had a large impact on reliable supply chain performance. Flynn et al. (2010) found a positive effect of internal integration on both operational performance and firm performance and customer integration on operational performance. Although supplier integration did not have a significant effect on any performance indicators, an interaction with customer integration had a positive impact on operational performance.

Furthermore, Serdarasan (2013) argued supply chain integration as the solution to reducing adverse effects of supply chain complexity on firm performance. He contended that supply chain integration enables managing complexity drivers, such as lack of control due to outsourcing and unpredictable order patterns. According to van der Vaart and van Donk (2008) and Giménez et al. (2012), supply chain integration constructs include supply chain practices, supply chain patterns, and supply chain attitudes. Supply chain practices are divided into the integration in physical flows, information exchange, and collaborative activities between the supplier and the key buyer. Supply chain patterns refer to how the supplier communicates with its key buyers and supply chain attitudes represent attitudes with respect to the relationship with the key buyer or supplier.

Based on the arguments above, this study treats supply chain integration as a moderating factor in the relationship between supply chain complexity and firm performance and proposes the following hypotheses.

H2: Supply chain practices will positively moderate the relationship between supply chain complexity and firm performance.

H2a: Supply chain practices will positively moderate the relationship between supply chain complexity and cost.

H2b: Supply chain practices will positively moderate the relationship between supply chain complexity and delivery.

H2c: Supply chain practices will positively moderate the relationship between supply chain complexity and quality.

H2d: Supply chain practices will positively moderate the relationship between supply chain complexity and flexibility.

H3: Supply chain patterns will positively moderate the relationship between supply chain complexity and firm performance.

H3a: Supply chain patterns will positively moderate the relationship between supply chain complexity and cost.

H3b: Supply chain patterns will positively moderate the relationship between supply chain complexity and delivery.

H3c: Supply chain patterns will positively moderate the relationship between supply chain complexity and quality.

H3d: Supply chain patterns will positively moderate the relationship between supply chain complexity and flexibility.

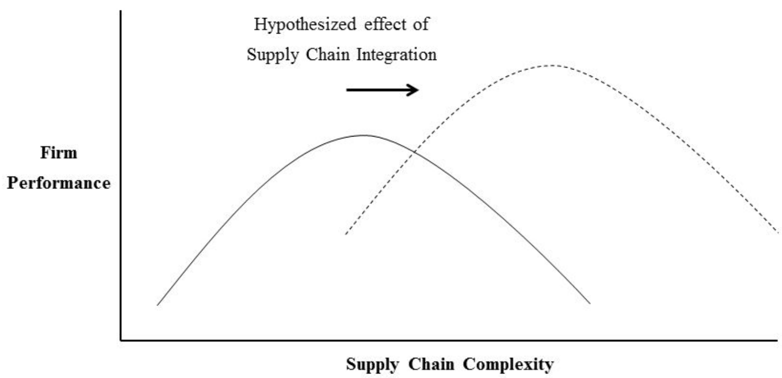
H4: Supply chain attitudes will positively moderate the relationship between supply chain complexity and firm performance.

H4a: Supply chain attitudes will positively moderate the relationship between supply chain complexity and cost.

H4b: Supply chain attitudes will positively moderate the relationship between supply chain complexity and delivery.

H4c: Supply chain attitudes will positively moderate the relationship between supply chain complexity and quality.

H4d: Supply chain attitudes will positively moderate the relationship between supply chain complexity and flexibility.



[Figure 2] Hypothesized Effect of Supply Chain Integration

3. Operational Definition and Measurement of the Constructs

This study uses measurement indicators that have been proven reliable and valid in prior studies. All measurement items use the 7-point Likert scale for respondent answers, in which 1 represents "strongly disagree," 2 represents "disagree," 3 "somewhat disagree," 4 "neutral," 5 "somewhat agree," 6 "agree," and 7 "strongly agree."

Supply chain complexity represents structural properties and interactions among constructs such as the number of suppliers, the number of customers, and product diversity (Vachon and Klassen, 2002; Bozarth et al., 2009). This study organizes and measures supply chain complexity using a 3×3 matrix by origin and form based on the review of existing literature. Supply chain complexity is classified as upstream complexity, internal complexity, and downstream complexity based on its origin, then as organizational complexity, product complexity, and process complexity based on its form.

Upstream complexity involves a firm's suppliers, internal complexity involves a firm's systems, and downstream complexity involves a firm's customers (Bozarth et al., 2009; Isik, 2010). Organizational complexity refers to the number of facilities, asset amount, and the number of internal systems, among others (Jablin, 1987). Product complexity refers to the diversity of products available to customers (Orfi et al., 2011). Finally, process complexity refers to the number of business processes and contact points in business activities involved in providing and supporting company products (Cardoso, 2008).

[Table 2] Measurement Items of Supply Chain Complexity

Construct	Organization	Product	Process
Upstream Complexity	Number of Suppliers Number of Tiers in the Supply Chain	Number of Parts	Supplier Lead Time Compatibility of IT Systems among Suppliers Diversity among Departmental Contact Points
Internal Complexity	Hierarchy of Structures Number of Branches	Number of Products Number of Product Functions	Number of Production Processes Differentiation of IT Systems across Departments
Down stream Complexity	Number of Customers Number of Global Markets Served	Product Life Cycle Changing Needs of Customers	Number of Sales Channels

In addition, supply chain integration describes the degree to which the manufacturer strategically collaborates with supply chain partners and collaboratively manages intra- and inter-organizational processes (Flynn et al., 2010; Zhao et al., 2011). Based on the existing literature on supply chain integration, this study classifies supply chain integration, depending on its dimension, into supplier integration, internal integration, and customer integration. These categories are further divided, depending on their constructs, into the integration in physical flows, information exchange, collaborative activities, communication methods, and long-term relationship building. Lastly, firm performance was divided into cost, delivery, quality, and flexibility. Each measurement item is explained in appendix.

IV. Empirical Analysis of Research Model

1. Data Collection

1.1. Survey Subjects

The purpose of this study is to examine the impact of supply chain complexity on firm performance and to analyze the moderating effect of supply chain integration on the relationship between supply chain complexity and firm performance. Toward this aim, 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.

1.2. Survey Methods

A survey was used as the research method. To ensure accuracy, a professional research firm was employed to conduct the surveys. To improve content validity, the survey was pre-tested prior to carrying out the full-scale study.

Through pre-test responses, each respondent was asked to identify questions that require modification. Based on this pre-test, expansive general questions were made more specific, and complex questions were broken down and modified.

The study largely divided the industries into consumer-goods, heavy machinery, and assembly, and extracted a sample from each industry. Among the selected companies, 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 (Frohlich, 2002). The survey lasted for a month, from September 29 to October 28 in 2014. A total of 1,854 companies were contacted to participate, of which 594 gave consent and 181 actually completed the survey, resulting in a 9.8% response rate based on the number of companies contacted by telephone and a 30.5% response rate based on the number of questionnaires distributed, which is comparable to other operations management studies. Malhotra and Grover (1998) recommended that response rate might be over 20% in production and operations research. Among the respondents, 9 companies were excluded from the analysis because of numerous missing values. Analysis was carried out based on the remaining 172 responses.

1.3. Sample Characteristics

Companies that responded to the survey represent 15 of the industries listed in the 9th Korea Standard Industry Code (KSIC). Firm size was evenly distributed across large corporations and SMEs. Diversity in the sample increases the external validity of the study.

[Table 3] organizes sample characteristics by industry type. Following the design of the survey, the sample was evenly obtained from the consumer-goods industry (30.8%), the heavy machinery industry (33.7%), and the assembly industry (35.5%). Specifically, the electronic components, computer, imaging, sound, and telecommunication equipment manufacturing industry had the largest representation, with 23 companies (13.4%), and the medical, precision, and optical instruments and watch making industry had the second-largest representation, with 20 companies (11.6%).

[Table 3] Industry Composition of the Sample

(Unit: Count, %)

Industry		Frequency	Ratio	
Consumer-Goods Industries	Food manufacturing	17	9.9	30.8
	Textile manufacturing: Apparel excluded	5	2.9	
	Apparel, clothing accessories and fur clothing manufacturing	4	2.3	
	Leather, bag, and shoes manufacturing	9	5.2	
	Wood and wooden products manufacturing : Furniture excluded	12	7.0	

	Medicinal chemicals and pharmaceutical products manufacturing	6	3.5	
Heavy Machinery Industries	Rubber and plastic products manufacturing	9	5.2	33.7
	Primary metal manufacturing	8	4.7	
	Metal products manufacturing : Machinery and furniture excluded	13	7.6	
	Electrical equipment manufacturing	8	4.7	
	Other machinery and equipment manufacturing	16	9.3	
	Other transportation equipment manufacturing	4	2.3	
Assembly Industries	Electronic components, computer, imaging, sound, and telecommunication equipment manufacturing	23	13.4	35.5
	Medical, precision, and optical instruments and watchmaking	20	11.6	
	Automobile and trailer manufacturing	18	10.5	
Total		172	100.0	100.0

[Table 4] organizes the sample by company size. In sales, the 500 billion to 1 trillion Korean won category was the largest group, with 43 companies (25.0%), and the 50 billion to 100 billion Korean won category was the second largest, with 37 companies (21.5%). In terms of the number of employees, the 500–1,000 category contained the highest number, with 52 companies (30.2%), and the 1,000–5,000 category contained the second-highest number, with 38 companies (22.1%).

[Table 4] Organization of the Sample by Size

(Unit: Count, %)

Category		Frequency	Ratio
Sales	Over 1 trillion	30	17.4
	500 billion–1 trillion	43	25.0
	100 billion–500 billion	29	16.9
	50 billion–100 billion	37	21.5
	10 billion–50 billion	8	4.7
	Less than 10 billion	25	14.5
	Total	172	100.0
Number of Employees	Over 5,000	24	14.0
	1,000–5,000	38	22.1
	500–1,000	52	30.2
	300–500	27	15.7
	Less than 300	31	18.0
	Total	172	100.0

To ensure that the sample was representative of the population, a comparison was made with the distribution of the population by industry and size based on data of domestic manufacturing companies from the Statistics Bureau. First, a chi-square test for distribution across industries showed that the difference between the sample and the population was not statistically significant ($\chi^2 = 15.523$, df = 16, $p > 0.10$). Next, a chi-square test on distribution by size showed that the difference between the sample and the population was not statistically significant ($\chi^2 = 3.094$, df = 4, $p > 0.10$). Therefore, because the difference between the sample and the population was not significant across industry and size, the sample adequately represents the population.

In addition, survey-based empirical research must deal with or correct for nonresponse bias. To test for nonresponse bias, this study used an approach akin to the one used by Armstrong and Overton (1977), wherein the survey responses are divided into two groups depending on the time of the survey, and differences in the mean values on each questionnaire item were compared between the groups. The 69 responses received within one week after the survey request went out comprise the early response group, and the 103 responses received a week after the survey request went out comprise the late response group. T-test results for the questionnaire items showed no significant differences between the mean values. Therefore, the data used in this study does not contain nonresponse bias.

Lastly, common method bias may exist in this study because survey responses came from one respondent per company. According to Harmon's single-factor test, when common method bias exists, non-rotated exploratory factor analysis (EFA) results show all the questionnaire items as bound to a single factor or a particular factor accounting for most of the total variance (Podsakoff et al., 2003). Results of EFA for all measured variables in this study indicated that 12 factors with an eigenvalue greater than 1.0 explained 78.2% of the total variance. Based on non-rotated results, the first factor explained 16.3% of the total variance. According to Flynn et al. (2010), this is a generally acceptable level for studies with correlations among the constructs. Therefore, the data used in this study are assumed to be free from common method bias.

[Table 5] Results of Factor Analysis and Factor Names

Construct (Name)		Factor (Name)	Factor Loading
Upstream Complexity (UC)	Organizational Complexity (OC)	Number of suppliers (NS)	.808
		Number of tiers in the supply chain (NTSC)	.764
	Product Complexity (PC)	Number of parts (NP)	.826
	Process Complexity (P_C)	Supplier lead time (SLT)	.793
		Compatibility of IT systems among suppliers (CITSS)	.710
		Diversity among departmental contact points (DDCP)	.751
Internal Complexity (IC)	Organizational Complexity (OC)	Hierarchy of structures (HS)	.684
		Number of branches (NB)	.611
	Product Complexity (PC)	Number of products (N_P)	.779
		Number of product functions (NPF)	.668
	Process Complexity (P_C)	Number of production processes (NPP)	.648
		Differentiation of IT systems across departments (DITSD)	.751
Down-stream Complexity (DC)	Organizational Complexity (OC)	Number of customers (NC)	.683
		Number of global markets served (NGMS)	682
	Product Complexity (PC)	Product life cycle (PLC)	.710
		Changing needs of customers (CNC)	.678
	Process Complexity (P_C)	Number of sales channels (NSC)	.786
Supply Chain Integration	Integration in Physical Flows (IPF)	Automatic recognition (AR)	.831
		Fast delivery (FD)	.816
		Frequent delivery (F_D)	.715

Practices (SCIP)	Information Exchange (IE)	IT usage (ITU)	.747
		Exchange of production schedule information (EPSI)	.676
		Exchange of inventory information (EII)	.786
	Collaborative Activities (CA)	Quality improvement (QI)	.713
		Process improvement (PI)	.579
		Commitment to common goals (CCG)	.753
Supply Chain Integration Patterns (SCI_P)	Communi cation Methods (CM)	Communication face-to-face (CFF)	.791
		Communication via email (CE)	.698
		Computer-based communication (CBC)	.703
Supply Chain Integration Attitudes (SCIA)	Long-Term Relationship Building (LTRB)	Effort in a long-term relationship (ELTR)	.676
		Portion of the company (PC)	.780
		Long-term process improvement (LTPI)	.565
Cost (C)		Order-management cost (OMC)	.791
		Production cost (PC)	.758
		Inventory cost (IC)	.679
		Distribution cost (DC)	.758
Delivery (D)		Delivery accuracy (DA)	.701
		Timely delivery (TD)	.728
		Inventory guarantee (IG)	.570
		Delivery speed (DS)	.670
Quality (Q)		Production over defect ratio (PDR)	.715
		Sales volume over rework ratio (SVRR)	.854
		Overall quality (OQ)	.693
Flexibility (F)		Ability to respond to delivery (ARD)	.642
		Ability to respond to special orders (ARSO)	.684
		New products launching duration (NPLD)	.708
		Amount of new products launched (ANPL)	.745

2. Analytical Methods

2.1. Measurement Model Assessment Methods

In order to evaluate the measurement model prior to testing the research model, Amos 18.0 was used to run a confirmatory factor analysis (CFA). This study broadly investigated previous studies and identified each construct with proven reliability and validity. Furthermore, a CFA was used to test whether the measured items, which are observed variables, appropriately constitute the latent variables.

2.2. Research Model Hypotheses Testing Methods

To test the research model, SPSS 18.0 was used to run hierarchical regression analyses. Unlike multiple regression analysis, hierarchical regression analysis enables researchers to set the order of the independent variables based on theoretical rationale. The analysis is also appropriate for hypothesis testing studies that determine the relative effect of the independent variables. Therefore, hierarchical regression analysis was deemed suitable for hypotheses testing in this study.

Analysis was done in the order of control variables, independent variables, moderating variables, and interaction variables (Cohen et al., 2003). However, because many variables have correlations, problems of multi-collinearity may result. 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 (Hair et al., 2006). Therefore, in order to address the problem of multi-collinearity, all the independent and moderating variables were centered on the mean (Rawlings et al., 1998).

3. Measurement Model Assessment

To check for normality in the observed data, the cumulative probability was drawn on a normal distribution curve. The results show that none of the variables departs significantly from the normal distribution. Prior to hypotheses testing, the validity and the reliability of the measured constructs were assessed.

3.1. Validity Assessment

Before analyzing the hypotheses test, the validity and reliability of the measured constructs were examined. Validity refers to whether the observed variables measured the intended concept of the latent variables. Among them, construct validity is the most general and encompasses three other validity types (Bae, 2013). In addition, content validity and criterion-related validity are conceptually abstract and difficult to actually measure, whereas construct validity can be operationalized, and must, therefore, be assessed in social sciences research (Lee, 2001).

Convergent validity, discriminant validity, and nomological validity must be determined in order to evaluate construct validity. Convergent validity is related to indicators that show the extent of correspondence or convergence among variables that measure the same or similar constructs. Discriminant validity is related to indicators that show dissimilarity among variables that measure unrelated constructs. Nomological validity refers to the indication that the structural relationships among theoretical constructs are consistent with the direction of the actual measurements.

First, in order to assess convergent validity, confirmatory factor analysis, as proposed by O'Leary-Kelly and Vokurka (1998), was performed. The measurement variables were linked to a set of intended latent variables, and the measurement model was set to estimate the covariance between the latent variables. If the goodness-of-fit measures fall within the following statistics, $\chi^2 < 3.0$, Goodness of Fit Index (GFI) > 0.90, Tucker-Lewis Index (TLI) > 0.90, Comparative Fit Index (CFI) > 0.90, Root Mean Square Error of Approximation (RMSEA) < 0.08, Standardized Root Mean Square Residual (SRMR) < 0.08, then the overall model is deemed satisfactory (Hair et al., 2010; Cao and Zhang, 2011). The goodness-of-fit indices for the measurement model in this study were found to be $\chi^2 = 1.680$, GFI = 0.936, TLI = 0.949, CFI = 0.963, RMSEA = 0.060, SRMR = 0.064. This demonstrates that the model fits the data well and confirms convergent validity.

Convergent validity is evaluated by the following three methods (Hair et al., 2006). First, the factor loading must be at least 0.5, though ideally over 0.7, and must be statistically significant. Convergent validity testing showed a factor loading above 0.7 and statistical significance (Anderson and Gerbing, 1988). Squared multiple correlation (SMC), the verification measure for the sum of the squared factor loadings known as communality, shows how much a factor explains an item. Analysis results showed that all were over 0.5. More than half of the factor loadings can be explained by the observed items. Therefore, the constructs have been determined to have convergent validity.

Second, convergent validity requires the average variance extracted (AVE) value to be above 0.5 (Bagozzi and Yi, 1988). Calculation results from the AVE method as introduced by Hair et al. (2006) show that all the constructs have an AVE value over 0.5 and, therefore, indicates convergent validity.

Third, convergent validity requires construct reliability (CR) to be above 0.7 (Bagozzi and Yi, 1988). CR calculations based on the formula introduced by Fornell and Larcker (1981) showed that the CR values for all the constructs were higher than 0.7, thus indicating convergent validity of the constructs.

[Table 6] Convergent Validity of the Constructs

Construct		Mean	Std. Dev.	Cronbach's α	AVE	CR
UC		4.480	1.154	.917	.812	.963
IC		4.256	1.074	.871	.621	.907
DC		3.983	1.338	.897	.634	.896
SCIP	IPF	4.448	.797	.809	.669	.858
	IE	4.307	1.038	.820	.654	.850
	CA	4.475	.668	.773	.656	.915
SCI_P	CM	5.104	1.317	.872	.729	.833
SCIA	LTRB	4.428	.882	.885	.625	.889
C		3.904	1.013	.766	.709	.906
D		4.920	.963	.852	.682	.894
Q		4.781	.865	.803	.793	.920
F		4.455	1.121	.752	.694	.914

Discriminant validity is assessed by examining whether the AVE value is higher than the square of the correlation coefficient between the constructs (φ^2) (Fornell and Larcker, 1981). Analysis results showed that all AVE values were higher than the square of the correlation coefficient between the constructs (φ^2), thus confirming discriminant validity of the constructs.

[Table 7] Discriminant Validity of the Constructs

Construct	AVE	φ	φ²
UC , IC	UC = .812, IC = .621	.470	.221
UC , DC	UC = .812, DC = .634	.501	.251
UC , IPF	UC = .812, IPF = .669	.221	.049
UC, IE	UC = .812, IE = .654	.252	.064

UC, CA	UC = .812, CA = .656	.231	.053
UC, CM	UC = .812, CM = .729	.246	.061
UC, LTRB	UC = .812, LTRB = .625	-.214	.046
UC, C	UC = .812, C = .709	.291	.085
UC, D	UC = .812, D = .682	.269	.072
UC, Q	UC = .812, Q = .793	-.283	.080
UC, F	UC = .812, F = .694	.220	.048
IC, DC	IC = .621, DC = .634	.510	.260
IC, IPF	IC = .621, IPF = .669	.382	.146
IC, IE	IC = .621, IE = .654	.416	.173
IC, CA	IC = .621, CA = .656	.142	.020
IC, CM	IC = .621, CM = .729	-.413	.171
IC, LTRB	IC = .621, LTRB = .625	-.366	.134
IC, C	IC = .621, C = .709	.144	.021
IC, D	IC = .621, D = .682	.116	.013
IC, Q	IC = .621, Q = .793	.156	.024
IC, F	IC = .621, F = .694	.123	.015
DC, IPF	DC = .634, IPF = .669	-.368	.135
DC, IE	DC = .634, IE = .654	.431	.186
DC, CA	DC = .634, CA = .656	.312	.097
DC, CM	DC = .634, CM = .729	-.412	.170
DC, LTRB	DC = .634, LTRB = .625	.308	.095
DC, C	DC = .634, C = .709	.277	.077

DC, D	DC = .634, D = .682	.188	.035
DC, Q	DC = .634, Q = .793	.184	.034
DC, F	DC = .634, F = .694	.242	.059
IPF, IE	IPF = .669, IE = .654	.455	.207
IPF, CA	IPF = .669, CA = .656	.352	.124
IPF, CM	IPF = .669, CM = .729	.412	.170
IPF, LTRB	IPF = .669, LTRB = .625	.439	.193
IPF, C	IPF = .669, C = .709	.236	.056
IPF, D	IPF = .669, D = .682	.219	.048
IPF, Q	IPF = .669, Q = .793	.210	.044
IPF, F	IPF = .669, F = .694	.139	.019
IE, CA	IE = .654, CA = .656	.370	.137
IE, CM	IE = .654, CM = .729	.441	.194
IE, LTRB	IE = .654, LTRB = .625	.259	.067
IE, C	IE = .654, C = .709	.236	.056
IE, D	IE = .654, D = .682	.452	.204
IE, Q	IE = .654, Q = .793	.206	.042
IE, F	IE = .654, F = .694	.154	.024
CA, CM	CA = .656, CM = .729	.429	.184
CA, LTRB	CA = .656, LTRB = .625	.259	.067
CA, C	CA = .656, C = .709	.472	.223
CA, D	CA = .656, D = .682	.465	.216
CA, Q	CA = .656, Q = .793	.402	.162

CA, F	CA = .656, F = .694	.463	.214
CM, LTRB	CM = .729, LTRB = .625	.452	.204
CM, C	CM = .729, C = .709	.279	.078
CM, D	CM = .729, D = .682	.144	.021
CM, Q	CM = .729, Q = .793	.214	.046
CM, F	CM = .729, F = .694	.163	.027
LTRB, C	LTRB = .625, C = .709	.179	.032
LTRB, D	LTRB = .625, D = .682	.328	.108
LTRB, Q	LTRB = .625, Q = .793	.153	.023
LTRB, F	LTRB = .625, F = .694	.134	.018
C, D	C = .709, D = .682	.515	.265
C, Q	C = .709, Q = .793	.527	.278
C, F	C = .709, F = .694	.453	.205
D, Q	D = .682, Q = .793	.612	.375
D, F	D = .682, F = .694	.597	.356
Q, F	Q = .793, F = .694	.610	.372

Lastly, nomological validity is assessed by examining the consistency among the direction of the researcher's hypotheses and evidence obtained from observed data. Analysis results showed consistency between the directions of the correlation coefficient among the constructs obtained from observed data and the direction of the hypotheses. Therefore, the constructs are confirmed to be nomologically valid.

3.2. Reliability Assessment

Reliability means measurement consistency, and a highly reliable measure is not subject to great impact from random error. The types of reliability includes test-retest reliability, interrater reliability, split-half reliability, and internal consistency reliability. Among them, internal consistency reliability is the most commonly used (Bae, 2013).

To test for reliability, Cronbach's α, CR, and AVE must be examined. Cronbach's α above 0.7 secures adequate reliability, but in an exploratory study, the α value must be above 0.6 (Nunally, 1978). Analysis results show that all the constructs have a Cronbach's α value greater than 0.7. Furthermore, AVE must be above 0.5 and CR must be above 0.7 to confirm construct reliability (Bagozzi and Yi, 1988). [Table 6] shows that all the constructs met this requirement.

4. Research Model Hypotheses Testing

This study carried out hierarchical regression analysis to analyze the relationship between supply chain complexity and firm performance and the impact of supply chain integration on the relationship between supply chain complexity and firm performance. Analysis was performed in the order of control variables, independent variables, moderating variables, and interaction variables (Cohen et al., 2003). Independent variables and moderating variables were centered on the mean to avoid problems with multi-collinearity (Rawlings et al., 1998). Industry type and company size, factors that may affect firm performance, were set as the control variables.

4.1. Moderating Effect of Supply Chain Integration on the Relationship between Upstream Complexity and Firm Performance

After testing for linearity and nonlinearity in the relationships between upstream complexity and firm performance, including cost, delivery, quality, and flexibility, the impact of upstream complexity on firm performance and the moderating effect of supply chain integration were analyzed.

First, the inverted U-shaped relationship between upstream complexity and cost was tested. [Table 8] shows the analysis results for the linear and the nonlinear model for the effect of upstream complexity on cost. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was no difference in the R^2 values of the two models, and the b2 value was very small. Moreover, the scatter plots showed that the first model was more appropriate than the second model. Therefore, upstream complexity and cost were found to have a linear relationship.

[Table 8] Model Statistics and Parameter Estimates for Upstream Complexity and Cost

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.170	34.715	1	170	.000	5.523***	-.362***	
Second Model	.170	17.258	2	169	.000	5.566	-.382***	-.002***

* p<0.10, ** p<0.05, *** p<0.01

[Table 9] shows the hierarchical regression analysis results for the main effect of upstream complexity on cost as well as the moderating effect of supply chain integration. The main effect of upstream complexity on cost was found to be negative (β = −0.404, p<0.01). In addition, the relationship between upstream complexity and cost was found to be moderated by the integration in physical flows (β = −0.587, p<0.05) and information exchange (β = −0.916, p<0.01). The negative relationship between upstream complexity and cost was observed to weaken as the integration in physical flows and information exchange became more active. In other words, taking supply chain integration into consideration, the integration in physical flows and information exchange, under supply chain practices, were found to moderate the relationship between upstream complexity and cost.

[Table 9] Moderating Effect of Supply Chain Integration on Upstream Complexity and Cost

Variable	Cost		
	I	II	III
UC	-.404***	-.317**	-.330***
IPF		.619*	.453
IE		.390***	.378
CA		.309***	.345***
CM		.145	.301
LTRB		.302***	.330
UC x IPF			-.587**
UC x IE			-.916***
UC x CA			-.108
UC x CM			-.356
UC x LTRB			-.079
R^2	.182	.324	.359
F	12.461***	9.771***	6.822***
ΔR^2		.142	.035

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Second, the inverted U-shaped relationship between upstream complexity and delivery was tested. [Table 10] shows the analysis results for the linear and the nonlinear model for the effect of upstream complexity on delivery. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was a minor difference between the R^2 values of the two models, and the b2 value was very small. Moreover, the scatter plots showed that the first model was more appropriate than the second model. Therefore, upstream complexity and delivery were found to have a linear relationship.

[Table 10] Model Statistics and Parameter Estimates for Upstream Complexity and Delivery

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.311	76.690	1	170	.000	6.911***	-.471***	
Second Model	.312	41.691	2	169	.000	5.646	.137***	-.018***

* p<0.10, ** p<0.05, *** p<0.01

[Table 11] shows the hierarchical regression analysis results for the main effect of upstream complexity on delivery as well as the moderating effect of supply chain integration. The main effect of upstream complexity on delivery was found to be negative (β = −0.555, p<0.01). In addition, the relationship between upstream complexity and delivery was found to be moderated by information exchange (β = −0.656, p<0.05) and collaborative activities (β = −0.184, p<0.05). The negative relationship between upstream complexity and delivery was observed to weaken as information exchange and collaborative activities became more active. In other words, taking supply chain integration into consideration, information exchange and collaborative activities, under supply chain practices, were found to moderate the relationship between upstream complexity and delivery.

[Table 11] Moderating Effect of Supply Chain Integration on Upstream Complexity and Delivery

Variable	Delivery		
	I	II	III
UC	-.555***	-.457***	-.455*
IPF		.213	.055
IE		.443*	.442*
CA		.382***	.340***
CM		.435**	.575***
LTRB		.163	.090
UC x IPF			-.541
UC x IE			-.656**
UC x CA			-.184**
UC x CM			-.311
UC x LTRB			-.150
R^2	.316	.429	.481
F	25.878***	15.307***	11.250***
ΔR^2		.113	.052

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Third, the inverted U-shaped relationship between upstream complexity and quality was tested. [Table 12] shows the analysis results for the linear and the nonlinear model for the effect of upstream complexity on quality. The first model was not found to be statistically significant at the 90% confidence level, whereas the second model was found to be statistically significant at the 95% confidence level. However, the difference between the R^2 values of the two models was not small, and the R^2 value for the second model was less than the determination coefficient of 0.13, as suggested by Cohen (1988) for social sciences research. Nonetheless, it was larger than the minimum coefficient of 0.02. Additionally, the scatter plots showed the second model to be more appropriate than the linear model. This indicates an inverted U-shaped relationship between upstream complexity and quality.

Furthermore, differentiating the quality with respect to upstream complexity and determining the point at which the value is zero on the second model yielded a maximum value of approximately 4.622. Although increasing upstream complexity improved quality up to this maximum value, any increase beyond this point reduced quality. Thus, a company achieves the highest quality when upstream complexity falls near 4.622 on a 7-point Likert scale.

[Table 12] Model Statistics and Parameter Estimates for Upstream Complexity and Quality

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.006	1.052	1	170	.306	4.173	-.047	
Second Model	.038	3.364	2	169	.037	2.920	.684**	-.074**

* p<0.10, ** p<0.05, *** p<0.01

[Table 13] shows the hierarchical regression analysis results for the main effect of upstream complexity on quality and the moderating effect of supply chain integration. With regard to the main effect of upstream complexity on quality, upstream complexity had a positive effect on quality (β = 0.982, $p<0.05$), whereas upstream complexity squared had a negative effect (β = −0.916, $p<0.10$). These results indicate an inverted U-shaped relationship between upstream complexity and quality. Additionally, the relationship between upstream complexity and quality was found be moderated by communication methods (β = −3.918, $p<0.10$ and β = 4.477, $p<0.05$). The inverted U-shaped relationship between upstream complexity and quality was observed to move upward and to the right as communication methods became more diverse. In other words, taking supply chain integration into consideration, communication methods, under supply chain patterns, was found to moderate the relationship between upstream complexity and quality.

[Table 13] Moderating Effect of Supply Chain Integration on Upstream Complexity and Quality

Variable	Quality		
	I	II	III
UC	.982**	.764*	1.137**
UC^2	-.916*	-.794*	-1.179**
IPF		.419	.434
IE		.075	.134
CA		.365***	.393***
CM		.121	.013
LTRB		.186	.249
UC x IPF			-1.301
UC x IE			-2.200

UC x CA			-.114
UC x CM			-3.918*
UC x LTRB			-.518
UC^2 x IPF			1.277
UC^2 x IE			2.802
UC^2 x CA			.111
UC^2 x CM			4.477**
UC^2 x LTRB			.394
R^2	.053	.196	.269
F	2.346*	4.382***	2.947***
ΔR^2		.143	.073

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* p<0.10, ** p<0.05, *** p<0.01

Fourth, the inverted U-shaped relationship between upstream complexity and flexibility was tested. [Table 14] shows the analysis results for the linear and the nonlinear model for the effect of upstream complexity on flexibility. 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 (1988) for social sciences research. Additionally, the scatter plots showed the second model to be more appropriate than the linear model. This indicates an inverted U-shaped relationship between upstream complexity and flexibility.

Furthermore, differentiating the flexibility with respect to upstream complexity and determining the point at which the value is zero on the second model yielded a maximum value of approximately 3.185. Although increasing upstream complexity improved flexibility up to this maximum value, any increase beyond this point reduced flexibility. Thus, a company achieves the highest flexibility when upstream complexity falls near 3.185 on a 7-point Likert scale.

[Table 14] Model Statistics and Parameter Estimates for Upstream Complexity and Flexibility

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.077	14.231	1	170	.000	3.023***	-.219***	
Second Model	.139	7.269	2	169	.001	2.698*	.395***	-.062***

* p<0.10, ** p<0.05, *** p<0.01

[Table 15] shows the hierarchical regression analysis results for the main effect of upstream complexity on flexibility and the moderating effect of supply chain integration. With regard to the main effect of upstream complexity on flexibility, upstream complexity had a positive effect on flexibility ($\beta = 1.867$, $p<0.05$), whereas upstream complexity squared had a negative effect ($\beta = -1.794$, $p<0.05$). These results indicate an inverted U-shaped relationship between upstream complexity and flexibility. Additionally, the relationship between upstream complexity and flexibility was found be moderated by the integration in physical flows ($\beta = -2.200$, $p<0.10$ and $\beta = 3.104$, $p<0.10$) and communication methods (β = −2.642, p<0.10 and β = 2.722, p<0.10). The inverted U-shaped relationship between upstream complexity and flexibility was observed to move upward and to the right as the integration in physical flows became more active and communication methods became more varied. In other words, taking supply chain integration into consideration, the integration in physical flows, under supply chain practices, and communication methods, under supply chain patterns, were found to moderate the relationship between upstream complexity and flexibility.

[Table 15] Moderating Effect of Supply Chain Integration on Upstream Complexity and Flexibility

Variable	Flexibility		
	I	II	III
UC	1.867**	1.417**	1.800*
UC^2	-1.794**	-1.307**	-1.649*
IPF		.481	.355
IE		.345	.319
CA		.387***	.457***
CM		.120	.128
LTRB		.264	.215
UC x IPF			-2.200*
UC x IE			-.606
UC x CA			-.770
UC x CM			-2.642*
UC x LTRB			-.036
UC^2 x IPF			3.104*
UC^2 x IE			.043

UC^2 x CA			.721
UC^2 x CM			2.722*
UC^2 x LTRB			.535
R^2	.101	.265	.332
F	4.676***	6.487***	3.973***
ΔR^2		.164	.067

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.

* p<0.10, ** p<0.05, *** p<0.01

4.2. Moderating Effect of Supply Chain Integration on the Relationship between Internal Complexity and Firm Performance

After testing for linearity and nonlinearity in the relationships between internal complexity and firm performance, including cost, delivery, quality, and flexibility, the impact of internal complexity on firm performance and the moderating effect of supply chain integration were analyzed.

First, the inverted U-shaped relationship between internal complexity and cost was tested. [Table 16] shows the analysis results for the linear and the nonlinear model for the effect of internal complexity on cost. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was a minor difference between the R^2 values of the two models, and the b2 value was very small. Moreover, the scatter plots showed that the first model was more appropriate than the second model. Therefore, internal complexity and cost were found to have a linear relationship.

[Table 16] Model Statistics and Parameter Estimates for Internal Complexity and Cost

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.201	42.802	1	170	.000	5.606***	-.395**	
Second Model	.204	22.190	2	169	.000	6.350**	-.767**	-.023**

* p<0.10, ** p<0.05, *** p<0.01

[Table 17] shows the hierarchical regression analysis results for the main effect of internal complexity on cost as well as the moderating effect of supply chain integration. The main effect of internal complexity on cost was found to be negative (β = −0.445, p<0.01). In addition, the relationship between internal complexity and cost was found to be moderated by information exchange (β = −0.893, p<0.01) and collaborative activities (β = −0.133, p<0.10). The negative relationship between internal complexity and cost was observed to weaken as information exchange and collaborative activities became more active. In other words, taking supply chain integration into consideration, information exchange and collaborative activities, under supply chain practices, were found to moderate the relationship between internal complexity and cost.

[Table 17] Moderating Effect of Supply Chain Integration on Internal Complexity and Cost

Variable	Cost		
	I	II	III
IC	-.445***	-.358**	-.353***
IPF		.472	.572*
IE		.346	.329
CA		.311***	.298***
CM		.169	.088
LTRB		.215	.270
IC x IPF			-.432
IC x IE			-.893***
IC x CA			-.133*
IC x CM			-.379
IC x LTRB			-.009
R^2	.221	.357	.400
F	15.921***	11.315***	8.088***
ΔR^2		.144	.043

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.

* p<0.10, ** p<0.05, *** p<0.01

Second, the inverted U-shaped relationship between internal complexity and delivery was tested. [Table 18] shows the analysis results for the linear and the nonlinear model for the effect of internal complexity on delivery. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was a minor difference between the R^2 values of the two models, and the b2 value was very small. Moreover, the scatter plots showed that the first model was more appropriate than the second model. Therefore, internal complexity and delivery were found to have a linear relationship.

[Table 18] Model Statistics and Parameter Estimates for Internal Complexity and Delivery

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.396	110.950	1	170	.000	7.094***	-.532***	
Second Model	.398	56.362	2	169	.000	6.469	-.220***	-.027***

* p<0.10, ** p<0.05, *** p<0.01

[Table 19] shows the hierarchical regression analysis results for the main effect of internal complexity on delivery as well as the moderating effect of supply chain integration. The main effect of internal complexity on delivery was found to be negative ($\beta = -0.621$, $p<0.01$). In addition, the relationship between internal complexity and delivery was found to be moderated by collaborative activities ($\beta = -0.150$, $p<0.05$). The negative relationship between internal complexity and delivery was observed to weaken as collaborative activities became more active. In other words, taking supply chain integration into consideration, collaborative activities, under supply chain practices, was found to moderate the relationship between internal complexity and delivery.

[Table 19] Moderating Effect of Supply Chain Integration on Internal Complexity and Delivery

Variable	Delivery		
	I	II	III
IC	-.621***	-.534***	-.519***
IPF		.417	.342
IE		.502**	.498**
CA		.380***	.351***
CM		.403***	.467***
LTRB		.286*	.249
IC x IPF			-.047
IC x IE			-.158
IC x CA			-.150**
IC x CM			-.178
IC x LTRB			-.019
R^2	.402	.515	.546
F	37.636***	21.616***	14.633***
ΔR^2		.113	.032

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* p<0.10, ** p<0.05, *** p<0.01

Third, the inverted U-shaped relationship between internal complexity and quality was tested. [Table 20] shows the analysis results for the linear and the nonlinear model for the effect of internal complexity on quality. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, the difference between the R^2 values of the two models was not small, and the R^2 value for the second model was less than the determination coefficient of 0.13, as suggested by Cohen (1988) for social sciences research. Nonetheless, it was larger than the minimum coefficient of 0.02. Additionally, the scatter plots showed the second model to be more appropriate than the linear model. This indicates an inverted U-shaped relationship between internal complexity and quality.

Furthermore, differentiating the quality with respect to internal complexity and determining the point at which the value is zero on the second model yielded a maximum value of approximately 5.515. Although increasing internal complexity improved quality up to this maximum value, any increase beyond this point reduced quality. Thus, a company achieves the highest quality when internal complexity falls near 5.515 on a 7-point Likert scale.

[Table 20] Model Statistics and Parameter Estimates for Internal Complexity and Quality

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.085	15.831	1	170	.000	2.927***	-.230***	
Second Model	.121	11.640	2	169	.000	1.200*	1.092***	-.099***

* p<0.10, ** p<0.05, *** p<0.01

[Table 21] shows the hierarchical regression analysis results for the main effect of internal complexity on quality and the moderating effect of supply chain integration. With regard to the main effect of internal complexity on quality, internal complexity had a positive effect on quality (β = 1.295, p<0.01), whereas internal complexity squared had a negative effect (β = −1.024, $p<0.05$). These results indicate an inverted U-shaped relationship between internal complexity and quality. Additionally, the relationship between internal complexity and quality was found be moderated by information exchange (β = −3.421, $p<0.10$ and β = 3.876, $p<0.10$) and communication methods (β = −3.756, $p<0.10$ and β = 4.162, $p<0.05$). The inverted U-shaped relationship between internal complexity and quality was observed to move upward and to the right as information exchange became more active and communication methods became more diverse. In other words, taking supply chain integration into consideration, information exchange, under supply chain practices, and communication methods, under supply chain patterns, were found to moderate the relationship between the internal complexity and quality.

[Table 21] Moderating Effect of Supply Chain Integration on Internal Complexity and Quality

Variable	**Quality**		
	I	**II**	**III**
IC	1.295***	.847**	1.169*
IC^2	-1.024**	-.714*	-1.067*
IPF		.494	.453
IE		.370	.378
CA		.335***	.345***
CM		.178	.301
LTRB		.256	.330
IC x IPF			-.411
IC x IE			-3.421*

IC x CA			-.377
IC x CM			-3.756*
IC x LTRB			-.386
IC^2 x IPF			.470
IC^2 x IE			3.876*
IC^2 x CA			.353
IC^2 x CM			4.162**
IC^2 x LTRB			.286
R^2	.134	.262	.338
F	7.400***	6.821***	4.523***
ΔR^2		.128	.075

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* p<0.10, ** p<0.05, *** p<0.01

Fourth, the inverted U-shaped relationship between internal complexity and flexibility was tested. [Table 22] shows the analysis results for the linear and the nonlinear model for the effect of internal complexity on flexibility. The first model was found to be statistically significant at the 95% confidence level, whereas the second model was found to be 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 (1988) for social sciences research. Additionally, the scatter plots showed the second model to be more appropriate than the linear model. This indicates an inverted U-shaped relationship between internal complexity and flexibility.

Furthermore, differentiating the flexibility with respect to internal complexity and determining the point at which the value is zero on the second model yielded a maximum value of approximately 4.705. Although increasing internal complexity improved flexibility up to this maximum value, any increase beyond this point reduced flexibility. Thus, a company achieves the highest flexibility when internal complexity falls near 4.705 on a 7-point Likert scale.

[Table 22] Model Statistics and Parameter Estimates for Internal Complexity and Flexibility

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.024	4.092	1	170	.045	4.349	-.116**	
Second Model	.140	13.711	2	169	.000	1.360***	1.609***	-.171***

* p<0.10, ** p<0.05, *** p<0.01

[Table 23] shows the hierarchical regression analysis results for the main effect of internal complexity on flexibility and the moderating effect of supply chain integration. With regard to the main effect of internal complexity on flexibility, internal complexity had a positive effect on flexibility ($\beta = 1.295$, $p<0.01$), whereas internal complexity squared had a negative effect ($\beta = -1.024$, $p<0.05$). These results indicate an inverted U-shaped relationship between internal complexity and flexibility. Additionally, the relationship between internal complexity and flexibility was found be moderated by information exchange (β =

−3.421, $p<0.10$ and $\beta = 3.876$, $p<0.10$) and communication methods ($\beta = -3.756$, $p<0.10$ and $\beta = 4.162$, $p<0.05$). The inverted U-shaped relationship between internal complexity and flexibility were observed to move upward and to the right as information exchange became more active and communication methods became more diverse. In other words, taking supply chain integration into consideration, information exchange, under supply chain practices, and communication methods, under supply chain patterns, were found to moderate the relationship between internal complexity and flexibility.

[Table 23] Moderating Effect of Supply Chain Integration on Internal Complexity and Flexibility

Variable	Flexibility		
	I	II	III
IC	1.295***	.847**	1.169*
IC^2	-1.024**	-.714*	-1.067*
IPF		.494	.453
IE		.370	.378
CA		.335***	.345***
CM		.178	.301
LTRB		.256	.330
IC x IPF			-.411
IC x IE			-3.421*
IC x CA			-.377
IC x CM			-3.756*
IC x LTRB			-.386
IC^2 x IPF			.470

IC^2 x IE			3.876*
IC^2 x CA			.353
IC^2 x CM			4.162**
IC^2 x LTRB			.286
R^2	.134	.262	.338
F	7.400***	6.821***	4.523***
ΔR^2		.128	.075

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

4.3. Moderating Effect of Supply Chain Integration on the Relationship between Downstream Complexity and Firm Performance

After testing for linearity and nonlinearity in the relationships between downstream complexity and firm performance, including cost, delivery, quality, and flexibility, the impact of downstream complexity on firm performance and the moderating effect of supply chain integration were analyzed.

First, the inverted U-shaped relationship between downstream complexity and cost was tested. [Table 24] shows the analysis results for the linear and the nonlinear model for the effect of downstream complexity on cost. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was a minor difference between the R^2 values of the two models, and the b2 value was very small. Moreover, the scatter plots showed that the first model was more appropriate than the second model. Therefore, downstream complexity and cost were found to have a linear relationship.

[Table 24] Model Statistics and Parameter Estimates for Downstream Complexity and Cost

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.123	23.739	1	170	.000	5.183***	-.281***	
Second Model	.125	12.031	2	169	.000	5.599***	-.189***	-.014***

* p<0.10, ** p<0.05, *** p<0.01

[Table 25] shows the hierarchical regression analysis results for the main effect of downstream complexity on cost as well as the moderating effect of supply chain integration. The main effect of downstream complexity on cost was found to be negative (β = −0.351, p<0.01). In addition, the relationship between downstream complexity and cost was found to be moderated by information exchange (β = −0.616, p<0.10). The negative relationship between downstream complexity and cost was observed to weaken as information exchange became more active. In other words, taking supply chain integration into consideration, information exchange, under supply chain practices, was found to moderate the relationship between downstream complexity and cost.

[Table 25] Moderating Effect of Supply Chain Integration on Downstream Complexity and Cost

Variable	Cost		
	I	II	III
DC	-.351***	-.262***	-.261***
IPF		.408	.460
IE		.292	.324
CA		.342***	.311***
CM		.148	.107
LTRB		.173	.172
DC x IPF			-.017
DC x IE			-.616*
DC x CA			-.091
DC x CM			-.379
DC x LTRB			-.104
R^2	.148	.303	.431
F	7.988***	6.148***	5.124***
ΔR^2		.156	.127

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Second, the inverted U-shaped relationship between downstream complexity and delivery was tested. [Table 26] shows the analysis results for the linear and the nonlinear model for the effect of downstream complexity on delivery. The first model and the second model were both found to be statistically significant at the 99% confidence level. However, there was a minor difference between the R^2 values of the two models, and the b2 value was very small. Moreover, the scatter plots showed that the first model was more appropriate than the second model.

Therefore, downstream complexity and delivery were found to have a linear relationship.

[Table 26] Model Statistics and Parameter Estimates for Downstream Complexity and Delivery

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.332	76.807	1	170	.000	6.750***	-.431***	
Second Model	.329	41.425	2	169	.000	5.587***	.152***	-.017***

* p<0.10, ** p<0.05, *** p<0.01

[Table 27] shows the hierarchical regression analysis results for the main effect of downstream complexity on delivery as well as the moderating effect of supply chain integration. The main effect of downstream complexity on delivery was found to be negative (β = −0.553, p<0.01). In addition, the relationship between downstream complexity and delivery was found to be moderated by long-term relationship building (β = −0.526, p<0.10). The negative relationship between downstream complexity and delivery was observed to weaken as long-term relationship building became more active. In other words, taking supply chain integration into consideration, long-term relationship building, under supply chain attitudes, was found to moderate the relationship between downstream complexity and delivery.

[Table 27] Moderating Effect of Supply Chain Integration on Downstream Complexity and Delivery

Variable	Delivery		
	I	II	III
DC	-.553***	-.473***	-.482*
IPF		.482**	.364
IE		.572**	.523**
CA		.404***	.354***
CM		.448**	.485***
LTRB		.347*	.294
DC x IPF			-.272
DC x IE			-.042
DC x CA			-.183
DC x CM			-.271
DC x LTRB			-.526*
R^2	.324	.460	.497
F	26.887***	17.337***	11.994***
ΔR^2		.135	.037

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Third, the inverted U-shaped relationship between downstream complexity and quality was tested. [Table 28] shows the analysis results for the linear and the nonlinear model for the effect of downstream complexity on quality. The first model was found to be statistically significant at the 95% confidence level, whereas the second model was found to be statistically significant at the 99% confidence level. However, the difference between the R^2 values of the two models was not small, and the R^2 value for the second model was less than the determination coefficient of 0.13, as suggested by Cohen (1988) for social sciences research. Nonetheless, it was larger than the minimum coefficient of 0.02. Additionally, the scatter plots showed the second model to be more appropriate than the linear model. This indicates an inverted U-shaped relationship between downstream complexity and quality.

Furthermore, differentiating the quality with respect to downstream complexity and determining the point at which the value is zero on the second model yielded a maximum value of approximately 5.012. Although increasing downstream complexity improved quality performance up to this maximum value, any increase beyond this point reduced quality performance. Thus, a company achieves the highest quality performance when downstream complexity falls near 5.012 on a 7-point Likert scale.

[Table 28] Model Statistics and Parameter Estimates for Downstream Complexity and Quality

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.033	5.749	1	170	.018	3.896	-.108***	
Second Model	.078	7.134	2	169	.001	2.426	.842***	-.084***

* p<0.10, ** p<0.05, *** p<0.01

[Table 29] shows the hierarchical regression analysis results for the main effect of downstream complexity on quality and the moderating effect of supply chain integration. With regard to the main effect of downstream complexity on quality, downstream complexity had a positive effect on quality (β = 1.312, $p<0.01$), whereas downstream complexity squared had a negative effect (β = −1.154, $p<0.01$). These results indicate an inverted U-shaped relationship between downstream complexity and quality. Additionally, the relationship between downstream complexity and quality was found be moderated by communication methods (β = −4.103, $p<0.10$ and β = 4.232, $p<0.10$). The inverted U-shaped relationship between downstream complexity and quality were observed to move upward and to the right as communication methods became more diverse. In other words, taking supply chain integration into consideration, communication methods, under supply chain patterns, was found to moderate the relationship between downstream complexity and quality.

[Table 29] Moderating Effect of Supply Chain Integration on Downstream Complexity and Quality

Variable	Quality		
	I	II	III
DC	1.312***	.909**	.790*
DC^2	-1.154***	-.880**	-.770*
IPF		.526	.627
IE		.104	.245***
CA		.320***	.290***
CM		.148	.023
LTRB		.243**	.359
DC x IPF			-1.140

DC x IE			-1.788
DC x CA			-.351
DC x CM			-4.103*
DC x LTRB			-.692
DC^2 x IPF			.247
DC^2 x IE			2.669
DC^2 x CA			.357
DC^2 x CM			4.232*
DC^2 x LTRB			.899
R^2	.092	.200	.259
F	4.253***	4.489***	2.801***
ΔR^2		.107	.060

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* p<0.10, ** p<0.05, *** p<0.01

Fourth, the inverted U-shaped relationship between downstream complexity and flexibility was tested. [Table 30] shows the analysis results for the linear and the nonlinear model for the effect of downstream complexity on flexibility. The linear model was not found to be statistically significant at the 90% confidence level, whereas the second model was found to be statistically significant at the 99% confidence level. However, the difference between the R^2 values of the two models was not small, and the R^2 value for the second model was less than the determination coefficient of 0.13, as suggested by Cohen (1988) for social sciences research. Nonetheless, it was larger than the minimum coefficient of 0.02. Additionally, the scatter plots showed the second model to be more appropriate than the linear model. This indicates an inverted U-shaped relationship between downstream complexity and flexibility.

Furthermore, differentiating the flexibility with respect to downstream complexity and determining the point at which the value is zero on the second model yielded a maximum value of approximately 4.438. Although increasing downstream complexity improved flexibility up to this maximum value, any increase beyond this point reduced flexibility. Thus, a company achieves the highest flexibility when downstream complexity falls near 4.438 on a 7-point Likert scale.

[Table 30] Model Statistics and Parameter Estimates for Downstream Complexity and Flexibility

Equation	Model Statistics					Parameter Estimates		
	R^2	F	df1	df2	p	Constant	b1	b2
Linear Model	.002	.411	1	170	.523	4.321	-.030	
Second Model	.064	5.819	2	169	.004	2.565	.923	-.104

* p<0.10, ** p<0.05, *** p<0.01

[Table 31] shows the hierarchical regression analysis results for the main effect of downstream complexity on flexibility and the moderating effect of supply chain integration. With regard to the main effect of downstream complexity on flexibility, downstream complexity had a positive effect on flexibility (β = 1.477, p<0.01), whereas downstream complexity squared had a negative effect (β =

−1.440, p<0.01). These results indicate an inverted U-shaped relationship between downstream complexity and flexibility. Additionally, the relationship between downstream complexity and flexibility was found be moderated by communication methods (β = −2.911, p<0.10 and β = 3.086, p<0.10). The inverted U-shaped relationship between downstream complexity and flexibility were observed to move upward and to the right as the communication methods became more varied. In other words, taking supply chain integration into consideration, communication methods, under supply chain patterns, was found to moderate the relationship between downstream complexity and quality.

[Table 31] Moderating Effect of Supply Chain Integration on Downstream Complexity and Flexibility

Variable		**Flexibility**	
	I	**II**	**III**
DC	1.477***	1.081**	1.223**
DC^2	-1.440***	-1.211***	-1.379***
IPF		.605*	.696**
IE		.423	.344
CA		.543***	.556***
CM		.288	.268
LTRB		.455**	.545**
DC x IPF			-1.715
DC x IE			-.513
DC x CA			-.207
DC x CM			-2.911*
DC x LTRB			-.060
DC^2 x IPF			1.923
DC^2 x IE			.277

DC^2 x CA			.340
DC^2 x CM			3.086*
DC^2 x LTRB			.378
R^2	.071	.287	.367
F	3.177**	7.252***	4.631***
ΔR^2		.216	.079

Industry dummy variables and the company size variable are included in the models, but regression coefficients are not show for them.
* p<0.10, ** p<0.05, *** p<0.01

[Table 32] summarizes the hypotheses testing results based on the performed analyses.

[Table 32] Hypotheses Testing Results

Hypothesis	Description	Result
H1	Supply chain complexity and firm performance will have an inverted U-shaped relationship.	Partially supported
H1a	Supply chain complexity and cost will have an inverted U-shaped relationship.	Not supported
H1b	Supply chain complexity and delivery will have an inverted U-shaped relationship.	Not supported
H1c	Supply chain complexity and quality will have an inverted U-shaped relationship.	Supported
H1d	Supply chain complexity and flexibility will have an inverted U-shaped relationship.	Supported
H2	Supply chain practices will positively moderate the relationship between supply chain complexity and firm performance.	Partially supported
H2a	Supply chain practices will positively moderate the relationship between supply chain complexity and cost.	Supported
H2b	Supply chain practices will positively moderate the relationship between supply chain complexity and delivery.	Partially supported

H2c	Supply chain practices will positively moderate the relationship between supply chain complexity and quality.	Partially supported
H2d	Supply chain practices will positively moderate the relationship between supply chain complexity and flexibility.	Partially supported
H3	Supply chain patterns will positively moderate the relationship between supply chain complexity and firm performance.	Partially supported
H3a	Supply chain patterns will positively moderate the relationship between supply chain complexity and cost.	Not supported
H3b	Supply chain patterns will positively moderate the relationship between supply chain complexity and delivery.	Not supported
H3c	Supply chain patterns will positively moderate the relationship between supply chain complexity and quality.	Supported
H3d	Supply chain patterns will positively moderate the relationship between supply chain complexity and flexibility.	Supported
H4	Supply chain attitudes will positively moderate the relationship between supply chain complexity and firm performance.	Partially supported
H4a	Supply chain attitudes will positively moderate the relationship between supply chain complexity and cost.	Not supported
H4b	Supply chain attitudes will positively moderate the relationship between supply chain complexity and delivery.	Partially supported
H4c	Supply chain attitudes will positively moderate the relationship between supply chain complexity and quality.	Not supported
H4d	Supply chain attitudes will positively moderate the relationship between supply chain complexity and flexibility.	Not supported

V. Conclusion

Supply chains involve networks of various companies that create value-added in the process of transforming raw materials into products and delivering them to end consumers. Thus, supply chains are inherently complex. Studies on supply chain complexity are based on the premise that the supply chain represents an intricate network of companies, each with its own goals. Recently, supply chain complexity has increased, as companies are aiming to meet customer needs through various means, such as diversifying products and identifying new suppliers. Although the impact of supply chain complexity on firm performance has been widely investigated, research on supply chain complexity management is much needed not only for scholars but for practitioners as well.

Undoubtedly, 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. In addition, most prior research has neglected to offer solutions for corporate leaders charged with managing supply chain complexity.

The present 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 analyzed whether supply chain complexity has only negative effects on firm performance, or both positive and negative effects. Furthermore, supply chain integration was presented to moderate the relationship between supply chain complexity and firm performance. Components of supply chain integration were categorized in detail and examined. Taking a systematic approach to classifying and analyzing supply chain complexity and supply chain integration enabled this study to propose directions for useful supply chain integration strategies that companies can utilize in mitigating specific problems related to supply chain complexity. Therefore, the present research proposed supply chain management strategies based on a comprehensive study of the various components of supply chain complexity and supply chain integration.

As mentioned earlier, prior studies made theoretical presumptions that all supply chain complexities have negative impacts. However, in practice, companies have no choice but to increase supply chain complexity through activities such as new product development and securing additional suppliers to enhance competitiveness. This study has eliminated this gap between the theoretical and practical perspectives, and provided valuable insight to scholars and practitioners in supply chain management.

1. Summary of Results

This study examined the relationship between supply chain complexity and firm performance and the moderating effect of supply chain integration on the relationship between supply chain complexity and firm performance. Taken together, the results can be summarized as follows. First, [Table 33] summarizes the test results for linearity and nonlinearity in the relationship between each supply chain complexity and firm performance. Measured items that have an inverted U-shaped relationship with firm performance are indicated with numerical values in the table. These numbers represent the maximum value at which the firm achieves maximum performance. Measured items that do not show a numerical value in the table have a linear relationship with firm performance.

The results of this study suggest that all supply chain complexities have an inversely proportional linear relationship with cost and delivery in firm performance. As a result, a maximum value does not exist. This is consistent with previous studies suggesting that higher supply chain complexity reduces the cost and delivery of firms (Frizelle and Woodcock, 1995; Perona et al., 2001; Vachon and Klassen, 2002; Bozarth et al., 2009).

In addition, all supply chain complexities have an inverted U-shaped relationship with quality and flexibility in firm performance. The maximum value found in the inverted U-shaped relationships indicates the specific point at which firm performance no longer increases with an increase in supply chain complexity.

Instead, firm performance begins to decrease once complexity moves beyond that point. A comparison of the maximum values by supply chain complexity type places internal complexity (5.110), downstream complexity (4.725), and upstream complexity (3.904), in that order. Thus, compared to other types of complexity, internal complexity can increase more before yielding a negative influence on firm performance. This finding contrasts with the results of previous studies, which had showed that supply chain complexity has only a negative effect on firm performance. However, the result of the present study corroborate Serdarasan's (2013) study. He argued that firms need to selectively eliminate and reduce some supply chain complexities and manage the remaining supply chain complexities, not just simply eliminating or reducing all of them.

[Table 33] Analysis Results of the Relationship between Supply Chain Complexity and Firm Performance

Supply Chain Complexity	Cost	Delivery	Quality	Flexibility
Upstream Complexity	Negative	Negative	Inverted U-Shaped (4.622)	Inverted U-Shaped (3.185)
Internal Complexity	Negative	Negative	Inverted U-Shaped (5.515)	Inverted U-Shaped (4.705)
Downstream Complexity	Negative	Negative	Inverted U-Shaped (5.012)	Inverted U-Shaped (4.438)

Next, [Table 34] summarizes the results from analyzing the moderating effect of supply chain integration on the relationship between various supply chain complexity and firm performance. This study found that the type of supply chain integration that had a statistically significant moderating effect on the relationship between supply chain complexity and firm performance differed depending on the performance indicator. The specific moderating effects of supply chain integration are as follows: First, with regard to upstream complexity, the integration in physical flows and information exchange had a significant moderating effect on its relationship with cost; information exchange and collaborative activities had a significant moderating effect on its relationship with delivery; communication methods had a significant moderating effect on its relationship with quality; and the integration in physical flows and communication methods had a significant moderating effect on its relationship with flexibility.

Second, as for internal complexity, information exchange and collaborative activities had a significant moderating effect on its relationship with cost; collaborative activities had a moderating effect on its relationship with delivery; information exchange and communication methods had a significant moderating effect on its relationship with quality; and information exchange and communication methods had a significant moderating effect on its relationship with flexibility.

Third, regarding downstream complexity, information exchange had a significant moderating effect on its relationship with cost; long-term relationship building had a significant moderating effect on its relationship with delivery; communication methods had a significant moderating effect on its relationship with quality and flexibility.

[Table 34] Moderating Effect of Supply Chain Integration

Supply Chain Complexity	Cost	Delivery	Quality	Flexibility
Upstream Complexity	SCIP (IPF, IE)	SCIP (IE, CA)	SCI_P (CM)	SCIP (IPF) SCI_P (CM)
Internal Complexity	SCIP (IE, CA)	SCIP (CA)	SCIP (IE) SCI_P (CM)	SCIP (IE) SCI_P (CM)
Downstream Complexity	SCIP (IE)	SCIA (LTRB)	SCI_P (CM)	SCI_P (CM)

Overall, it can be concluded that supply chain integration practices play an important role in the effect of supply chain complexity on cost and delivery, while supply chain integration patterns play an important role in the effect of supply chain complexity on quality and flexibility. This result shows how specific forms of supply chain integration can improve firm performance under specific circumstances, expanding the study of Sousa and Voss (2008), who argued that the context needs to be emphasized in the field of operations management, and that of Ho et al. (2002), who suggested that the context needs to be considered in the field of SCM. Particularly, in this study, the moderating effects of supply chain practices and supply chain patterns were particularly greater than that of supply chain attitudes. It should be noted that the moderation effect of supply chain integration patterns was significant in this study. This is consistent with the finding of Giménez et al. (2012), who emphasized investment in supply chain patterns. In addition, this study indicates the supply chain activities that should be performed with priority among the supply chain integration of supply chain practices, supply chain patterns, and supply chain attitudes (Van der Vaart and van Donk, 2008; Giménez et al., 2012).

2. Research Implications

2.1. Theoretical Implications of the Research

This study offers the following theoretical implications. First, supply chain complexity measurement items were classified and systematically analyzed using a 3×3 matrix based on the origin of the complexity (i.e., upstream for the supplier side, internal, and downstream for the customer side) and form of the complexity (i.e., organization, product, and process). Prior studies took different analytical approaches to examining supply chain complexity measurement items and, thus, presented mixed 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. Although some components of supply chain complexity were found to have a negative effect on firm performance, thereby confirming prior studies, other 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 inverted U-shaped relationships, thus presenting a perspective that previous studies have not offered.

Third, this study proposed a supply chain integration strategy for managing the effect of supply chain complexity on firm performance. Previous research did not sufficiently investigate how companies should manage supply chain complexity. Although a number of studies proposed supply chain integration as a way to manage supply chain complexity, very few studies empirically analyzed the effectiveness of integration. In response, this study divided supply chain integration into supply chain practices, supply chain patterns, and supply chain attitudes based on prior studies, and investigated the integration in physical flows, information exchange, and collaborative activities (i.e., supply chain practices), communication methods (i.e., supply chain patterns), and long-term relationship building (i.e., supply chain attitudes). This expands existing discussions on whether supply chain integration weakens the relationship between supply chain complexity and firm performance. Taking a more nuanced approach, this study made a significant contribution by identifying the appropriate combined relations among each supply chain complexity and supply chain integration components.

2.2. Practical Implications of the Research

This research provides the following practical implications. First, it proposed specific points that corporate bodies should be aware of as they manage supply chain complexities. Prior studies considered only the negative effects of supply chain complexity on firm performance and argued for reducing supply chain complexity. In practice, however, most companies make decisions that increase supply chain complexity in order to secure competitive advantage. Thus, the results of this study can bridge the gap between theory and practice. Specifically, firm performance increases as supply chain complexity increases up to a certain point. However, after crossing that threshold, an increase in supply chain complexity results in decreased firm performance, thus revealing an inverted U-shaped relationship.

Second, this study proposed the relational mechanisms between supply chain complexity and supply chain integration. In this way, companies can analyze their own supply chain complexities and pursue appropriate supply chain integration strategies according to future organizational goals. Because resources are finite, companies must use resources effectively and efficiently. This study demonstrated that supply chain integration can widen the area in which supply chain complexity positively affects firm performance and, conversely, shrink the area in which supply chain complexity negatively affects firm performance. In other words, supply chain integration can mitigate the negative effects of supply chain complexity on firm performance. In addition, the results of this study demonstrated that each component of supply chain integration addresses only some of the issues associated with supply chain complexity. Therefore, when managing increasingly growing supply chain complexities, companies must first assess which components of supply chain complexity are particularly problematic prior to implementing the relevant supply chain integration strategies. Thus, the results of this study have meaningful implications by presenting useful strategic guidelines for introducing supply chain integration into supply chain complexity management.

3. Limitations and Future Research Directions

The limitations of this study and future research directions are as follows. First, it may be difficult to generalize the results because the data used in this study are confined to domestic manufacturing industries. Although large corporations and SMEs that belong to over fifteen different industries were surveyed in order to ensure validity, the study should be supplemented with data collected from various other countries to achieve better generalizability.

Second, it is difficult to obtain most secondary sources on supply chain complexity measurement items. Moreover, the data reflects the responses of company personnel responsible for answering the survey. Thus, the respondents' bias cannot be fully eliminated. To mitigate this effect, a professional research firm was hired to conduct the survey. In addition, responses were gathered from personnel who were at least deputy general managers in the supply chain management, planning, purchasing, production, or sales departments. Despite a careful selection of the respondents, future research should further ensure more objectivity by securing secondary sources.

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Appendix. References for Questionnaire

I. Supply Chain Complexity

Constructs and Questions	References
Upstream Complexity	Wu and Choi (2005) Goffin et al. (2006) Bozarth et al. (2009) Huang and Inman (2010)
Organizational Complexity	
· There are many suppliers that deliver parts to the company · The supply chain that our company belongs in has many tiers	
Product Complexity	Huang et al. (2005) Bozarth et al. (2009)
· Our company's products require many different types of parts	
Process Complexity	Childerhouse et al. (2002) Vollmann et al. (2005) Bozarth et al. (2009) Serdarasan (2013) Fast-Berglund (2013)
· Our suppliers have a long lead time · Our suppliers' IT system is well compatible with that of our company (r) · Various departments in our company contact our suppliers	
Internal Complexity	Fast-Berglund (2013) Mariotti (2008)
Organizational Complexity	
· There are many hierarchies within our organizational structure · Our company has many branches	
Product Complexity	Thonemann and Bradley (2002) Bozarth et al. (2009) Fast-Berglunch (2013) AT Kearney (2014)
· Our company has many kinds of products · Our company's products are equipped with multiple functions	
Process Complexity	Deshmukh et al. (1998) Chapman and Hyland (2004) Serdarasan (2013) AT Kearney (2014)
· Our company's products require multi-step processes to be produced · Our company uses various IT systems	
Downstream Complexity	Simchi-Levy et al. (2000) Vollman et al. (2005) Bozarth et al. (2009) Serdarasan (2013)
Organizational Complexity	
· Our company has many customers who purchase our products · Our company's customers come from various countries around the world	

Product Complexity	Krishnan and Gupta (2001) Bozarth et al. (2009) Serdarasan (2013) AT Kearney (2014)
· The lifecycle of our company products is becoming shorter over time · Customer demands for our company products have changed over time	
Process Complexity	Chapman and Hyland (2004)
· Our company has many sales channels with our customers	

(r) Indicates reverse-coded items.

II. Supply Chain Integration

Constructs and Questions	References
Integration in Physical Flows	de Toni and Nassimbeni (2000) Frohlich and Westbrook (2001)
Supplier Integration	
· The raw materials and parts that our key suppliers deliver are automatically recognized through bar-cording · Our key suppliers deliver raw materials and parts on short notice · Our key suppliers often ship raw materials and parts	
Internal Integration	
· Work-in-process (WIP) inventory that flows among the key departments in our company is automatically recognized through bar-coding · The key departments in our company deliver WIP inventory on short notice · The key departments in our company often ship WIP inventory	
Customer Integration	
· The products that our company delivers to key customers are automatically recognized through bar-coding · Our company delivers its products to key customers on short notice · Our company often ship to key customers	
Information Exchange	Narasimhan and Carter

Supplier Integration	(1998) Frohlich and Westbrook (2001) Kim (2002) Zhao et al. (2011)
· Our company and key suppliers use information technology to exchange information · Our company and key suppliers exchange production schedule information · Our company and key suppliers exchange inventory information	
Internal Integration	
· The key departments in our company use information technology to exchange information · The key departments in our company exchange production schedule information · The key departments in our company exchange inventory information	
Customer Integration	
· Our company and key customers use information technology to exchange information · Our company and key customers exchange production schedule information · Our company and key customers exchange inventory information	
Collaborative Activities	Saraph et al. (1989) Giménez and Ventura (2005) Zaheer et al. (1998) Gulati and Sytch (2007)
Supplier Integration	
· Our company continually monitors and improves key suppliers' quality · We work together with key suppliers to improve operations and logistics processes · We are jointly responsible with key suppliers for achieving common goals	
Internal Integration	
· The key departments in our company continually engage in quality monitoring and improvement · The key departments in our company work together to improve operations and logistics processes · The key departments in our company are jointly responsible with other departments for achieving common goals	

Customer Integration	
· The key customers of our company frequently visit our production sites and constantly engage in quality monitoring and improvement · We work together with key customers to improve operations and logistics processes · We are jointly responsible with key customers for achieving common goals	
Communication Methods	Carr and Pearson (1999) Frohlich and Westbrook (2001) Giménez et al. (2012)
Supplier Integration	
· Our company and key suppliers communicate face-to-face · Our company and our key suppliers communicate via email · Our company and our key suppliers communicate via Electronic Data Interchange (EDI) or direct computer-to-computer links through the Internet	
Internal Integration	
· The key departments in our company communicate face-to-face · The key departments in our company communicate via email · The key departments in our company communicate via Electronic Data Interchange (EDI) or direct computer-to-computer links through the Internet	
Customer Integration	
· Our company and key customers communicate face-to-face · Our company and key customers communicate via email · Our company and key customers communicate via Electronic Data Interchange (EDI) or direct computer-to-computer links through the Internet	
Long-Term Relationship Building	Flynn et al. (1994) Chen and Paulraj (2004)
Supplier Integration	
· Our company strives to maintain a long-term relationship with key suppliers · Our company considers key supplier as an extension of our firm · We are willing to work with key supplier to improve our processes in the long run	
Internal Integration	

· The key departments in our company strive to maintain a long-term relationship · The key departments in our company consider other departments as an extension of our firm · The key departments in our company work together with other key departments to improve our processes in the long run	
Customer Integration	
· Our company strives to maintain a long-term relationships with key customers · Our company considers key customers as an extension of our firm · Our company work with key customers to improve our processes in the long run	

III. Firm Performance

Constructs and Questions	References
Cost	Lai et al. (2008) Bozarth et al. (2009) Vanichchinchai and Igel (2009)
· Our company has relatively low order-management costs · Our company has relatively low production costs · Our company has relatively low inventory costs · Our company has relatively low distribution costs	
Delivery	Samson and Terziovski (1999) Chen and Paulraj (2004) Narasimhan et al. (2006) Bozarth et al. (2009) Kim (2014)
· Key suppliers accurately ship the products that our company orders · Key suppliers deliver their products on the set delivery date · Key suppliers tend to have shipment inventory of the products that our company orders at the time of the order · Key suppliers have fast product delivery	
Quality	Maani et al. (1994) Samson and Terziovski (1999) Kaynak and Hartley (2008) Chen and Paulraj (2004) Kim (2014)
· Our company has a relatively low production-to-defect ratio · Our company has a relatively low sales-to-rework ratio · The overall quality of our products is relatively high	

Flexibility	Chen and Paulraj (2004) Narasimhan et al. (2006) Vanichchinchai and Igel (2011)
· Our company has a relatively high ability to respond to changing delivery requirements · Our company has a relatively high ability to respond to special orders placed by customers · Our company requires a short lead time to launch new products · Our company launches many new products annually	

국문초록

공급사슬 통합 이니셔티브가 공급사슬 복잡성과 기업 성과 간의 관계에 미치는 영향에 관한 연구

산업이 고도화되면서 기업의 복잡성은 점차 증가하여 왔다. 환경 변화에 대응하기 위하여 기업은 다른 기업과 전략적 제휴를 맺거나 아웃소싱(outsourcing)을 하며 새로운 제품과 서비스를 출시하고 새로운 시장에 진출하는데, 이로 인해 공급사슬은 더욱 복잡해지고 있다. 따라서 많은 학자들이 공급사슬 복잡성에 관심을 가지게 되었다.

그러나 이러한 선행연구들은 몇 가지 측면에서 한계를 지닌다. 첫째, 선행연구들을 살펴보면 기업의 복잡성을 측정하는 구성요소에 관해 합의된 결론을 갖고 있지 못하다. 둘째, 많은 연구자들은 여전히 공급사슬 복잡성이 기업 성과에 미치는 부정적인 영향을 밝히는데 주목하고 있을 뿐, 기업의 경쟁력을 향상시키기 위하여 일정 수준의 공급사슬 복잡성이 필요하다는 것을 간과하였다. 셋째, 기업이 공급사슬 복잡성을 어떻게 관리해야 하는지에 관한 선행연구는 거의 이루어지지 않았다. 몇몇 연구들이 공급사슬 복잡성을 관리하는 방안으로 공급사슬 통합을 제시하였지만, 그 효과를 실증적으로 분석한 연구는 아직 없다.

따라서 본 연구의 목적은 공급사슬 복잡성의 측정 요소를 파악하고, 공급사슬 복잡성이 기업 성과에 미치는 부정적인 영향을 위주로 살펴본 선행연구들의 논의를 확장하여, 기업이 공급사슬 복잡성을 어떻게

효과적으로 관리할 것인가를 살펴보고자 하였다. 본 연구는 공급사슬 복잡성에 관한 기존 연구에서 그 동안 합의되지 않았던 측정 요소들을 3×3 매트릭스(matrix)에 따라 출처를 기준으로 공급사슬의 상류, 기업 내부, 공급사슬의 하류, 형태를 기준으로 조직, 제품, 프로세스로 구분하여 체계적으로 살펴보았다. 뿐만 아니라 공급사슬 복잡성과 기업 성과 간의 관계를 조절하는 요소로 공급사슬 통합을 제시하고, 공급사슬 통합을 구성하는 요소들을 보다 세부적으로 분류하여 살펴보았다. 공급사슬 복잡성과 공급사슬 통합을 구체적으로 분류하여 분석함으로써 기업이 특정 공급사슬 복잡성 문제가 발생했을 때, 어떠한 공급사슬 통합 전략이 유용한지에 관한 방향을 제안하였다.

본 연구는 공급사슬 복잡성, 기업 성과, 공급사슬 통합에 관한 선행연구들을 토대로 연구 모형과 가설을 설정하였다. 선행연구들을 참고하여 연구 모형을 분석하기 위한 설문지를 구성하고 전문리서치 업체를 이용하여 실증조사 하였다. 국내 제조업의 다양한 산업에서 여러 규모를 지닌 172개 기업에 관한 데이터를 수집하였다. 실증조사 후 Amos 18.0 프로그램과 SPSS 18.0 프로그램을 이용하여 카이 제곱 분석(chi-square test), 확인적 요인분석(confirmatory factor analysis), 위계적 회귀분석(hierarchical regression analysis) 등을 실시하였다.

본 연구의 결과, 공급사슬 복잡성은 비용과 납기를 제외한 기업 성과와 역 U자형의 관계를 보였다. 이러한 역 U자형에서 극대값은 공급사슬 복잡성이 증가할수록 기업 성과가 증가하다가 일정 수준 이상이 되면 공급사슬 복잡성이 증가할수록 기업 성과가 감소되는

것으로 변경되는 포인트이다. 공급사슬 복잡성의 유형별로 극대값을 비교하면, 내부의 복잡성(5.110), 하류의 복잡성(4.725), 상류의 복잡성(3.904)의 순이었다.

다음으로, 공급사슬 통합이 공급사슬 복잡성과 기업 성과의 관계에 미치는 조절효과를 분석한 결과, 공급사슬 복잡성과 기업 성과 간의 관계에 유의한 조절효과를 미치는 공급사슬 통합의 유형은 성과 지표에 따라 차이가 존재하였다. 공급사슬 복잡성이 비용에 미치는 영향에 물리적 통합, 정보 교환, 협력 활동, 납기에 미치는 영향에 정보 교환, 협력 활동, 장기적 관계 형성, 품질에 미치는 영향에 의사소통 방식, 정보 교환, 유연성에 미치는 영향에 물리적 통합, 의사소통 방식, 정보 교환이 유의한 조절 효과를 보였다.

본 연구의 이론적 시사점은 다음과 같다. 첫째, 본 연구에서는 기존 연구에서 그동안 합의되지 않았던 공급사슬 복잡성의 측정 요소들을 구체적으로 살펴보았으며, 이를 통해 여러 가지 요소들 중에서 기업이 중점적으로 관리해야 하는 요소를 제시하였다.

둘째, 공급사슬 복잡성이 기업 성과에 미치는 영향을 살펴보는 새로운 시각을 제시하였다. 본 연구는 선행연구들이 주장한대로 일부 공급사슬 복잡성은 기업 성과에 부정적인 영향을 미치지만, 다른 공급사슬 복잡성은 기업 성과에 일정 수준까지는 긍정적인 영향을 미치다가 일정 수준이 넘어서면 부정적인 영향을 미치는 것을 밝혀냈다.

셋째, 공급사슬 복잡성이 기업 성과에 미치는 영향을 관리할 수 있는 공급사슬 통합 전략을 제시하였다. 본 연구는 공급사슬 통합이 공급사슬 복잡성과 기업 성과 간의 부정적인 관계를 약화시킬 것이라는

기존의 단순한 논의를 확장하여, 공급사슬 복잡성과 공급사슬 통합 구성요소의 적절한 결합관계를 규명하였다는 점에서 큰 시사점을 지닌다.

본 연구의 실무적 시사점은 다음과 같다. 첫째, 본 연구는 기업의 실무자에게 공급사슬 복잡성을 관리함에 있어서 유의해야 할 사항을 제시하였다. 일정한 수준까지는 공급사슬 복잡성이 증가할수록 기업 성과가 증가하지만, 그 수준이 초과되면 공급사슬 복잡성이 증가할수록 기업 성과가 감소하는 역 U자형의 관계를 지니는 것을 밝혔다.

둘째, 본 연구는 기업에게 공급사슬 복잡성과 공급사슬 통합 간의 관계적 메커니즘을 제시하였다. 이를 통해 기업이 각자 자사가 처한 공급사슬 복잡성을 분석하고, 기업이 추구하는 목표에 따라 향후 적절한 공급사슬 통합 전략을 실시할 수 있는 토대를 마련하였다. 즉, 본 연구는 실무자들이 그들의 공급사슬 복잡성 관리에 공급사슬 통합 전략을 도입하고 활용하는데 있어 유용한 전략적 가이드라인을 제공해준다는 측면에서 의의가 있다.

주요어: 공급사슬 복잡성; 공급사슬 통합; 공급사슬관리; 기업 성과

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