MANAGING FOR ADAPTIVITY IN THE SUPPLY CHAIN BASE:

STRATEGIC CHOICES OF MANUFACTURERS

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ABSTRACT

MEHMET MURAT KRISTAL: Managing for Adaptivity in the Supply Chain Base:

Strategic Choices of Manufacturers

(Under the direction of Professor Aleda V. Roth)

This dissertation addresses manufacturers' ability to influence their supply chain base (SCB) in order to adapt to their competitive environment. From the perspective of a manufacturer, the supply chain comprises a network of suppliers and customers, and is theoretically viewed as a Complex Adaptive System (CAS). The SCB is the set of suppliers and customers whose strategies, products, technologies, and systems can be influenced by the manufacturer. Different degrees of SCB adaptivity emerge, which we define as the ability of the SCB to reconfigure and adjust its operations in the face of changing competitive environments.

In this dissertation, we consider the following questions: (1) How can SCB adaptivity be operationally defined? (2) How does SCB adaptivity lead to combinative competitive capabilities? (3) What is the influence of SCB adaptivity on business performance? Drawing on literature streams in supply chain management, operations strategy, organizational change and learning, and complexity theory, along with a series of structured interviews with practitioners, we develop and test the constructs and operational measures of SCB adaptivity and model the nomological set of relationships among constructs that form the basis of our theory. We then develop and test a model describing the outcomes of SCB adaptivity and its influence on competitive capabilities and firm performance.

Using data from 294 supply chain managers, we test for the effects of exploitation and exploration activities on SCB adaptivity and for the effects of SCB adaptivity on combinative competitive capabilities. Based on CAS theory, we develop eight competencies that characterize exploitation and exploration SCB practices: partner compatibility, supplier information exchange, customer information exchange, implementation capacity, management openness, supplier empowerment, customer openness, and landscape awareness.

Our empirical results show that SCB adaptivity directly and positively affects combinative competitive capabilities. Further, we find that SCB adaptivity does not impact business performance directly, but rather is mediated through combinative competitive capabilities, which provide the requisite variety for firms to survive and thrive in dynamic environments. Ultimately, it is possible and desirable for manufacturers to strengthen exploration and exploitation practices simultaneously in order to enhance the adaptivity of SCB and improve business performance.

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LIST OF ABBREVIATIONS

A	Exploitation Activity
AVE	Average Variance Extracted
CAP	Combined Competitive Capabilities
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CIE	Customer Information Exchange
CO	Customer Openness
df	degrees of freedom
DS	Delivery Speed
EA	Exploration Activity
ED	Environmental Dynamism
EM	Environmental Munificence
IC	Implementation Capacity
IFI	Bollen's Incremental Fit Index
ISM	Institute for Supply Management
LA	Landscape Awareness
MO	Management Openness
MS	Market Share
NCI	McDonald's Non-Centrality Index
NFI	Normed Fit Index
NNFI	Bentler-Bonett Non-Normed Fit Index

PC	Partner Compatibility
PF	Process Flexibility
PL	Price Leadership
PROF	Profit Level
QUAL	Product Quality
RMSEA	Root Mean Square Error Approximation
SCB	Supply Chain Base
SCBA	Supply Chain Base Adaptivity
SE	Supplier Empowerment
SEM	Structural Equation Modeling
SIE	Supplier Information Exchange
TFI	Tucker-Lewis Fit Index

CHAPTER 1

INTRODUCTION

> Companies need to develop a supply chain that is adaptive and capable of responding to the changes of market place and customers. If you can't keep up, your company will not be competitive in the long run.
>
> —Hau Lee, 2003

In today's hypercompetitive environment, supply chain management is fast becoming a necessary condition for corporate survival. However, managers struggle with the dynamic and complex nature of supply chain networks, unpredictable competitive environments, and the resulting lack of control (Choi et al., 2001). According to Jim Limperis, manufacturing outsourcing manager at Motorola Inc.'s Mansfield (Mass.) Information Systems Group, a good supply chain manager, in addition to seeking ever-lower prices and higher quality, must often act as an ombudsman among different functions of the value chain, so he or she will not be the "weakest link" (Levine, 1999). Negotiating between his Motorola customers and outside suppliers, Limperis states that he has to offer communication and feedback to both suppliers and customers, thus making supply chain management more complex than traditional purchasing or warehouse management. Although there are various definitions of supply chain management, the simplest and the most straight forward definition is given by the Stanford Supply Chain Forum: "Supply chain management deals with the management of materials, information and financial flows in a network consisting of suppliers, manufacturers, distributors, and customers" (http://www.stanford.edu/group/scforum/Welcome/).

As indicated by this definition, supply chain management consists of interaction with various agents (i.e., customers, suppliers) of the competitive environment. The unit of analysis in this study is the manufacturing firm that leads a supply chain base, which is defined as the subset of customers and suppliers of a supply chain network that is visible to the manufacturer (Choi and Hong, 2002).

In order to survive in the long run, manufacturers need to develop supply chains that are capable of responding to the changes of the competitive environment and these agents. Lee (2004) uses the notion of "adaptability" to characterize a supply chain's ability to readjust its design to meet structural shifts in markets and to modify supply networks to strategies, products, and technologies. In other words, supply chains need to be "adaptive": they need to continuously reconfigure their competence base (i.e., their requisite competitive capabilities) to develop a sustainable competitive advantage in rapidly changing and unpredictable environments (Eisenhardt and Martin, 2000; Teece et al., 1997). In this study we investigate the underlying structure of supply chain base adaptivity, from the strategic perspective of a single manufacturer. We define supply chain base adaptivity as a manufacturer's ability to manage its supply chain base in order to ensure its long-term viability by searching for future opportunities in order to shape future market conditions in its favor, while at the same time improving its existing capabilities and supply chain efficiency in order to ensure its short-term viability (Chakravarthy, 1982; Choi et al., 2001; Lewin et al., 1999; March, 1991).

Based on this operational definition, we identify eight key attributes of adaptive supply chains using complex adaptive systems theory and subject them to empirical scrutiny. We investigate the influence of these attributes of complex adaptive systems on supply chain base adaptivity and business performance, and empirically demonstrate successful ways to manage supply chains as complex adaptive systems.

Based on grounded theory and using rigorous statistical methods, this dissertation addresses the following research questions:

RQ 1 How can the concept of supply chain base adaptivity be operationally defined?

RQ 2 How does supply chain base adaptivity lead to combinative competitive capabilities?

RQ 3 What is the influence of supply chain base adaptivity on business performance?

As operations management scholars, we need to capture both the operational and strategic aspects of supply chain management. Porter (1996) states that although operational effectiveness is essential for success, unless it is coupled with strategy, it is destined to erode. To gain a better understanding of supply chain management and performance, our discipline needs to apply multiple methodologies ranging from case studies to empirical and analytic modeling. To date, however, the empirical research base in supply chain management is comparatively sparse.

Major topics in supply chain management include demand chain management (Frohlich and Westbrook, 2002), the buyer-supplier relationship (Krause, 1999), the bullwhip effect (Lee et al., 1997), the retail supply chain (Fisher, 1997), the green supply chain (Corbett and Kleindorfer, 2001), supply chain integration (Frohlich and Westbrook, 2001; Lee and Whang, 1999), supply chain coordination (Kulp et al., 2003), and enterprise logistics (Stock et al., 2000). These articles look at supply chain management from a variety of perspectives, but usually at either a conceptual or operational level (Harrison et al., 2003; Lamming et al., 2000). On the other hand,

> ...due to its wide scope, supply-chain management must address complex interdependencies, in effect creating an 'extended enterprise' that reaches far beyond the factory door. Today, material and service suppliers, channel supply partners (wholesalers/distributors and retailers), and customers themselves, as well as supply-chain management consultants, software product suppliers and system developers, are all key players in supply-chain management. (Supply Chain Council, 2003)

The goals of this dissertation are twofold. Our first goal is to provide an enhanced understanding of how manufacturers can better manage all their supply chains in order to adapt to fast-changing competitive environments. We study the dimensions of supply chain base adaptivity from the manufacturer's viewpoint. This viewpoint is defined as a firm's ability to withstand most environmental changes because it has learned to respond to changes in its business environment. These manufacturers have invested in the requisite adaptive ability to seek out new products and or solutions (i.e., exploration), while at the same time improving their existing capabilities and supply chain efficiencies (i.e., exploitation).

The second goal of this study is to provide concrete empirical evidence of the significant benefit of a paradigm shift towards adaptive supply chain management on key operational and financial benefits across the network. Although various exploratory studies have been conducted (Fine, 1996; Mendelson and Pillai, 1999), most of the existing research involves case-based, conceptual models that establish guidelines for how supply chains should be structured in order to compete in today's competitive environment (Choi et al., 2001; Choi and Hong, 2002). There is little supply chain research in the area of theory building and justification. This research therefore aims to contribute to theory building and testing in the emerging area of complex adaptive systems in the operations management literature, as applied to supply chain management.

This dissertation is organized into six chapters. In this introductory chapter we present the research questions and briefly describe the problem. In Chapter 2, we develop our theory and conceptual model, as well as presenting an extensive literature review on the topic of our study. In Chapter 3 we discuss the details of our scale development, and in Chapter 4 we describe our data collection method. In Chapter 5 we discuss the measurement model. In Chapter 6, we report the results of our statistical analyses, and lastly, in Chapter 7, we discuss the study's research and managerial contribution, as well as its limitations and directions for future research.

CHAPTER 2

THEORY DEVELOPMENT AND CONCEPTUAL MODEL

In a number of research streams, such as that of management information systems, strategic management, marketing, and operations management, there has been an increase in the number of articles focused on supply chain management research. Most of these articles are based upon observations, and lack a reliable theoretical base (Chen and Paulraj, 2004; New, 1996). There remains a strong need for theory development in supply chain management research. In this study we aim to contribute to theory building and testing in the emerging area of complex adaptive systems in the operations management literature, as applied specifically to manufacturers ability to influence their supply chain base (SCB).

Bacharach (1989, p. 496) defines theory as "a statement of relations among concepts within a set of boundary assumptions and constraints." Parallel to this definition, Wacker (1998, p. 361) states that theory "defines the variables, specifies the domain, builds internally consistent relationships, and makes specific predictions." One of the most important steps in theory building is to clearly define the domain of the study. This research interprets and integrates concepts from five main research streams: (i) complex adaptive systems, (ii) supply chain management, (iii) manufacturing strategy, (iv) organizational learning, and (v) strategic management. While discussing complex adaptive systems in detail, we utilize other literature in building our conceptual model and hypotheses. This chapter is organized as follows: first, we summarize the conceptualization of adaptation in different research streams; second, we define supply chain base adaptivity; third, we establish the link between complex adaptive systems and supply chain base adaptivity; and finally, we conclude with a proposal for a conceptual model.

Adaptation

The first concept that is crucially important to our study is adaptation. What is adaptation? We give an example from the human body to further explain this topic:

> The human immune system is a combination of large numbers of highly mobile units called *antibodies* that continually repel or destroy an ever-changing cast of invaders called *antigens*. The invaders come in endless varieties. Because of this variety, and because new invaders are always appearing, the immune system cannot simply list all possible invaders. It must change or *adapt* (Latin "*to fit*") its antibodies to new invaders as they appear, never settling to a fixed configuration (Holland, 1995, p. 2).

This example clearly parallels what happens to business entities and supply chains in today's competitive world. New competitors are always appearing, niche players are entering the markets with new innovations, and new markets are opening while old ones are becoming tighter. Manufacturers can no longer rely on an unchanging, stable supply chain network configuration, nor can they form all possible supply chain strategies to counter all possible "invaders" of the competitive world. But we propose that they can make choices that will enable their supply chain base to better adapt to changing market conditions. One key obvious characteristic of adaptive firm behavior is coherence in the face of change. The coherence and persistence of each system depends on extensive interactions, the aggregation of diverse elements, and adaptation or learning (Holland, 1995). The problems of adaptation (conceptualized as the maintenance of the *fit* of the organism with its environment) in complex adaptive systems enable us to learn how complicated structures such as supply chains should be managed. As Kauffman (1995, pp. 246–247) states,

> Why would I, the other scientists at Santa Fe, or our colleagues around the globe studying complexity be interested in potential connections to the practical problems of business, management, government, and organizations? What are biologists and physicists doing poking into this new arena? The themes of self organization and selection, of the blind watchmaker and the invisible hand all collaborating in the historical unfolding of life from its molecular inception to cells to organisms to ecosystems and finally to the emergent social structures we humans have evolved—all these might be the locus of law embedded in history. No molecule in the bacterium *E.Coli* 'knows' the world *E.Coli* lives in, yet *E.Coli* makes its way. No single person at IBM, now downsizing and becoming a flatter organization, knows the world of IBM, yet collectively IBM acts....Organisms, artifacts, and organizations all evolve and co-evolve on rugged, deforming, fitness landscapes....We are all, cells and CEOs, rather blindly climbing deforming fitness landscapes. If so, then the problems confronted by an organization—cellular, organismic, business, governmental, or otherwise—living in niches created by other organizations, are preeminently how to evolve on its deforming landscape, to track the moving peaks.

Parallel to Kaufman's statements, a key premise in strategy literature on organizational change and adaptation is that managers can cope with changes in their firm's external environment through the choice of an appropriate strategy and the design of a matching structure (Andrews, 1971). Another conceptual argument is that an optimum strategy-structure match yields superior performance (Chakravarthy, 1982). Adaptation is a general term that describes a period of gradual, long-continued, and incremental change in response to environmental jolts (Tushman and Romanelli, 1985). Thus, adaptation differs from discontinuous, revolutionary change leading to a major transformation and reorientation of an organization (Miller and Friesen, 1980).

Chakravarthy (1982) developed a framework that includes three states of adaptation. He argued that there are several niches available to an organization for surviving in a given environment. These niches can be ordered in a hierarchy based on the extent of adaptivity, ranging from the weakest to strongest levels of adaptivity. This framework is built on three concepts borrowed from Simon's (1969) definition of the three models that are available to a system for coping with its environment: passive insulation, reactive negative feedback, and predictive adaptation. Each of Chakravarthy's levels of adaptation represents a cluster of niches that have a common characteristic and correspond to a state of adaptation. In the weakest state of adaptivity, the long-term viability of a firm is in serious question. On the other hand, firms in the strongest state can withstand the most environmental turbulence and changes. They either anticipate the changes or can shape the market conditions in their favor.

Another important framework for adaptivity is based on Miles and Snow's (1978) strategic groups (i.e., prospectors, defenders, analyzers, and reactors). In this classification, prospectors are generally concerned with the location and development of market opportunities, while defenders focus on creating a stable set of products and customers. Analyzers focus on efficiency and product/market breadth, and finally reactors represent a "residual" type of behavior where organizations cannot pursue one of the other three strategies. Although the conceptual frameworks of Chakravarthy and Miles and Snow are helpful in terms of explaining the adaptive stages of firms, in this research we take a step further in the context of supply chain networks by integrating March's (1991) concepts of exploration and exploitation activities with complex adaptive system behaviors.

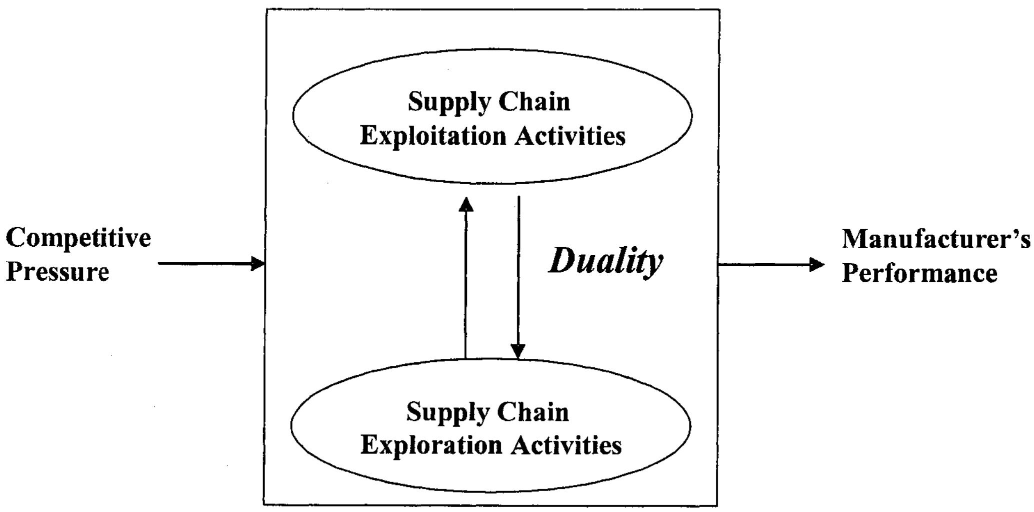
Supply Chain Base Adaptivity

In this study, we define supply chain base adaptivity as a manufacturer's ability to influence its supply base chain in order to ensure its long-term viability by searching for future opportunities in order to shape future market conditions in its favor, while at the same time improving its existing capabilities and supply chain efficiency in order to ensure its short-term viability (Chakravarthy, 1982; Choi et al., 2001; Lewin et al., 1999; March, 1991). This definition is closely linked with the organizational learning process proposed by March (1991). According to March, in general firms engage in two basic activities in order to facilitate organizational learning: exploitation and exploration. March links exploration activities with complex search, innovation, variation, risk-taking, loose discipline, and flexibility. On the other hand, exploitation is associated with efficiency. It involves improving existing capabilities, processes, and technologies, as well as rationalizing and reducing costs (Lewin et al., 1999; Lewin and Volberda, 1999). As Kauffman (1995) states, an adaptive process can be seen as a search process. Complex adaptive systems conduct this search process by simultaneously using two types of activities: exploration and exploitation.

The difference between exploration and exploitation, emphasized in a wide range of management literature, mainly stems from the fact that firms have limited resources. Since firms rarely have sufficient resources for both activities, they usually focus on one or the other. Managers facing competitive pressures need to perform well in the short term, and they usually focus on exploitation. The resulting behavior *competence trap* (Levinthal and March, 1993) leads firms to develop core rigidities that enhance the short-term performance of the firm at the expense of adaptability (Volberda, 1996).

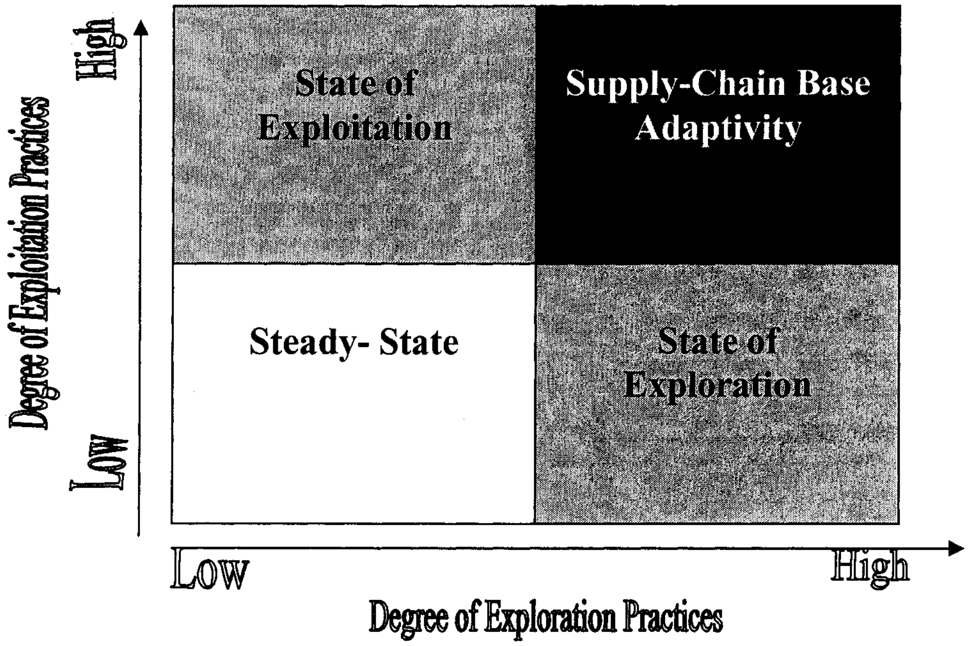
Although there is a certain trade-off between exploration and exploitation in practice, recent research has suggested that exploitation and exploration are not separate, mutually independent activities, and that organizations go through periods of exploitation and exploration sequentially (Weick and Westley, 1996). March (1991) suggests that maintaining a balance between exploration and exploitation is critical for firm survival and adaptivity. As Levinthal and March (1993, p. 105) state, "The basic problem confronting an organization is to engage in sufficient exploitation to ensure its current viability and, at the same time, to devote enough energy to exploration to ensure its future viability." Here the crucial point is the duality of exploitation and exploration activities that an organization must simultaneously pursue. We reflect the notion of duality for supply chain management in Figure 1.

Figure 1. **The Duality of Exploitation and Exploration SCB Practices**



In this research, we posit that the combined effect of manufacturer's exploitation and exploration activities leads to adaptation in manufacturer's supply chain base. We define exploitation activities as the intensity of a manufacturer's efforts to utilize its existing resources in order to achieve greater supply chain efficiency and effectiveness. In a similar vein, we describe exploration activities as the intensity of a manufacturer's efforts to search for new supply chain opportunities in the face of changing competitive environments. In turn, we conceptualize supply chain base adaptivity as a combination of the intensity of both exploration and exploitation activities, which enable a firm to manage its supply chain in order to ensure its long-term viability. We investigate the underlying dimensions of exploitation and exploration activity of a firm in the context of the manufacturer's supply chain. Figure 2 further illustrates the states of supply chain base adaptivity, which is a combination of the manufacturer's exploration and exploitation activity.

Figure 2. **Resulting States of Manufacturers' Choices of SCB Practices**



Supply Chain Base Adaptivity and Complex Adaptive Systems

In general, supply chain management tries to unify the collective productive competencies and resources of the business functions both within the enterprise and outside of the firm's business partners in order to synchronize the flow of products, services, and information to create unique value-added solutions for customers' needs (Ross, 1998). This view of supply chains, a network consisting of members such as manufacturers, suppliers, and customers, leads us to the notion of complex adaptive systems (CASs), which are "systems that emerge over time into a coherent form and adapt and organize themselves without any singular entity deliberately managing or controlling them" (Choi et al., 2001 p. 352; Holland, 1995).

The behavior of CASs can be summarized as follows: (i) there is a "seemingly random" behavior of the system that may result from simple interactions among the members of the system, (ii) there is a sensitive dependence on initial conditions of the system, (iii) the system can spontaneously self-organize into new structures in the face of change, and (iv) the system has the ability to learn (Dooley, 1997). Choi et al. (2001) propose that supply chains are an example of a CAS. Rather than being managed based on functional orientations, sequential information flows, and decision-making, supply chains can be managed in a relatively unplanned, serendipitous way (Burgelman, 1983), enabling autonomous behavior of the supply chain members to lead to requisite variety that is essential to adaptation (Ashby, 1956, 1958; Miller, 1993; Van de Ven, 1986).

Looking at supply chains through the lens of CASs, we observe that the members of the supply chain have simple interactions among themselves in terms of dyadic relations, but once these interactions are studied as a whole the system seems to be complex. The initial conditions of the supply chain, such as the performance of the supply chain in previous years, will definitely affect the performance of the supply chain in the future. Although leading firms such as HP, Ford, or Caterpillar can control their supply chains to a certain extent, there are still things that they cannot control, such as oil prices or innovations within their suppliers; thus, supply chains are prone to undergo self-organization despite the fact that there is a certain amount of control that can be exerted by the supply chain leader. Therefore, similar to Choi et al. (2001) we posit that supply chains are a good example of a CAS.

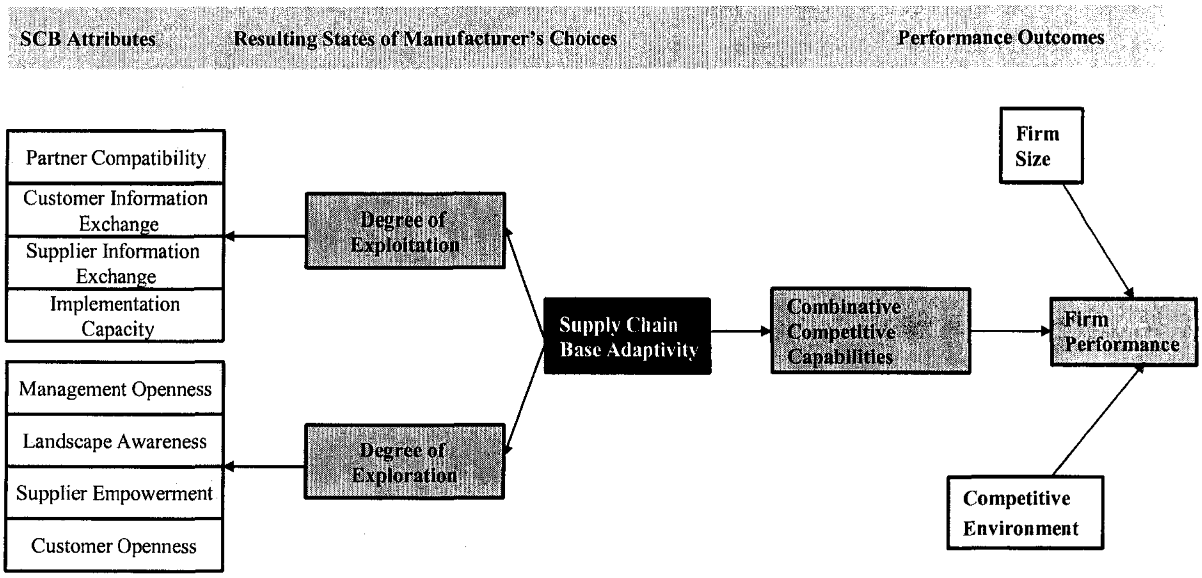
The study of complex adaptive systems has revealed that in order to produce creative, innovative, continually changeable behavior, systems must operate far from equilibrium, where they are driven by negative and positive feedback to alternate states of stability and instability, predictability and unpredictability (Choi et al., 2001). Based on the notions of positive and negative feedback loops, researchers such as Arthur (1991), Kauffman (1995) and Holland (1995) link the behavior of complex adaptive systems to the notions of exploitation and exploration. The basic logic behind this relationship is that complex adaptive systems have a certain learning algorithm that consists of exploitation and exploration. While this learning algorithm leads to adaptation, it is also closely related to the attributes of complex adaptive systems, since each of the attributes of complex adaptive systems enable the system either to work more efficiently (i.e. exploitation), or help the system to discover new resources or patterns (i.e. exploration). In this research, we posit that the cumulative effect of exploitation and exploration adaptations leads to supply chain base adaptivity. We investigate the underlying dimensions of the exploitation and exploration activity of a firm in the context of the manufacturer's supply chain. In the following section, we establish our conceptual model and describe exploitation and exploration activities based on the dimensions of complex adaptive systems.

Conceptual Model

We begin by laying out a conceptual model of exploitation and exploration activity, whose combination forms the basis of supply chain base adaptivity (Figure 3). Then we investigate the relationship of exploitation and exploration activity with the attributes of complex adaptive systems in the context of supply chain management. Lastly, our conceptual model links supply chain base adaptivity to combinative competitive capabilities and firm performance, which is affected by firm size and competitive environment.

Operations management literature has articulated several approaches for developing competitive capabilities. The Harvard school of thought (Hayes, 1985; Hayes and Jaikumar, 1988; Hayes and Pisano, 1996; Hayes and Upton, 1998; Hayes and Wheelwright, 1984; Hayes et al., 1988) posits that since manufacturing capabilities play a significant role in how firms compete in competitive markets, firms need to develop these capabilities on an ongoing basis. Others "link capabilities or competencies based on specific manufacturing process innovations to the ability of the organization to achieve low cost, high flexibility, dependability and quality" (Schroeder et al., 2002, p. 106). Following the latter stream, we define *competitive capabilities* as the manufacturers' actual, or 'realized', competitive strength relative to primary competitors in its target markets (Cleveland et al., 1989; Hayes and Wheelwright, 1984; Hill, 1994; Rosenzweig et al., 2003; Roth and Jackson, 1995; Stalk et al., 1992; Vickery et al., 1993; Ward et al., 1994), and define *combinative competitive capabilities* as the combination of distinct competitive capabilities.

Figure 3. **Conceptual Model Linking Attributes, SCB Adaptivity, and Performance Outcomes**



Before we go into the details of the relationships among the constructs, we present in Tables 1 and 2 the definitions of the supply chain activities and combinative competitive capabilities depicted in Figure 3. In our conceptual model, exploitation activity is captured by partner compatibility, customer information exchange, and supplier information exchange. These supply chain characteristics are based upon three attributes of complex adaptive systems, namely schema, connectivity, and absorptive capacity. In contrast, exploration activity is captured by management openness, landscape awareness, supplier empowerment, and customer openness. These supply chain characteristics are related to two other attributes of complex adaptive systems, namely: self-emergence and dimensionality.

Table 1. Operational Definitions of Constructs Related to Supply Chain Base Adaptivity

Operational Constructs	Operational Definitions	References
Supply Chain Base Adaptivity	A manufacturer's ability to manage its supply chain base in order to ensure its long-term viability by searching for future opportunities in order to shape future market conditions in its favor, while at the same time improving its existing capabilities and supply chain efficiency in order to ensure its short-term viability.	Chakravarthy, 1982; Choi et al., 2001; Lewin et al., 1999; March, 1991
Exploration Activity	The intensity of a manufacturer's efforts to search for new supply chain opportunities in the face of changing competitive environments.	March, 1991
Exploitation Activity	The intensity of a manufacturer's efforts to utilize its existing resources in order to achieve greater supply chain efficiency and effectiveness.	March, 1991
Partner Compatibility	The degree to which supply chain partners have compatible processes and standards among the supply chain.	Choi et al., 2001
Customer Information Exchange	The degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between the manufacturer and its customers.	Frohlich and Westbrook, 2001, 2002
Supplier Information Exchange	The degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between the manufacturer and its customers.	Frohlich and Westbrook, 2001, 2002
Implementation Capacity	Supply chain manager's ability to implement new methods in order to improve supply chain performance.	Holland, 1995
Management Openness	The degree to which the expertise of the supervisors and middle management is considered by the top management when making strategic supply chain decisions.	Burgelman, 1983
Landscape Awareness	The degree to which supply chain managers are aware of changes in industry and technology trends.	Choi et al., 2001
Supplier Empowerment	The degree of supplier involvement in decision-making in supply chain planning and implementations.	Ahmad and Schroeder, 2001; Narasimhan et al., 2001; Krause, 1999
Customer Openness	Establishment and maintenance of relationships with customers in order to better understand their needs.	Ahmad and Schroeder, 2001; Sousa, 2003; Flynn et al., 1995

Table 2. Operational Definitions of Constructs Related to Competitive Capabilities and Competitive Environment

Operational Constructs	Operational Definitions	References
Combinative Competitive Capabilities	The holistic combination of individual capabilities that build on each other and are mutually reinforcing.	Boyer and Lewis, 2002; Noble, 1995; Rosenzwieg and Roth, 2004
Product Quality	A manufacturer's capability to consistently achieve conformance to specifications, fitness for use, and value for price paid in its products.	Rosenzwieg and Roth, 2004
Delivery Speed	A manufacturer's capability to deliver products in a short time.	Rosenzwieg and Roth, 2004
Process Flexibility	A manufacturer's capability to adjust or modify the operational processes to speedily accommodate changes, for example, in production volumes or product mix.	Rosenzwieg and Roth, 2004
Price Leadership	A manufacturer's capability to compete on price.	Miller and Roth, 1994
Environmental Munificence	The extent to which the competitive environment can support sustained growth.	Kotha and Nair, 1995; Starbuck, 1976
Environmental Dynamism	The degree of turbulence in products, technologies, and demand for products in a market.	Dess and Beard, 1984; Ward and Duray, 2000

We noted above that the duality of exploitation and exploration activity leads to supply chain base adaptivity. As March (1991, p. 71) states:

> Adaptive systems that engage in exploration to the exclusion of exploitation are likely to find that they suffer the costs of experimentation without gaining many of its benefits. They exhibit too many undeveloped new ideas and too little distinctive competence. Conversely, systems that engage in exploitation to the exclusion of exploration are likely to find themselves trapped in *suboptimal stable equilibria.* As a result, maintaining an appropriate balance between exploration and exploitation is a primary factor in system survival and prosperity.

In supply chain management terms, exploitation activity is primarily related to the incremental improvement of existing capabilities, such as cost reductions and efficiencies gained in inventory management that are represented in the supply chain's business plan (i.e., cost and revenue architecture). Since exploitation activity is highly imitable, any advantages gained from exploitation are likely to be short-lived. Lee (2004, p. 102) states: "Ceteris paribus, companies whose supply chains become more efficient and cost effective didn't gain a sustainable advantage over their rivals. In fact, the performance of those supply chains steadily deteriorated." Supply chains also need to focus on exploration activity in order to identify and invest in new opportunities that will yield higher potential returns in the long run.

In summary, supply chain base adaptivity is the underlying concept of two closely related but different supply chain activities: *exploration* and *exploitation*. We posit that the interplay between these two types of activities leads firms to search for future opportunities in order to shape future market conditions in their favor and at the same time improve their existing capabilities and supply chain efficiency in order to ensure their short-term viability (Chakravarthy, 1982; Choi et al., 2001; Lewin et al., 1999; March, 1991). More formally,

Hypothesis 1. Supply chain base adaptivity is a second-order multidimensional construct that is reflected by exploitation and exploration activities.

Hypothesis 1a. Supply chain base adaptivity is positively reflected by exploitation activity.

Hypothesis 1b. Supply chain base adaptivity is positively reflected by exploration activity.

Although the attributes of CASs have been discussed in conceptual articles (Choi et al., 2001; Lewin et al., 1999; Lewin and Volberda, 1999), to our knowledge this is the first time that such a model has been developed and tested empirically in the context of supply chain management. In Table 3, we summarize the relationships among the dimensions of CASs in the existing literature with our operational constructs, and modes of supply chain base adaptivity.

Table 3. Relationships between the Attributes of Complex Adaptive Systems and Operational Variables

Supply Chain Base Adaptivity	Attributes of Complex Adaptive Systems	Operational Constructs
Supply Chain Exploitative Activity	Schema	Partner Compatibility
	Connectivity	Customer Information Exchange
		Supplier Information Exchange
	Absorptive Capacity	Implementation Capacity
Supply Chain Exploratory Activity	Self-Emergence	Management Openness
		Landscape Awareness
	Dimensionality	Supplier Empowerment
		Customer Openness

In next section, we continue with the definition of our model constructs related to the attributes of CASs, and set forth hypotheses that we will investigate in our project to evaluate a manufacturing supply chain using the dimensions of CASs.

Exploitation Activities

"Exploitation involves improving existing capabilities, processes and technologies, as well as rationalizing and reducing costs" (Lewin et al., 1999, p. 536). Accordingly, we define supply chain base exploitation activity as the intensity of a manufacturer's efforts to improve existing supply chain capabilities, processes and technologies (March, 1991).Given that the following constructs are the results of manufacturer's efforts or activities, we propose that the construct of exploitation activity is reflected by four operational constructs: partner compatibility, customer information exchange, supplier information exchange, and absorptive capacity. These constructs are rooted in three basic attributes of complex adaptive systems; namely, schema, connectivity, and absorptive capacity (see Table 3).

Schema

Schema refers to the norms, values, beliefs, and assumptions that are shared among the agents of a complex adaptive system (Schein, 1997; as in Choi et al., 2001, p. 353). Complex adaptive networks are formed by agents—that is, entities that populate an adaptive system—and these agents (e.g., atoms, suppliers or buyers in a supply chain, or individual people in an organization) partake in the process of spontaneous change in such a system. Agents have the ability to intervene meaningfully in the course of events. Agency is the key characteristic of the CAS. For instance, "water is a complex system but not a CAS since its interacting objects (e.g., oxygen and hydrogen atoms) lack agency" (Choi, et al., 2001, p. 353).

Depending on the level of analysis, agents can be anything from a group of workers on the shop floor to an entire organization (Choi et al., 2001; Holland, 1995). Agents have various types and degrees of relationships. From flow of information to flow of materials, these relationships can be collected under the heading of "connectivity" (Choi et al., 2001). Agents need to communicate with each other in order to establish connectivity. Gell-Mann (1994) distinguishes a complex adaptive system from evolving, yet nonadaptive, systems such as galaxies by emphasizing the ability of the CAS to condense environmental regularities into schema. Schemas reduce information uncertainty and serve to control "decision premises" about how to define a situation and take action (Perrow, 1972).

Shared norms go beyond simple market transactions or formal authority relationships; for example, they confer benefits without expecting immediate benefits in return. Shared norms and community orientation allow network members to transcend rivalry, minimize the need for constant monitoring and sanctions to lessen opportunistic behavior, and focus efforts on the learning process—the acquisition and incorporation of new insights and knowledge (Lane and Bachmann, 1996). That is, the members of the community share a common, experienced-based body of heuristics (e.g., how to do things, where to search), and have broad agreement on the key technological and organizational obstacles and opportunities likely to be encountered in the future evolution of the trajectory. The community will also have broad agreement regarding how to advance the state of the art (Cimoli and Dosi, 1995). In the context of supply chain management we operationally define the dimension of schema among supply chain partners as *partner compatibility*. We define partner compatibility as the general compatibility of people, technology, processes, and standards among supply chain partners, which enables them to work smoothly together (Choi et al., 2001).

Interestingly, the usefulness of a "common language" is often emphasized to be independent of the organizational affiliation of the workers (Clark and Wheelwright, 1992). Thus, partner compatibility within the supply chain will enable effective communication and the reduction of transaction costs, and may even lead supplier firms to coordinate product development or manufacturing processes with the partners (Choi, et al., 2001; Heinrich and Betts, 2003; Rosenzweig et al., 2003). In other words, the establishment of a "common language" within the supply chain network will enable the supply chain to work more efficiently and smoothly. More formally:

> **Hypothesis 2.** Exploitation activity is positively reflected by partner compatibility (e.g., shared work norms and procedures, shared language) within a manufacturer's supply chain.

Connectivity

Social network theory defines *network connectivity* as ties that link agents within a network (Wasserman and Faust, 1994). These ties can be in various forms, such as

- Transfers of material resources
- Association or affiliation (e.g., jointly attending a social event, or belonging to the same club) (Wasserman and Faust, 1994)
- Relationship between the components that an inventor combines, and the interdependence among these components (Fleming and Sorenson, 2001)

Complex adaptive systems can be defined as Boolean networks consisting of two variables: *N*, the interaction size or the number of agents in a network, and *K*, the interdependence of agents. These two notions establish the starting point of network connectivity. From a supply chain perspective, the level of connectivity determines the complexity of the network (Choi et al., 2001). If no connections exist, then agents will behave independently, and the aggregate response will be unstructured and random (Dooley and Van de Ven, 1999). If the agents are connected, they can create a harmonic behavior that will enable them to survive the competition. In order to achieve this harmonic behavior, supply chains integrate their operations in some way. Such a connection among the partners enables communication and increases the efficiency of the supply chain. Thus, it is an integral part of the exploitation adaptation.

In simple terms, we see integration as the supply chain's nervous system, which carries messages throughout the supply chain network to functional areas or to agents of a complex adaptive system. Supply chain integration has been extensively studied in operations management literature. Two main streams have been studied in supply chain integration studies. The first stream focuses on the integration of manufacturers with their customers, where as the second stream focuses on the in the integration of manufacturers with their suppliers. The main finding of these studies is that integration between manufactures and their customers and/or suppliers result in efficient information exchange among the supply chain partners and increase the efficiency of the supply chain. In Table 4 we provide a brief overview of integration literature adapted from Frohlich and Westbrook (2002).

Table 4. Literature on Supply and Demand Integration*

Types of Integration	Studies
Demand Integration	
Efficient Delivery	Cachon (1999), Cachon and Fisher (2000), Clark and Hammond (1997) Daugherty et al. (1999), Johnson and Scudder (1999)
Delivery/logistics communication	Corbett et al. (1999), Kopczak (1997), Waller et al. (1999)
Speed of delivery/route	Clark and Hammond (1997), Kopczak (1997)
Inventory stocking points	Kopczak (1997)
Demand planning	Fisher et al. (1994), Gavirneni et al. (1999), Gilbert and Ballou (1999), Hariharan and Zipkin (1995), Lummus and Vokurka (1999), Magretta (1998)
Supply Integration	
Supplier reliability	Carr and Pearson (1999), Chapman (1989), Choi and Hartley (1996), Fawcett and Birou (1993), Freeland (1991), Grout (1998), Hill and Vollman (1986), Krause (1999), Krause et al. (1998), Narasimhan and Jayaram (1998)
Multiple sourcing	Bozarth et al (1998)
Responsive/flexible supply base	Krause (1999), Narasimhan and Das (1999)
Inbound logistics communication	Grout (1998)
Supplier planning	Fisher et al. (1994), Magretta (1998)

*Source: Frochlich and Westbrook, 2002, p. 730.

In the extant literature, there exist different definitions of supply chain integration. We see supply chain integration as the information exchange among supply chain partners, represented by the flow of routine information among the supply chain partners (Frohlich and Westbrook, 2001; Martin, 1992; Trent and Monczka, 1998). Information exchange has two components: *customer information exchange* and *supply information exchange* (Frohlich and Westbrook, 2002).

Following Frohlich and Westbrook (2002), Mabert and Venkatraman (1998), and Rosenzwieg and Roth (2004), we define *customer information exchange* as the degree to which supply chain information is exchanged between the manufacturer and its customers for routine transactions. One of the major problems of supply chain networks is the "bullwhip effect" caused by information distortion from one end of the supply chain to the other (Lee et al., 1997). In order to overcome this problem, one trend is to facilitate the information exchange between the customers and the manufacturer of the supply chain in order to coordinate the information flow.

We define *supplier information exchange* as the degree to which supply chain information is exchanged between manufacturer and the suppliers for routine transactions. On the supplier side, integration yields improvements in delivery and cost (Krause et al., 1998).

Both customer and supplier information exchange lead the members of the supply chain to be connected to each other, enabling them to share or exchange information in real-time or with only short delays. Such an information exchange increases the efficiency of the supply chain network. More formally, we propose the following hypotheses:

Hypothesis 3a. Exploitation activity is positively reflected by customer information exchange.

Hypothesis 3b. Exploitation activity is positively reflected by supplier information exchange.

Implementation Capacity

Absorptive capacity has long been studied in the organization science and strategic management literatures. Cohen and Levinthal (1990) argue that absorptive capacity is a function of the firm's level of prior knowledge. Since absorptive capacity is path-dependent (i.e., cumulative), "the way that a firm (or an individual) learns is typically by building on what it (he or she) has learned before" (Cohen and Levinthal, 1994, p. 229). Also, it is easier for someone to build absorptive capacity on previously gained knowledge; that is to say, "by having already developed some expertise in an area, a firm knows more precisely what additional information it will require to be able to exploit effectively any new advances that may materialize, and also knows better where and how to find that information" (Cohen and Levinthal, 1994, p. 229). The crucial part of absorptive capacity is the conversion of existing or new knowledge into action, which enables firms to increase their efficiencies, an integral part of exploitation adaptation. By analogy, we use the term *implementation capacity* to connote the supply chain managers' ability to recognize the value of knowledge, and to assimilate and apply it in order to improve supply chain performance (Cohen and Levinthal, 1990). Thus, following Lewin et al. (1999), we hypothesize that

Hypothesis 4. Exploitation activity is positively reflected by implementation capacity.

Exploration Activities

"Exploration involves experimenting with ideas, paradigms, technologies, strategies, and knowledge in hope of finding new alternatives that are superior to obsolete practices" (Lewin et al., 1999, p. 536). In turn we define supply chain exploration activity as the intensity of a manufacturer's efforts to search for new supply chain opportunities in the face of changing competitive environments (March, 1991). An organization facing competition is likely to engage in a search for ways to improve performance. When successful, this search results in learning that is likely to increase the organization's competitive strength, which in turn triggers learning in its rivals—consequently making them stronger competitors and so again triggering learning in the first organization (Barnett and Hansen, 1996). We propose that the construct of exploration activity has four operational constructs (management openness, landscape awareness, supplier empowerment, and customer openness), which are rooted in two basic attributes of complex adaptive systems: self-emergence and dimensionality.

Self-Emergence

One of the basic premises of firm adaptivity is the focal firm's ability to create a supply chain network that has the ability to self-organize. Self-organization is defined as "a process … whereby new emergent structures, patterns, and properties arise without being externally imposed on the system" (Goldstein, in Zimmerman et al., 1998, p. 270; as in Choi et al., 2001). Such networks are also self-emergent: "the arising of new, unexpected structures, patterns, properties, or processes in a self-organizing system….Emergent phenomena seem to have a life of their own with their own rules, laws and possibilities" (Goldstein, in Zimmerman et al., 1998, p. 265; as in Choi et al., 2001).

Once we focus on the informal feedback networks in organizations, we can understand this notion better. In these networks, individuals randomly establish links among themselves.

> The possibility of emergent order is a fundamental property of such feedback networks, and changeability is also a fundamental property when the pattern of connectivity is rich enough. From this perspective the central evolutionary and transformational processes in organizations are ones of spontaneous self-organization, close to Hayek's notion (1948), which make an organization changeable and produce emergent new patterns of behavior in this manner (Stacey, 1995, p. 489).

In the supply chain context, self-organization and self-emergence are exhibited in two forms: *management openness* and *landscape awareness*.

Management Openness

We posit that in organizations that are self-emergent, new ideas can be freely discussed and facts can come before the organizational ranks. The business literature has long discussed whether the members of an organization should be given some degree of autonomy in the strategy-making process or whether a top-down approach should instead be followed. The organizational forms associated with autonomy can be classified into two major groups: vertical organizations and horizontal organizations. The basic premise of vertical organizations is high efficiency and ease of control of the organization. Usually, vertical organizations are more effective in mature industries where the competitive advantage stems from high efficiency. On the other hand, horizontal organizations are usually found in highly turbulent environments. In fact, there is a certain trade-off between these two types of organizations, and by strictly focusing on the organizational type, the enterprise may suffer in the long run (Eisenhardt, 1989).

For both vertical and horizontal organizations, continuous renewal of existing business strategies is essential for survival in the long run. One way to achieve this is to combine the firm's existing resources and the competencies already available in the firm in unique ways in order to form new competencies (Burgelman, 1991). This can be accomplished by allowing the lower levels of management to intervene in the strategy-making process and by creating an environment where new ideas can be discussed freely. According to Burgelman (1991), such initiatives are most likely to emerge at a level at which managers are directly in contact with new technological developments and changes in market conditions, and have some budgetary discretion. Such a strategy will enable upper-level management to follow the new developments in changing external environments via interaction with lower level management who are in daily contact with the changing market conditions. We call such behavior *management openness* and define it as the degree to which the expertise of supervisors and middle management are considered by top management when making strategic supply chain decisions. In other words, we posit that one of the components of exploration activity is the freedom given to lower-level management to search for new and innovative ideas that will help supply chain managers cope with the uncertainties of the competitive environment. Thus, we propose the following hypothesis:

Hypothesis 5. Exploration activity is positively reflected by the management openness of the firm.

Landscape Awareness

In the previous section, we posited that one of the crucial elements of exploration activity is management openness, which enables supply chain managers to consider new ideas within the organization. In the same vein, supply chain managers need to monitor their environment in order to observe new trends on both the supplier and the customer sides. Choi et al. (2001, p. 359) explain the benefits of environmental scanning among supply chain networks with an example:

> … Honeywell (aircraft engine manufacturer) finds itself closely monitoring the world of raw material, such as steel, copper, and aluminum as well as an assortment of other composite materials. A shortage of raw material can result in skyrocketing costs and send delivery schedules askew. Therefore, it is obvious that Honeywell would consider itself connected or coupled with various mining companies.

Rich and Hines (1997) illustrate this type of low-intensity interaction with a high number of agents using an example from Japan: *kyoryoku kai,* which is defined as "a mutually benefiting group of a company's most important subcontractors, brought together on a regular basis for the basis of co-ordination and co-operation as well as to assist all the members to benefit from the type of development associated with large Japanese assemblers: such as kaizen, just in time, kanban, U-cell production and the achievement of zero defects" (Rich and Hines, 1997, p. 218; see also Hines, 1994). On the market or customer side, Brown and Eisenhardt (1997) found that successful firms rely on a wide variety of low-cost probes into the future, including experimental products and futurists. Similar to the concept of *executive scanning*, which is defined as the managers' efforts to seek information from the competitive environment (Garg et al., 2003), we define *landscape awareness* as the degree to which the supply chain managers are aware of what is happening in their industry.

Hypothesis 6. Exploration activity is positively reflected by landscape awareness.

Dimensionality

Dooley and Van de Ven (1999) define *dimensionality* as the degrees of freedom that individual agents within a system have to enact behavior in a somewhat autonomous fashion. The organization science literature has been focusing on dimensionality for quite a long time in terms of new organizational forms. For example, Galunic and Eisenhardt (1996) describe a multidivisional organizational form built upon independent divisions that are "chartered" to look after one or more business areas. The key point here is that these divisions are loosely coupled and susceptible to change. The capability of these divisions to change is seen as an adaptive device for large, multidivisional corporations in fast-paced environments (Galunic and Eisenhardt, 1996).

In a similar vein, Ciborra (1996) defines a platform organization as a metaorganization—a formative context that molds structures and routines, shaping them into well-known forms such as the hierarchical or modular organizational structures. Although such an organization is confusing at first sight, the strength of a platform organization is its readiness to support whatever organizational form is required under the new business circumstances.

To summarize, when a higher degree of autonomy is given to agents to make decisions locally or when dimensionality is enlarged, creative activities that emerge from such freedom help firms to adapt to their changing business environments (Choi et al., 2001; Dooley and Van de Ven, 1999).

We define two constructs that will represent dimensionality in supply chain networks: *supplier empowerment* and *customer openness*. As managers become open to emergent structures in the supply chain network, they also start to rely on the suggestions and innovative ideas of suppliers. In the human resources literature, employee empowerment has been well studied. Jayaram and Vickery (1998) found that empowerment has a significant impact on lead-time reduction, as well as on firm performance. Similarly, Snell and Dean (1992) found that employee empowerment helps transform a firm's product according to new emergent needs and adds tangible value through employees' increased ability to solve problems, coordinate the work of departments, and exercise judgment in novel situations. Powell (1995) defines employee empowerment as increased employee involvement in design and planning, and greater autonomy in decision making. In the same vein, we define *supplier empowerment* as the degree of supplier involvement and autonomy regarding decision-making in supply chain planning and implementations.

Such an approach has been increasingly emphasized in the management literature in the context of organizational design (Levinthal and Warglien, 1999). Organizational design suggests that agents should act independently in their local area, but in a coordinated fashion in terms of global search activities. This is called the robust design, "a design in which, thanks to low interdependence among the agents of a system, the asymptotic behavior of autonomous agents can be predetermined with high probability, independent of the knowledge of specific choice process and their starting point in the landscape" (Levinthal and Warglien, 1999, p. 346).

Supply chains are in a constant search process in a *rugged landscape*. Levinthal and Warglien (1999) formally define a landscape as a mapping from an organism's genetic structure to its fitness level. This definition helps us to use the concept of landscape[1] as a metaphor in order to describe the competitive environment that the supply chains are operating in. In other words, adaptation can be viewed as a search process, in which the goal is to reach the highest peak. If the landscape consists of a single peak, then the search process is a fairly easy one, but on the other hand if the landscape consists of multiple peaks then the search process is more complicated. Multiple peaks are the direct result of interdependence among a set of actors or policy choices. Such landscapes are called "rugged landscapes" (Kauffman, 1995).

Since supply chains try to survive in a rugged landscape, where it is nearly impossible to find the global optima with easy heuristics, supply chains have to create efficient search methods among the supply network. One of the ways to create an efficient search process is to give autonomy to the members of the supply chain, which will enable the entire supply chain to achieve better results than if the manufacturer alone searches the landscape. This point of view also coincides with the organizational behavior perspective on empowerment. "In sum, empowered organizations are continuously learning, self-organizing systems whose members are equal partners, not employees governed by others" (Ehin, 1995, p. 666). Studies in the automotive industry (Womack et al., 1994) have shown that when suppliers are given the autonomy to think creatively, they can come up with innovative ideas to improve current product configurations. Choi et al. (2001, p. 361) give the example of how a wire harness problem was solved in the Lexus. "Empowered to suggest design changes, suppliers broke up the harness into smaller pieces and connected them with 'smart' junction boxes with

[1]Here the concept of *landscape* is used as a metaphor in order to show the complexity of the competitive environment that supply chains compete in thus it should not be confused with our operational construct *landscape awareness* which indicates the extent to which supply chain managers are aware of what is going on in their respective industries.

microchips and microprocessors. The final outcome was a new configuration that offered more flexibility if design changes were needed." Thus, we hypothesize that

Hypothesis 7. Exploration activity is positively reflected by supplier empowerment.

Customer focus has been studied in the total quality management, new product (service) development, and service management literatures for a quite a long time (Flynn et al., 1995; Goldstein et al., 2002; Menor et al., 2002). Based on this literature, we define *customer openness* as the establishment of open relationships with customers in order to clarify their needs and desires (Flynn et al., 1995; Sousa, 2003). We hypothesize:

Hypothesis 8. Exploration activity is positively reflected by customer openness.

Combinative Competitive Capabilities

Competitive capabilities have been studied extensively in both the operations management and the strategic management literatures (Clark, 1996; Hayes and Pisano, 1996; Menor and Roth, 2003; Roth, 1996; Schroeder et al., 2002). The establishment of competitive capabilities has usually been associated with the resource-based view (RBV) of the firm. In the strategy literature, competitive capabilities are defined as "the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997, p. 516). Parallel to this definition, the operations management literature ties competitive capabilities to the ability of the organization to achieve low cost, high flexibility, dependability, and quality (Schroeder et al., 2002; Cleveland et al., 1989; Giffi et al., 1990; Hayes and Wheelwright, 1984; Hill, 1994; Rosenzweig et al., 2003; Skinner, 1978; Stalk et al., 1992; Vickery et al., 1993; Ward et al., 1994). Following this research stream, we apply the definition given by Roth and Jackson

(1995) that *competitive capabilities* are the manufacturers' actual, or 'realized,' competitive strength relative to primary competitors in its target markets. The list of generic operations competitive capabilities includes quality, cost/efficiency, delivery/responsiveness, and flexibility, which are defined below.

a) Product Quality: As Garvin (1987) states, quality is a multidimensional construct, and each of its dimensions can be used to gain competitive advantage. In our quality construct, we follow Rosenzweig et al. (2003) and utilize three dimensions of quality: conformance to specifications, fitness for use (Reid and Sanders, 2001).

b) Delivery Speed: We define delivery speed as the capability to deliver products in a short time (Ward and Duray, 2000).

c) Process Flexibility: Process flexibility has widely been recognized as one of the fundamental operations-based capabilities (along with quality, delivery, and cost) by which a firm can differentiate itself (Anderson et al., 1989; Berry and Cooper, 1999; Koste and Malhotra, 1999; Ward et al., 1998). We define process flexibility as the ability to adjust or modify the operational processes to speedily accommodate changes, for example, in production volumes or product mix (Menor et al., 2003). This type of flexibility is required as a means of proactively or defensively responding to uncertainty in the operating environment (de Groote, 1994; Gerwin, 1993; Koste and Malhotra, 1999; Swamidass and Newell, 1987).

d) Price Leadership: We define price leadership as the capability of the supply chain to compete on price (Miller and Roth, 1994; Roth 1996).

One of the important aspects of the notion of competitive capabilities is the discussion about the concept of *traded-off* versus *combinative* capabilities. Classical thinking in manufacturing strategy posits that in order to achieve high performance in one of the competitive capabilities, firms need to trade off for low performance in others (Hayes and Wheelwright, 1984; Skinner, 1978). However, new findings suggest that due to global competition (with the concomitant development and dissemination of advanced manufacturing technologies) firms can achieve high levels in more than one capability (Flynn and Flynn, 2004). Roth's (1996) competitive progression theory posits that cumulative competitive capabilities are due to organizational learning, and that manufacturers can achieve high performance in more than one capability simultaneously (Rosenzwieg and Roth, 2004). In summary, the notion of combinative competitive capabilities can be viewed as the holistic combination of individual capabilities that build on each other and are mutually reinforcing (Boyer and Lewis, 2002; Noble, 1995). As a result, the construct of combinative competitive capabilities is posited to reflect a combination of distinct competitive capabilities, and we set forth the following hypotheses:

Hypothesis 9. Combinative competitive capabilities is a second-order construct that is reflected by multiple capabilities such as product quality, delivery speed, process flexibility, and price leadership.

Hypothesis 9a. Combinative competitive capabilities are positively reflected by product quality.

Hypothesis 9b. Combinative competitive capabilities are positively reflected by delivery speed.

Hypothesis 9c. Combinative competitive capabilities are positively reflected by process flexibility.

Hypothesis 9d. Combinative competitive capabilities are positively reflected by price leadership.

Linking Supply Chain Base Adaptivity and Combinative Competitive Capabilities

Capabilities-based competition has been studied both in the operations management and the strategic management literature (Clark, 1996; Hayes and Pisano, 1996; Menor and Roth, 2003; Roth, 1996; Schroeder et al., 2002). The establishment of competitive capabilities has usually been associated with the resource-based view (RBV) of the firm. In general, the RBV has focused on the characteristics of the resources with respect to competitors rather than their development within the firm (Schroeder et al., 2002). Other discussions have centered on the reasons that resources may be difficult to acquire in the short term, if they can be acquired at all (Teece et al., 1997). Our research provides insight into the ways that the dimensions of complex adaptive systems create a valuable resource in terms of competitive capabilities and supply chain management.

Given that the competitive environment is constantly changing, today's strength for a supply chain might become tomorrow's weakness. Based on this fact, D'Aveni (1994) suggested that firms cannot build competitive advantage that is sustainable for a long time. Rather than trying to create stability and equilibrium, manufacturers need to develop these capabilities on an ongoing basis (Hayes, 1985; Hayes and Jaikumar, 1988; Hayes and Pisano, 1996; Hayes and Upton, 1998; Hayes and Wheelwright, 1984; Hayes et al., 1988; Roth 1996). Porter (1991, p. 97) states that "strategy is the act of aligning a company and its environment. That environment, as well as the firm's own capabilities, is subject to change. Thus, the task of strategy is to maintain a dynamic, not a static, balance." The *dynamic balance* that Porter discusses can be maintained only by the firm's ability to integrate its current competencies while simultaneously developing fundamentally new capabilities. In order to achieve this integration, firms need to conduct a search process. Our theory posits that this search process can be conducted in two ways. Either firms can exploit high-payoff actions that have been undertaken several times and are therefore well understood, leading to supply chain efficiency; or they can explore seldom-tried actions that may have a higher average payoff (Arthur, 1991; Levinthal, 1997). Thus, capabilities can be built upon the dynamic balance between the exploration and exploitation activities in which a firm engages (Benner and Tushman, 2003). Therefore, by analogy firms should constantly seek out supply chains that enable combinative capabilities, which will provide them temporary advantage over their competitors. In other words, they will have the requisite variety of competitive capabilities (Menor et al., 2001). As we discussed previously, since supply chain base adaptivity involves the combination of exploitation and exploration, we posit that the oscillations between exploitation and exploration activities will lead to constant regeneration of combinative competitive capabilities, and we hypothesize that

Hypothesis 10. Supply chain base adaptivity directly and positively affects combinative competitive capabilities.

Linking Combinative Competitive Capabilities and Firm Performance

In this research, we examine the mediating role of competitive capabilities between supply chain base adaptivity and business performance. Except for recent works (Frohlich and Westbrook, 2001; Rosenzweig et al., 2003), prior research on the competitive capabilities has usually focused on the manufacturing function (Flynn et al., 1999; Hill, 1994; Miller and Roth, 1994; Swamidass and Newell, 1987; Ward et al., 1994). Thus, this research also contributes to the supply chain management literature by studying the relationship between competitive capabilities and business performance from a supply chain management perspective.

In this study we measure firms' economic performance in terms of two categories: financial performance and growth performance. For financial performance, we employ a measure widely used in the management literature, namely, profit level (Rosenzweig et al., 2003). For growth performance, a leading indicator (Rosenzweig et al., 2003), we use market share. Many studies link competitive capabilities to business performance (Cleveland et al., 1989; Ferdows and DeMeyer, 1990; Flynn et al., 1999; Kim and Arnold, 1992; Miller and Roth, 1994; Rosenzweig, 2003; Roth and Miller, 1992; Swamidass and Newell, 1987; Vickery et al., 1993, 1994; Ward et al., 1994, 1998). Conventional wisdom states that competitive capabilities improve an organization's chances for survival (Hayes and Upton, 1998; Porter, 1996); thus, we propose that

Hypothesis 11a. Combinative competitive capabilities positively affect market share.

Hypothesis 11b. Combinative competitive capabilities positively affect profit level.

Since the mid-seventies, many studies investigated the relationship between market share and profit level. Although some studies documented the positive relationship between market share and profit level (Buzzell et al., 1975), there are other studies that showed the positive relationship between market share and profit level is context specific (Prescott et al., 1986). One of the rationales behind this significant effect is economies of scale. In other words, high-market-share businesses can achieve lower costs when higher production rates lead to reduced variable costs (Levinthal and Myatt, 1994). Also, as in the Wal-Mart case, for example, firms with high market share can exert power on their suppliers in order to lower their material costs as well. Therefore we propose that

Hypothesis 12. Market share positively affects profit level.

Competitive Environment

A prevailing notion in strategic management is that managers cope with changes in their firm's external environment through the choice of an appropriate structure and the design of a matching strategy (Andrews, 1971). Thus, while measuring the impact of competitive capabilities on firm performance, we need to consider the competitive environment in which the complex adaptive systems compete.

We consider three environmental factors that affect a firm's performance: *environmental munificence* and *environmental dynamism*, which are rooted in the literature of strategic management (Porter, 1980; Suarez and Utterback, 1995), and organization theory (Dess and Beard, 1984).

Environmental Munificence

Environmental munificence is defined as the extent to which the environment can support sustained growth (Kotha and Nair, 1995; Starbuck, 1976). We measure environmental munificence as the growth or decline in sales over time in an industry (Dess and Beard, 1984). Population ecologists posit that organizations seek out environments that permit organizational growth and stability in order to generate slack resources (Cyert and March, 1963). Porter explains this phenomenon as follows: "Slow industry growth turns industry competition into a market share game [in which] rapid industry growth ensures that firms can improve results just by keeping up with the industry growth" (Porter, 1980, p. 18, as in Dean and Snell, 1996, p. 465). We hypothesize that

> **Hypothesis 13a.** Increased environmental munificence leads to increased levels of market share.

Hypothesis 13b. Increased environmental munificence leads to increased levels of profit levels.

Environmental Dynamism

We define environmental dynamism as the degree of turbulence in products, technologies, and demand for products in a market (Dess and Beard, 1984; Ward and Duray, 2000). Dynamism arises when a decision-maker cannot forecast future events based on the information he or she has on hand. In dynamic environments the ability of managers to predict or foresee the future is greatly reduced (Anderson and Tushman, 2001). Thus, we hypothesize that

Hypothesis 14a. Increased environmental dynamism leads to decreased levels of market share.

Hypothesis 14b. Increased environmental dynamism leads to decreased levels of net profit.

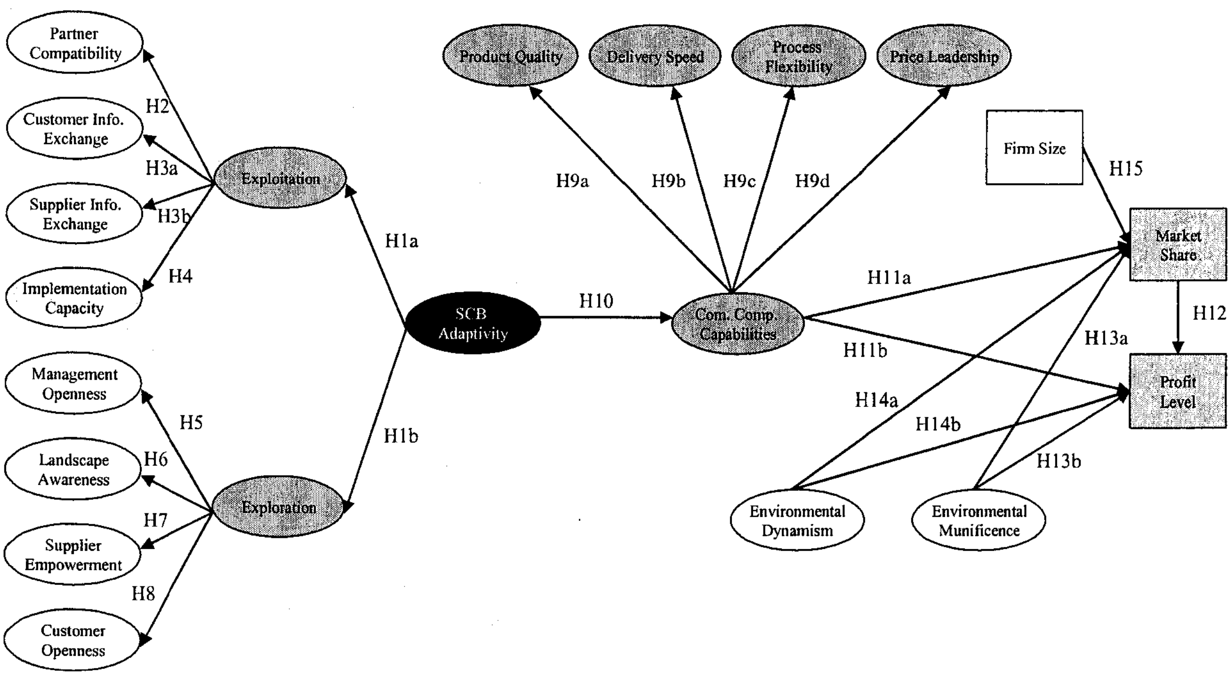
Firm Size

Firm size has been one of the most important variables in organizational studies. Various overviews on the importance of firm size have been published in various research streams (Chen and Hambrick, 1995; Mintzberg, 1979). Usually, larger firms tend to have a larger market size and greater control over the competitive environment (Dean et al., 1998). Larger firms tend to be more bureaucratic and contain more management levels than smaller firms (Daft, 1995). This leads to "inertia," which is defined as inadequate or slow adaptation to change, or resistance to fundamental changes in conducting business (Miller and Chen, 1994). Based on these arguments, we control for firm size while measuring firm performance and hypothesize

Hypothesis 15. Firm size positively affects market share.

To summarize, we present our full hypothesized model in Figure 4 below.

Figure 4. **Full Hypothesized Model**



CHAPTER 3

SCALE DEVELOPMENT

One of the main contributions of this study to operations management literature is the measurement of supply chain base adaptivity based on theoretical constructs. In other words, by utilizing psychometric methods, we provide new measures that enable us to evaluate supply chain base adaptivity and provide important constructs showing that supply chains can behave as complex adaptive systems. For scale development purposes we followed a three-phase approach that is summarized in Figure 5. As discussed in Chapter 2, in phase one of our research we first specified the domain of various articles in the areas of complexity theory, organization change, complex adaptive systems, and supply chain management. From these articles, we now extract the relevant constructs and scales, and then develop our own original scales for constructs that lack them. The current chapter focuses on actual scale development and the analysis of these newly developed measures.

In order to achieve high-quality (or "high-validity") measurement items, after development of the constructs theoretically important to this study we followed a two-stage, multi-item scale development approach. Consistent with the rigorous approach for new scale development proposed by Menor and Roth (2004), the two stages enabled us both to reduce measurement error by providing a more robust representation of complex variables (Drolet and Morrison, 2004) and to cover the construct domains with desired reliability and validity

(Hensley, 1999). In this chapter, we focus on the first stage, namely the front-end stage. In this stage we employed item-sorting exercises that enabled us to gauge four types of validity important for survey research. By extensive review of the literature and interviews with supply chain professionals we ensured that our measurement items were a proper sample of the theoretical content domain (i.e., that they exhibited content validity). Then by employing an item-to-factor sorting process, we ensured that our measures (i) were reflective of the theoretical constructs of interest (i.e., exhibited substantive validity) (Anderson and Gerbing, 1991); and (ii) were operational indicators of the constructs of interest (i.e., exhibited convergent and discriminant validity) (Schriesheim et al., 1993).

Figure 5. **Research Approach**

Theory Development
- Literature review
- Model specification
- Hypothesis development

↓

Front-End Stage: Scale Development
- **Content Validity**
  - Quality of item pool
- **Interrater Reliability**
  - Pair-wise agreements
  - Cohen's K
  - Perreault and Leigh's I_r
- **Substantive Validity**
  - Proportion of substantive agreement
  - Coefficient of substantive validity
- **Convergent & Divergent Validity**
  - Overall placement ratio

(Substantive Validity and Convergent & Divergent Validity: ***Construct Validity***)

↓

Back-End Stage: Confirmatory Factor Analyses of the Measurement Model
- **Calibration**
  - Confirmatory analysis of the measurement model (using calibration sample)
  - Analysis (fit indices, estimates, and modification indices) and modifications
- **Validation**
  - Confirmatory analysis of the measurement model (using calibration sample)
  - Multi-group analysis (using calibration and validation samples)
  - Confirmatory analysis of the measurement model (combined sample)
  - Analysis (fit indices, estimates)

Source: Menor and Roth (2004)

Item Generation

Having defined the theoretically important constructs pertaining to supply chain base adaptivity, our next task was the development of reliable and valid measurement scales. Generating a representation of the set of items tapping into each of the constructs is a necessary and important first step. For new scale development, we followed an iterative item-generation approach. Multi-item scales help reduce measurement error by providing a more robust construct of complex variables. As several constructs central to this research have not been operationalized in previous literature, we needed to create our own scales.

To obtain a tentative assessment of our scales' reliability and validity, we applied Menor and Roth's (2004) iterative, pre-scale development process, which is a variant of the Q-sort technique. We used expert judges who are knowledgeable about supply chain management and are generally representative of the sample of respondents who would complete the final survey instrument. We subjected the scale items and associated constructs to multiple rounds of sorting, each with a different set of judges, to determine which items should be used in the various scales (Moore and Benbasat, 1991; Menor and Roth, 2004). In an item-sorting exercise, items are matched into their theoretical categories. In contrast, usual statistical procedures produce similarity indices (i.e., correlations) among the column entries of a data matrix (i.e., questionnaire items) (Schriesheim, et al., 1993). We formed our new scales and items with tentative reliability and validity after three rounds of sorting. In Appendix 1, we report the progression of our item generation across the sorting rounds. In Appendix 3 we provide the most recent version of the survey instrument that we used in our pretest item-sorting exercise.

Refining and pretesting items after each sorting round was extremely important because it gave us the chance to assess the tentative reliability and validity of our measures before developing our survey instrument and testing it on large samples. According to Schriesheim et al. (1993), satisfactory results in substantive, convergent, and divergent validity are necessary for judging a measure to have reasonable construct validity.

In order to judge substantive validity in our first three presort testing exercises we followed Anderson and Gerbing (1991). They propose two indices of substantive validity. The first index is called the *proportion of substantive agreement*, p_{sa}, which is defined as the proportion of the respondents who assign an item to its intended construct:

$$p_{sa} = \frac{n_c}{N} \tag{1}$$

In Equation 1, the number of respondents assigning a measure to its posited construct is represented by n_c. N represents the total number of respondents. The value of p_{sa} ranges from 0.0 to 1.0, with larger values indicating greater validity. Although this index shows the extent to which an item reflects its intended construct, it does not indicate the extent to which an item might also be tapping other, unintended constructs. In order to overcome this problem, Anderson and Gerbing suggest a second index that reflects the extent to which respondents assign an item to its posited construct more than to any other construct. They call this index the *substantive validity coefficient*, c_{sv}, which is defined as follows:

$$c_{sv} = \frac{n_c - n_o}{N} \tag{2}$$

In Equation 2, n_c and N are defined as before, and n_o indicates the highest number of assignments of the item to any other construct. The values of c_{sv} range from –1.0 to 1.0. Values of c_{sv} closer to 1.0 indicate greater validity, whereas values closer to –1.0 indicate that the item has validity but for a different construct.

Lastly, we calculated Moore and Benbasat's (1991) item-placement ratio, which involves a comparison of the number of items placed by the panel of judges within the target construct. The term *hits* corresponds to the right matching of the definition of the constructs with the items utilized to measure the constructs. The item-placement ratio measures the percentage of actual hits to the total number of potential hits. Item-placement ratio is in fact the average of the *proportion of substantive agreement* index for each construct based on each item proposed by the researcher. Scales based upon categories that have a high item-placement ratio are considered to have a high degree of construct validity, and potentially high reliability scores (Menor and Roth, 2004). Similar to Oliveira (2004), Rosenzweig (2002), and Stratman and Roth (2002), we used an individual hit ratio of 75% as our target minimum rule-of-thumb value.

Note that these indices do not represent interrater reliability. In order to measure the interrater reliability, we utilized Perreault and Leigh's (1989) measure of interjudge agreement and Cohen's κ statistic. These measures were calculated after each of the first three rounds of item sorting to show how we could improve our classification scheme, definitions, and survey directions. Perreault and Leigh's (1989) interjudge agreement statistic captures the observed proportion of agreement between all possible pairs of judges for each round of Q-sorts, taking into account the number of construct categories. The formula is given as follows:

$$\text{If } A \geq (1/K) \text{ then } \quad I_r = \{[A-(1/K)][K/(K-1)]\}^{1/2}$$
$$\text{else} \quad I_r = 0 \qquad (3)$$

where A = agreement between all possible pairs of judges = F_0 / TOT

F_0 = pair-wise agreements between judges

TOT = total number of pair-wise judgments

K = number of categories

The formula in Equation 3 is used when the pair-wise percentage of interjudge agreement (A) is greater than or equal to what would be expected by chance ($1/K$). If A is less than $1/K$, then I_r equals zero (Perreault and Leigh, 1989). As a result, the values of I_r range between 0 and 1, where a score of 0 indicates that the observed agreement is by chance, and a score of 1 indicates perfect interjudge agreement. Scores greater than 65% are generally considered to be an acceptable level of agreement (Menor and Roth, 2004; Stratman and Roth, 2002; Moore and Benbasat, 1991). Cohen's κ statistic also indicates an adequate interjudge agreement when it is greater than 0.65 (Moore and Benbasat, 1991).

Item-Sorting Analysis Results

In all three rounds of item-sorting iterations, we used expert judges from companies such as IBM, DuPont, Johnson and Johnson, Home Depot, and HP. For each round, we first scrutinized the measurement items in terms of interrater reliability. Listed in Table 5 are the raw interjudge agreement percentages, Cohen's κ (Cohen, 1960), and Perreault and Leigh's I_r. For each round we used 10 independently drawn judges, yielding 45 interjudge combinations.

The interjudge agreement percentage (A) is the ratio of pair-wise agreements in item classifications made between judges to the total number of pair-wise judgments possible in each round. The average scores for interjudge agreement are 69 %, 85%, and 70% for the first three sorting rounds, respectively. Since there are no established standards for assessing the adequate percentages of agreement, we use this measure as a baseline in conjunction with other measures of reliability, such as I_r and Cohen's κ.

Table 5. Comparison of Interrater Reliability

Interjudge Combination $C_{a/b}$*	Interjudge Agreement Percentage (*A*) (by Sorting Round)			Cohen's κ (by Sorting Round)			Perreault & Leigh's I_r (by Sorting Round)		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
$C_{1/2}$	.69	.85	.76	.65	.83	.73	.81	.91	.86
$C_{1/3}$	.72	.88	.78	.68	.86	.75	.83	.93	.87
$C_{1/4}$	.67	.82	.70	.62	.79	.66	.79	.89	.82
$C_{1/5}$	.83	.88	.78	.81	.86	.75	.90	.93	.87
$C_{1/6}$	.72	.82	.70	.68	.79	.66	.83	.89	.82
$C_{1/7}$	.86	.88	.78	.84	.86	.75	.92	.93	.87
$C_{1/8}$	.69	.82	.68	.65	.79	.64	.81	.89	.80
$C_{1/9}$	.72	.82	.74	.68	.79	.71	.83	.89	.84
$C_{1/10}$	.92	.88	.66	.90	.86	.71	.95	.93	.79
$C_{2/3}$	.64	.88	.72	.58	.86	.68	.77	.93	.83
$C_{2/4}$	.47	.76	.68	.39	.72	.64	.63	.85	.80
$C_{2/5}$	.58	.88	.74	.52	.86	.71	.72	.93	.84
$C_{2/6}$	.47	.82	.68	.40	.79	.64	.63	.89	.80
$C_{2/7}$	.75	.88	.72	.71	.86	.69	.85	.93	.83
$C_{2/8}$	.53	.82	.60	.47	.79	.55	.68	.89	.75
$C_{2/9}$	.58	.76	.70	.52	.72	.66	.72	.85	.82
$C_{2/10}$	.64	.88	.72	.59	.86	.69	.77	.93	.83
$C_{3/4}$	.56	.82	.68	.49	.79	.64	.70	.89	.80
$C_{3/5}$	.61	.94	.74	.55	.93	.71	.75	.96	.84
$C_{3/6}$	.67	.88	.68	.62	.86	.64	.79	.93	.80
$C_{3/7}$	.72	.94	.74	.68	.93	.71	.83	.96	.84
$C_{3/8}$	.64	.88	.66	.59	.86	.62	.77	.93	.79
$C_{3/9}$	.67	.79	.72	.62	.76	.69	.79	.87	.83
$C_{3/10}$	.72	.94	.68	.68	.93	.64	.83	.96	.80
$C_{4/5}$	.61	.82	.76	.56	.79	.73	.75	.89	.86
$C_{4/6}$	.72	.82	.64	.68	.79	.60	.83	.89	.78
$C_{4/7}$	.72	.85	.66	.68	.83	.62	.83	.91	.79
$C_{4/8}$	.67	.79	.56	.62	.76	.51	.79	.87	.72
$C_{4/9}$	.61	.76	.66	.55	.72	.62	.75	.85	.79
$C_{4/10}$	.69	.82	.66	.65	.79	.62	.81	.89	.79
$C_{5/6}$	.67	.94	.76	.62	.93	.73	.79	.96	.86
$C_{5/7}$	.81	.94	.82	.78	.93	.80	.88	.96	.90
$C_{5/8}$	.67	.94	.70	.62	.93	.66	.79	.96	.82
$C_{5/9}$	.72	.79	.78	.68	.76	.75	.83	.87	.87
$C_{5/10}$	.80	.94	.78	.78	.93	.76	.88	.96	.87
$C_{6/7}$	.72	.88	.74	.68	.86	.71	.83	.93	.84
$C_{6/8}$	.64	.88	.64	.58	.86	.60	.77	.93	.78
$C_{6/9}$	.67	.73	.66	.62	.69	.62	.79	.83	.79
$C_{6/10}$	.69	.88	.72	.65	.86	.69	.81	.93	.83
$C_{7/8}$	.72	.88	.74	.68	.86	.71	.83	.93	.84
$C_{7/9}$	.81	.79	.72	.77	.76	.69	.88	.87	.83
$C_{7/10}$	.86	.94	.68	.84	.93	.64	.92	.96	.80

$C_{8/9}$	.58	.79	.66	.53	.76	.62	.72	.87	.79
$C_{8/10}$	.72	.88	.58	.68	.86	.53	.83	.93	.73
$C_{9/10}$	.72	.79	.68	.68	.76	.64	.83	.87	.80
Average	**.69**	**.85**	**.70**	**.64**	**.83**	**.67**	**.80**	**.91**	**.82**

* Independent samples of 10 judges are used in each round

According to Perreault and Leigh (1989), values greater than .80 are acceptable for interjudge reliability for a subsample of responses initially coded and evaluated. Our average values of I_r are 80%, 91%, and 82%, indicating an acceptable level of interrater reliability. This observation is further supported by our results for Cohen's κ, which is generally regarded as a conservative estimator of interrater reliability. Except for the first sorting round, the values of κ are greater than the acceptable level of .65, which indicates that adequate interjudge agreement occurs beyond chance. Thus, these measures indicate that our items have overall tentative reliability.

Having established the tentative reliability of our measures, we next scrutinized the validity of our items. Although we obtained satisfactory reliability scores, further investigation indicated that we could achieve better results by reviewing some of the items as well as the operational constructs. We therefore refined our measures based on the agreement between the judges' item classifications and the intended construct. This was facilitated by utilizing two substantive validity measures: the proportion of substantive validity (p_{sa}) and the coefficient of substantive validity (c_{sv}) (Anderson and Gerbing, 1991). The values of proportion of substantive validity range from 0 to 1.0, with larger values indicating greater substantive validity; and the values of the coefficient of the substantive validity range from –1.0 to 1.0, with larger positive values indicating greater substantive validity. Usually, cutoff values of .70 for proportion of substantive validity and .41 for the coefficient of substantive validity are acceptable (Menor and Roth, 2004). For parsimony, we present the values of p_{sa} and c_{sv} for each round and the progression of item-sorting exercises in Appendix 1.

Pedhazur and Schmelkin (1991) stress the importance of examining a construct definition to determine whether it is too vague or inconsistent with the theoretical structure within which the construct is embedded. Based on p_{sa} and c_{sv} values and our interviews with the expert judges, for the second round we dropped "schema," and introduced "partner compatibility," which makes more sense in the world than the concept of schema. The results of our second round were very satisfactory, but after discussion with other researchers and supply chain professionals, we decided to measure the Exploratory and Exploitative Adaptivity of a supply chain as well. In order to achieve our goal we established operational definitions of these constructs and we also generated items for these based on the literature. In the third round we included Exploratory and Exploitative Adaptivity measures, which led to more refinement of our previously existing constructs.

In the third round, we found that items for Exploratory and Exploitative Adaptivity were problematic: Our expert judges confused them especially with Implementation Capacity and Landscape Awareness. Based on these results, we deleted some measures from Exploitative Adaptivity, Exploratory Adaptivity, and Implementation Capacity. Also, we retained but reworded certain measures in order to make them more comprehensible to supply chain managers.

Lastly, we assessed the tentative convergent and discriminant validity of our measures (see Table 6), using Moore and Benbasat's (1991) item-placement ratio, which involves a comparison of the number of items placed by the panel of judges within the target construct. This measure is a summary statistic that provides evidence of item misclassifications. We used this measure in combination with the results of p_{sa} and c_{sv} in order to detect any sources of measurement item error. As can be seen in Table 6, the item-placement ratio values for Implementation Capacity and Exploitative Adaptivity fall below the cutoff value of .75 (Moore and Benbasat, 1991). These results indicated the need to drop some of the measures with low p_{sa} and c_{sv} values.

Table 6. Overall Placement Ratios

	Overall Placement Ratio		
		Round	
Operational Constructs	**1**	**2**	**3**
Schema[b]	.58	n.a.	n.a.
Customer Information Exchange	.68	.83	.95
Supplier Information Exchange	.84	.83	.93
Landscape Awareness	.86	.88	.88
Management Openness	1.00	1.00	.97
Supplier Empowerment	.83	.80	.93
Implementation Capacity	.86	.80	.70
Partner Compatibility[c]	n.a.	.85	.80
Customer Openness	.80	.86	.84
Exploratory Activity[d]	n.a.	n.a.	.82
Exploitative Activity[d]	n.a.	n.a.	.56
Sorting Round Average	.81	.86	.81

[a] Proportion of substantive agreement and substantive validity coefficients are presented in Appendix 1.
[b] Dropped after the first round
[c] Introduced in the second round
[d] Introduced in the third round

As described above, the degree of agreement between judges forms the basis for qualitatively assessing validity and improving the reliability of the constructs (Nahm et al., 2000). While the item-sorting exercise provides some evidence that our constructs are both reliable and valid, it is predominantly qualitative in nature and most applicable during the pretest, design stage of survey research (Nahm et al., 2000). Essentially, item- sorting exercises help researchers to prepare questionnaire items for survey research. Further empirical testing is needed to ensure that the scales have the characteristics required to form the foundation for theory building and testing in the area of supply chain base adaptivity

(Stratman and Roth 2002). Item-sorting exercises enabled us to purify our measures in preparation for data collection with our pilot study. In the next section, we focus on our data collection process, the database as well as the front-end stage of our scale development process.

CHAPTER 4

EMPIRICAL DATA COLLECTION

As described in the previous chapter, item-sorting exercises enabled us to gauge the tentative reliability and validity of our measures and operational constructs. But while item-sorting exercises provide some evidence that our constructs are both reliable and valid, they are qualitative in nature and based on a small sample size. Thus, further empirical testing is needed to ensure that we have reliable and valid scales, based on a larger sample. In this section, we lay out the details of our data collection procedure, and then assess the quality of our data.

Research Design

Having developed and tested our constructs for tentative reliability and validity in the back-end stage of our scale-development process, we then designed and pilot-tested a survey instrument. The refined survey instrument was used to collect data for calibration and validation samples, which are defined in detail in later sections. The data were collected through a web-based survey. We used the membership database of the Institute for Supply Management™ (ISM), formerly called the National Association of Purchasing Managers, as the sample frame. Founded in 1915, ISM is the largest supply management association in the world, as well as one of the most respected. ISM's mission is to lead the supply management profession by establishing standards of excellence in research, promotional activities, and education. It is a not-for-profit association that provides opportunities for the promotion of the profession and the expansion of professional skills and knowledge (www.ism.ws). ISM's membership base includes more than 45,000 supply management professionals with a network of domestic and international affiliated associations. The pool of potential respondents for this study was randomly chosen by ISM administration.

In this research, although our unit of analysis is the manufacturing firm that leads the supply chain base (i.e., the leading partner of the supply chain), such as Ford, HP, or Dell, we also study the relations of the leading firm with its supply chain partners, such as their customers and suppliers. The leading partner manages the brands to which customers respond and the sales channels through which network participants distribute those products. Our pool of companies includes companies such as Caterpillar, DuPont (which also acts as a participating company in other supply chains), Ford, GM, and IBM.

Data Collection Method

We utilized a cross-sectional web-based survey of US manufacturing companies drawn from the Institute for Supply Management's membership directory. According to Couper (2000), the use of web-based surveys might be a potential source of sample-frame error, which would result when potential respondents are missing from the frame since they do not have web access. Klassen and Jacobs (2001) state that limited access to technology and computer implementation might favor larger firms and may be due to management practices and personal characteristics that may confound both descriptive and confirmatory research. On the other hand, Dillman (2000) notes that certain populations, such as workers in many companies and corporations and members of some professional organizations, generally have Internet addresses and access. For populations such as these, the use of web-based surveys might only create minor coverage problems. Since our research population consist of professionals who are members of ISM, we judged that the use of a web-based survey would not create any additional sample frame error in our study.

We conducted our data collection in two steps. We obtained contact information (i.e., e-mail addresses as well as phone numbers) for 3,300 supply chain managers from ISM and randomly split this database into two parts to be used in the pilot-test and final data collection steps of our study. We then conducted a pilot study. For the pilot study we administered our web-based survey to 800 of the supply chain managers. Of those 800 surveys, we received 81 usable responses, yielding a response rate of 10 percent. After conducting our preliminary analysis on the pilot-test data, we sent our final study to the rest of the potential respondents. For our final study, we sent out a modified survey and invited an additional 2,500 supply chain managers to participate in our study. We received 213 usable responses, a response rate of 9 percent.

For the data collection process, we followed a combination of Dillman's (2000) and Frohlich's (2002) guidelines. For each round of data collection, we first e-mailed an initial invitation to potential respondents to participate in our study. Then, after two days we sent another e-mail that included the link to our web-based survey (please see Appendix 5 for invitation letters). A week after this e-mail, we sent another reminder e-mail with the link to our survey included. We sent a follow-up round of e-mails a week after our reminder e-mail.

Frohlich (2002) states that when response rates are low, a study is immediately open to concerns about the existence of nonresponse bias. Therefore, after the final data collection, we contacted by phone more than 200 randomly chosen respondents from the potential list in order to secure their cooperation and representation. From the intensive phone interviews with our potential respondents, we concluded that the main reason for the failure to reply was the length of the survey (18 web pages). Given that our survey took approximately 45 minutes to complete, the 9% response rate was not unusual (Dillman, 2000).

Data Description

In this study, we have chosen industries that either are manufacturing-intense or have considerable supply chain applications. Specifically, the following two-digit SIC codes are covered in the study: 20 "food & kindred products"; 23 "apparel & other finished products"; 25 "furniture & fixtures"; 28 "chemicals & allied products"; 30 "rubber & miscellaneous plastics"; 34 "fabricated metal products"; 36 "electronic & other electrical equipment"; 37 "transportation equipment"; 38 "measuring & analyzing instruments"; 50 "durable goods"; 51 "non-durable goods"; 52 "building materials, hardware, garden supplies and mobile home dealers"; 54 "food stores". Target respondents were Title 1 and 2 ISM members with titles of president, vice president, director, general manager, supply chain manager, and purchasing manager.

The final sample consisted of 31 presidents/vice presidents (10.5%), 62 directors (21.1%), 6 general managers (2.0%), 69 supply chain managers (23.5%), 108 purchasing managers (36.7%), and 18 others (6.1%). The respondents worked primarily for medium- to large-size firms. Approximately 35% of the respondents' firms have more than 1,000 employees, and more than 57% of the firms have a market share larger than 32%.

Although we collected data in two stages, we carried out our statistical analyses in four stages. First we analyzed the data from the first stage (the pilot study). Then we made some minor changes to our questionnaire and continued to collect the data for the final study. We present the items used in pilot and final questionnaires in Appendix 2 and the final questionnaire in Appendix 4. Following this two-stage approach, we then randomly chose 50 observations from our final study and combined these observations with our pilot study in order to create a calibration sample for the measurement model. After finalizing our measurement model, we used a multi-group analysis approach to confirm that our measures were valid and reliable. Following the multi-group analyses, we combined the data from the pilot and final studies and analyzed the hypothesized model with the combined data. Thus, we ended up working with four data sets: (i) the pilot study data; (ii) a calibration sample combining the pilot-test data with 50 randomly sampled observations from the final study; (iii) a validation sample, which comprises the rest of the observations other than the 50 sampled from the final study; and (iv) the pilot-test and final study data combined. In Table 7, we present the descriptive statistics of the respondent profile of the four samples. As seen in Table 8, where we report the profile of the companies represented by our respondents, our data is skewed towards manufacturers that have high market share.

Table 7. Descriptive Statistics for the Respondents

	Pilot Study (*N*=81)	Calibration Sample (*N*= 131)	Validation Sample (*N*=163)	Combined Sample (*N*= 294)
Business Unit Represented				
Entire Company	40.70%	48.85%	50.93%	50.35%
Division or Group Level	38.30%	35.88%	33.54%	34.38%
Process-Based Organization	1.30%	1.53%	1.86%	1.74%
Plant Level	16.00%	12.21%	11.80%	12.15%
Other	3.70%	1.53%	1.86%	1.39%
Total	100.00%	100.00%	100.00%	100.00%
Position in the Company				
President, CEO, COO, or Chairman	-	0.81%	1.45%	1.15%
Vice President	7.69%	13.81%	6.52%	9.58%
Director	14.10%	23.58%	18.84%	21.07%
General Manager	1.28%	2.44%	1.45%	1.92%
Supply Chain Manager	26.92%	19.52%	26.81%	23.37%
Purchasing Manager	41.03%	34.96%	38.41%	36.78%
Other*	8.97%	5.69%	6.52%	6.13%
Total	100.00%	100.00%	100.00%	100.00%

* Includes positions such as Supply Chain Team Leader, Senior Buyer

Table 8. Descriptive Statistics for the Company Characteristics

	Pilot Study (*N*=81)	Calibration Sample (*N*=131)	Validation Sample (*N*=163)	Combined Sample (*N* = 294)
Primary Industry				
Automotive	13.92%	9.45%	8.81%	9.09%
High Tech	18.99%	22.83%	17.61%	19.93%
Chemical	6.33%	6.30%	15.72%	11.54%
Aerospace and Defense	10.13%	7.09%	5.66%	6.29%
Pharmaceutical	6.33%	3.94%	6.92%	5.59%
Consumer Goods	27.85%	32.28%	31.45%	31.82%
Food Services	6.33%	5.51%	3.77%	4.55%
Information Technologies	1.27%	0.79%	--	0.35%
Transportation and Warehousing	1.27%	3.15%	3.14%	3.15%
Health Care	1.27%	1.57%	1.89%	1.75%
Other*	6.33%	7.09%	5.03%	5.94%
Total	100.00%	100.00%	100.00%	100.00%
Number of Employees**	**(*N*=73)**	**(*N*=111)**	**(*N*=117)**	**(*N*=228)**
Under 50	19.18%	17.12%	17.09%	17.11%
50-99	4.11%	3.60%	7.69%	5.70%
100-499	20.55%	24.32%	35.04%	29.82%
500-999	12.33%	12.61%	11.97%	12.28%
1,000-2,499	15.07%	16.22%	12.82%	14.47%
Over 2,500	28.77%	26.13%	15.38%	20.61%
Total	100.00%	100.00%	100.00%	100.00%
Market Share**	**(*N*=54)**	**(*N*=92)**	**(*N*=100)**	**(*N*=192)**
Under 8%	11.11%	9.78%	10%	9.90%
8%-16%	9.26%	9.78%	8%	8.85%
16%-24%	12.96%	9.78%	14%	11.98%
24%-32%	12.96%	13.04%	8%	10.42%
32%-40%	12.96%	11.96%	24%	18.23%
40%-48%	5.56%	16.30%	10%	13.02%
Over 48%	35.19%	29.35%	26%	27.60%
Total	100.00%	100.00%	100.00%	100.00%
Profit Level (before taxes)**	**(*N*=54)**	**(*N*=88)**	**(*N*=95)**	**(*N*=183)**
Negative	7.41%	5.68%	3.16%	4.37%
Breakeven	1.85%	6.82%	7.37%	7.10%
Under 5%	14.81%	12.50%	16.84%	14.75%
5%-10%	20.37%	15.91%	25.26%	20.77%
10%-15%	24.07%	22.73%	16.84%	19.67%
15%-20%	14.81%	19.32%	15.79%	17.49%
Over 20%	16.67%	17.05%	14.74%	15.85%
Total	100.00%	100.00%	100.00%	100.00%

* Includes industry sectors such as Appliance Manufacturing, Medical Electronics, Hydraulic Valves Manufacturing, Manufacturing of Electrical Distribution and Automated Products, Office Equipment Manufacturing, Printing Ink and Cartridges, Plastics Molding, Food and Beverage Manufacturing.

** Because of missing observations, we present the number of available observations for each of the samples.

Lastly, in Table 9 we present the results of the chi-square tests that show whether the respondent profiles differ from one sample to another. As one can see, our results do not show a significant difference among the respondent profiles of each data sample.

Table 9. Statistical Comparison of Respondent and Company Characteristics for Validation and Calibration Samples

Respondent and Company Characteristics	Pearson Chi-square	df	*p* -value
Business Unit Represented	1.47	4	0.83
Position in the Company	5.88	6	0.44
Primary Industry	10.06	10	0.44
Number of Employees	7.53	5	0.18
Market Share	7.53	6	0.27
Profit Level (before taxes)	4.48	6	0.61

Data Treatment

Before starting our data analyses, we also checked the normality of our data distribution. The normal distribution is symmetric, and has a skewness value of zero. Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. Excessive skewness might affect the reliability of the statistical analyses. Values outside the range of –2 to +2 are considered to indicate high skewness (Curran et al., 1996).

On the other hand, kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case. In Appendix 6, we present the descriptive statistics for the items that are used in this study for each individual sample.

Missing Data

In an empirical study missing data are inevitable. In the present study, the missing data total less than 2 percent. For our statistical purposes, the missing data were treated as completely at random. The statistical package we used to estimate our models, AMOS 5.0, utilizes a missing-data treatment method similar to Little and Rubin's (1987) approach:

> Amos's full information maximum likelihood (FIML) estimation uses all information of the observed data. The likelihood is computed for the observed portion of each case's data and then accumulated and maximized. Amos's ML approach usually yields results equivalent to Don Rubin's EM approach, except that Amos also incorporates constrained moment matrix estimation. In addition, FIML requires no imputation (or E-step) and typically converges faster (http://www.smallwaters.com/amos/faq/ faqamissdat.html#t1q5).

Common-Method/Source Variance

Boyer and Verma (2000) state that survey research based upon a single respondent is susceptible to common-method or source bias. However, while a single respondent might have a biased perspective or limited access to information; senior managers such as the ones targeted in this research tend to have fairly accurate perceptions (Miller and Roth, 1994). Nevertheless, we studied the common-methods/source effects on the relationship among our constructs. As Kemery and Dunlap (1986, p. 325) state:

> Method variance has been defined as all systematic effects associated with a given measurement procedure (Campbell & Fiske, 1959). The method variance problem can occur whenever researchers collect multiple measures with a single measurement format, such as paper-and-pencil testing, or from the same source, such as previous ratings. Of particular concern is that the correlations among the measures are inflated by method variance, thus suggesting relationships that may in fact not exist, or may overestimate effect size.

Although there is not a consensus on how to address common-methods variance, one of the widely used methods for addressing this problem is Harman's one-factor test (Podsakoff and Organ, 1986). In this procedure, an explanatory factor analysis is conducted. As Podsakoff et al., (2003) states, the basic assumption behind this procedure is to see whether there is a substantial amount of method variance present among the constructs we study. If there is a common-method bias, then either a single factor will emerge from the factor analysis or one general factor will account for the majority of the covariance among the measures (Podsakoff, et al., 2003). In our factor analysis, 11 factors emerged (Table 10). The first factor accounts for approximately 25% of the variance. Although there are not clear guidelines on how much variance the first factor should extract before it is considered a general factor, it is generally accepted that if it extracts less than 30% of the variance, common-method variance is not a threat to the study (Christmann, 2000; Arbaugh, 2002; Hoskinsson et al., 2004).

Table 10. Results of Harman's One-Factor Test

Factor	Total	% of Variance	Cumulative %
1	11.933	24.859	24.859
2	4.166	8.679	33.538
3	3.473	7.236	40.774
4	2.696	5.616	46.390
5	2.162	4.505	50.895
6	1.972	4.109	55.005
7	1.454	3.029	58.034
8	1.300	2.708	60.742
9	1.143	2.381	63.123
10	1.102	2.297	65.419
11	1.063	2.216	67.635

Single-Item Measures

Before starting our empirical analysis of the validity and reliability of our measures, we examined the utilization of single-item measures for our study. As indicated in Chapter 2, we faced two problems in terms of performance measurement. It is a fact that it is often very difficult to obtain objective data on business performance (Narasimhan and Das, 2001); thus, we had to rely on the senior managers' perceptions of their companies. This way of measuring business performance has been adapted by various researchers (e.g., Germain et al., 2001), and prior studies have demonstrated statistically significant correlations between perceptual and corresponding objective measures of performance (Dess and Robinson, 1984; Vickery et al., 1997; Ward et al., 1994, 1998), indicating that the perceptual ratings of performance can be considered as reliable indicators.

Once we decided to use subjective data, we faced the problem of how best to measure firm performance given the potential subjectivity of the questions. Following Dillman (2000), Ketoviki and Schroeder (2004), in order to increase the accuracy of our responses we decided to use *quasi-perceptual* measures rather than items that ask the respondents to compare their business performance relative to their competitors. Quasi-perceptual measures lead the respondents to choose categories based on objective measures. For our market share measure, for example, we used the item: "Considering the one product that yields the highest percentage of revenue for your business unit, what is your business unit's average market share?" with the possible answers of under 8%, 8%–16%, 16%–24%, 24%–32%, 32%–40%, 40%–48%, and over 48%. This forced our respondents to give answers as objectively as possible. In a similar vein, for profit level we used the item: "On average, what has been your company's profit level (before taxes)?" with the possible answers of negative, breakeven, under 5%, 5%–10%, 10%–15%, 15%–20%, and over 20% . As a result we were able to collect fairly objective performance measures for our respondents' companies.

Although single items are a potential limitation, they are infrequent in this study: we used multiple item measures throughout, except in the case of market share and profit level. These two items have been developed and analyzed in various studies in manufacturing strategy research (Roth et al., 1997). To summarize, as Hausman et al. (2002, p. 247) have suggested, "We neither claim that these single item scales exhaustively measure all aspects of the theoretically derived framework nor that they are measured without error; however, we believe them to be reasonable and sufficient proxies."

CHAPTER 5

MEASUREMENT MODEL

In order to confirm the reliability and validity of measures with a large sample, we move to the back-end stage of our multi-item development process, which involves the analysis of web-based survey data. This back-end stage is also called the measurement model. Bollen (1989, p. 182) defines measurement model thus: "A measurement model specifies a structural model connecting latent variables to one or more measures or observed variables. The latent variable is the formal representation of a concept. The measurement model describes the relation between the measure and latent variables."

Confirmatory Factor Analysis

Our measurement model is developed primarily through confirmatory factor analysis, using AMOS 5.0. In the next chapter we focus on the structural model, which is developed primarily through path analysis with latent variables, also using AMOS 5.0. We first test the measurement model using the calibration sample. After some modification of our items and scales, we repeated the tests on the calibration sample. After our measurement model was finalized with the calibration sample, we validated our results by comparing the results of our analysis for both the calibration and validation samples (i.e., we carry out a multigroup analysis). Lastly, we carried out an analysis using the combined sample. In the following sections, we continue with our empirical analysis of the reliability and validity of the items and constructs used in this study.

For purposes of clarity, in Table 11 we present the standard notation used in SEM, based on Bollen (1989), which will be used in this chapter as well as in Chapter 6.

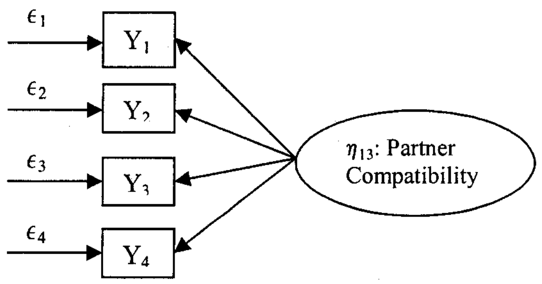
Table 11. Notation for the Structural Equation Modeling

	Structural Equation for the Latent Variable Model $\eta = B\eta + \Gamma\xi + \zeta$	
Symbol	**Name**	**Definition**
η	Eta	latent endogenous variables
ξ	Xi	latent exogenous variables
ζ	Zeta	latent errors in equations
B	Beta	coefficient matrix for latent endogenous variables
Γ	Gamma	coefficient matrix for latent exogenous variables
	Structural Equations for the Measurement Model $x = \Lambda_x\xi + \delta$ $y = \Lambda_y\xi + \varepsilon$	
y		observed indicators of η
x		observed indicators of ξ
ε	Epsilon	measurement errors for y
δ	Delta	measurement errors for x
Λ_y	lamda y	coefficients relating y to η
Λ_x	lamda x	coefficients relating x to ξ

The structural equation for our latent variable model represents the relationship among the latent variables or the constructs, whereas the structural equations for the measurement model represent the relationship between the latent variables and the observed variables. We started by estimating and refining the measurement models prior to the estimation of the latent variable model path coefficients. This approach is called confirmatory factor analysis and ensures the reliability and validity of the items in the scale—in other words, that they measure a single construct (Anderson and Gerbing, 1991).

Figure 6 illustrates the measurement model for partner compatibility. This model is specified as $y_i = \lambda_i \eta_{13} + \varepsilon_i$, where y_i represents the questions related to partnership compatibility, λ_i represents the factor loadings depicting the magnitude of the effect of partner compatibility (i.e., η_{13}) on y_i, and ε_i, represents the random measurement error. Following Figure 6 we provide the list of partner compatibility measurement items in Table 12.

***Figure 6.* Measurement Model of Partner Compatibility**



$$y_1 = \lambda_{113}\eta_{13} + \varepsilon_1$$
$$y_2 = \lambda_{213}\eta_{13} + \varepsilon_2$$
$$y_3 = \lambda_{313}\eta_{13} + \varepsilon_3$$
$$y_4 = \lambda_{413}\eta_{13} + \varepsilon_4$$

Table 12. Partner Compatibility Measurement Items

Definition of Partner Compatibility:
General compatibility of people, technology, processes, and standards among supply chain partners that enables them to work together smoothly.
Items for Partner Compatibility:
Y1. All activities that take place among the supply chain partners are clearly defined.
Y2. We established common business processes with our supply chain partners.
Y3. We established consistent operating standards with our supply chain partners.
Y4. We tried to synchronize the technological standards among our supply chain partners.

As stated in chapter four, we conducted our data collection in two stages. In Appendix 7, we present the results of the confirmatory factor analyses with the pilot study data. In this preliminary analysis, we focused on the reliability of the items. Reliability is necessary but not a sufficient condition for good items (Pedhazur and Schmelkin, 1991). Although reliability does not guarantee validity of the measures, it provided a good basis for the initial screening of items.

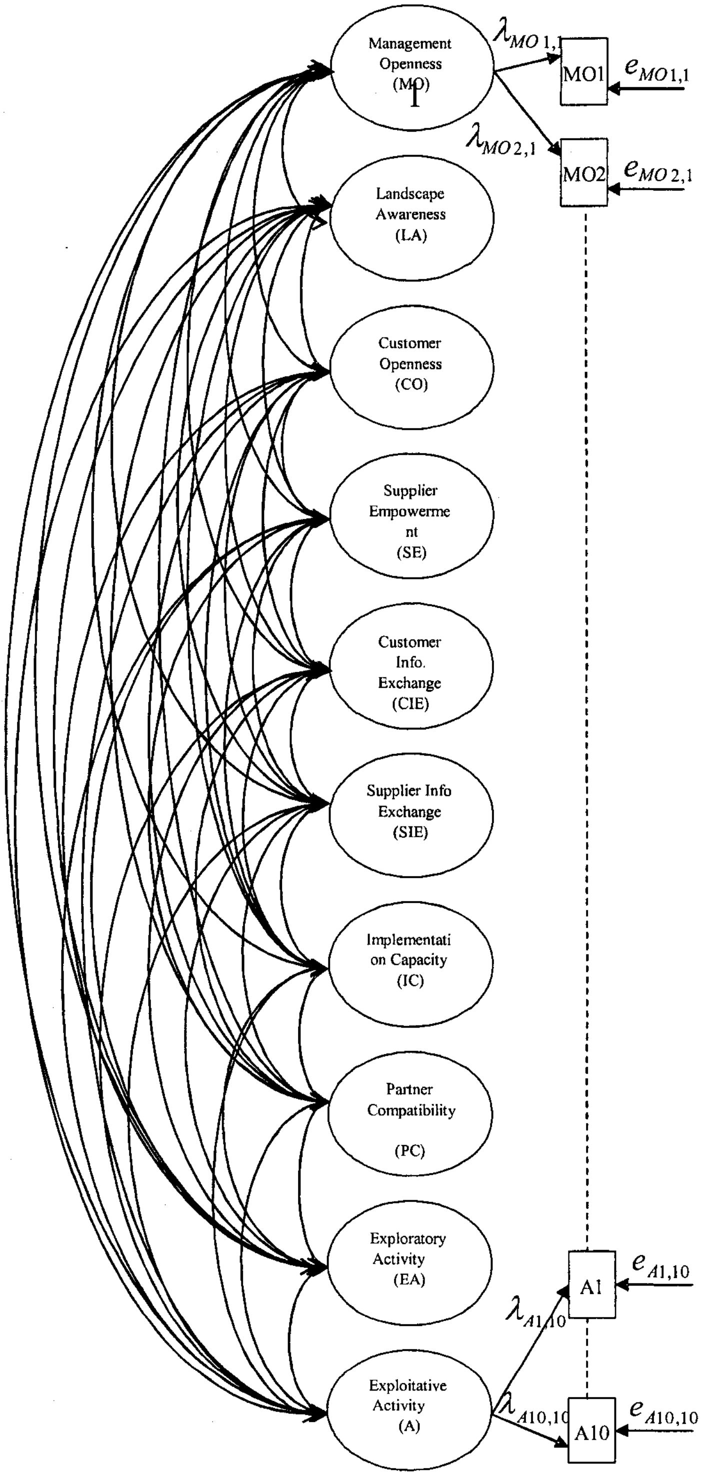
Scale development is a dynamic process by nature, and while we needed to ensure that the measurement items cover the theoretical domain of a particular study, we also needed to make sure that the supply chain managers understood what was meant when they read a particular item. Based on our analysis of pilot study data and our ongoing conversations with supply chain managers, we determined that the some of the items with low reliability values were indeed causing some confusion with the managers. For example, the meaning of item A7 (one of the items that represent Exploitative Adaptivity), "*When dealing with supply chain problems, we seek out 'tried and true' solutions,*" was not clearly understood by the supply chain managers. In a similar vein, the meanings of items A2, CIE1, and PC1 were not clear to supply chain managers. On the other hand, some items such as CO1,"*We have formal processes to help us maintain customer openness*" did not adequately represent their targeted theoretical domain. As a result, based on our initial pilot study results, we dropped some items from the final study questionnaire.

After the pilot study, we collected our final round of data. As indicated previously, from our final sample we randomly sampled 50 observations and combined these with the pilot study data. Using this new data set, we studied the validity and reliability of our measures by conducting three confirmatory factor analyses for each of the theoretical construct groups in our model: (i) dimensions of supply chain base adaptivity, (ii) combinative competitive capabilities, and (iii) competitive environment.

Dimensions of Supply Chain Base Adaptivity

For our reliability and validity analysis of the dimensions of supply chain base adaptivity, we performed confirmatory factor analysis on the measurement model of 10 constructs theoretically related to supply chain base adaptivity illustrated in Figure 7.

Figure 7. **Measurement Model of the Dimensions of Supply Chain Base Adaptivity**



To assess the measurement model, we employed three widely used fit indices, namely, Bollen's Incremental Fit Index (IFI; Bollen, 1989), the Bentler-Bonett Non-Normed Fit Index (NNFI; Bentler and Bonett, 1980), and the Comparative Fit Index (CFI; Bentler, 1990). We also used chi-square statistics and root mean square error approximation (RMSEA). The fit results of our initial confirmatory analysis indicated that we had poor fit in our measurement model (χ^2 = 1072.475, Df = 734, χ^2/df = 1.461, p = .000, IFI = .891, TFI = .866, CFI = .886, RMSEA = .06). We present the CFA and reliability results of the measurement model for the items related to supply chain base adaptivity in Table 13. The fit indices and reliability analysis indicate problems with some of the items. For example, items LA7, LA8, CO3, SE3, and IC7 have low item-reliability values. Based on the recommendation of Hair et al. (1998), we modified our analysis, combining the statistical results with the theoretical background of our items. Utilizing the fit measures of the item loadings to modify our measurement models would simply be "data fitting." In our modified measurement model we incorporate three basic notions of scale development: (i) the overall theory behind the constructs, (ii) the theoretical relationship between the construct definitions and items, and (iii) the parsimony of the scales.

Table 13. CFA Results: Assessment of Reliability and Construct Validity of the Measurement Model for the Items Related to Supply Chain Base Adaptivity (calibration sample, n = 131)

Constructs and Indicators	Standardized Path Loadings	Standard *Error*	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Management Openness				.65	.85
MO1	.83		.69		
MO2	.86	.11	.73		
MO3	.73	.12	.54		
Landscape Awareness				.53	.87
LA2	.79		.63		
LA3	.66	.10	.44		
LA4	.83	.11	.68		
LA5	.81	.11	.66		
LA7	.55	.12	.31		
LA8	.68	.13	.46		
Customer Openness				.44	.76
CO2	.61		.37		
CO3	.54	.21	.29		
CO4	.68	.23	.47		
CO5	.81	.25	.65		
Supplier Empowerment				.55	.78
SE1	.82		.66		
SE2	.81	.11	.66		
SE3	.57	.12	.33		
Partner Compatibility				.58	.79
PC2	.66		.44		
PC3	.76	.17	.58		
PC4	.85	.17	.73		
Implementation Capacity				.56	.88
IC1	.81		.66		
IC3	.71	.11	.51		
IC4	.76	.10	.58		
IC5	.79	.10	.62		
IC6	.78	.10	.61		
IC7	.63	.11	.40		
Customer Information Exchange				.55	.78
CIE2	.77		.59		
CIE3	.81	.15	.66		
CIE4	.65	.17	.42		
Supplier Information Exchange				.65	.85
SIE1	.85		.73		
SIE2	.79	.09	.63		
SIE4	.77	.12	.59		
Exploitation Activity				.52	.85
A3	.77	.10	.59		
A4	.64	.11	.41		
A5	.73	.12	.54		
A8	.71	.11	.51		
A10	.76		.57		
Exploration Activity				.60	.88
EA1	.73		.54		
EA2	.80	.13	.64		
EA4	.87	.11	.76		
EA5	.74	.14	.55		
EA7	.73	.12	.54		

Based on the criteria discussed above, we dropped the following items from our study: LA3, LA7, LA8, CO3, SE3, PC2, IC3, IC4, IC7, A4, A5, EA5, and EA7, from the constructs Landscape Awareness, Customer Openness, Supplier Empowerment, Partner Compatibility, Implementation Capacity, Exploitation Activity, and Exploration Activity, respectively. After the modification of the measurement model, all of our items were left with at least two items. This is consistent with the two-indicator rule, stating that "a measurement model is identified if there is more than one latent variable, if each latent variable is correlated with at least one other latent variable, if there is only one nonzero element per row of lambda, if there are two or more indicators per factor, and if theta is diagonal" (O'Brien 1994, p. 139).

After these modifications, we conducted another round of confirmatory factor analysis on the measurement model of the dimensions of supply chain base adaptivity. Our results showed a significant improvement in the fit measures of the measurement model (χ^2 = 374.246, df = 305, χ^2/df = 1.227, p = .004, IFI = .964, TFI = .950, CFI = .962, RMSEA = .04). Also, the individual item loadings presented in Table 14 show that our results for the measurement items meet the criteria for reliability and validity, which are discussed in detail below.

Table 14. CFA Results: Assessment of Reliability and Construct Validity of the Modified Measurement Model for the Items Related to Supply Chain Base Adaptivity (calibration sample, n = 131)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Management Openness				.65	.85
MO1	.80		.65		
MO2	.85	.11	.72		
MO3	.76	.12	.58		
Landscape Awareness				.61	.82
LA2	.74		.55		
LA4	.81	.13	.66		
LA5	.79	.13	.63		
Customer Openness				.49	.73
CO2	.57	.15	.32		
CO4	.64		.41		
CO5	.84	.19	.72		
Supplier Empowerment				.64	.71
SE1	.83		.68		
SE2	.78	.12	.60		
Partner Compatibility				.71	.82
PC3	.85	.13	.72		
PC4	.84		.70		
Implementation Capacity				.68	.86
IC1	.83	.09	.68		
IC5	.81	.09	.66		
IC6	.84		.70		
Customer Information Exchange					
CIE2	.82	.15	.68	.56	.79
CIE3	.74	.16	.55		
CIE4	.67		.45		
Supplier Information Exchange				.60	.81
SIE1	.75		.57		
SIE2	.86	.13	.73		
SIE4	.70	.16	.49		
Exploitation Activity				.58	.80
A3	.79		.62		
A8	.73	.11	.54		
A10	.76	.11	.57		
Exploration Activity				.65	.85
EA1	.78	.09	.60		
EA2	.80		.65		
EA4	.83	.08	.70		

Based on the satisfactory results of the confirmatory factor analysis of the modified measurement model for the dimensions of supply chain base adaptivity, we continued the validation of our measurement model using the validation sample. As previously indicated, we followed a split-sample approach for our analyses. Equivalence between the calibration and validation samples provides sufficient evidence that the results achieved by the different groups indicate similar results, which ensures that the results did not depend on the specific data. A systematic way of testing the factorial invariance of the measures involves the testing of a series of hierarchical hypotheses (Bollen, 1989). For all the multigroup analyses, we followed a four-step approach as suggested by Bollen (1989). We first tested the invariance of the form of the models, without restricting any of the nonfixed parameters. In a similar vein, we continued our group analyses by comparing the measurement weights, intercepts, variances, and covariances.

The assessment of multigroup analyses is usually based on chi-square differences between the nested models. However, researchers have demonstrated that differences in chi-square are also dependent on sample size (Brannick, 1995; Kelloway, 1995). Therefore, rather than relying solely on chi-square difference, we preferred to use the differences between the goodness of fit indices. Until recently there have not been any criteria available for determining whether the changes in goodness-of-fit indices are significant when measurement invariance constraints are added. Based on simulation analyses, Cheung and Rensvold (2002) suggest that for the comparison of nested models in multigroup analyses, researchers should use three fit indices: the Comparative Fit Index (CFI); McDonald's (1989) Non-Centrality Index (NCI); and a variation of Jöreskog andSörbom's (1984) goodness-of-fit index called Gamma Hat, as suggested by Steiger (1989). Cheung and Rensvold also suggest that the following difference values in the suggested goodness-of-fit indices can be used as an indication that the null hypothesis of invariance should not be rejected: For ΔCFI .01, for ΔGamma Hat .001, and for ΔNCI .02. Thus, in addition to the indices we used to assess model fit, we included these three indices to assess the differences in the nested models. In

Table 15, we present the comparison measurement model of the dimensions of supply chain base adaptivity using the calibration and validation samples in multigroup analysis.

Table 15. Test of Invariance of the Modified Measurement Model of Supply Chain Base Adaptivity across the Calibration and Validation Samples

Stand-alone indices	Unrestricted Model (1)	Restricted Model (2)[a]	Restricted Model (3)[b]	Restricted Model (4)[c]
Chi-square (χ^2)	815.011	865.679	921.888	973.563
Degrees of freedom (df)	610	656	694	739
Probability level	<.001	<.001	<.001	<.001
Chi-square/df	1.336	1.320	1.328	1.317
Chi-square difference[d]		50.668	106.878	158.552
Degrees of freedom difference		46	84	129
Significance of χ^2 difference		.295	.047	.040
RMSEA	.034	.033	.034	.033
Fit Indices				
IFI	.948	.946	.941	.938
TFI	.926	.930	.928	.931
CFI	.945	.944	.939	.937
ΔCFI		.001	.006	.008
Gamma Hat	.995	.993	.991	.988
ΔGamma Hat		.002	.004	.007
NCI	.945	.944	.939	.937
ΔNCI		.001	.006	.008

[a] Restricted Model: Measurement weights and intercepts
[b] Restricted Model: Measurement weights, intercepts, and variances
[c] Restricted Model: Measurement weights, intercepts, variances, and covariances
[d] All the restricted models are compared to unrestricted model.

As depicted in Table 15, although the chi-square difference is significant, the differences in CFI and NFI are below the cutoff values that Cheung and Rensvold suggest. On the other hand, in models three and four, the difference in Gamma Hat are little bit more than the suggested cutoff value, but given that the difference values are not well above the cutoff values, we concluded that there is invariance across the calibration and validation samples in the measurement model of dimensions of supply chain base adaptivity. Thus, we continued our analysis with the combined sample.

Based on the results of the confirmatory analysis of the measurement model for the dimensions of supply chain base adaptivity using the combined sample, we summarize the reliability and validity of our item measures related to supply chain base adaptivity. The fit statistics of the confirmatory factor analysis are very satisfactory (χ^2 = 409.926, df = 305, χ^2/df = 1.344, $p < .001$, IFI = .972, TFI = .962, CFI = .971, RMSEA = .03). In Table 16, we present the results of the confirmatory factor analysis for the combined sample.

Table 16. CFA Results: Assessment of Reliability and Construct Validity of the Modified Measurement Model for the Items Related to Supply Chain Base Adaptivity (combined sample, *n* = 294)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Management Openness				.63	.83
MO1	.79		.63		
MO2	.87	.08	.76		
MO3	.71	.08	.50		
Landscape Awareness				.59	.81
LA2	.74		.54		
LA4	.80	.09	.64		
LA5	.76	.08	.57		
Customer Openness				.47	.72
CO2	.60	.09	.36		
CO4	.67		.45		
CO5	.78	.11	.61		
Supplier Empowerment				.61	.76
SE1	.81		.66		
SE2	.75	.09	.56		
Partner Compatibility				.60	.75
PC3	.78	.11	.61		
PC4	.76		.58		
Implementation Capacity				.60	.81
IC1	.77		.60		
IC5	.71	.08	.51		
IC6	.82	.08	.68		
Customer Information Exchange				.55	.78
CIE2	.77	.09	.59		
CIE3	.78		.60		
CIE4	.67	.11	.45		
Supplier Information Exchange				.59	.81
SIE1	.81		.65		
SIE2	.81	.08	.66		
SIE4	.68	.10	.47		
Exploitation Activity				.52	.77
A3	.73		.53		
A8	.69	.10	.48		
A10	.75	.09	.56		
Exploration Activity				.60	.82
EA1	.73	.08	.54		
EA2	.76		.58		
EA4	.83	.07	.68		

Reliability

We assessed the reliability of our item measures based on three criteria: (i) indicator reliability, which represents the percentage of variation in the indicator that is explained by the factor that it is supposed to measure (Hatcher, 2003); (ii) composite reliability, which is analogous to Cronbach's alpha, reflecting the internal consistency of the indicators measuring a given factor (Hatcher, 2003); and (iii) average variance extracted (AVE), which assesses the amount of variance that is captured by an underlying factor in relation to the amount of variance due to measurement error (Hatcher, 2003; Fornell and Larcker, 1981). In previous studies in operations management literature, indicator reliability values greater .30 have been considered acceptable (e.g., Carr and Pearson, 1999; Froehle and Roth, 2004). Except for CO2, all the indicator reliability values are well above the .30 cutoff point. The minimum acceptable level for composite reliability is usually .70. As can be seen in Table 22, our composite reliability values are above this cutoff value, indicating sufficient reliability for our item measures. Lastly, we assessed the average variance extracted. Proposed by Fornell and Larcker (1981), the cutoff value for this statistic is .50. The results for all of the constructs except Customer Openness fall above this threshold value. On the other hand, as Hatcher (2003) states, AVE is a conservative measure, and our AVE value for Customer Openness is not much below.50. Thus, we conclude that our items related to the dimensions of supply chain base adaptivity have sufficient reliability.

Unidimensionality

Another important criterion is the unidimensionality of the item measures. Unidimensionality refers to the "characteristics of a set of indicators that has only one underlying trait or concept in common" (Hair et al., 1998, p. 584). In other words, unidimensionality ensures that a set of indicators in a scale measure a single construct (Gerbing and Anderson, 1988). There are two implicit conditions for establishing unidimensionality of the measurement items: (i) an item measure must be significantly associated with the operational construct; (ii) it should be related to one and only one construct (Hair et al., 1998; Gerbing and Anderson, 1988). In order to ensure unidimensionality, Anderson and Gerbing suggest two statistics. The first one is related to the internal consistency of the item measures for a specific construct. Internal consistency ensures that the items of a given construct behave in a similar way. Internal consistency can be assessed by the following equation:

$$\rho_{ab} = \rho_{a\xi}\,\rho_{b\xi} \tag{4}$$

In Equation 4, ρ_{ab} is the Pearson correlation of the two measurement items used to measure the construct ξ. $\rho_{a\xi}$ and $\rho_{b\xi}$ are the standardized path loadings for each of the items obtained from confirmatory factor analysis. In other words, internal consistency observes whether the relationship between two measurement items (i.e., correlation) is indicated by the confirmatory factor analysis as well. In order to demonstrate internal consistency, the left-hand side of Equation 4 should equal the right-hand side of the equation within the sampling error (Spearman and Holzinger, 1924).

The second criterion for unidimensionality is external consistency. External consistency indicates whether the item measures are related to only one construct or more. The equation for external consistency is

$$\rho_{ad} = \rho_{a\xi}\,\rho_{\xi\xi^*}\,\rho_{d\xi^*} \tag{5}$$

In Equation 5, *a* represents any indicator of construct ξ, and *d* represents any indicator of construct ξ^*. In order to show external consistency, the left-hand side of the equation (i.e., the correlation between *a* and *d*) should equal the right-hand side of the equation, within sampling error limits.

Following Anderson and Gerbing (1991), we assessed the unidimensionality of the item measures based on the results of the initial confirmatory factor analysis. In order to achieve consistency in assessing external consistency, we chose to use A8 and EA1, since these two items have the lowest item loadings in the measurement model, and both the Exploitation Activity and Exploration Activity constructs are theoretically related to the rest of the constructs used in the measurement model. *Z* test is used to assess the equivalence of the left and right sides of Equations 4 and 5. In Table 17 we present the results of the unidimensionality analysis of the item measures related to the dimensions of supply chain base adaptivity based on internal and external consistency.

Lastly, unidimensionality is also assessed by the overall fit of the measurement model. A good overall fit indicates the unidimensionality of the operational constructs. One indication of acceptable fit is the ratio of the chi-square statistic to the degrees of freedom. Although there is not a strict threshold value available for this statistic, ratios less than two indicate good fit (Stratman and Roth, 2002; Froehle and Roth, 2004). The fit statistics used to assess the fit of our measurement model fall above the threshold value of .95, and the root mean square error of approximation statistic is below .05 (RMSEA = .03), signifying the unidimensionality of the constructs.

Table 17. Assessment of the Unidimensionality of the Items Related to the Dimensions of Supply Chain Base Adaptivity

Constructs and Indicators	Indicators	Pearson Correlation	Internal Consistency	External Consistency	Z – score*
Management Openness					
MO1	MO2	.697	.689		.19
	MO3	.578	.561		.30
	A8	.300		.309	-.12
	EA1	.380		.337	.60
MO2	MO3	.587	.614		-.51
	A8	.382		.338	.61
	EA1	.388		.369	.27
MO3	A8	.255		.275	-.26
	EA1	.347		.300	.63
Landscape Awareness					
LA2	LA4	.549	.591		-.75
	LA5	.594	.559		.63
	A8	.493		.425	1.04
	EA1	.426		.453	-.40
LA4	LA5	.614	.608		.12
	A8	.428		.463	-.53
	EA1	.529		.493	.59
LA5	A8	.451		.438	.20
	EA1	.415		.466	-.76
Customer Openness					
CO2	CO4	.382	.402		-.29
	CO5	.479	.465		.22
	A8	.301		.265	.47
	EA1	.153		.218	-.81
CO4	CO5	.532	.526		.10
	A8	.300		.300	.00
	EA1	.242		.247	-.06
CO5	A8	.366		.347	.26
	EA1	.238		.286	-.62
Supplier Empowerment					
SE1	SE2	.606	.608		-.04
	A8	.305		.290	.20
	EA1	.393		.325	.94
SE2	A8	.308		.268	.53
	EA1	.277		.301	-.32
Partner Compatibility					
PC3	PC4	.596	.598		-.04
	A8	.372		.375	-.04
	EA1	.331		.333	-.03
PC4	A8	.420		.365	.78
	EA1	.258		.324	-.87

* Z–scores greater than 1.96 indicate that the difference between the two values is significant at 0.05 level.

Table 17 (cont'd).

Constructs and Indicators	Indicators	Pearson Correlation	Internal Consistency	External Consistency	Z – score*
Implementation Capacity					
IC1	IC5	.507	.552		-.75
	IC6	.684	.638		.99
	A8	.367		.410	-.61
	EA1	.426		.431	-.07
IC5	IC6	.566	.588		-.40
	A8	.354		.378	-.33
	EA1	.469		.397	1.07
IC6	A8	.355		.437	-1.17
	EA1	.472		.459	.20
Customer Information Exchange					
CIE2	CIE3	.621	.596		.48
	CIE4	.504	.516		-.20
	A8	.022		.076	-.67
	EA1	.133		.135	-.02
CIE3	CIE4	.504	.520		-.26
	A8	.098		.077	.26
	EA1	.082		.136	-.66
CIE4	A8	.070		.066	-.05
	EA8	.196		.118	.97
Supplier Information Exchange					
SIE1	SIE2	.669	.654		.32
	SIE4	.549	.546		.05
	A8	.099		.160	-.75
	EA1	.181		.174	.09
SIE2	SIE4	.538	.548		-.17
	A8	.127		.160	-.41
	EA1	.163		.175	-.15
SIE4	A8	.169		.134	.43
	EA1	.237		.146	1.14
Exploitation Activity					
A3	A8	.506	.507		-.02
	A10	.517	.545		-.47
	EA1	.472		.468	-.06
A8	A10	.558	.517		.70
	EA1	.394		.443	-.72
A10	EA1	.449		.477	-.43
Exploration Activity					
EA1	EA2	.594	.559		.63
	EA4	.585	.605		-.37
EA2	EA4	.627	.629		-.04
	A8	.435		.461	-.39
EA4	A8	.495		.499	-.06

* Z – scores greater than 1.96 indicate that the difference between the two values is significant at the 0.05 level

Content Validity

"Content validity is a qualitative type of validity where the domain of a concept is made clear and the analyst judges whether the measures fully represent the domain. To the extent they do, content validity is met" (Bollen, 1989, p. 185). According to Bagozzi and Foxall (1996), a scale is said to have content validity if the scale's items form a representative sample of the theoretical domain of the construct. We established content validity by grounding our research on an extensive literature review. Also, as indicated in Chapter 3, in our presort testing exercise we interviewed supply chain managers, ensuring content validity.

Criterion-Related Validity

"Criterion validity is the degree of correspondence between a measure and criterion variable, usually measured by their correlation" (Bollen, 1989, p. 186). How well a scale represents business performance related to other objective measures of business performance is a good example of criterion-related validity. As Bollen (1989) indicated, for many measures no criterion validity is available. We tried to ensure criterion validity of our adaptivity measures by analyzing the correlation coefficients of the final items of Exploitative Adaptivity and Exploratory Adaptivity with the item: "Please assess the adaptivity of your business unit's supply chain compared to your competitors." Although this item is a single and subjective measure, the correlation between this item and the other adaptivity measures indicates whether there is a serious problem with the criterion validity. As reported in Table 18, the correlations between this item and the final measurement items of Exploitation and Exploration Activity measures are significant at 0.01 level and above

0.25, which is used as a cut – off value in Operations Management literature (Chen and Paulraj, 2004), indicating that our measures have criterion-related validity.

Table 18. Assessment of Criterion Validity: Pearson Correlation Coefficient

Items	BP9
a3	.377
a8	.306
a10	.351
ea1	.259
ea2	.319
ea4	.424

Note: All the correlation values are significant at the 0.01 level (2-tailed).

Construct Validity

Construct validity assesses the extent to which item measures relate to their targeted theoretical construct (Bollen, 1989). In order to have construct validity, Campbell and Fiske (1959) suggest, an item should load significantly on the theoretical construct that it is measuring—convergent validity—but at the same time should not measure another theoretical construct—discriminant validity.

Convergent validity ensures the similarity or convergence between the items and the theoretical constructs that they are measuring. In confirmatory factor analysis, convergent validity can be determined by assessing the magnitude and the direction of the factor loadings onto their respective latent constructs. According to Gerbing and Anderson (1988), factor loadings greater than twice the standard error indicate convergent validity. In a similar vein, Bollen (1989) states that the larger the *t*-values, the stronger the confirmation that the individual items characterize the underlying constructs. Based upon the confirmatory factor analysis results reported above in Table 16, we conclude that all indicators are significantly related to their respective constructs, ensuring the convergent validity of the measures.

Discriminant validity represents the degree to which the measures of different constructs are unique (O'Leary-Kelly and Vokurka, 1998). In other words, the correlations between two constructs should be at a level that would not raise the question of whether they are significantly different from each other. Following Hair et al. (1998) and Stratman and Roth (2002), we used the chi-square test to test for discriminant validity. This procedure entails running two CFAs on each pair of constructs. In the first run, the two constructs are allowed to freely correlate. In the second, the correlation between the two constructs is set to 1. Then a chi-square test is conducted for each pair of tested models. If the chi-square difference test is statistically significant, then one can conclude that the two constructs under consideration are different from each other (Hair et al., 1998). In Table 19, we present the results of the discriminant validity analysis for the dimensions of supply chain base adaptivity.

Table 19. Assessment of Discriminant Validity: Chi-square Differences between Fixed and Free Models

Operational Constructs*	A	EA	MO	CIE	SIE	LA	PC	IC	SE
Exploitation Activity (A)									
Exploration Activity (EA)	19.76								
Management Openness (MO)	130.52	168.31							
Customer Info. Exchange (CIE)	219.53	204.60	209.71						
Supplier Info. Exchange (SIE)	199.22	245.34	257.31	106.08					
Landscape Awareness (LA)	28.96	36.25	162.59	206.44	212.91				
Partner Compatibility (PC)	49.23	77.84	99.60	123.25	107.89	63.12			
Implementation Capacity (IC)	48.58	65.73	167.57	222.10	250.37	44.86	68.74		
Supplier Empowerment (SE)	86.98	84.67	68.96	133.38	123.31	75.95	100.17	81.76	
Customer Openness (CO)	75.30	118.20	105.51	174.86	170.20	77.59	90.92	115.10	48.17

* All the chi-square differences are significant at the .001 level (for 1 d.f.)

The results reveal that all the chi-square differences are significantly different from each other at the $p < .001$ confidence level, ensuring the discriminant validity of our constructs. In Table 20 we present the list of the final item measures that were used in the rest of the study

Table 20. Dimensions of Supply Chain Base Adaptivity: Final List (Combined sample, *n* = 294)

Operational Constructs and Item Measures	References
Management Openness (MO): The degree to which the expertise of the supervisors and middle management is considered by the top management when making strategic supply chain decisions. **MO1:** Our top managers are open to thoughts that originate from supervisors and middle management. **MO2:** Our top management listens to the ideas that originate from middle management concerning supply chain decisions. **MO3:** Top management allows strategic ideas to be freely championed by anyone with relevant insight within our organization.	Burgelman, 1983
Landscape Awareness (LA): The degree to which the supply chain managers are aware of changes in industry and technology trends. **LA2:** We are generally ahead of our competitors in knowing the emerging industry trends in supply chain management. **LA4:** Our firm is highly receptive of new supply chain technologies. **LA5:** Technological advances that will improve our supply chain performance are closely monitored.	
Customer Openness (CO): Establishment and maintenance of relationships with customers in order to better understand their needs. **CO2:** We strive to be highly responsive to our customers' needs. **CO4:** We incorporate our customers' suggestions in supply chain decision-making processes. **CO5:** Customers' needs are considered in our supply chain design.	Ahmad and Schroeder, 2001; Sousa, 2003; Flynn et al., 1995
Supplier Empowerment (SE): The degree of supplier involvement in decision-making in supply chain planning and implementations. **SE1:** We typically give merit to strategic ideas that are raised by our suppliers. **SE2:** We listen to our suppliers regarding design changes to our supply chain	Ahmad and Schroeder, 2001; Narasimhan et al., 2001; Krause, 1999
Partner Compatibility (PC): The degree to which supply chain partners have compatible processes and standards among the supply chain. **PC3:** We try to develop compatible technological processes among our supply chain. **PC4:** We created operating processes that are compatible with those of our supply chain partners.	Choi et al., 2001
Implementation Capacity (IC): Supply chain managers' ability to implement new methods in order to improve supply chain performance. **IC1:** We have the ability to implement supply chain innovations. **IC5:** Our supply chain managers transform new ideas into actions. **IC6:** We are able to implement new supply chain concepts.	Holland, 1995

Table 20 (cont'd.).

Operational Constructs and Item Measures	References
Supplier Information Exchange (SIE): Degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between the manufacturer and its suppliers.	Frohlich and Westbrook, 2001, 2002
SIE1: We routinely exchange inventory information with our suppliers. **SIE2:** We routinely exchange demand forecasts with our suppliers. **SIE4:** We implement integrated order–scheduling with our suppliers.	
Customer Information Exchange (CIE): Degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between the manufacturer and its customers. **CIE2:** Our customers provide us with their demand forecasts. **CIE3:** Our customers routinely share inventory information with us. **CIE4:** We implement integrated order-scheduling with our customers.	Frohlich and Westbrook, 2001, 2002
Exploitation Activity (A): The intensity of a manufacturer's efforts to improve existing supply chain capabilities, processes and technologies **A3:** We focus on improving our existing supply chain competencies by refining our current supply chain processes. **A8:** In order to stay competitive, our supply chain managers focus on improving our existing technologies. **A10:** Our managers focus on developing stronger competencies in our existing supply chain processes.	March, 1991
Exploration Activity (EA): The intensity of a manufacturer's efforts to search for new supply chain opportunities in the face of changing competitive environments. **EA1:** We proactively pursue new supply chain solutions. **EA2:** We continually experiment to find new solutions that will improve our supply chain. **EA4:** To improve our supply chain we continually explore for new opportunities.	March, 1991

In Table 21 we present the correlation matrix for the dimensions of supply chain base adaptivity. As one can observe the correlation between Exploitation and Exploration Activities is high (e.g. 0.87). This finding is supports our argument that these constructs are distinct but closely related constructs and there exits an underlying concept such as supply chain base adaptivity beneath these constructs. On the other hand the correlation between Customer Information Exchange (CIE) and Customer Openness (CO) is unexpectedly low indicating the distinction between these two constructs. CIE is based upon the notion of the efficiency of transactions between the customers and manufacturer. On the other hand

Customer Openness is geared towards establishing strong relationships between the manufacturer and its customers in order to understand customers' needs in a supply chain. Thus having efficient transaction processes does not necessarily helps manufacturers to build strong relationships with their customers.

Table 21. Dimensions of Supply Chain Base Adaptivity: Correlation Matrix (combined sample, *n* = 294)

Operational Constructs	A	EA	MO	CIE	SIE	LA	PC	IC	SE
Exploitation Activity (A)									
Exploration Activity (EA)	.87***								
Management Openness (MO)	.56***	.58***							
Customer Info. Exchange (CIE)	.14*	.23***	.21**						
Supplier Info. Exchange (SIE)	.29***	.30***	.27***	.60***					
Landscape Awareness (LA)	.84***	.84***	.57***	.22**	.40***				
Partner Compatibility (PC)	.69***	.57***	.44***	.16*	.37***	.64***			
Implementation Capacity (IC)	.77***	.76***	.58***	.09	.29***	.81***	.62***		
Supplier Empowerment (SE)	.52***	.55***	.64***	.03	.25***	.59***	.41***	.58***	
Customer Openness (CO)	.64***	.49***	.54***	.07	.17*	.64***	.47***	.50***	.68***

*** $p < .001$
** $p < .01$
* $p < .05$

Combinative Competitive Capabilities

Parallel to our analysis of the reliability and validity of the dimensions of supply chain base adaptivity, we analyzed the reliability and validity of the items used for combinative competitive capabilities. As presented in Figure 8, we analyzed four competitive capability constructs: product quality, process flexibility, price leadership, and delivery speed. Since we used existing scales for combinative competitive capabilities, we started our analysis directly with the calibration sample. Our initial confirmatory factor analysis results indicated that we could improve the overall fit of the measurement model of the combinative competitive capabilities (χ^2 = 138.802, df = 98, χ^2/df = 1.416, p = .004, IFI = .960, TFI = .943, CFI = .959, RMSEA = .06). Based on the discussion in the previous subsection and the results reported in Table 22, we modified the initial measurement model for the combinative competitive capabilities.

Figure 8. **Measurement Model of the Dimensions of Competitive Capabilities**

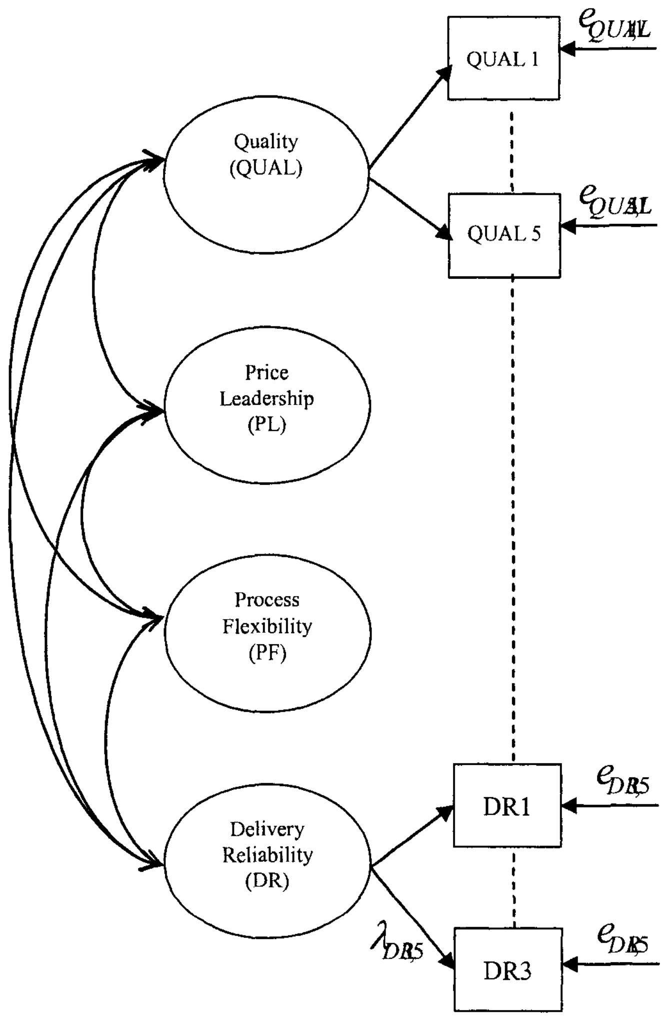


Table 22. Confirmatory Factor Analysis Results: Reliability and Construct Validity of the Measurement Model for Combinative Competitive Capabilities Items (calibration sample, n = 131)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Product Quality				.61	.89
QUAL 1	.86		.74		
QUAL 2	.83	.07	.68		
QUAL 3	.78	.08	.61		
QUAL 4	.75	.10	.57		
QUAL 5	.67	.10	.44		
Process Flexibility				.50	.83
PF1	.68	.12	.46		
PF2	.77		.59		
PF3	.74	.11	.54		
PF4	.59	.14	.35		
PF5	.74	.13	.55		
Price Leadership				.51	.74
PL1	.88		.78		
PL2	.46	.12	.21		
PL3	.73	.12	.53		
Delivery Speed				.73	.89
DS1	.91	.07	.83		
DS2	.82	.07	.67		
DS3	.84	.12	.70		

Our initial analysis indicated that PL2 had an unacceptable level of item reliability and that items PF4 and PF1 had borderline reliability values. We dropped PF1, "ability to rapidly change product mix," since item PF3, "manufacture broad product mix within same facilities," was a similar measure with a better defined theoretical boundary. Because PF1 could be applied to the ability to change product mix either within the whole supply chain or within the same manufacturing facility, it could create confusion regarding the unit of analysis (i.e., the supply chain or the manufacturing unit that the respondent represents). Thus, we chose to capture the ability of a manufacturer to have a broad product mix with PF3. In a similar vein, item PF4, "rapidly handle custom orders (i.e., engineer to order)," could be related both to the flexibility of the manufacturer and also to the product type manufactured within a given manufacturing unit. In the case of continuous processes, although the manufacturer might be flexible compared to its competitors, the manufacturing requirements might cause the respondent to answer this question in another way. Thus, in order to have a crisp measure of process flexibility, we dropped measure PF4 as well. Lastly, although the item reliability of QUAL5, "overall product quality as perceived by the customer," is acceptable, this question forces the respondent to make a guess about customer perceptions. Given that our respondents are supply chain managers rather than marketing managers, we also decided to drop this measure. With these modifications we ran the measurement model once again. Our fit measures ($\chi^2 = 66.51$, df = 48, χ^2/df = 1.386, $p = .04$, IFI = .977, TFI = .962, CFI = .976, RMSEA = .05) and the item loadings showed a significant improvement, as reported in Table 23.

Table 23. Confirmatory Factor Analysis Results: Reliability and Construct Validity of the Modified Measurement Model for Combinative Competitive Capabilities Items (calibration sample, n = 131)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Product Quality				.65	.88
QUAL 1	.87		.75		
QUAL 2	.82	.07	.68		
QUAL 3	.80	.08	.63		
QUAL 4	.73	.10	.54		
Process Flexibility				.56	.79
PF2	.76		.57		
PF3	.73	.12	.53		
PF5	.76	.14	.57		
Price Leadership				.65	.79
PL1	.80		.64		
PL3	.81	.16	.66		
Delivery Speed				.73	.89
DS1	.90		.82		
DS2	.82	.08	.67		
DS3	.84	.07	.71		

Following the split-sample approach, we conducted a multigroup analysis using the calibration and validation samples for the item measures of combinative competitive capabilities. The results of this analysis are presented in Table 24.

Table 24. Test of Invariance of Modified Measurement Model of Combinative Competitive Capabilities across the Calibration and Validation Samples

Stand-alone indices	Unrestricted Model (1)	Restricted Model (2)[a]	Restricted Model (3)[b]	Restricted Model (4)[c]
Chi-square (χ^2)	112.349	132.405	154.675	161.699
Degrees of freedom (df)	96	116	132	138
Probability level	.122	.142	.086	.082
Chi-square/df	1.170	1.141	1.172	1.172
Chi-square difference[d]		20.056	42.326	49.350
Degrees of freedom difference		20	36	42
Significance of χ^2 difference		.454	.217	.203
RMSEA	.024	.022	.024	.024
Fit Indices				
IFI	.991	.990	.987	.986
TFI	.984	.987	.984	.984
CFI	.990	.990	.987	.986
ΔCFI		.001	.003	.004
Gamma Hat	.999	.998	.997	.996
ΔGamma Hat		.001	.002	.003
NCI	.990	.990	.987	.986
ΔNCI		.001	.003	.004

[a] Restricted Model: Measurement weights and intercepts
[b] Restricted Model: Measurement weights, intercepts, and variances
[c] Restricted Model: Measurement weights, intercepts, variances, and covariances
[d] All the restricted models are compared to the unrestricted model.

The multigroup analysis of the combinative competitive capabilities item measures across the calibration and validation samples reveals that the two groups are not statistically different. Both the criteria that Cheung and Rensvold (2002) suggested and the chi-square tests indicate that the samples are not statistically different from each other.

Based on the results of the multigroup analysis, we continued our analysis with the combined sample. The fit statistics of the measurement model (χ^2 = 68.08, df = 48, χ^2/df = 1.418, p = .03, IFI = .988, TFI = .981, CFI = .988, RMSEA = .04) and the individual item loadings presented in Table 25 are satisfactory.

Table 25. Confirmatory Factor Analysis Results: Reliability and Construct Validity of the Modified Measurement Model for Combinative Competitive Capabilities Items (combined sample, *n* = 294)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Product Quality				.65	.85
QUAL 1	.81		.66		
QUAL 2	.81	.06	.65		
QUAL 3	.76	.07	.58		
QUAL 4	.68	.09	.47		
Process Flexibility				.63	.79
PF2	.77		.59		
PF3	.75	.07	.56		
PF5	.72	.08	.52		
Price Leadership				.70	.79
PL1	.76		.57		
PL3	.86	.11	.74		
Delivery Speed				.78	.90
DS1	.90		.80		
DS2	.84	.05	.70		
DS3	.88	.05	.77		

Reliability

As indicated in the previous subsection, we assessed the reliability of our item measures based on three criteria: (i) indicator reliability, (ii) composite reliability, and (iii) average variance extracted (AVE). All the indicator reliability values are greater than the accepted cutoff value of .30 used in previous operations management studies (e.g., Carr and Pearson, 1999; Froehle and Roth, 2004). The minimum acceptable level for composite reliability is usually .70. As can be seen in Table 25, our composite reliability values are all above the cutoff value, indicating sufficient reliability for our item measures. Lastly, we assessed the average variance extracted. The cutoff value for the AVE is .50 (Fornell and Larcker, 1981). All of the combinative competitive capabilities constructs have AVE values above this threshold value; thus, we conclude that the items related to the combinative competitive capabilities have sufficient reliability.

Unidimensionality

Given that our measures for these constructs have been previously studied and validated (Rosenzweig and Roth, 2004), we did not follow the detailed procedure suggested by Anderson and Gerbing (1991). Rather, we assessed the unidimensionality of the constructs related to combinative competitive capabilities based on the overall fit of the measurement model. A good overall fit indicates unidimensionality of the operational constructs. One measure of acceptable fit is the ratio of the chi-square statistic to the degrees of freedom. Although there is not a strict threshold value available for this statistic, ratios less than two indicate good fit (Stratman and Roth, 2002; Froehle and Roth, 2004). The fit statistics for our measurement model fall above the threshold value of .95, and the root mean square error of approximation statistic is below .05 (RMSEA = .04), signifying the unidimensionality of the constructs related to combinative competitive capabilities.

Content Validity

According to Bagozzi and Foxall (1996), a scale is said to have content validity if the scale's items form a representative sample of the theoretical domain of the construct. Items used for combinative competitive capabilities are based on previous research and have been used several times in different studies (Roth, 1996; Rosenzweig and Roth, 2004). The results of these studies show that the combinative competitive capabilities measures represent the theoretical domain, indicating content validity.

Construct Validity

As indicated in the previous section, construct validity can be assessed by using convergent validity—whether an item loads significantly to the theoretical construct it represents (Campbell and Fiske 1959)—and discriminant validity—whether an item measures one and only one construct (Bollen, 1989).

We assessed convergent validity based on the magnitude and the direction of the factor loadings onto their respective latent constructs. According to Gerbing and Anderson (1988), factor loadings greater than twice the standard error indicates convergent validity. In a similar vein, Bollen (1989) states that the larger the *t*-values, the stronger the confirmation that the individual items characterize the underlying constructs. We conclude from the results of the confirmatory factor analysis reported in Table 25 that all indicators of the combinative competitive capabilities are significantly related to their respective constructs, ensuring the convergent validity of the model.

Discriminant validity represents the degree to which measures of different constructs are unique (O'Leary-Kelly and Vokurka, 1998). In order to test discriminant validity, as noted in the previous subsection, we used a chi-square test among these constructs. The results of the discriminant validity analysis for the combinative competitive capabilities indicate that all of our constructs are significantly different from each other (see Table 26).

Table 26. Assessment of Discriminant Validity: Chi-Square Differences between Fixed and Free Models

Operational Constructs*	QUAL	PF	PL
Product Quality (QUAL)			
Process Flexibility (PF)	134.12		
Price Leadership (PL)	140.96	70.37	
Delivery Speed (DS)	278.17	42.28	109.81

* All the chi-square differences are significant at the .001 level (for 1 d.f.).

In Table 27 we present the list of the final item measures of the combinative competitive capabilities that were used in the rest of the study, and in Table 28 we present the correlation matrix for the constructs of dimensions of combinative competitive capabilities.

Table 27. Combinative Competitive Capabilities Items: Final List (combined sample, *n* = 294)

Operational Constructs and Item Measures	References
Product Quality: A manufacturer's capability to consistently achieve conformance to specifications, fitness for use, and value for price paid in its products. **QUAL1:** Conformance quality (i.e., the degree to which a product's operating characteristics meet established standards). **QUAL2:** Product durability (i.e., the amount of time or use before the product breaks down and replacement is preferred to continued repair). **QUAL3:** Product reliability (i.e., the probability of a product malfunctioning or failing within a specified time period). **QUAL4:** Performance quality (i.e., a product's primary operating characteristics).	Roth, 1996
Process Flexibility: A manufacturer's capability to adjust or modify the operational processes to speedily accommodate changes, for example, in production volumes or production mix. **PF2:** Ability to rapidly change production volumes. **PF3:** Manufacture broad product mix within same facilities. **PF5:** Ability to rapidly modify methods for materials.	Roth, 1996
Price Leadership: A manufacturer's capability to compete on price. **PF1:** Offering lower priced products. **PF3:** Meeting competitors' prices.	Roth, 1996
Delivery Speed: A manufacturer's capability to deliver products in a short time. **DS1:** Being able to provide fast response deliveries from order to end customer. **DS2:** Order fulfillment lead time. **DS3:** Delivery lead time.	Roth, 1996

Table 28. Correlation Matrix for Combinative Competitive Capabilities (combined sample, *n* = 294)

Operational Constructs	QUAL	PF	PL
Product Quality (QUAL)			
Process Flexibility (PF)	.58 ***		
Price Leadership (PL)	.19 **	.64 ***	
Delivery Speed (DS)	.56 ***	.82 ***	.49 ***

*** $p < .001$
** $p < .01$
* $p < .05$

Competitive Environment

Parallel to our analysis of reliability and validity of the dimensions of supply chain base adaptivity and combinative competitive capabilities, we also analyzed the reliability and validity of the items used for competitive environment. As depicted in Figure 9, we analyzed two competitive environment constructs: environmental dynamism and environmental munificence. Since we were using existing scales for combinative competitive capabilities, we started our analysis directly with the calibration sample. Our initial confirmatory factor analysis results indicated that we could improve the overall fit of the measurement model of the competitive environment (χ^2 = 38.478, df = 13, χ^2/df = 2.960, p = .000, IFI = .878, TFI = .716, CFI = .868, RMSEA = .12). Based on the discussion in the previous subsections and the results reported in Table 29, we modified the initial measurement model for the competitive environment.

***Figure 9.* Measurement Model of the Dimensions of Competitive Environment**

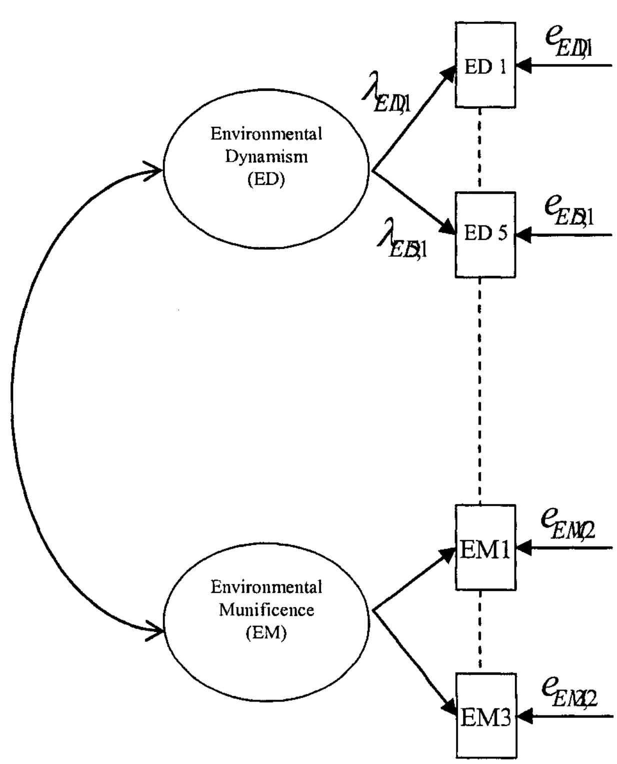


Table 29. Confirmatory Factor Analysis Results: Reliability and Construct Validity of the Measurement Model for Competitive Environment Items (calibration sample, n = 131)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Environmental Dynamism				.48	.78
ED1	.67		.45		
ED2	.73	.16	.53		
ED3	.44	.12	.20		
ED4	.86	.19	.74		
Environmental Munificence				.28	.46
EM1	.61		.37		
EM2	.68	.32	.47		
EM3	.06	.18	.00		

Results of the confirmatory factor analysis revealed that EM3, "demand for our primary products is highly predictable," does not fall into the same category as the rest of the environmental munificence items. Environmental munificence represents the growth in a given industry, but EM3 can be applied to both a growing industry as well as a shrinking competitive environment. Thus, we dropped this measure from further analysis. In a similar vein, ED3, "the rate of innovation of new operating processes," was somewhat confusing to the respondents. The other environmental dynamism items would be known to the supply chain managers, since they are specific to the industry in which they compete. But the rate of innovation of new operating processes would be specific to the individual manufacturers, and the respondents might not have had enough information to draw conclusions on this item. As a result, we dropped ED3 from our study as well.

After making these modifications to the measurement model, we ran the confirmatory factor analysis once more. The resulting fit indices (χ^2 = 3.870, df = 4, χ^2/df = .967, p = .424, IFI = 1.001, TFI = 1.003, CFI = 1.000, RMSEA = .01) and the individual item loadings of the modified measurement model presented in Table 30 are satisfactory.

Table 30. Confirmatory Factor Analysis Results: Reliability and Construct Validity of the Modified Measurement Model for Competitive Environment Items (calibration sample, n = 131)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Environmental Dynamism				.57	.80
ED1	.68	.15	.46		
ED2	.69		.48		
ED4	.88	.19	.78		
Environmental Munificence				.41	.58
EM1	.62		.38		
EM2	.65	.29	.43		

Based on these results, following the split-sample approach we continued with the multigroup analysis, in which we analyzed the invariance of the measurement model across the calibration and validation samples. In Table 31, we present the results of the multigroup analysis for the competitive environment measures.

Table 31. Test of Invariance of Modified Measurement Model of Competitive Environment across the Calibration and Validation Samples

Stand-Alone Indices	Unrestricted Model (1)	Restricted Model (2)[a]	Restricted Model (3)[b]	Restricted Model (4)[c]
Chi-square (χ^2)	7.147	19.405	25.366	25.912
Degrees of freedom (df)	8	16	23	24
Probability level	.521	.248	.332	.358
Chi-square/df	.893	1.213	1.103	1.080
Chi-square difference[d]		12.258	18.218	18.765
Degrees of freedom difference		8	15	16
Significance of χ^2 difference		.140	.251	.281
RMSEA				
Fit Indices	.001	.027	.019	.017
IFI	1.002	.991	.993	.995
TFI	1.009	.982	.991	.993
CFI	1.000	.990	.993	.995
ΔCFI		.01	.01	.01
Gamma Hat	1.000	.999	.999	.999
ΔGamma Hat		.001	.001	.001
NCI	1.002	.990	.993	.995
ΔNCI		.012	.009	.007

[a] Restricted Model: Measurement weights and intercepts
[b] Restricted Model: Measurement weights, intercepts, and variances
[c] Restricted Model: Measurement weights, intercepts, variances, and covariances
[d] All the restricted models are compared to the unrestricted model.

The multigroup analysis of the competitive environment item measures across the calibration and validation samples reveals that the two groups are not statistically different. Both the criteria that Cheung and Rensvold (2002) suggested and the chi-square tests indicate that the samples are not statistically different from each other.

We then continued our analysis with the combined sample. The fit statistics of the measurement model (χ^2 = 4.79, df = 4, χ^2/df = 1.197, p = .31, IFI = .998, TFI = .992, CFI = .998, RMSEA = .03) and the individual item loadings presented in Table 32 are satisfactory.

Table 32. Confirmatory Factor Analysis Results: Reliability and Construct Validity of the Modified Measurement Model for Competitive Environment Items (combined sample, *n*= 294)

Constructs and Indicators	Standardized Path Loadings	Standard Error	Item Reliability (R^2)	Variance Extracted	Composite Reliability
Environmental Dynamism				.57	.80
ED1	.74	.21	.55		
ED2	.73		.53		
ED4	.80	.33	.64		
Environmental Munificence				.46	.63
EM1	.70		.49		
EM2	.66	.26	.44		

Reliability

As in previous subsections, we assessed the reliability of our item measures based on three criteria: (i) indicator reliability, (ii) composite reliability, and (iii) AVE. All the indicator reliability values are greater than the accepted cutoff value of .30 used in previous operations management studies (e.g., Carr and Pearson, 1999; Froehle and Roth, 2004). The minimum acceptable level for composite reliability is usually .70. Unfortunately, the composite reliability measure for Environmental Munificence falls below this cutoff value. One of the drawbacks of reliability measures is that they are affected by the number of items in a construct. Given that we have only two items in this construct, we decided to retain this construct in our further analyses. Also, although the AVE value is lower than .50, AVE is a conservative measure, as indicated by Hatcher (2003), and the AVE value for Environmental Munificence is not much below the cutoff value. All three of the reliability measures for Environmental Dynamism are satisfactory.

Unidimensionality

Given that our measures for these constructs have been previously studied and validated (Dess and Beard, 1984; Kotha and Nair, 1995; Starbuck, 1976) we did not follow the detailed procedure suggested by Anderson and Gerbing (1991). Rather, we assessed the unidimensionality of the constructs related to combinative competitive capabilities based on the overall fit of the measurement model. A good overall fit indicates unidimensionality of the operational constructs. One indication of acceptable fit is the ratio of the chi-square statistic to the degrees of freedom. Although there is not a strict threshold value available for this statistic, ratios of less than two indicate a good fit (Stratman and Roth, 2002; Froehle and Roth, 2004). Our fit statistics fall above the threshold value of .95, and the root mean square error of approximation statistic is below .05 (RMSEA = .03), signifying the unidimensionality of the constructs related to competitive environment.

Content Validity

According to Bagozzi and Foxall (1996), a scale is said to have content validity if the scale's items form a representative sample of the theoretical domain of the construct. The items used other studies (Dess and Beard, 1984; Kotha and Nair, 1995; Starbuck, 1976). The results of these studies show that the competitive environment measures represent the theoretical domain, indicating content validity.

Construct Validity

As indicated in the previous sections, construct validity can be assessed by using convergent validity (Campbell and Fiske, 1959) and discriminant validity (Bollen, 1989). We assessed convergent validity based on the magnitude and the direction of the factor loadings onto their respective latent constructs. According to Gerbing and Anderson (1988), factor loadings greater than twice the standard error indicate convergent validity. In a similar vein, Bollen (1989) states that the larger the *t*-values, the stronger the confirmation that the individual items characterize the underlying constructs. The results of the confirmatory factor analysis reported in Table 32 lead us to conclude that all indicators of the competitive environment are significantly related to their respective constructs, ensuring convergent validity.

In order to test discriminant validity, as previously, we used a chi-square test among these constructs. The result of the chi-square difference test is 11.16, indicating that the correlation between these two constructs is statistically different from 1.0 at the .001 level. This result ensures the discriminant validity of these two constructs. The correlation between these constructs is .60 ($p < .001$). In Table 33 we present the list of the final competitive environment item measures that were used in the rest of the study.

Table 33. Competitive Environment Items: Final List (combined sample, *n*= 294)

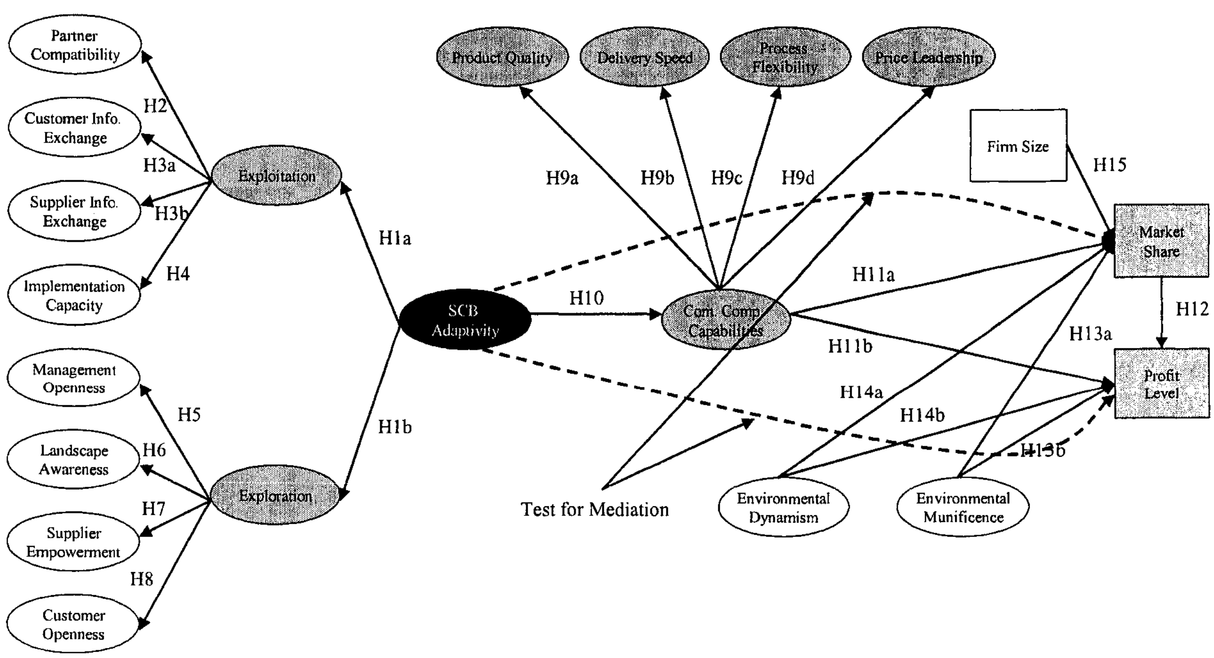
Operational Constructs and Item Measures	References
Environmental Dynamism: The degree of turbulence in products, technologies, and demand for products in a market. **ED1:** The rate at which products and services become outdated. **ED2:** The rate of innovation of new products and services. **ED4:** The rate of change of tastes and preferences of customers in your industry.	Dess and Beard, 1984; Kotha and Nair, 1995; Starbuck, 1976
Environmental Munificence: The extent to which the competitive environment can support sustained growth. **EM1:** Our business environment is characterized by rapidly changing prices. **EM2:** A high growth rate of demand characterized this industry.	Dess and Beard, 1984; Kotha and Nair, 1995; Starbuck, 1976

CHAPTER 6

MODEL ESTIMATION AND ANALYSIS

In this chapter, we test our hypotheses using structural equation modeling (SEM). In SEM, variables are expressed as weighted linear combinations of other variables. Variables that depend on other variables are called endogenous variables (η), whereas variables that do not depend on other variables are called exogenous variables (ξ). In Chapter 5 we completed the first part of the SEM, the development of the measurement model. We now continue with our investigation of the hypothesized structural relations among our constructs as depicted in Figure 10.

***Figure 10.* Hypothesized Model of the Relation between Supply Chain Base Adaptivity and Combinative Competitive Capabilities**



For our SEM analysis, we proceeded in three steps. Since we were using a multigroup approach for our analyses, we needed first to consider the sample size relative to the size of our model. The full model was too big for a sample size of 131 observations; thus, in order to analyze the structural model, we divided it into three parts. First, we analyzed the relationships between supply chain base adaptivity, exploration activity, and exploitation activity. We then analyzed the relationship between combinative competitive capabilities and firm performance. Finally, we analyzed the full model using a combined sample of 294 observations.

In our structural equation model, we utilized the second-order latent variables Supply Chain Base Adaptivity and Combinative Competitive Capabilities. A second-order factor analysis is one in which the latent variable influencing the observed variables is itself influenced by another latent variable that may not have a direct impact on the observed variables. Gerbing and Anderson (1988) argue that higher-order factors are more informative than the correlated error representation. Thus, by utilizing second-order factor analysis we were able to mitigate the problem arising from correlated errors that are common in factor analysis (Narasimhan et al., 2001).

Before going into detail about our analysis, we first present the mathematical representation for our model. We laid out the foundations of our mathematical representation in Chapter 5, Table 11. In Tables 34 and 35 we list the variables, parameters, and associated symbols used in the structural equation modeling.

Table 34. Operational Construct Variables and Parameters in the Hypothesized Structural Model

Operational Construct	Structural Equation Modeling Representation
Partner Compatibility (PC)	η_1
Customer Information Exchange (CIE)	η_2
Supplier Information Exchange (SIE)	η_3
Implementation Capacity (IC)	η_4
Management Openness (MO)	η_5
Landscape Awareness (LA)	η_6
Supplier Empowerment (SE)	η_7
Customer Openness (CO)	η_8
Exploitation Activity (A)	η_9
Exploration Activity (EA)	η_{10}
Supply chain base adaptivity (SCBA)	ξ_1
Product Quality (QUAL)	η_{11}
Delivery Speed (DS)	η_{12}
Process Flexibility (PF)	η_{13}
Price Leadership (PL)	η_{14}
Combinative Competitive Capabilities (CC)	η_{15}
Firm Size (FS)	x_{16}
Environmental Dynamism (ED)	ξ_2
Environmental Munificence (EM)	ξ_3
Market Share (MS)	y_{17}
Profit Level (Profit)	y_{18}

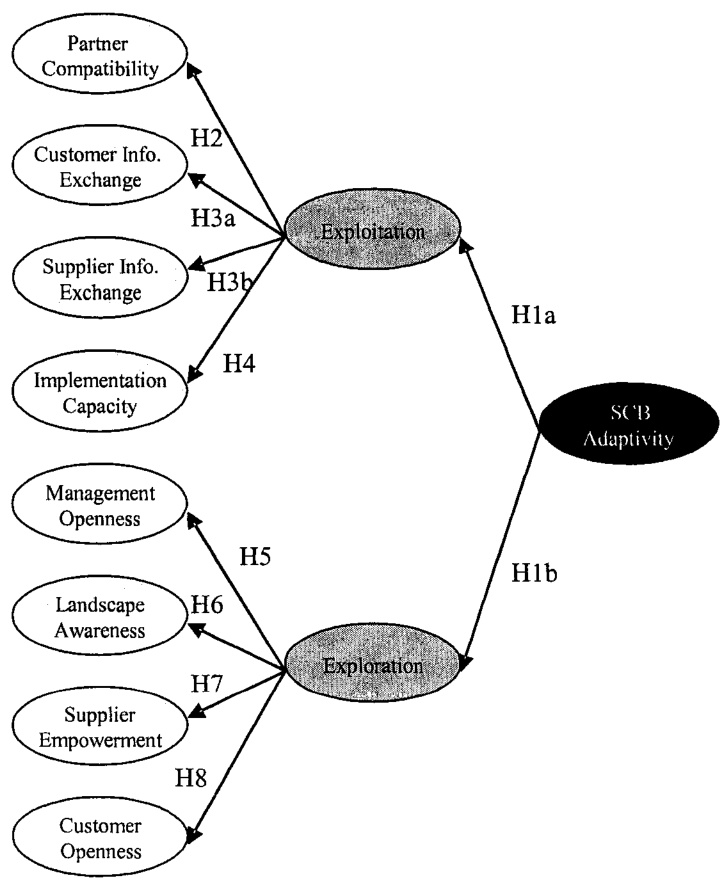
Table 35. Parameters for Construct Relationships in the Hypothesized Structural Model

Relationships among the Constructs	Structural Equation Modeling Representation
Exploitation Activity – Partner Compatibility	β_{19}
Exploitation Activity – Customer Information Exchange	β_{29}
Exploitation Activity – Supplier Information Exchange	β_{39}
Exploitation Activity – Implementation Capacity	β_{49}
Exploration Activity – Management Openness	β_{510}
Exploration Activity – Landscape Awareness	β_{610}
Exploration Activity – Supplier Empowerment	β_{710}
Exploration Activity – Customer Openness	β_{810}
Supply Chain Base Adaptivity – Exploitation Activity	γ_{91}
Supply Chain Base Adaptivity – Exploration Activity	γ_{101}
Supply Chain Base Adaptivity – Combinative Competitive Capabilities	γ_{151}
Combinative Competitive Capabilities – Product Quality	β_{1115}
Combinative Competitive Capabilities – Delivery Speed	β_{1215}
Combinative Competitive Capabilities – Process Flexibility	β_{1315}
Combinative Competitive Capabilities – Price Leadership	β_{1415}
Combinative Competitive Capabilities – Market Share	β_{1715}
Combinative Competitive Capabilities – Profit	β_{1815}
Market Share – Profit	β_{1718}
Firm Size – Market Share	γ_{1716}
Environmental Dynamism – Market Share	γ_{172}
Environmental Dynamism – Profit	γ_{182}
Environmental Munificence – Market Share	γ_{173}
Environmental Munificence – Profit	γ_{183}

Using the symbols listed in Tables 34 and 35, the mathematical representation of the relations among the constructs depicted in Figure 11 is as follows:

$$\eta_1 = \beta_{19}\eta_9 + \zeta_1$$
$$\eta_2 = \beta_{29}\eta_9 + \zeta_2$$
$$\eta_3 = \beta_{39}\eta_9 + \zeta_3$$
$$\eta_4 = \beta_{49}\eta_9 + \zeta_4$$
$$\eta_5 = \beta_{510}\eta_{10} + \zeta_5$$
$$\eta_6 = \beta_{610}\eta_{10} + \zeta_6$$
$$\eta_7 = \beta_{710}\eta_{10} + \zeta_7$$
$$\eta_8 = \beta_{810}\eta_{10} + \zeta_8$$
$$\eta_9 = \beta_{91}\xi_1 + \zeta_9$$
$$\eta_{10} = \beta_{101}\xi_1 + \zeta_{10}$$

***Figure 11.* The Relationship among Supply Chain Base Adaptivity and Its Reflecting Variables**



Analysis of the Relationship among Supply Chain Base Adaptivity and Its Reflecting Variables

In this section we analyze the relationships in the first part of our model in (Figure 11) using the calibration sample. In this partial model, since supply chain base adaptivity is a second-order construct, in order to achieve identification of our model following Bollen (1989) we set the variance of supply chain base adaptivity to 1. This constraint was removed for the analysis of the full model, since the effect of supply chain base adaptivity on competitive capabilities provides the additional constraint required for our model to be identified.

In order to assess the fit of our model, in addition to the chi-square measures we also used three widely used fit indices (Bollen, 1989), namely the incremental fit index (IFI), the Tucker-Lewis Index (TFI), and the comparative fit index (CFI) (χ^2 = 494.380, df = 338, χ^2/df = 1.463, p = .000, IFI = .921, TFI = .910, CFI = .919, RMSEA = .06). Although the p-value of the model's chi-square is significant, the χ^2 / df is 1.463. Since the chi-square measure is a conservative measure, researchers look at the chi-square degrees of freedom ratio as well. Although there is no clear-cut metric for this ratio, the rule of thumb is that as long as this ratio is less than 2.0 the model demonstrates a good fit (Bollen, 1989). All these indices are above 0.90, indicating a good fit for our model. The root mean square of approximation (RMSEA) is less than 0.10, also indicating a moderate fit (Bollen, 1989). The structural relationships among the theoretical constructs are statistically significant and in the expected directions (see Table 36).

Table 36. Second-Order Adaptation Model: Standardized Parameter Maximum Likelihood Estimates (calibration sample, n = 131)

Outcomes		Predictor	Hyp.	Predictor Sign	Parameter	Stand. Reg. Coefficient	S.E.	C.R.	P
Exploitation Activity	<---	Supply Chain Base Adaptivity	H1a	+	γ_{91}	.999	-	-	a
Exploration Activity	<---	Supply Chain Base Adaptivity	H1b	+	γ_{102}	.999	.255	3.122	***
Partner Compatibility	<---	Exploitation Activity	H2	+	β_{19}	.744	.161	4.525	***
Customer Info. Exchange	<---	Exploitation Activity	H3a	+	β_{29}	.218	.141	5.727	***
Supplier Info. Exchange	<---	Exploitation Activity	H3b	+	β_{39}	.423	.154	3.942	***
Implementation Capacity	<---	Exploitation Activity	H4	+	β_{49}	.912	.215	4.567	***
Management Openness	<---	Exploration Activity	H5	+	β_{510}	.723	.154	3.934	***
Landscape Awareness	<---	Exploration Activity	H6	+	β_{610}	.917	.179	4.664	***
Supplier Empowerment	<---	Exploration Activity	H7	+	β_{710}	.672	.145	3.598	***
Customer Openness	<---	Exploration Activity	H8	+	β_{810}	.681	.147	3.806	***

[a] This regression weight was fixed at 1.0. The S.E., C.R. and p-value were not estimated. By fixing a different parameter we determined that the p-value is significant at the 0.001 level.
*** Parameters are significant at the 0.01 level (two-tailed).

Since we were following a split-sample approach, we continued our analysis of the structural model with the calibration sample. Invariance of the structural relationships among the theoretical constructs across the calibration and validation samples would allow us to conduct our analysis with the full theoretical model using the combined sample. In Table 37, we present the results of the invariance tests of the hypothesized model across these two samples. We assessed the invariance of the structural model by looking at the differences in CFI, Gamma Hat, and NCI, as suggested by Cheung and Rensvold (2002).

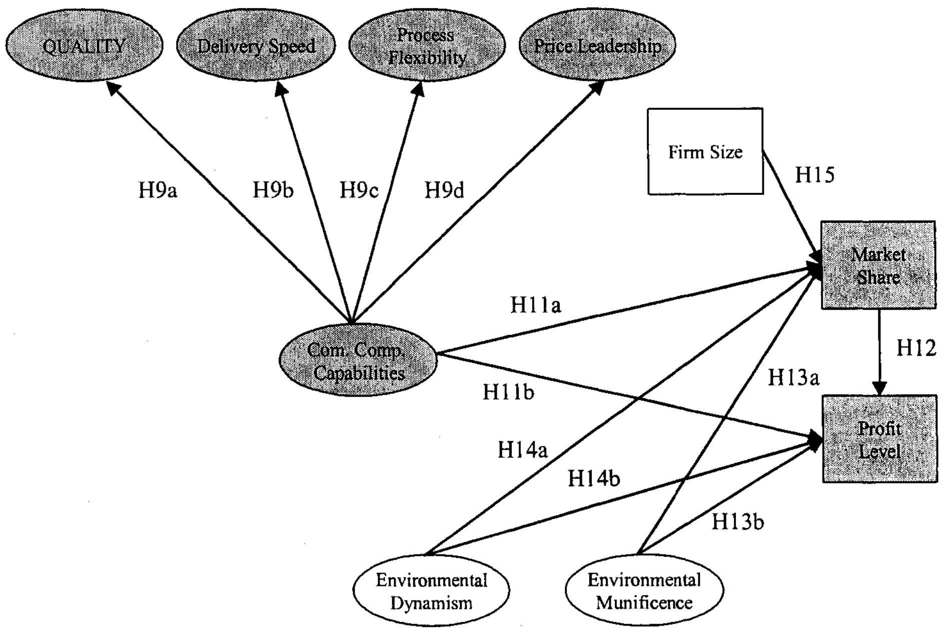
Table 37. Test of the Invariance of the Second-Order Adaptation Model across the Calibration and Validation Samples

Stand-alone indices	Unrestricted Model (1)	Restricted Model (2)[a]	Restricted Model (3)[b]	Restricted Model (4)[c]
Chi-square (χ^2)	943.261	1001.784	1071.058	1076.543
Degrees of freedom (df)	676	730	768	771
Probability level	<.001	<.001	<.001	<.001
Chi-square/df	1.395	1.372	1.395	1.396
Chi-square difference[d]		58.523	127.797	133.282
Degrees of freedom difference		54	92	95
Significance of χ^2 difference		.313	.008	.006
RMSEA	.037	.036	.037	.037
Fit Indices				
IFI	.931	.928	.919	.919
TFI	.914	.919	.914	.913
CFI	.928	.927	.918	.918
ΔCFI		.001	.010	.010
Gamma Hat	.991	.987	.980	.979
ΔGamma Hat		.004	.011	.012
NCI	.928	.927	.918	.918
ΔNCI		.001	.010	.010

[a] Restricted Model: Measurement weights and intercepts
[b] Restricted Model: Measurement weights, intercepts, and variances
[c] Restricted Model: Measurement weights, intercepts, variances, and covariances
[d] All the restricted models are compared to the unrestricted model.

A comparison of the nested models reveals that the two groups do not significantly differ. Although the chi-square difference is significant, for the last two columns in Table 37 the difference in CFI and NCI values are within the acceptable limits suggested by Cheung and Rensvold (2002) (i.e., $\Delta CFI \leq .01$; $\Delta NCI \leq .02$). Thus, we concluded that the model depicted in Figure 11 does not show a statistical difference across the validation and calibration samples. This finding allowed us to combine the two data samples in order to analyze the hypothesized model. However, we first continued our analysis of the relationship among combinative competitive capabilities and firm performance. Once the invariance of the structural relationships among combinative competitive capabilities and firm performance (see Figure 12) was established, we were able to analyze our full model (see Figure 10) using the combined data set.

***Figure 12.* The Relationship among Combinative Competitive Capabilities and Firm Performance**



Analysis of the Relationship between Combinative Competitive Capabilities and Firm Performance

In this section we report the results of our analysis of the structural relationships presented in Figure 12. Our results reveal acceptable fit measures (χ^2 = 223.733, df = 160, χ^2/df = 1.398, p = .001, IFI = .940, TFI = .917, CFI = .937, RMSEA = .06) for the structural model depicted in Figure 12. Although the chi-square value is significant, χ^2/df is lower than 2.0, the three fit indices are greater than 0.90, and the root mean square of approximation (RMSEA) is less than 0.10, indicating a moderate fit (Bollen, 1989).

We present the parameter estimates for the relationships presented in Figure 12 in Table 38. All the hypotheses, except the relationships among the firm performance and competitive environment, were supported. Based on the significance levels of parameter estimates on the relationship among the variables, we decided to omit the competitive environment variables from further analysis. After this modification, we have a better fit (χ^2 = 115.231, df = 85, χ^2/df = 1.356, p = .016, IFI = .965, TFI = .948, CFI = .963, RMSEA = .05) for our modified model.

Table 38. Structural Model for the Relationship between Combinative Competitive Capabilities and Firm Performance: Standardized Parameter Maximum Likelihood Estimates (calibration sample, *n*= 131)

Outcomes		Predictor	Hyp.	Predictor Sign	Parameter	Stand. Reg. Coefficient	S.E.	C.R.	*P*
Product Quality	<---	Combinative Competitive Capabilities	H9a	+	β_{1115}	.678	.094	6.669	***
Delivery Speed	<---	Combinative Competitive Capabilities	H9b	+	β_{1215}	.915			A
Process Flexibility	<---	Combinative Competitive Capabilities	H9c	+	β_{1315}	.949	0.113	7.626	***
Price Leadership	<---	Combinative Competitive Capabilities	H9d	+	β_{1415}	.569	.114	4.725	***
Market Share	<---	Combinative Competitive Capabilities	H11a	+	β_{1715}	.290	.273	2.676	.007
Profit Level	<---	Combinative Competitive Capabilities	H11b	+	β_{1815}	.418	.252	3.734	***
Profit Level	<---	Market Share	H12	+	β_{1718}	.214	.094	2.036	.042
Market Share	<---	Environmental Munificence	H13a	+	γ_{173}	-.053	.558	-.285	.775
Profit Level	<---	Environmental Munificence	H13b	+	γ_{183}	.110	.483	.610	.542
Market Share	<---	Environmental Dynamism	H14a	-	γ_{172}	.079	.498	.481	.631
Profit Level	<---	Environmental Dynamism	H14b	-	γ_{182}	-.093	.430	-.589	.556
Market Share	<---	Firm Size	H15	+	γ_{1716}	.240	.112	2.394	.017

[a] This regression weight was fixed at 1.0. The S.E., C.R. and *p*-value were not estimated. By fixing a different parameter we determined that the *p*-value is significant at the 0.001 level.
*** Parameters are significant at the 0.001 level (two-tailed).

The next step was to test the invariance of the structural relationship between combinative competitive capabilities and firm performance across the calibration and validation samples. In Table 39, we present the results of the multigroup analysis. As can be seen, the restricted models do not differ from the unrestricted model. Also, although ΔGamma Hat is little bit larger than the cutoff value that Cheung and Rensvold (2002) suggested (i.e., .001), the differences in CFI and NCI are lower than their suggested cutoff values.

Table 39. Test of the Invariance of the Structural Model for the Relationship between Combinative Competitive Capabilities and Firm Performance across the Calibration and Validation Samples

Stand-alone indices	Unrestricted Model (1)	Restricted Model (2)[a]	Restricted Model (3)[b]
Chi-square (χ^2)	210.775	244.325	268.901
Degrees of freedom (df)	170	200	220
Probability level	.018	.018	.014
Chi-square/df	1.240	1.222	1.222
Chi-square difference[c]		33.550	58.126
Degrees of freedom difference		30	50
Significance of χ^2 difference		.299	.201
RMSEA	.029	.028	.028
Fit Indices			
IFI	.978	.975	.972
TFI	.967	.970	.969
CFI	.977	.975	.972
ΔCFI		.002	.005
Gamma Hat	.997	.997	.993
ΔGamma Hat		.001	.004
NCI	.977	.975	.972
ΔNCI		.002	.005

[a] Restricted Model: Measurement weights, intercepts, and means
[b] Restricted Model: Measurement weights, intercepts, means, and variances
[c] All the restricted models are compared to the unrestricted model.

These results, together with the invariance of the calibration and validation samples described in the previous subsection, enabled us to continue our analysis of the full hypothesized model (see Figure 10) using the combined sample.

Analysis of the Full Model

In the concluding section of this chapter, we analyze the full model as depicted in Figure 13 using the combined sample. Fit statistics for the full model (χ^2 = 1257.623, df = 842, χ^2/df = 1.494, p < .001, IFI = .930, TFI = .920, CFI = .929, RMSEA = .04) indicate that we have satisfactory results. Although the chi-square value is significant, χ^2/df is lower than 2.0, the three fit indices are greater than 0.90, and RMSEA is at the level of 0.05, indicating a good fit (Bollen, 1989). Based on the significance levels of the parameter estimates on the relationship among the variables presented in Table 40, we once again conclude that most of our hypotheses, except the ones related with competitive environment, are supported by the results of our statistical analyses.

Figure 13. **Full Model with Standardized Estimates**

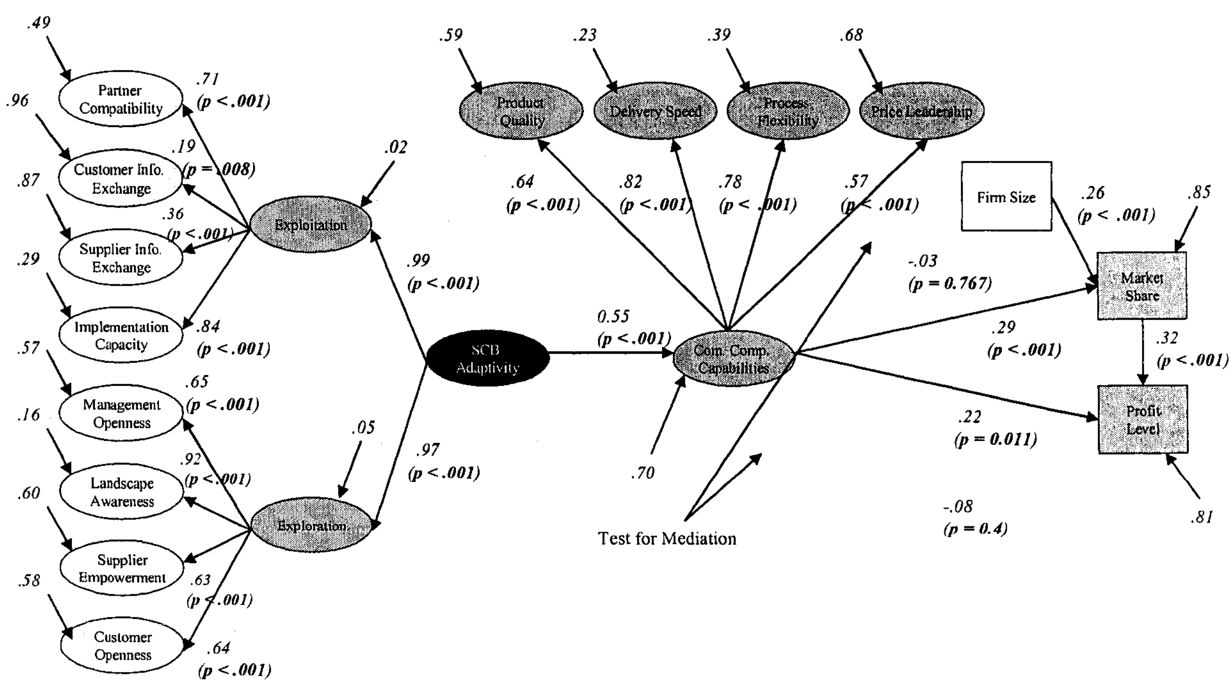


Table 40. Standardized Parameter Maximum Likelihood Estimates for the Full Structural Model (calibration sample, n = 294)

Outcomes		Predictor	Hyp.	Predictor Sign	Parameter	Stand. Reg. Coefficient	S.E.	C.R.	P
Exploitation Activity	<---	Supply Chain Base Adaptivity	H1a	+	γ_{91}	.988	.043	12.259	***
Exploration Activity	<---	Supply Base Chain Adaptivity	H1b	+	γ_{101}	.972	.049	13.417	***
Combinative Competitive Capabilities	<---	Supply Base Chain Adaptivity	H10	+	γ_{151}	.551	.040	5.323	***
Partner Compatibility	<---	Exploitation Activity	H2	+	β_{19}	.710	.101	9.104	***
Customer Info. Exchange	<---	Exploitation Activity	H3a	+	β_{29}	.193	.129	2.654	.008
Supplier Info. Exchange	<---	Exploitation Activity	H3b	+	β_{39}	.359	.142	4.906	***
Implementation Capacity	<---	Exploitation Activity	H4	+	β_{49}	.842	.098	11.456	***
Management Openness	<---	Exploration Activity	H5	+	β_{510}	.652	.073	8.869	***
Landscape Awareness	<---	Exploration Activity	H6	+	β_{610}	.919	.079	13.400	***
Supplier Empowerment	<---	Exploration Activity	H7	+	β_{710}	.629	.066	8.475	***
Customer Openness	<---	Exploration Activity	H8	+	β_{810}	.643	.067	8.825	***
Product Quality	<---	Combinative Competitive Capabilities	H9a	+	β_{1115}	.636	.172	5.470	***
Delivery Speed	<---	Combinative Competitive Capabilities	H9b	+	β_{1215}	.820	.273	6.117	***
Process Flexibility	<---	Combinative Competitive Capabilities	H9c	+	β_{1315}	.781	.174	5.427	***
Price Leadership	<---	Combinative Competitive Capabilities	H9d	+	β_{1415}	.565			a
Market Share	<---	Combinative Competitive Capabilities	H11a	+	β_{1715}	.288	.446	3.357	***
Profit Level	<---	Combinative Competitive Capabilities	H11b	+	β_{1815}	.219	.366	2.558	.011
Profit Level	<---	Market Share	H12	+	β_{1718}	.321	.060	4.381	***
Market Share	<---	Firm Size	H15	+	γ_{1716}	.263	.081	3.855	***

[a] This regression weight was fixed at 1.0. The S.E., C.R. and p-value were not estimated. By fixing a different parameter we determined that the p-value is significant at the 0.001 level.
[***] Parameters are significant at the 0.001 level (two-tailed).

We also tested the mediating effect of combinative competitive capabilities on the relationship between supply chain base adaptivity and firm performance. In other words, unless the supply chain enables combinative competitive capabilities, there should be no performance benefit. The first condition for mediation is that the independent variable should directly affect the dependent variable in the absence of the mediator. Thus, supply chain base adaptivity should directly affect market share. The second condition for mediation is that the independent variable must significantly affect the mediator. The final condition for mediation is that when the dependent variable is regressed on both the independent and the mediating variables, the direct effect of the independent variable should diminish significantly, indicating partial mediation, or should be nonsignificant, indicating full mediation.

In order to be able to draw conclusions on the mediation effects, we tested for both the direct and indirect effects of supply chain base adaptivity on market share. The significant direct effect of supply chain base adaptivity on market share becomes insignificant once combinative competitive capabilities are introduced into the model. We also needed to decompose the total effect of supply chain base adaptivity on market share into direct and indirect effects. In the direct effects model, the total effect is equal to the direct effect itself, since there are not any indirect effects; whereas in the mediated model, the total effect consists of the direct effect plus an indirect effect of supply chain base adaptivity on market share through combinative competitive capabilities. Thus, the significant indirect effect indicates that a significant amount of the independent variable's total effect on the dependent variable occurs through the mediator. In our mediation model, the direct effect of supply chain base adaptivity on market share is insignificant, indicating that we have full mediation of combinative competitive capabilities on the relationship between supply chain base adaptivity and market share (MacKinnon and Dwyer, 1993). Lastly, we tested for the significance of the indirect effect using the Goodman test (Goodman, 1960)[2]. The indirect unstandardized effect of supply chain base adaptivity on market share is 0.21, and the Goodman test statistic is 3.45 ($p < 0.001$), indicating that we have very significant indirect effects.

In Appendix 8 we present the direct (unmediated), indirect (mediated) and total effects (direct and indirect effects) of all the relationships represented in Figure 13 and show that supply chain base adaptivity indeed affects firm performance via competitive capabilities. In Table 41, we summarize the hypotheses analyzed in this dissertation and indicate whether they were supported by our results. The only hypotheses that were not supported were those relating competitive environment and firm performance. We discuss these results further in Chapter 7.

[2]Following Krull and MacKinnon (1999), in order to test for the significance of the indirect effect, we first regressed combinative competitive capabilities on supply chain base adaptivity to obtain the unstandardized coefficient for the association between the mediator (combinative competitive capabilities) and the independent variable (supply chain base adaptivity). Then we regressed the market share on combinative competitive capabilities and supply chain base adaptivity in order to get the unstandardized coefficient for the association between the mediator (combinative competitive capabilities) and the dependent variable (market share).

Table 41. Summary of Support for Tested Hypotheses

Hypothesis Description	Hypothesis Number	Support?
Supply chain base adaptivity is a second-order multidimensional construct that is reflected by exploitation and exploration activity.	1	Yes
Supply chain base adaptivity is positively reflected by exploitation activity.	1A	Yes
Supply chain base adaptivity is positively reflected by exploration activity	1B	Yes
Exploitation activity is positively reflected by partner compatibility (e.g., shared work norms and procedures, shared language) within a manufacturer's supply chain.	2	Yes
Exploitation activity is positively reflected by customer information exchange.	3A	Yes
Exploitation activity is positively reflected by supplier information exchange.	3B	Yes
Exploitation activity is positively reflected by implementation capacity.	4	Yes
Exploration activity is positively reflected by the management openness of the firm.	5	Yes
Exploration activity is positively reflected by landscape awareness.	6	Yes
Exploration activity is positively reflected by supplier empowerment.	7	Yes
Exploration activity is positively reflected by customer Openness.	8	Yes
Combinative competitive capabilities is a second-order construct that is reflected by capabilities such as product quality, delivery speed, process flexibility, and low price.	9	Yes
Combinative competitive capabilities is positively reflected by product quality.	9a	Yes
Combinative competitive capabilities is positively reflected by delivery speed.	9b	Yes
Combinative competitive capabilities is positively reflected by process flexibility.	9c	Yes
Combinative competitive capabilities is positively reflected by price leadership.	9d	Yes
Supply chain base adaptivity directly and positively affects combinative competitive capabilities.	10	Yes
Combinative competitive capabilities positively affect market share.	11a	Yes
Combinative competitive capabilities positively affect profit level.	11b	Yes
Market share positively affects profit level.	12	Yes
Increased environmental munificence leads to increased levels of market share.	13a	No
Increased environmental munificence leads to increased levels of net profit.	13b	No
Increased environmental dynamism leads to decreased levels of market share.	14a	No
Increased environmental dynamism leads to decreased levels of net profit.	14b	No
Firm size positively affects market share.	15	Yes
The relationship between supply chain base adaptivity and market share is mediated by combinative competitive capabilities.	Mediation	Yes

To better understand our results, we need to link the theory underlying this study (i.e., the notion of supply chain base adaptivity) with our empirical findings. First, we bridge the notions of exploitation and exploration activity with the behavior of supply chains as complex adaptive systems (CASs). According to Holland and Miller (1991), many economic systems can be classified as complex adaptive systems. The basic characteristics of these systems can be summarized as follows: (i) they consist of a network of interacting agents, (ii) they exhibit a dynamic behavior that emerges from the individual activities of the agents, and (iii) their aggregate behavior can be described without specific knowledge of the behavior of the specific agents. These characteristics definitely apply to today's supply chain networks (Choi et al., 2001). For this study, we identified eight dimensions of adaptive supply chain behavior based on various dimensions of complex adaptive systems. These dimensions represent the attributes a supply chain network would have if it behaved like a CAS. Supply chains show adaptive behavior, since their actions can be assigned a value (e.g., profit, market share); and they behave so as to increase this value over time (Holland and Miller, 1991). There are two actions in particular taken by CASs that enable them to become adaptive: *exploitation* and *exploration*. A system increases its value either by achieving higher efficiency in a given setting (i.e., exploitation) or by trying new venues that will potentially bring higher payoffs (i.e., exploration). Thus, we theoretically link the dimensions of complex adaptive systems represented in supply chain networks to the notions of *exploitation* and *exploration*.

Hypotheses 2, 3a, 3b, and 4 link the dimensions of supply chain networks such as partner compatibility, supplier information exchange, customer information exchange, and implementation capacity to exploitation activity. These four constructs represent ways that a supply chain can be managed more efficiently. One of the basic characteristics of a CAS is that the system has a shared *schema*. Schemas enable the members of a system to speak the same language. Similar to this notion of schema is partner compatibility, which states that by setting common process standards among the supply chain partners, a common language can be established throughout the supply chain network enabling the partners to understand each other in a clear and concise way. Once the common process standards are set up, the next step is to exchange information based on these standards.

In a CAS all the agents are *connected* together one way or another. In supply chain networks, *connectivity* is established by information exchange among the supply chain members. The customer information exchange and supplier information exchange constructs represent whether the supply chain information is exchanged among the supply chain partners using information technologies. Here we need to discuss the relative effect of exploitation activities on customer information exchange and supplier information exchange. The effects of exploitation activity on CIE and SIE are relatively low when compared to to its effect on implementation capacity and partner compatibility. This result suggests that contrary to general belief in order to achieve high levels of efficiency in the supply chain base manufacturers need to focus on establishing a "common language" and focus on implementation capacity rather than taking orders electronically from their customers or giving orders to their suppliers electronically. As Heinrich and Betts (2003) state, one plausible reason for this result is that establishing electronic transaction channels do not increase the efficiency of a supply chain unless the supply chain members first establish the "common language" among themselves. Thus our respondents may be in the stage of establishing the common language and therefore the effects of exploitation activity on CIE and SIE are relatively low when compared to partner compatibility and implementation capacity.

Lastly, CASs have the ability to apply new knowledge in their given states (Holland, 1995). Similarly, implementation capacity indicates the strength of a manufacturer to efficiently apply the new concepts that are introduced. The results of our analyses support our hypotheses that the notion underlying partner compatibility, information exchange, and implementation capacity is exploitation activity.

Hypotheses 5–8 link the dimensions of supply chain networks such as management openness, supplier empowerment, customer openness, and landscape awareness to exploration activity. These four constructs represent ways that a supply chain can search for new ideas, resources, and opportunities. One of the basic dimensions of a CAS is *self-emergence*. Self-emergence can be defined as a system's capacity to create new structures, ideas, or developments without deliberately planning for them (Holland, 1995). For a manufacturer, such developments either can emerge from within the organization or can be inspired by developments in the competitive environment. Management openness represents the ease with which new ideas can emerge from within the manufacturing organization, especially from the middle-level management. Although in many manufacturing organizations manufacturing strategy is still seen as a top-down approach, middle managers are the ones that face supply chain problems on a daily basis. Thus, their contributions can lead to new developments in the management of the supply chain network. In a similar vein, new developments in the competitive environment can lead to new applications for the supply chain. Landscape awareness enables supply chain managers to scan their competitive environment and gather new ideas relevant to their supply chain network from the competitive environment. The last dimension of a CAS is *dimensionality*, which can be defined as the degrees of freedom that individual agents within the system have to enact behavior in a somewhat autonomous fashion (Dooley and Van de Ven, 1999). Such an interdependent structure within a supply chain can be achieved by the cultivation of strong relationships among the members of the supply chain network. The supplier empowerment and customer openness constructs enable the integration of the ideas and needs of the supply chain partners, leading to *dimensionality* within the supply chain. The results of our analyses support our hypotheses that the notion underlying management openness, landscape awareness, supplier empowerment, and customer openness is exploration activity.

The second main result of our empirical findings is the balance between *exploitation* and *exploration* in supply chain base adaptivity. The differences between exploration and exploitation have been emphasized in a wide range of management literature. These differences mainly stem from the fact that firms have limited resources. Since firms rarely have sufficient resources for both activities, they tend to focus on one or the other. Managers facing competitive pressures need to perform well in the short term, and they usually focus on exploitation. The resulting competence trap (Levinthal and March, 1993) leads firms to develop core rigidities that enhance the short-term performance of the firm at the expense of adaptability (Volberda, 1996).

Although there is a certain trade-off between exploration and exploitation in practice, recent research has suggested that exploitation and exploration are not separate, mutually independent activities, and that organizations go through periods of exploitation and exploration sequentially (Weick and Westley, 1996). March (1991) suggests that maintaining a balance between exploration and exploitation is critical for firm survival and adaptivity. Our results presented in Table 40 illustrate empirically that adaptation has two facets, exploitation and exploration, which are not independent activities and which are both necessary for supply chain base adaptivity.

Third, in Hypotheses 9–11 we investigate the relationships among supply chain base adaptivity, combinative competitive capabilities, and firm performance. Business strategy literature has long recognized the importance of dynamic capabilities for the competitiveness of firms. The significant finding regarding the relationship between supply chain base adaptivity and combinative competitive capabilities constitutes a contribution to supply chain management in terms of identifying the ways that combinative competitive capabilities can be acquired by firms with supply chain base adaptivity. Parallel to the findings in the evolutionary economics and dynamic capabilities literatures, our results suggest that combinative competitive capabilities mediate the effect of supply chain base adaptivity on firm performance. Along the same lines, our research shows that it is possible to achieve various competitive capabilities at the same time (i.e., Hypotheses 9a–d). Although this is not an easy task for supply chain managers, with careful examination of their exploration and exploitation activities they can achieve high levels in different capabilities simultaneously. Since our study is one of the first attempts to measure such relations, we contribute to the supply chain management literature by providing solid empirical evidence that combinative competitive capabilities mediate the effect of supply chain base adaptivity on firm performance.

In Hypothesis 12 we study the effect of market share on profit level. In line with existing literature (Levinthal and Myatt, 1994; Buzell et al., 1975), we find a positive effect of market share on profit levels. Lastly, in Hypotheses 13–14 we looked at the effect of the competitive environment on firm performance. We did not find any empirical evidence for such an effect. One of the possible reasons for this is the discrepancy between the perceptions of the supply chain managers and the realized competitive environment. In our study we used subjective measures of competitive environment as control variables; we might have obtained a different result if it had been possible to use objective measures of the state of the competitive environment. This finding opens a new venue for future research in supply chain management.

CHAPTER 7

CONCLUSIONS

This study contributes to supply chain management in three ways. First, we provide a grounded-theory-based definition of supply chain base adaptivity and its measurement. Second, we provide empirical evidence that supply chains need to focus not only on efficiency but also at the same time on seeking out new capabilities and opportunities that exist among them. Third, in this research we examine the relationship among supply chain base adaptivity, competitive capabilities, and business performance. Except for recent works (Frohlich and Westbrook, 2001; Rosenzweig et al., 2003), prior research on competitive capabilities has usually focused on the manufacturing function (Flynn, Schroeder and Flynn, 1999; Hill, 1994; Miller and Roth, 1994; Swamidass and Newell, 1987; Ward, Leong and Boyer, 1994). Our research also contributes to the supply chain management literature by investigating and describing the relationship between competitive capabilities and business performance from a supply chain management perspective.

We conceptualize supply chain base adaptivity as a combination of the intensity of both exploration and exploitation activities, which enable a firm to manage its supply chain in order to ensure its long-term viability. We show that the interplay between these two types of activities leads firms to search for future opportunities in order to shape future market conditions in their favor, and at the same time to improve their existing capabilities and supply chain efficiency in order to ensure their short-term viability (Chakravarthy, 1982;

Choi et al., 2001; Lewin et al., 1999; March, 1991). We continue our conclusions with the specific contributions of our study from both the research and managerial perspectives, and close with a discussion of the limitations of the study and future research directions.

Research Contributions

Three main research questions guided and motivated this research. First, we sought to determine how to operationally define the concept of supply chain base adaptivity. We also looked to identify how supply chain base adaptivity influences supply chain's combinative competitive capabilities. Finally, we also wanted to determine the influence of supply chain performance on business performance. The answers to these questions form the key research contributions of our study, which we outline below.

Supply Chain Management and Complex Adaptive Systems

One of the basic principles upon which this research is founded is the notion of complex adaptive systems (CAS). CAS has been studied both in physics and biology and is considered one of the most important emerging fields of the scientific achievement (Gell-Mann, 1994). There have been numerous applications of CAS to business-world problems (Kauffman, 1995). One of the revolutionary impacts of CAS is to help managers recognize that business strategy cannot be planned for a certain period of time and then applied without any diversions from this strategy (Pascale, 1999). Another important aspect of CAS is that it is comprises a set of semi-autonomous members. These two aspects of CAS are a perfect fit for applications in supply chain networks, which compete in continuously changing environments and consist of thousands of members. In this dissertation we operationalized the notion of CAS in the supply chain setting and developed a model for measuring it.

In this process we also linked the notion of CAS with the well known concepts of exploitation and exploration capabilities in the organizational science literature (March, 1991). Taking a closer look at CAS, one can see that some of its underlying concepts, such as connectivity or schema, enable it to function in an efficient and effective way. Its dimensionality and self-emergence lead to the exploration of new opportunities within the environment. By connecting these concepts we were able to apply the concept of CAS to supply chain management in a tangible manner. As a result, one of the main contributions of this research is to show that supply chain networks can be conceptualized as a set of living organisms. Supply chain strategy should therefore evolve around the interactions of the supply chain members in order for them to survive in the competitive environment.

Supply Chain Management and the Balance of Exploitation and Exploration Activity

A second, and perhaps more important, contribution of this research is that it sheds light on the balance between exploitation and exploration in the supply chain management literature. Historically, supply chain management scholars have focused on the importance of the efficiency of the supply chain. However, the exploration of new opportunities is at least as important as supply chain efficiency. Without exploration, supply chain management can be locked in a path that would lead the supply chain to lose all its competitive advantage. Supply chain management literature has traditionally viewed management as a top-down approach; in other areas of management, the importance of the interaction of high-level management with other management levels has been emphasized for a long time

(Burgelman, 1991). One of the reasons for a top-down approach is the dominant engineering thinking in operations management, where most actions are assumed to work well if they are designed well. But in real life, companies face too many uncertainties; therefore the design of a perfect organization is nearly impossible. Thus, an integrated approach in which companies integrate both exploitation and exploration activities, should take place in supply chain management. For exploration activity we showed that this integrated approach to supply chain strategy is at least as important as exploitation activity.

Another important contribution of this research on supply chain management is to show that in order to achieve efficiency, exchanging information among supply chain partners is not enough; perhaps more important than the frequency of data exchange is the ability to establish communication among supply chain partners. Many supply chains employ electronic data exchange among their partners, but still lack the level of efficiency that they would like to achieve with these systems (Heinrich and Betts, 2003). One of the main reasons is that the people sitting at the end of the information highways do not understand each other in a simple and clear way. In most cases, the supply chain problems can be solved by the establishment of simple and clear communication channels rather than by the implementation of costly software solutions.

Supply Chain Base Adaptivity and Combinative Competitive Capabilities

Another research contribution of this project regards the development of competitive capabilities in supply chain management. In general, current manufacturing literature focuses on the effect of competitive capabilities on business performance (Flynn and Flynn, 2004; Ward and Duray, 2000), with a few exceptions (e.g., Schroeder et al., 2002) that focus on how these capabilities are acquired by manufacturers. This study points out an alternative way that these capabilities are acquired. By measuring the effect of supply chain base adaptivity on combinative competitive capabilities, we show that the acquisition of competitive capabilities can be achieved through the adaptation activities that a supply chain performs. These activities either focus on the efficiency of the existing supply chain structure such as establishing partner compatibility, exchanging information on real-time with supply chain members or they can focus on exploration such empowering the suppliers or listening to middle level management in regards to supply chain problems. Our results also lead us to conclude, like Flynn and Flynn (2004), that combinative competitive capabilities can be viewed as an accumulation of individual capabilities that companies can simultaneously improve upon and strengthen. Rather than having to trade off one set of capabilities for another, with careful planning and appropriate allocation of resources, firms can achieve high levels of competence in multiple capabilities at the same time. Finally, we also find that combinative competitive capabilities mediate the effect of supply chain base adaptivity on business performance.

Scale Development and Methodological Contribution

Using rigorous psychometric measurement theory, we developed a set of reliable and valid scales for all the latent constructs used in this research. We used measurement models to study the validation and reliability of our scales, first with a calibration sample and later using a validation sample. Also, we studied the invariance of these two samples with multigroup analyses. The resulting scales allowed us to measure the main components of our theory: the dynamics of complex adaptive systems in the supply chain setting, specifically exploitation and exploration activity. The measurement scale development is an integral part of this research, since they will enable us to validate our theory in future studies in different settings, or in international studies.

Managerial Contributions

This research project makes three main managerial contributions. First, it provides evidence that exploration activity activities are as important as those of exploitation activity. This implies that decisions by supply chain managers on the utilization and development of resources and competencies should be made in a way that reflects a balance between exploration and exploitation. Though pressured by short-term performance measures and cost-cutting incentives, supply chain managers should not be forced to focus only on short-term efficiency plans for their supply chains. As Lee (2004) illustrated in numerous examples, the long-term survival of supply chains depends not only on cost and delivery efficiency but also at the same time on maintaining a high-quality, flexible supply chain. Thus, supply chains should continuously search for new competence bases to enhance their existing capabilities.

Second, our results help supply chain managers to understand what problems they face and why and where these problems arise, along with their remedies. For example, although partnership compatibility is in fact a very simple concept, it is hard to implement in a real sense. Though managers may think that they can easily communicate with their supply chain partners, the diversity of people with whom they have to deal can lead to significant misunderstandings among supply chain members. Once any communication problems have been solved, the supply chain network can function quite smoothly, and in place of using expensive data exchange programs, most data can be exchanged via fax messages or in short conversations. This leads us to the second important managerial contribution of our study. Our analyses show that in order to achieve an efficient supply chain it is more important to establish a "common language" rather than to exchange information on a frequent basis. Although supply chain information proved to be very important, we believe that the understanding of supply chain partners' needs is more important than the rapid exchange of a large volume of information.

The third managerial contribution of this study is to show managers that it is possible to strengthen various competitive capabilities at the same time. Although this is not an easy task for supply chain managers, with careful examination of their exploration and exploitation activities they can achieve high levels in different capabilities simultaneously.

Limitations

As in all research this project has its limitations. Our findings are limited by certain choices and by the inevitable constraints imposed on us by circumstances during the time that this project was being conducted. Some of the limitations discussed in this section have led us to delve deeper into specific areas, which will be addressed in the future research section to follow.

Our first limitation regards the use of single respondents. The issue of single respondents and common-method variance, which is a result of single-respondent research, has been discussed widely in various areas (Podsakoff and Organ, 1986). In order to overcome this drawback, we used respondents who were experts in their areas, which was one of the main reasons that we collaborated with the Institute for Supply Management to contact supply chain managers within various companies. By utilizing Harman's test, we also analyzed our data for possible common-method bias and found no evidence of a significant effect. In future studies we plan to solicit multiple respondents from each company, insofar as is possible, to overcome this limitation.

A second limitation of our study is the time aspect of adaptation. By definition, adaptation is a process that takes time. For this study, we were not able to collect data in consecutive time periods in order to capture the evolution of the supply chains over time and observe how they adapt to their competitive environments. This limitation, however, has opened potential new avenues in our research, in particular the opportunity to observe the companies that responded to our survey in order to track how they adapt to their competitive environments over time.

Another issue involves the two-item scales that we used in our analyses. After refinement, two of our constructs (partner compatibility and supplier empowerment) were left with only two items. Although supplier empowerment measures are based on previous literature, partnership compatibility measures were created new for this study. Further work is needed in the development of additional measures for these constructs for future research.

Finally, we had to use single items for firm performance. In future research, we will use multiple items and objective measures for firm performance whenever possible.

Future Research

As indicated in the previous section, a number of the limitations of this study point toward future research opportunities. The first research direction is to continue to collect data in order to capture the adaptation of supply chains over time. While collecting data, we will also focus on the issues of single respondents and objective measures in order to address the problem of common-method variance.

A second potential research avenue is to extend this study to include a network perspective. This research focused on single firms; however, the notions of complex adaptive systems and supply chain management are built upon networks. By including both the suppliers and the customers of the manufacturers, we hope to capture the network effects in our future studies.

Third, although we did not find a significant effect of the competitive environment on firm performance in this study, we nevertheless believe that future research should look at the ways that the competitive environment affects the relationship between supply chain base adaptivity and firm performance, and under which circumstances the two adaptivity types (exploitation and exploration activity) would play a greater role in the survival of the supply chain.

Lastly, we plan to extend this research into different regional settings, such as Europe and East Asia. Such an international study will enable us to compare different perspectives on supply chain base adaptivity and help us better understand the concept by observing different competitive environments with different regulations and practices. In many ways, the present study is an initial step in exploring the adaptivity of supply chains. We hope that this project will be a catalyst for further research in this area.

APPENDIX 1

Proportion of Substantive Agreement and Substantive Validity Coefficients for Items Used in the Pre-test Sorting Exercise

Table A1. Proportion of Substantive Agreement and Substantive Validity Coefficients for Items Used in the Pre-test Sorting Exercise

	Proportion of Substantive Agreement			Substantive Validity Coefficient		
	Round			Round		
Operational Constructs	1	2	3	1	2	3
Schema (S): General compatibility of processes and standards among supply chain partners, which enables them to work smoothly together.	References: Choi et al., 2001					
All activities that take place among the supply chain partners are clearly defined.	.70	n.a.	n.a.	.40	n.a.	n.a.
We established common business processes with our supply chain partners.	.30	n.a.	n.a.	-.10	n.a.	n.a.
We established consistent operating standards with our supply chain partners.	.30	n.a.	n.a.	-.20	n.a.	n.a.
We try to synchronize the technological standards among our supply chain.	1.00	n.a.	n.a.	1.00	n.a.	n.a.
Partner Compatibility (PC): The degree to which our supply chain partners have compatible processes and standards among the supply chain.	References: Choi et al., 2001					
All processes and standards of the supply chain partners are clearly defined.	n.a.	.80	.70	n.a.	.70	.70
Our supply chain partners have compatible processes to ours.	n.a.	1.00	1.00	n.a.	1.00	1.00
We established compatible operating standards with our supply chain partners.	n.a.	1.00	1.00	n.a.	1.00	1.00
We try to develop compatible technological standards among our supply chain.	n.a.	.80	.90	n.a.	.70	.80
Management Openness (MO): The degree to which the expertise of the supervisors and middle management are considered by the top management when making strategic supply chain decisions.	References: Burgelman, 1983					
Our top management listens to ideas that originate from supervisors and middle management concerning supply chain decisions.	1.00	1.00	1.00	1.00	1.00	1.00
Our top managers are open to thoughts that originate from supervisors and middle management.	1.00	1.00	1.00	1.00	1.00	1.00
Top management lets strategic ideas be freely championed by anyone with relevant insight concerning our supply chain.	1.00	1.00	.90	1.00	1.00	.80

Table A1 (continued)

Operational Constructs	Proportion of Substantive Agreement Round 1	2	3	Substantive Validity Coefficient Round 1	2	3
Supplier Empowerment (SE): The degree of supplier involvement in decision-making in supply chain planning and implementations.	References: Ahmad and Schroeder, 2001; Narasimhan et al., 2001; Krause, 1999					
We typically give merit to strategic ideas that are raised by our suppliers.	.80	.90	.80	.70	.80	.70
Our suppliers are actively involved in supply chain decision-making processes.	.80	1.00	1.00	.70	1.00	1.00
We listen to our suppliers about quality considerations and design changes, regarding our supply chain.	.80	.90	.90	.70	.80	.80
Our suppliers take an active role in planning supply chain strategies.	.90	.80	1.00	.80	.60	1.00
Customer Openness (CO): Establishment and maintenance of relationships with customers in order to better understand their needs.	References: Ahmad and Schroeder, 2001; Sousa, 2003; Flynn et al., 1995					
Customers' needs are considered in our supply chain design.	.80	1.00	.90	.70	1.00	.80
We incorporate our customers' suggestions in supply chain decision-making processes.	.70	.70	.70	.50	.50	.50
We have formed processes to assess our customers' requirements.	1.00	1.00	.70	1.00	1.00	.50
We strive to be highly responsive to our customers' needs.	.80	.90	.90	.60	.80	.80
Our strong relationship with our customers provides us with valuable information.	.70	1.00	1.00	.60	1.00	1.00
Customer Information Exchange (CIE): Degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between our firm and our customers.	References: Frohlich and Westbrook, 2001, 2002					
We employ electronic order taking with our customers.	.70	.70	.90	.50	.50	.80
Our customers provide us with their demand forecasts.	.70	1.00	.90	.50	1.00	.80
Our customers routinely share inventory information with us.	.90	.90	1.00	.80	.80	1.00
We implement integrated order scheduling with our customers.	.80	1.00	1.00	.70	1.00	1.00
We regularly exchange our production plans with our customers.	.30	n.a.	n.a.	-.30	n.a.	n.a.
Supplier Information Exchange (SIE): Degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between our firm and our suppliers.	References: Frohlich and Westbrook, 2001, 2002					
We routinely exchange demand forecasts with our suppliers.	.90	.70	.80	.80	.50	.60
We routinely exchange inventory information with our suppliers.	.90	.90	.90	.80	.80	.80
Production plans are routinely exchanged among our firm and our suppliers.	.70	n.a.	n.a.	.60	n.a	n.a.
Our suppliers take orders by electronic means (i.e., web-based technologies, e-mail).	.70	1.00	1.00	.60	1.00	1.00
We implement integrated order scheduling with our suppliers.	1.00	1.00	1.00	1.00	1.00	1.00

Table A1 (continued)

Operational Constructs	Proportion of Substantive Agreement Round			Substantive Validity Coefficient Round		
	1	2	3	1	2	3
Landscape Awareness (LA): The degree to which the supply chain managers are aware of changes in industry and technology trends.						
Our supply chain managers are aware of new developments in our industry.	.80	1.00	.90	.70	1.00	1.00
Technological advances that will improve our supply chain performance are closely monitored.	.80	.70	.70	.70	.40	.50
We are rarely taken by surprise by the changes in our competitors' strategies.	.80	1.00	.90	.60	1.00	.80
We have procedures (e.g., attend trade shows, competitor intelligence service) to gain information on changes important to our industry.	.90	1.00	.90	.80	1.00	.80
We are generally ahead of our competitors in knowing what the emerging industry trends in supply chain management are.	1.00	1.00	1.00	1.00	1.00	1.00
Implementation Capacity (IC): Supply chain managers' ability to implement new methods in order to improve supply chain performance.						
Our firm is good at implementing new techniques for improving our supply chain performance.	.80	.90	n.a	.60	.80	n.a.
We are good at capitalizing on new ideas.	.80	.90	.70	.60	.80	.60
We can easily improve supply chain performance by assimilating new processes.	.90	.90	.70	.80	.80	.50
Our supply chain managers are able to transform new ideas into actions.	.80	.90	.60	.60	.80	.30
We are able to implement new supply chain concepts.	1.00	.90	.80	1.00	.80	.70
Exploration Activity (EA): A supply chain's ability to search, innovate, take risks, and experiment, in order to survive in the competitive environment.	Reference: March, 1991					
When dealing with supply chain problems, we seek out novel solutions.	n.a.	n.a.	.80	n.a.	n.a.	.70
We proactively pursue new supply chain solutions.	n.a.	n.a.	1.00	n.a.	n.a.	1.00
To improve our supply chain, we continually explore for new opportunities.	n.a.	n.a.	.80	n.a.	n.a.	.70
We are always on the lookout for new ideas that we can adopt for our supply chain.	n.a.	n.a.	.60	n.a.	n.a.	.30
Our supply chain managers continually seek out innovative ways to improve our supply chain.	n.a.	n.a.	.80	n.a.	n.a.	.60
We continually experiment to find new solutions that will improve our supply chain.	n.a.	n.a.	.90	n.a.	n.a.	.80

Table A1 (continued)

Operational Constructs	Proportion of Substantive Agreement			Substantive Validity Coefficient		
	Round			Round		
	1	2	3	1	2	3
Exploitation Activity (A): An organization's ability to improve its existing capabilities, processes, and technologies and diminish operating redundancies in order to achieve a more efficient, effective, and productive supply chain.	Reference: March, 1991					
In order to stay competitive, our supply chain managers focus on improving our existing capabilities.	n.a.	n.a.	.20	n.a.	n.a.	-.20
We focus on moving physical assets (e.g., inventory) quickly throughout our supply chain.	n.a.	n.a.	.30	n.a.	n.a.	-.10
We focus on cutting costs down in our supply chain.	n.a.	n.a.	.60	n.a.	n.a.	.30
In order to survive in the competitive environment, our supply chain managers focus on operational efficiency.	n.a.	n.a.	.60	n.a.	n.a.	.30
We focus on supply chain productivity.	n.a.	n.a.	.70	n.a.	n.a.	.50
In order to stay competitive, our supply chain managers focus on improving our existing technologies.	n.a.	n.a.	.90	n.a.	n.a.	.80
Our supply chain managers emphasize the use of existing supply chain practices.	n.a.	n.a.	.70	n.a.	n.a.	.60
When dealing with supply chain problems, we seek out "tried and true" solutions.	n.a.	n.a.	.70	n.a.	n.a.	.60
In order to stay competitive our supply chain managers focus on reducing operational redundancies.	n.a.	n.a.	.90	n.a.	n.a.	.80

APPENDIX 2

Items Included in the Pilot Study and Final Study

Table A2. Items Related to Supply Chain Base Adaptivity

("Y" indicates that a given item was included in that phase of the research process, and "b" represents that a given item was not included in that phase of the research process.)

Variable and Items	Calibration Sample	Validation Sample	Combined Sample
Partner Compatibility			
PC1: All supply chain processes are clearly defined.	b		
PC2: Our supply chain partners have processes compatible to ours.	Y	b	
PC3: We try to develop compatible technological processes among our supply chain.	Y	Y	Y
PC4: We created operating processes that are compatible with those of our supply chain partners.	Y	Y	Y
Management Openness			
MO1: Our top managers are open to thoughts that originate from supervisors and middle management.	Y	Y	Y
MO2: Our top management listens to ideas that originate from middle management concerning supply chain decisions.	Y	Y	Y
MO3: Top management allows strategic ideas to be freely championed by anyone with relevant insight within our organization.	Y	Y	Y
Supplier Empowerment			
SE1: We typically give merit to strategic ideas that are raised by our suppliers.	Y	Y	Y
SE2: We listen to our suppliers regarding design changes for our supply chain.	Y	Y	Y
SE3: Our suppliers are actively involved in supply chain decision-making processes.	Y	b	
SE4: Our suppliers can take an active role in planning supply chain strategies.	b		
Customer Openness			
CO1: We have formal processes to help us maintain customer relationships.	b		
CO2: We strive to be highly responsive to our customers' needs.	Y	Y	Y
CO3: Our strong relationships with our customers provide us with valuable information.	Y	b	
CO4: We incorporate our customers' suggestions in supply chain decision-making processes.	Y	Y	Y
CO5: Customers' needs are considered in our supply chain design.	Y	Y	Y

Table A2 (continued)

Variable and Items	Calibration Sample	Validation Sample	Combined Sample
Customer Information Exchange			
CIE1: We employ in-depth electronic order-taking with our customers.	b		
CIE2: Our customers provide us with their demand forecasts.	Y	Y	Y
CIE3: Our customers routinely share inventory information with us.	Y	Y	Y
CIE4: We implement integrated order-scheduling with our customers.	Y	Y	Y
Supplier Information Exchange			
SIE1: We routinely exchange inventory information with our suppliers.	Y	Y	Y
SIE2: We routinely exchange demand forecasts with our suppliers	Y	Y	Y
SIE3: Our suppliers take orders by electronic means (i.e., web-based technologies, and e-mail).	b		
SIE4: We implement integrated order-scheduling with our suppliers	Y	Y	Y
Landscape Awareness			
LA1: Our supply chain managers are aware of new developments in our industry.	Y	b	
LA2: We are generally ahead of our competitors in knowing the emergent industry trends in supply chain management.	Y	Y	Y
LA3: Our supply chain managers are rarely taken by surprise by the changes in our competitors' strategies.	Y	b	
LA4: Our firm is highly receptive of new supply chain technologies.	Y	Y	Y
LA5: Technological advances that will improve our supply chain performance are closely monitored.	Y	Y	Y
LA6: We have formal procedures for gaining information on changes important to our industry (e.g., trade show attendance, competitor intelligence service).	b		
LA7: We have a high level of expertise in successfully identifying new ideas that may be important in changing our existing supply chain practices.	Y	b	
LA8: We benchmark world-class supply chain practices.	Y	b	
Implementation Capacity			
IC1: We have the ability to implement supply chain innovations.	Y	Y	Y
IC2: We can improve supply chain performance by implementing new methods.	b		
IC3: Once they are introduced, we adjust quickly to new methods.	Y	b	
IC4: We are good at capitalizing on new ideas	Y	b	
IC5: Our supply chain managers transform new ideas to actions.	Y	Y	Y
IC6: We are able to implement new supply chain concepts.	Y	Y	Y
IC7: Our supply chain organization can solve problems quickly	Y	b	

Table A2 (continued)

Variable and Items	Calibration Sample	Validation Sample	Combined Sample
Exploration Activity			
EA1: We proactively pursue new supply chain solutions.	Y	Y	Y
EA2: We continually experiment to find new solutions that will improve our supply chain.	Y	Y	Y
EA3: Our managers are persistent in finding new ways of operating our supply chain.	b		
EA4: To improve our supply chain, we continually explore for new opportunities.	Y	Y	Y
EA5: To discover better ways of managing our supply chain, we have multiple ongoing projects.	Y	b	
EA6: We make significant investments in order to develop new supply chain strategies.	b		
EA7: We are constantly seeking novel approaches in order to solve supply chain problems.	Y	b	
Exploitation Activity			
A1: In order to stay competitive, our supply chain managers focus on improving our existing capabilities.	b		
A2: In order to survive in the competitive environment, our supply chain managers focus on increasing operational efficiencies of existing systems.	b		
A3: We focus on improving our existing supply chain competencies by refining our current supply chain processes.	Y	Y	Y
A4: In order to stay competitive, our supply chain managers focus on reducing operational redundancies in our existing processes.	Y	b	
A5: We have routine processes for improving our supply chain efficiency.	Y	b	
A6: Leveraging of our current supply chain technologies is important to our firm's strategy.	b		
A7: When dealing with supply chain problems, we seek out "tried and true" solutions.	b		
A8: In order to stay competitive, our supply chain managers focus our existing technologies.	Y	Y	Y
A10: Our managers focus on developing stronger competencies in our existing supply chain processes	Y	Y	Y

Table A3. Competitive Capability Items (measures based on Roth, 1996)

Variable and Items	Calibration Sample	Validation Sample	Combined Sample
Product Quality			
Conformance quality (i.e., the degree to which a product's operating characteristics meet established standards).	Y	Y	Y
Product durability (i.e., the amount of time or use before the product breaks down and replacement is preferred to continued repair).	Y	Y	Y
Product reliability (i.e., the probability of a product malfunctioning or failing within a specified time period).	Y	Y	Y
Performance quality (i.e., a product's primary operating characteristics).	Y	Y	Y
Overall product quality as perceived by the customer.	Y	b	
Delivery Speed			
Being able to provide fast response deliveries from order to end customer.	Y	Y	Y
Order fulfillment lead time.	Y	Y	Y
Delivery lead time.	Y	Y	Y
Process Flexibility			
Ability to rapidly change product mix.	Y	b	
Ability to rapidly change production volumes.	Y	Y	Y
Manufacture broad product mix within same facilities.	Y	Y	Y
Rapidly handle custom orders (i.e., engineer-to-order).	Y	b	
Ability to rapidly modify methods for materials.	Y	Y	Y
Cost Leadership			
Offering lower priced products than competitors.	Y	Y	Y
Manufacture products at lower internal costs than competition.	Y	b	
Meeting competitors' prices	Y	Y	Y

Table A4. Business Environment Items (measures based on Dess and Beard, 1984)

Variable and Items	Calibration Sample	Validation Sample	Combined Sample
Environmental Dynamism	Y	Y	Y
The rate at which products and services become outdated.	Y	Y	Y
The rate of innovation of new products and services.	Y	b	
The rate of innovation of new operating processes.	Y	Y	Y
The rate of change of tastes and preferences of customers in your industry.			
Environmental Munificence			
Our business environment is characterized by rapidly changing prices.	Y	Y	Y
A high growth rate of demand characterizes this industry.	Y	Y	Y
Demand for our primary products is highly predictable.	Y	b	

Table A5. Characterization of Company

Variable and Items	Calibration Sample	Validation Sample	Combined Sample
Characterization of Company			
What is the primary industry of your company?	Y	Y	Y
What is your business unit's number of employees?	Y	Y	Y
Business Performance			
Considering one product that yields the highest percentage of revenue of your business unit, what is your business unit's average market share?	Y	Y	Y
On average, what has been your company's profit level (before taxes)?	Y	Y	Y

APPENDIX 3

Q-Sorting Instrument

Pretest Sorting Exercise Instrument

Survey Development for Adaptive Supply Chain Networks

Project Directors:
Murat Kristal, Aleda V. Roth

In today's rapidly changing competitive environment, supply chain efficiency is a necessary condition for survival. However, firms' efforts to manage supply chains have often led to frustration and helplessness. Managers often struggle with the dynamic and complex nature of supply chain networks, unpredictable competitive environments, and the inevitable lack of prediction and control. As Haeckel (1999) states "The only kind of strategy that makes sense in the face of unpredictable change is a strategy to become adaptive.... It requires *appropriate* organizational response to change. And when change becomes unpredictable, it follows that the appropriate response will be equally so" (p. xvii).

This exercise is a first step in designing a reliable and valid questionnaire to measure a supply chain's adaptivity to the competitive environment. By adaptive, we mean a supply chain's ability to rapidly anticipate and/or respond to changing environmental conditions. The following pages contain a randomly listed set of items designed to capture different categories that describe a supply chain's adaptivity and the drivers that affect its adaptivity. The goal of this pilot phase exercise is to associate each of the listed items with a category. To facilitate your completion of the exercise, these different categories are first defined on the next page.

We ask that you carefully read the definitions of each category. Then, for each item, write down the letter of the category (e.g., "PC" for Partner Compatibility) that you feel is most closely associated with that item. Please use the space provided in front of each item and enter only one letter per item. *There are no right or wrong answers.* We are most interested in learning how you would classify the items into the categories. This questionnaire will take approximately 20 minutes, and it is completely voluntary. You decide on your own whether or not you want to participate in this study. All responses will be kept confidential and you do not need to identify yourself in your response. You will not be treated any differently if you decide not to participate in this study. If you decide to participate in this study, you will have the right to stop being in the study at any time.

The Academic Affairs Institutional Review Board (AA-IRB) at The University of North Carolina at Chapel Hill has approved this study. If you have any concerns about your rights as a participant in this study, you may contact the AA-IRB at (919) 962-7761 or at aa-irb@unc.edu.

Thank you in advance for your time and participation.

If you have any questions, please contact Murat Kristal at **(919) 843-6141**, **Office #: 4719, McColl Building**. If you are filling out this form electronically, please e-mail the completed form to **kristal@unc.edu** . If you are filling out a hardcopy of this form, or if you do not wish to reply by e-mail, please return the completed form by fax to **(919) 962-6949** or by mail to:

Murat Kristal
Kenan-Flagler Business School
CB# 3490, McColl Building
University of North Carolina at Chapel Hill
Chapel Hill NC 27599-3490

INSTRUCTIONS: On this page we provide you with definitions of the categories that will be used in our study. The pages following this page list items that are related to these different categories. You will be asked to sort the items into the categories, thus *we highly recommend that you print out the definitions on this page to assist you in completing the survey.*

Definitions for Different Drivers of Supply chain base adaptivity

(PC) Partner Compatibility
The degree to which our supply chain partners have compatible processes and standards among the supply chain.

(MO) Management Openness
The degree to which the expertise of the supervisors and middle management are considered by the top management when making strategic supply chain decisions.

(E) Supplier Empowerment
The degree of supplier involvement in decision making in supply chain planning and implementations.

(CO) Customer Openness
Establishment and maintenance of relationships with customers in order to better understand their needs.

(CIE) Customer Information Exchange
Degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between our firm and our customers.

(SIE) Supplier Information Exchange
Degree to which routine supply chain information (i.e., data exchange, forecasts, etc.) is exchanged between our firm and our suppliers.

(LA) Landscape Awareness
The degree to which the supply chain managers are aware of changes in industry and technology trends.

(IC) Implementation Capacity
Supply chain managers' ability to implement new methods in order to improve supply chain performance.

(EA) Exploration Activity
A supply chain's ability to search, innovate, take risks, and experiment in order to survive in the competitive environment.

(A) Exploitation Activity
An organization's ability to improve its existing capabilities, processes and technologies, and diminish operating redundancies in order to achieve a more efficient, effective, and productive supply chain.

Using the definitions provided on the previous page, please write the letter of the category you deem most appropriate for each item in the space provided. For example, you would put PC if you feel that the item best fits the definition of Partner Compatibility, etc.

(PC)	**Partner Compatibility**	**(CIE)**	**Customer Information Exchange**
(MO)	**Management Openness**	**(SIE)**	**Supplier Information Exchange**
(E)	**Supplier Empowerment**	**(LA)**	**Landscape Awareness**
(CO)	**Customer Openness**	**(IC)**	**Implementation Capacity**
(EA)	**Exploration Activity**	**(A)**	**Exploitation Activity**

(X) Doesn't fit any category. If possible, please specify a category title that may fit.

____ 1 All processes and standards of the supply chain partners are clearly defined.

____ 2 In order to stay competitive, our supply chain managers focus on improving our existing capabilities.

____ 3 Our top management listens to ideas that originate from supervisors and middle management concerning supply chain decisions.

____ 4 We focus on moving physical assets (e.g. inventory) quickly throughout our supply chain.

____ 5 We employ in-depth electronic order taking with our customers.

____ 6 Our supply chain managers are aware of new developments in our industry.

____ 7 We focus on cutting down costs in our supply chain.

____ 8 When dealing with supply chain problems, we seek out the novel solutions.

____ 9 We routinely exchange demand forecasts with our suppliers.

____ 10 Customers' needs are considered in our supply chain design.

____ 11 We proactively pursue new supply chain solutions.

____ 12 In order to survive in the competitive environment, our supply chain managers focus on operational efficiency.

____ 13 We typically give merit to strategic ideas that are raised by our suppliers.

____ 14 Our supply chain partners have compatible processes to ours.

____ 15 We are good at capitalizing on new ideas and methods.

____ 16 Our top managers are open to thoughts that originate from supervisors and middle management.

____ 17 Our customers provide us with their demand forecasts.

____ 18 To improve our supply chain, we continually explore for new opportunities.

____ 19 Technological advances that will improve our supply chain performance are closely monitored.

____ 20 We focus on supply chain productivity.

Using the definitions provided on page two, please write the letter of the category you deem most appropriate for each item in the space provided. For example, you would put PC if you feel that the item best fits the definition of Partner Compatibility, etc.

(PC)	**Partner Compatibility**	**(CIE)**	**Customer Information Exchange**
(MO)	**Management Openness**	**(SIE)**	**Supplier Information Exchange**
(E)	**Supplier Empowerment**	**(LA)**	**Landscape Awareness**
(CO)	**Customer Openness**	**(IC)**	**Implementation Capacity**
(EA)	**Exploration Activity**	**(A)**	**Exploitation Activity**

(X) Doesn't fit any category. If possible, please specify a category title that may fit.

____ 21 Our suppliers are actively involved in supply chain decision-making processes.

____ 22 We established compatible operating standards with our supply chain partners.

____ 23 We are always on the lookout for new ideas that we can adopt for our supply chain.

____ 24 We are generally ahead of our competitors in knowing the emerging industry trends in supply chain management.

____ 25 We emphasize effective coordination of our supply chain members.

____ 26 We incorporate our customers' suggestions in supply chain decision-making processes.

____ 27 Our supply chain managers are rarely taken by surprise by the changes in our competitors' strategies.

____ 28 In order to stay competitive, our supply chain managers focus on improving our existing technologies.

____ 29 We routinely exchange inventory information with our suppliers.

____ 30 Our customers routinely share inventory information with us.

____ 31 Our supply chain managers emphasize the use of existing supply chain practices.

____ 32 Our supply chain managers continually seek out for innovative ways to improve our supply chain.

____ 33 We try to develop compatible technological standards among our supply chain.

____ 34 Our strong relationship with our customers provide us with valuable information.

____ 35 We can easily improve supply chain performance by implementing new methods.

____ 36 Our supply chain managers are focused on improving our existing technologies.

____ 37 Top management lets strategic ideas be freely championed by anyone with relevant insight concerning our supply chain.

____ 38 We listen to our suppliers about quality considerations and design changes regarding our supply chain.

____ 39 When dealing with supply chain problems, we seek out "tried and true" solutions.

Using the definitions provided on page two, please write the letter of the category you deem most appropriate for each item in the space provided. For example, you would put PC if you feel that the item best fits the definition of Partner Compatibility, etc.

(PC)	**Partner Compatibility**	**(CIE)**	**Customer Information Exchange**
(MO)	**Management Openness**	**(SIE)**	**Supplier Information Exchange**
(E)	**Supplier Empowerment**	**(LA)**	**Landscape Awareness**
(CO)	**Customer Openness**	**(IC)**	**Implementation Capacity**
(EA)	**Exploration Activity**	**(A)**	**Exploitation Activity**

(X) Doesn't fit any category. If possible, please specify a category title that may fit.

____ 40 We continually experiment to find new solutions that will improve our supply chain.

____ 41 In order to stay competitive, our supply chain managers focus on reducing operational redundancies.

____ 42 We have formal processes to help us maintain customer openness.

____ 43 We implement integrated order scheduling with our customers.

____ 44 Our supply chain managers transform new ideas into actions.

____ 45 Our suppliers take orders by electronic means (i.e,. web based technologies, e-mail).

____ 46 We strive to be highly responsive to our customers' needs.

____ 47 We have formal procedures (e.g., attend trade shows, competitor intelligence service) to gain information on changes important to our industry.

____ 48 We are able to implement new supply chain concepts.

____ 49 Our suppliers take an active role in planning supply chain strategies.

____ 50 We implement integrated order scheduling with our suppliers.

THANK YOU!

APPENDIX 4

Final Questionnaire

Adaptive Supply Chain Management Survey

The Adaptive Supply Chain Management Study is an academic research project conducted by researchers at the Kenan-Flagler Business School of the University of North Carolina-Chapel Hill. The main purposes of this study are to measure a supply chain's adaptivity to competitive environment and to benchmark critical success factors for supply chain management from a manufacturer's perspective.

Another purpose of this study is to identify the broad-scale parameters of adaptive supply chain management by constructing predictive and evaluative models that incorporate industry sector, size, and the competitive environment. The study focuses on current supply chain strategies and performance, and contributes to the development of an agenda for improving supply chain management.

This survey gathers data on those factors that are important to the supply chain managers of manufacturing companies. The questions cover strategic supply chain directions, competitive capabilities, supply chain best practices, and supply chain performance. Your responses will be kept strictly confidential. Your complete confidentiality is assured by the agreement between the researchers conducting the study and the Academic Affairs Institutional Review Board (AA-IRB) of the University of North Carolina-Chapel Hill.

Instructions:

- Your e-mail address was obtained from the membership data-base of either the Institute of Supply Management (www.ism.ws) or the Supply Chain Council (www.supply-chain.org).

- All your answers will be kept strictly confidential. No individual or company will be identified. Only summary data and aggregate results from multiple firms will be published.

- Participation in this study is completely voluntary.

- Some questions ask you to mark a box or a circle, and some ask for specific data. There are no "right" or "wrong" answers.

- You have the right to skip any question you choose not to answer. But, we ask you to answer all questions to the best of your knowledge, as incomplete surveys create serious problems in the data analysis.

- A copy of the final findings will be sent to you, allowing you to benchmark your supply chain management practices to those of other companies.

- This questionnaire can be completed in about 40 minutes.

We will be happy to answer any questions or concerns you may have. Please contact:

----------------------------Murat Kristal------------------Prof. Aleda Roth
---------------------------- (919) 593-1101----------------(919) 962-3217
-----------------------------kristal@unc.edu--------------rotha@unc.edu

This questionnaire can be completed online. Alternatively, you can fax your completed questionnaire to (919) 962-6949.

THANK YOU FOR PARTICIPATING IN THIS STUDY

The Academic Affairs Institutional Review Board (AA-IRB) at the University of North Carolina-Chapel Hill has approved this study. If you have any questions about your rights as a research participant in this study, please contact the AA-IRB at (919) 962-7761 or at aa-irb@unc.edu.

Background Information

1. Describe the strategic business unit to which your answers apply:

[ ] Entire Company
[ ] Division or Group Level
[ ] Process-Based Organization
[ ] Plant Level
[ ] Other ____________________

2._Drivers of Supply Chain Base Adaptivity

Listed below are supply chain management practices that may affect firms' ability to compete in an industry. Please indicate your level of agreement with theses statements about your business unit's supply chain practices over the past 12 months.

	Strongly Disagree	Disagree	Neutral	Agree	Str. Agree
	1	2	3	4	5
a. Our top managers are open to thoughts that originate from supervisors and middle management.	[ ]	[ ]	[ ]	[ ]	[ ]
b. In order to stay competitive, our supply chain managers focus on improving our existing capabilities.	[ ]	[ ]	[ ]	[ ]	[ ]
c. We proactively pursue new supply chain solutions.	[ ]	[ ]	[ ]	[ ]	[ ]
d. We are good at capitalizing on new ideas.	[ ]	[ ]	[ ]	[ ]	[ ]
e. In order to survive in the competitive environment, our supply chain managers focus on increasing operational efficiencies of existing systems.	[ ]	[ ]	[ ]	[ ]	[ ]
f. Our supply chain managers transform new ideas into actions.	[ ]	[ ]	[ ]	[ ]	[ ]
g. We are able to implement new supply chain concepts.	[ ]	[ ]	[ ]	[ ]	[ ]
h. We typically give merit to strategic ideas that are raised by our suppliers.	[ ]	[ ]	[ ]	[ ]	[ ]
i. We have the ability to implement supply chain innovations.	[ ]	[ ]	[ ]	[ ]	[ ]
j. We strive to be highly responsive to our customers' needs.	[ ]	[ ]	[ ]	[ ]	[ ]
k. We continually experiment to find new solutions that will improve our supply chain.	[ ]	[ ]	[ ]	[ ]	[ ]
l. Our supply chain organization can solve problems quickly.	[ ]	[ ]	[ ]	[ ]	[ ]
m. Our top management listens to ideas that originate from middle management concerning supply chain decisions.	[ ]	[ ]	[ ]	[ ]	[ ]
n. Top management allows strategic ideas to be freely championed by anyone with relevant insight within our organization.	[ ]	[ ]	[ ]	[ ]	[ ]
o. We focus on improving our existing supply chain competencies by refining our current supply chain processes.	[ ]	[ ]	[ ]	[ ]	[ ]
p. Our strong relationships with our customers provide us with valuable information.	[ ]	[ ]	[ ]	[ ]	[ ]
q. In order to stay competitive, our supply chain managers focus on reducing operational redundancies in our existing processes.	[ ]	[ ]	[ ]	[ ]	[ ]
r. We listen to our suppliers regarding design changes for our supply chain.	[ ]	[ ]	[ ]	[ ]	[ ]
s. Our supply chain partners have processes compatible to ours.	[ ]	[ ]	[ ]	[ ]	[ ]

	Strongly Disagree	Disagree	Neutral	Agree	Str. Agree
	1	2	3	4	5
t. We are generally ahead of our competitors in knowing the emergent industry trends in supply chain management.	[ ]	[ ]	[ ]	[ ]	[ ]
u. Our supply chain managers are rarely taken by surprise by the changes in our competitors' strategies.	[ ]	[ ]	[ ]	[ ]	[ ]
v. Technological advances that will improve our supply chain performance are closely monitored.	[ ]	[ ]	[ ]	[ ]	[ ]
w. We incorporate our customers' suggestions in supply chain decision-making processes.	[ ]	[ ]	[ ]	[ ]	[ ]
x. We try to develop compatible technological processes among our supply chain.	[ ]	[ ]	[ ]	[ ]	[ ]
y. We created operating processes that are compatible with those of our supply chain partners.	[ ]	[ ]	[ ]	[ ]	[ ]
z. Our suppliers are actively involved in supply chain decision-making processes.	[ ]	[ ]	[ ]	[ ]	[ ]
aa. Once they are introduced, we adjust quickly to new methods.	[ ]	[ ]	[ ]	[ ]	[ ]
ab. Customers' needs are considered in our supply chain design.	[ ]	[ ]	[ ]	[ ]	[ ]
ac. Our firm is highly receptive of new supply chain technologies.	[ ]	[ ]	[ ]	[ ]	[ ]
ad. We have a high level of expertise in successfully identifying new ideas that may be important in changing our existing supply chain practices.	[ ]	[ ]	[ ]	[ ]	[ ]
ae. We have formal procedures for gaining information on changes important to our industry (e.g. trade show attendance, competitor intelligence service).	[ ]	[ ]	[ ]	[ ]	[ ]
af. Formal routines exist to uncover faulty assumptions about supply chain processes.	[ ]	[ ]	[ ]	[ ]	[ ]
ag. We draw on our past supply chain management experiences when we face new problems.	[ ]	[ ]	[ ]	[ ]	[ ]
ah. We benchmark world-class supply chain practices.	[ ]	[ ]	[ ]	[ ]	[ ]
ai. We have routine processes for improving our supply chain efficiency.	[ ]	[ ]	[ ]	[ ]	[ ]
aj. Leveraging of our current supply chain technologies is important to our firm's strategy.	[ ]	[ ]	[ ]	[ ]	[ ]
ak. When dealing with supply chain problems, we seek out "tried and true" solutions.	[ ]	[ ]	[ ]	[ ]	[ ]
al. In order to stay competitive, our supply chain managers focus on improving our existing technologies.	[ ]	[ ]	[ ]	[ ]	[ ]
am. To improve our supply chain, we continually explore for new opportunities.	[ ]	[ ]	[ ]	[ ]	[ ]
an. To discover better ways of managing our supply chain, we have multiple on-going projects.	[ ]	[ ]	[ ]	[ ]	[ ]
ao. We are constantly seeking novel approaches in order to solve supply chain problems.	[ ]	[ ]	[ ]	[ ]	[ ]
ap. Our managers focus on developing stronger competencies in our existing supply chain processes.	[ ]	[ ]	[ ]	[ ]	[ ]
aq. Our customers provide us with their demand forecasts.	[ ]	[ ]	[ ]	[ ]	[ ]
ar. Our customers share inventory information with us.	[ ]	[ ]	[ ]	[ ]	[ ]
as. We implement integrated order-scheduling with our customers.	[ ]	[ ]	[ ]	[ ]	[ ]
at. We exchange inventory information with our suppliers.	[ ]	[ ]	[ ]	[ ]	[ ]
au. We exchange demand forecasts with our suppliers.	[ ]	[ ]	[ ]	[ ]	[ ]
av. We use integrated order-scheduling and tracking with our suppliers.	[ ]	[ ]	[ ]	[ ]	[ ]

3. Competitive Capabilities

Listed below are the critical success factors for competing in an industry. Please assess your business unit's strength for each capability relative to your primary competitors in the same markets over the past 12 months. Please think of your **primary product(s)** while answering these questions.

	Relatively Weak 1	Below Average 2	Average 3	Above Average 4	Market Leader 5
a. Offering products with new technology content.	[ ]	[ ]	[ ]	[ ]	[ ]
b. Promptly handling customer complaints.	[ ]	[ ]	[ ]	[ ]	[ ]
c. Ability to rapidly introduce new products.	[ ]	[ ]	[ ]	[ ]	[ ]
d. Performance quality (i.e., A product's primary operating characteristics).	[ ]	[ ]	[ ]	[ ]	[ ]
e. Rapidly handling custom orders (i.e., engineer-to-order).	[ ]	[ ]	[ ]	[ ]	[ ]
f. Ability to rapidly change product mix.	[ ]	[ ]	[ ]	[ ]	[ ]
g. Being able to ship on time.	[ ]	[ ]	[ ]	[ ]	[ ]
h. Product aesthetics (i.e., how the product looks, feels, sounds, tastes, or smells).	[ ]	[ ]	[ ]	[ ]	[ ]
i. Ability to change production volumes.	[ ]	[ ]	[ ]	[ ]	[ ]
j. Offering innovative products.	[ ]	[ ]	[ ]	[ ]	[ ]
k. Manufacturing broad product mix within the same facility.	[ ]	[ ]	[ ]	[ ]	[ ]
l. Ability to rapidly modify methods for materials.	[ ]	[ ]	[ ]	[ ]	[ ]
m. Ability to rapidly modify methods for components.	[ ]	[ ]	[ ]	[ ]	[ ]
n. Overall product quality as perceived by customers.	[ ]	[ ]	[ ]	[ ]	[ ]
o. Offering products with high R&D content.	[ ]	[ ]	[ ]	[ ]	[ ]
p. Conformance quality (i.e., the degree to which a product's operating characteristics meet established standards).	[ ]	[ ]	[ ]	[ ]	[ ]
q. Ability to have a short development time for new products.	[ ]	[ ]	[ ]	[ ]	[ ]
r. Ability to generate revenues from products in the introduction and growth stages.	[ ]	[ ]	[ ]	[ ]	[ ]
s. Product durability (i.e., the amount of time or use before the product breaks down and replacement is preferred to continued repair).	[ ]	[ ]	[ ]	[ ]	[ ]
t. Offering lower priced products than our competitors.	[ ]	[ ]	[ ]	[ ]	[ ]
u. Rapidly confirming customer order delivery date.	[ ]	[ ]	[ ]	[ ]	[ ]
v. Introducing new versions of our current products simultaneously in several markets.	[ ]	[ ]	[ ]	[ ]	[ ]
w. Manufacturing similar products at a lower cost than our competitors.	[ ]	[ ]	[ ]	[ ]	[ ]
x. Product reliability (i.e., the probability of a product malfunctioning or failing within a specified time period).	[ ]	[ ]	[ ]	[ ]	[ ]
y. Being first in the market with new product introductions.	[ ]	[ ]	[ ]	[ ]	[ ]
z. Ability to develop products from new idea to production in a short period of time.	[ ]	[ ]	[ ]	[ ]	[ ]
aa. Ability to generate revenues from new technology.	[ ]	[ ]	[ ]	[ ]	[ ]

Business Environment
Listed below are critical business-environment factors for competing in an industry. Please indicate your perceptions regarding the following aspects of business environment change:

4. Environmental Dynamism

	Very Slow	Slow	Average	Rapid	Very Rapid
	1	**2**	**3**	**4**	**5**
a. The rate at which products and services become outdated.	[ ]	[ ]	[ ]	[ ]	[ ]
b. The rate of innovation of new products and services.	[ ]	[ ]	[ ]	[ ]	[ ]
c. The rate of innovation of new operating processes.	[ ]	[ ]	[ ]	[ ]	[ ]
d. The rate of change of tastes and preferences of customers in your industry.	[ ]	[ ]	[ ]	[ ]	[ ]

5. Industry Growth

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	**2**	**3**	**4**	**5**
a. Our business environment is characterized by rapidly changing prices.	[ ]	[ ]	[ ]	[ ]	[ ]
b. A high growth rate of demand characterizes this industry.	[ ]	[ ]	[ ]	[ ]	[ ]
c. Demand for our primary products is highly predictable.	[ ]	[ ]	[ ]	[ ]	[ ]

Characterization of Company and Products
Before you proceed in the following section, we would like to remind you that **all your answers will be kept strictly confidential. No individual or company will be identified.** Only summary data and aggregate results from multiple firms will be published.

6a. What is the primary industry of your company?
[ ] Automotive
[ ] High tech (electronics, etc.)
[ ] Chemical
[ ] Aerospace and Defense
[ ] Pharmaceutical
[ ] Consumer goods/products manufacturing
[ ] Food Services
[ ] Information
[ ] Finance and Insurance
[ ] Transportation and Warehousing
[ ] Health Care
[ ] Arts, Entertainment and Recreation
[ ] Other (please specify) ____________

6b. What is the primary SIC code for your company? SIC Code ____________

7. How do you perceive your business unit's performance?
7a. Considering one product that yields the highest percentage of revenue for your business unit, what is your business unit's average market share?
[ ] Under 8%
[ ] 8% - 16%
[ ] 16% - 24%
[ ] 24% - 32%
[ ] 32% - 40%
[ ] 40% - 48%
[ ] Over 48 %

7b. Over the last year, on average, what has been your company's profit level (before taxes)?
[ ] Under 5%
[ ] 5% - 10%
[ ] 10% - 15%
[ ] 15% - 20%
[ ] Over 20%

7c. On average, please rate the adaptivity of your business unit's supply chain compared to your competitors.
[ ] Relatively Weak
[ ] Below Average
[ ] Average
[ ] Above Average
[ ] Market Leader

8. Relative to your competitors, how would you assess your supply chain's current overall position?
[ ] Market leader – clear #1 or # 2 position
[ ] One of the top 5 in the market, but not the clear leader
[ ] Second tier – not as high as the market leaders but a strong competitor
[ ] A minor player in the market – serving a small niche or modest shares of the market

Contact Information
9. Thank you for your cooperation. We would like to send you a summary of our results. Please provide your
contact information below. It will be kept strictly confidential.

Name	
Job Title	
Business Unit (if applicable)	
Company	
Address	
Phone	
E-mail	

10. How knowledgeable did you feel answering this questionnaire?
[ ] Very knowledgeable
[ ] Above average
[ ] Average
[ ] Below average
[ ] Not knowledgeable

11. Your position or title in your organization is most closely described by which of the following:
[ ] President, CEO, COO, or Chairman
[ ] Vice President
[ ] Director
[ ] General Manager
[ ] Supply Chain Manager
[ ] Financial Manager
[ ] Purchasing Manager
[ ] Plant Manager
[ ] Manager, Engineer
[ ] Other (please specify) ______________

12. How long have you worked for your company?
Months ______________

Years ______________

13. How long have you been in your current position?
Months ______________

Years ______________

THANK YOU VERY MUCH FOR COMPLETING OUR SURVEY!

APPENDIX 5

Invitation Letters

Appendix 5A: Invitation to Participate in our Study

UNC
KENAN-FLAGLER
BUSINESS SCHOOL

March 28, 2005

Dear Mr. Parker:

As I indicated in our phone conversation, we are conducting a study regarding supply chain management that will help companies better understand how to manage their supply chains. The main purpose of the study is to measure a supply chain's adaptivity to its competitive environment and to benchmark the critical success factors for supply chain management from a manufacturer's perspective. The study focuses on supply chain strategies and performance and contributes to the development of an executive agenda for improving supply chain management.

Importantly, this research has been endorsed by Mr. Paul Novak, CEO, Institute for Supply Management (Please see the memorandum by Mr. Novak). As you are an experienced manager, we are inviting you to participate in our research. Our questionnaire asks for your judgments and perceptions about how supply chains can be managed in an adaptive way.

This survey should take approximately 40 minutes to complete. Upon completion of the full field study, we will send you an Executive Summary of our overall research findings and a benchmark profile of your firm against others. Our findings will enable you to gauge the relative strengths and weaknesses of your firm.

Your responses will be kept strictly confidential. Your complete confidentiality is assured by the agreement between the researchers that are conducting the study and the Academic Affairs Institutional Review Board (AA-IRB) at the University of North Carolina-Chapel Hill.

Once you finish the survey, you can either fax your survey back to **919 962 6949,** or mail it within the envelope that I have enclosed. If you need further assistance or have any questions, please do not hesitate to contact Murat Kristal of UNC-Chapel Hill at kristal@unc.edu or call 919-843-6141.

Best Regards,

Murat M. Kristal

Doctoral Candidate
The Kenan-Flagler Business School
The University of North Carolina at Chapel Hill
Campus Box 3490, McColl Building
Chapel Hill, NC 27599-3490
Office: 919 843 6141

Appendix 5B: Letter to Participants from Paul Novak, CEO of ISM

MEMORANDUM

June 2004

The enclosed survey is collecting information toward the completion of the research project, "Adaptive Supply Chain Management," by Murat M. Kristal, Ph.D. candidate at The Kenan-Flagler Business School in The University of North Carolina at Chapel Hill.

I encourage you to fill out the enclosed survey. Increasing the body of knowledge in the field and advancing the supply management profession depends on solid research, which benefits us all.

Paul Novak, C.P.M., A.P.P.
Chief Executive Officer
ISM

APPENDIX 6

Descriptive Statistics of the Items

Table A6. Descriptive Statistics of the Items Related to Supply Chain Base Adaptivity

	Pilot Study					Calibration Sample					Validation Sample					Combined Sample				
	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis
a1	81	4.15	0.74	-0.62	0.23	131	4.11	0.69	-0.57	0.62	163	4.01	0.71	-0.86	1.51	294	4.02	0.74	-0.80	1.03
a2	81	3.88	0.89	-0.86	0.81	131	3.78	0.86	-0.73	0.40	163	3.83	0.76	-0.65	0.47	294	3.84	0.80	-0.81	0.91
a3	80	3.56	0.88	-0.82	0.63	130	3.62	0.84	-0.77	0.63	162	3.77	0.67	-0.91	1.19	292	3.71	0.75	-0.90	1.11
a4	78	3.60	0.90	-0.53	-0.01	128	3.63	0.84	-0.75	0.67	163	3.60	0.83	-0.77	0.46	291	3.58	0.85	-0.69	0.15
a5	80	2.99	1.02	-0.05	-0.76	130	3.14	1.00	-0.24	-0.74	162	3.32	0.89	-0.25	-0.55	292	3.22	0.96	-0.25	-0.62
a6	81	3.60	1.16	-0.56	-0.55	130	3.70	1.04	-0.67	-0.09	161	3.75	0.94	-0.81	0.38	292	3.71	0.99	-0.74	0.04
a7	80	3.56	0.85	-0.51	0.18	130	3.47	0.87	-0.44	-0.05	162	3.20	0.94	-0.13	-0.39	292	3.31	0.93	-0.30	-0.36
a8	80	3.53	0.91	-0.64	0.24	130	3.52	0.86	-0.49	0.18	161	3.55	0.82	-0.43	-0.07	291	3.52	0.84	-0.51	-0.03
a10	79	3.43	0.98	-0.47	-0.07	129	3.52	0.88	-0.68	0.33	161	3.65	0.70	-0.81	0.44	290	3.56	0.79	-0.77	0.45
cie1	70	3.54	1.67	-0.45	-1.59	DROPPED AFTER PILOT STUDY														
cie2	76	2.71	1.30	0.45	-0.98	119	2.71	1.21	0.47	-0.72	150	2.61	1.13	0.55	-0.55	274	2.66	1.19	0.47	-0.74
cie3	69	2.39	1.24	0.97	0.01	111	2.35	1.24	0.96	-0.04	149	2.30	1.18	0.92	-0.09	266	2.33	1.19	0.91	-0.12
cie4	68	2.62	1.54	0.50	-1.30	110	2.55	1.49	0.60	-1.11	150	2.31	1.37	0.95	-0.38	265	2.45	1.44	0.73	-0.87
cr1	78	3.78	1.01	-0.46	-0.84	DROPPED AFTER PILOT STUDY														
cr2	78	4.42	0.83	-1.50	1.74	127	4.43	0.73	-1.38	2.03	160	4.29	0.69	-0.69	0.28	287	4.33	0.72	-0.93	0.67
cr3	81	3.90	0.94	-0.53	-0.56	131	3.89	0.86	-0.60	-0.08	163	3.71	0.82	-0.28	-0.38	294	3.75	0.86	-0.31	-0.51
cr4	80	3.56	0.87	-0.55	-0.47	130	3.60	0.87	-0.49	-0.44	163	3.55	0.83	-0.34	-0.44	293	3.55	0.83	-0.38	-0.47
cr5	80	3.99	1.02	-1.13	0.82	130	4.05	0.88	-1.27	1.97	161	3.97	0.72	-0.67	0.86	291	3.97	0.81	-0.90	1.18
ea1	81	3.90	0.98	-0.77	0.05	131	3.92	0.91	-0.82	0.35	163	3.91	0.87	-0.68	0.00	294	3.92	0.88	-0.74	0.17
ea2	80	3.50	1.03	-0.57	-0.25	129	3.49	0.96	-0.64	-0.04	162	3.46	0.86	-0.45	-0.12	292	3.49	0.91	-0.48	-0.21
ea3	81	3.42	0.82	-0.36	0.08	DROPPED AFTER PILOT STUDY														
ea4	81	3.57	0.87	-0.57	0.14	131	3.53	0.85	-0.45	-0.16	162	3.52	0.88	-0.61	-0.11	293	3.53	0.87	-0.63	0.04
ea5	81	3.42	1.07	-0.54	-0.44	131	3.47	1.05	-0.60	-0.28	162	3.57	0.90	-0.55	-0.11	292	3.50	0.96	-0.57	-0.15
ea6	80	2.98	1.17	0.20	-0.82	DROPPED AFTER PILOT STUDY														
ea7	80	3.34	0.97	-0.47	0.13	129	3.43	0.93	-0.54	0.25	161	3.50	0.94	-0.36	-0.46	291	3.45	0.94	-0.41	-0.24
ic1	80	3.74	0.91	-0.58	-0.34	129	3.73	0.85	-0.63	-0.06	161	3.70	0.74	-0.77	0.99	291	3.71	0.79	-0.68	0.37
ic2	78	4.18	0.75	-0.69	0.28	DROPPED AFTER PILOT STUDY														
ic3	81	3.19	1.03	-0.45	-0.32	131	3.21	0.96	-0.53	-0.09	162	3.29	0.88	-0.27	-0.83	293	3.24	0.91	-0.42	-0.42
ic4	80	3.49	0.90	-0.39	-0.25	130	3.41	0.88	-0.34	-0.20	163	3.38	0.92	-0.30	-0.15	293	3.38	0.90	-0.23	-0.33
ic5	81	3.53	0.82	-0.31	-0.43	131	3.53	0.84	-0.45	-0.48	163	3.61	0.73	-0.47	-0.01	294	3.55	0.79	-0.43	-0.30
ic6	81	3.48	0.92	-0.34	-0.83	131	3.50	0.91	-0.55	-0.47	163	3.55	0.81	-0.61	0.38	294	3.53	0.87	-0.45	-0.30
ic7	80	3.36	0.93	-0.41	-0.28	128	3.45	0.87	-0.56	0.25	160	3.53	0.87	-0.43	-0.05	290	3.44	0.90	-0.42	-0.20
la1	80	3.98	0.86	-0.57	-0.20	DROPPED AFTER PILOT STUDY														
la2	77	3.08	0.96	-0.34	-0.63	127	3.11	0.93	-0.16	-0.63	163	3.16	0.92	0.06	-0.54	290	3.11	0.94	0.02	-0.58
la3	78	3.29	0.93	-0.43	-0.01	129	3.28	0.87	-0.29	-0.15	162	3.25	0.84	-0.18	-0.36	292	3.24	0.85	-0.24	-0.23
la4	80	3.19	1.09	-0.44	-0.56	130	3.25	1.04	-0.44	-0.45	161	3.33	0.95	-0.35	-0.49	291	3.29	0.98	-0.41	-0.41
la5	81	3.17	1.03	-0.29	-0.51	131	3.20	1.00	-0.22	-0.53	163	3.20	0.91	0.00	-0.68	294	3.18	0.94	-0.09	-0.57
la6	79	3.03	0.96	-0.23	-0.75	128	3.02	0.99	-0.03	-0.96	161	3.05	1.00	0.01	-0.70	290	3.07	0.99	-0.05	-0.79
la7	80	3.15	0.92	-0.31	-0.36	129	3.22	0.94	-0.22	-0.40	160	3.26	0.84	0.13	-0.32	290	3.23	0.86	-0.14	-0.33
la8	80	2.84	1.12	0.00	-0.91	129	3.06	1.14	-0.16	-0.89	161	3.16	1.00	-0.05	-0.61	291	3.10	1.06	-0.07	-0.69
mo1	81	4.05	0.86	-1.17	1.77	131	3.98	0.85	-1.04	1.26	163	3.88	0.81	-1.02	1.61	294	3.94	0.85	-0.98	1.17
mo2	80	3.71	0.93	-0.65	0.06	128	3.73	0.91	-0.63	-0.04	161	3.70	0.84	-0.78	0.67	291	3.69	0.90	-0.71	0.25
mo3	81	3.49	1.07	-0.48	-0.52	131	3.47	1.00	-0.51	-0.35	163	3.45	0.91	-0.51	-0.24	294	3.48	0.95	-0.48	-0.35
pc1	81	3.05	1.02	-0.17	-0.44	DROPPED AFTER PILOT STUDY														
pc2	80	3.10	0.92	-0.20	-0.46	130	3.19	0.87	-0.24	-0.37	162	3.24	0.72	-0.30	-0.27	291	3.20	0.79	-0.37	-0.25
pc3	80	3.43	0.88	-0.62	-0.37	130	3.48	0.88	-0.89	0.50	162	3.42	0.87	-0.93	0.61	292	3.42	0.88	-0.84	0.28
pc4	81	3.14	0.85	0.11	-0.88	130	3.25	0.86	-0.22	-0.36	162	3.29	0.78	-0.32	-0.02	292	3.24	0.82	-0.28	-0.39
se1	81	3.69	0.88	-0.49	0.22	130	3.71	0.80	-0.52	0.44	162	3.64	0.70	-0.33	0.02	293	3.66	0.77	-0.38	0.13
se2	81	3.70	0.89	-0.70	0.36	131	3.69	0.81	-0.78	0.62	162	3.69	0.70	-0.36	0.11	293	3.67	0.79	-0.63	0.49
se3	81	3.02	0.92	-0.05	-0.95	131	3.12	0.89	-0.37	-0.74	161	3.17	0.87	-0.33	-0.55	292	3.10	0.89	-0.20	-0.74
se4	80	3.39	0.96	-0.24	-1.09	DROPPED AFTER PILOT STUDY														
sie1	79	2.58	1.38	0.70	-0.89	124	2.68	1.36	0.59	-1.02	153	2.70	1.15	0.71	-0.59	282	2.66	1.26	0.64	-0.81
sie2	78	2.85	1.24	0.38	-1.02	123	2.76	1.24	0.51	-0.89	153	2.78	1.16	0.52	-0.76	281	2.83	1.21	0.39	-0.98
sie3	77	3.56	1.62	-0.41	-1.62	DROPPED AFTER PILOT STUDY														
sie4	74	2.46	1.61	0.60	-1.33	119	2.54	1.60	0.51	-1.39	153	2.51	1.50	0.57	-1.19	276	2.53	1.55	0.54	-1.31

TableA7. Descriptive Statistics of the Items Related to Competitive Capabilities

	Pilot Study					Calibration Sample					Validation Sample					Combined Sample				
	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis
cl1	71	3.08	0.95	-0.07	0.10	116	3.11	0.93	0.04	0.10	149	3.08	0.93	-0.01	0.06	268	3.06	0.93	-0.01	0.01
cl2	71	3.31	0.98	-0.10	-0.38	115	3.22	0.93	0.01	-0.27	145	3.14	0.92	0.25	-0.18	264	3.15	0.93	0.10	-0.17
ds1	75	3.63	1.08	-0.81	0.42	119	3.61	0.96	-0.68	0.64	150	3.75	0.84	-0.39	0.01	275	3.75	0.90	-0.65	0.59
ds2	75	3.69	1.01	-0.39	-0.23	118	3.69	0.91	-0.29	-0.04	149	3.69	0.88	-0.33	-0.23	274	3.72	0.90	-0.32	-0.19
ds3	75	3.67	0.91	-0.29	-0.10	119	3.69	0.83	-0.17	-0.04	150	3.75	0.82	-0.04	-0.68	273	3.74	0.84	-0.16	-0.40
pf1	74	3.61	1.00	-0.72	0.29	119	3.58	0.93	-0.65	0.48	148	3.72	0.90	-0.55	0.39	271	3.66	0.92	-0.61	0.41
pf2	74	3.54	1.01	-0.44	0.04	118	3.52	0.96	-0.43	0.13	149	3.58	0.89	-0.17	-0.42	272	3.54	0.91	-0.32	-0.09
pf3	71	3.82	0.93	-0.72	0.31	117	3.74	0.85	-0.55	0.23	151	3.72	0.75	-0.34	-0.05	272	3.72	0.82	-0.48	0.27
pf4	71	3.72	1.06	-0.67	0.11	115	3.66	1.02	-0.45	-0.06	147	3.73	0.89	-0.27	-0.38	268	3.69	0.97	-0.57	0.19
pf5	70	3.09	1.14	-0.17	-0.47	114	3.18	1.05	-0.33	-0.14	145	3.39	0.78	0.14	-0.35	265	3.26	0.93	-0.25	0.06
pf6	69	3.07	1.09	-0.29	-0.51	112	3.17	0.99	-0.46	-0.13	143	3.37	0.77	0.21	-0.24	262	3.24	0.88	-0.25	0.05
qual1	74	4.00	0.91	-0.91	1.36	119	4.02	0.85	-0.70	0.84	151	4.04	0.71	-0.28	-0.30	274	4.06	0.77	-0.60	0.71
qual2	76	4.09	0.73	-0.35	-0.39	122	4.06	0.70	-0.23	-0.41	151	4.06	0.68	-0.33	0.11	277	4.09	0.68	-0.32	-0.11
qual3	75	4.05	0.88	-1.07	1.98	119	4.03	0.82	-0.90	1.71	149	4.02	0.72	-0.36	-0.08	274	4.04	0.75	-0.64	0.98
qual4	66	4.02	0.89	-0.72	0.61	107	3.92	0.90	-0.54	0.31	141	3.82	0.84	-0.39	0.39	256	3.93	0.86	-0.45	0.07
qual5	69	3.90	0.89	-0.31	-0.77	112	3.83	0.87	-0.17	-0.81	145	3.79	0.83	-0.47	0.19	264	3.85	0.85	-0.38	-0.27

Table A8. Descriptive Statistics of the Items Related to Competitive Environment

	Pilot Study					Calibration Sample					Validation Sample					Combined Sample				
	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis	N	Mean	Std. Dev.	Skeweness	Kurtosis
ed1	75	2.43	0.95	0.22	0.05	119	2.40	0.94	0.16	-0.29	147	2.51	1.00	0.16	-0.72	271	2.45	0.99	0.24	-0.53
ed2	76	3.05	0.88	0.26	-0.34	120	3.00	0.89	0.44	-0.39	147	2.93	0.94	0.10	-0.49	272	2.97	0.94	0.11	-0.36
ed3	76	2.83	0.77	-0.23	0.68	120	2.82	0.80	-0.06	0.35	146	2.85	0.80	0.11	0.18	271	2.80	0.79	0.01	0.14
ed4	74	2.77	0.91	0.15	0.29	117	2.78	1.05	0.23	-0.29	145	2.86	1.05	0.04	-0.72	268	2.81	1.03	0.09	-0.48
em1	76	2.97	1.10	0.24	-0.63	119	2.92	1.09	0.21	-0.74	147	3.03	1.03	0.12	-0.81	272	3.03	1.08	0.09	-0.80
em2	75	2.91	1.02	0.19	-0.39	118	2.81	1.05	0.29	-0.51	146	2.71	1.04	0.08	-0.78	270	2.77	1.04	0.14	-0.62
em3	76	3.18	1.03	-0.38	-0.44	118	3.13	1.06	-0.35	-0.67	146	3.05	1.00	-0.44	-0.57	271	3.13	1.02	-0.33	-0.58

APPENDIX 7

Preliminary Analysis of Reliability of Items (Pilot Data, *n* = 81)

Table A9. Confirmatory Factor Analysis Result of the Items Related to Supply Chain Base Adaptivity (Pilot Study, *n* =81)

	Reflective Measures of Supply Chain Adaptation and Associated Items	Standardized Path Loadings	Standard Error**	Item Reliability
Management Openness				
MO1	Our top managers are open to thoughts that originate from supervisors and middle management	0.87		0.76
MO2	Our top management listens to ideas that originate from middle management concerning supply chain decisions	0.88	0.13	0.78
MO3	Top management allows strategic ideas to be freely championed by anyone with relevant insight within our organization	0.76	0.14	0.58
Landscape Awareness				
LA1*	Our supply chain managers are aware of new developments in our industry	0.57		0.32
LA2	We are generally ahead of our competitors in knowing the emergent industry trends in supply chain management	0.88	0.32	0.78
LA3	Our supply chain managers are rarely taken by surprise by the changes in our competitors' strategies	0.67	0.28	0.44
LA4	Our firm is highly receptive of new supply chain technologies	0.77	0.35	0.60
LA5	Technological advances that will improve our supply chain performance are closely monitored	0.80	0.33	0.64
LA6*	We have formal procedures for gaining information on changes important to our industry (e.g. trade show attendance, competitor intelligence service)	0.53	0.27	0.28
LA7	We have a high level of expertise in successfully identifying new ideas that may be important in changing our existing supply chain practices	0.71	0.28	0.50
LA8	We benchmark world-class supply chain practices	0.65	0.33	0.42
Customer Relationships (Based on Ahmad and Schroeder, 2001; Sousa, 2003; Flynn et al., 1995)				
CR1*	We have formal processes to help us maintain customer relationships	0.48		0.23
CR2	We strive to be highly responsive to our customers' needs	0.65	0.28	0.42
CR3	Our strong relationships with our customers provide us with valuable information	0.80	0.43	0.64
CR4	We incorporate our customers' suggestions in supply chain decision-making processes	0.61	0.32	0.38
CR5	Customers' needs are considered in our supply chain design	0.83	0.51	0.70
Supplier Empowerment (Based on Ahmad and Schroeder, 2001; Narasimhan et al., 2001; Krause, 1999)				
SE1	We typically give merit to strategic ideas that are raised by our suppliers	0.64		0.41
SE2	We listen to our suppliers regarding design changes for our supply chain	0.65	0.17	0.42
SE3	Our suppliers are actively involved in supply chain decision-making processes	0.83	0.27	0.68
SE4*	Our suppliers can take an active role in planning supply chain strategies	0.74	0.25	0.55
Partner Compatibility				
PC1*	All supply chain processes are clearly defined	0.37		0.14
PC2	Our supply chain partners have processes compatible to ours	0.65	0.54	0.42
PC3	We try to develop compatible technological processes among our supply chain	0.82	0.62	0.67
PC4	We created operating processes that are compatible with those of our supply chain partners	0.84	0.61	0.70

Table A9 (continued)

Reflective Measures of Supply Chain Adaptation and Associated Items		Standard Path Loadings	Standard Error**	Item Reliability
Implementation Capacity				
IC1	We have the ability to implement supply chain innovations	0.86		0.74
IC2*	We can improve supply chain performance by implementing new methods	0.04	0.12	0.00
IC3	Once they are introduced, we adjust quickly to new methods	0.69	0.13	0.48
IC4	We are good at capitalizing on new ideas	0.73	0.11	0.53
IC5	Our supply chain managers transform new ideas into actions	0.81	0.10	0.66
IC6	We are able to implement new supply chain concepts	0.82	0.11	0.67
IC7	Our supply chain organization can solve problems quickly	0.68	0.12	0.46
Customer Information Exchange (Based on Frohlich and Westbrook, 2001, 2002)				
CIE1*	We employ in-depth electronic order-taking with our customers	0.36		
CIE2	Our customers provide us with their demand forecasts	0.82	0.68	
CIE3	Our customers routinely share inventory information with us	0.80	0.62	
CIE4	We implement integrated order-scheduling with our customers	0.60	0.52	
Supplier Information Exchange (Based on Frohlich and Westbrook, 2001, 2002)				
SIE1	We routinely exchange inventory information with our suppliers	0.81		0.66
SIE2	We routinely exchange demand forecasts with our suppliers	0.80	0.12	0.64
SIE3*	Our suppliers take orders by electronic means (i.e., web-based technologies, e-mail)	0.56	0.17	0.31
SIE4	We implement integrated order-scheduling with our suppliers	0.83	0.16	0.69
Exploitation Adaptation				
A1*	In order to stay competitive, our supply chain managers focus on improving our existing capabilities	0.58		0.33
A2*	In order to survive in the competitive environment, our supply chain managers focus on increasing operational efficiencies of existing systems	0.47	0.26	0.22
A3	We focus on improving our existing supply chain competencies by refining our current supply chain processes	0.83	0.33	0.69
A4	In order to stay competitive, our supply chain managers focus on reducing operational redundancies in our existing processes	0.65	0.29	0.42
A5	We have routine processes for improving our supply chain efficiency	0.70	0.34	0.49
A6*	Leveraging of our current supply chain technologies is important to our firm's strategy	0.46	0.34	0.21
A7*	When dealing with supply chain problems, we seek out "tried and true" solutions	0.40	0.26	0.16
A8	In order to stay competitive, our supply chain managers focus on improving our existing technologies	0.77	0.31	0.59
A10	Our managers focus on developing stronger competencies in our existing supply chain processes	0.89	0.37	0.78

Table A9 (continued)

Reflective Measures of Supply Chain Adaptation and Associated Items		Standard Path Loadings	Standard Error**	Item Reliability
Exploration Adaptation				
EA1	We proactively pursue new supply chain solutions	0.79		0.62
EA2	We continually experiment to find new solutions that will improve our supply chain	0.80	0.14	0.64
EA3*	Our managers are persistent in finding new ways of operating our supply chain	0.72	0.12	0.52
EA4	To improve our supply chain, we continually explore for new opportunities	0.86	0.12	0.74
EA5	To discover better ways of managing our supply chain, we have multiple on going projects	0.74	0.14	0.54
EA6*	We make significant investments in order to develop new supply chain strategies	0.62	0.17	0.38
EA7	We are constantly seeking novel approaches in order to solve supply chain problems	0.73	0.14	0.53

* Items dropped from further use.

** All item loadings are significant in the 0.05 level.

APPENDIX 8

Final Structural Model: Direct, Indirect and Total Effects

Table A10. Direct, Indirect and Total Effects (Standardized Parameter Estimates) of Supply Chain Base Adaptivity and Combined Competitive Capabilities

	Supply Chain Base Adaptivity			Combined Competitive Capabilities		
	Direct	Indirect	Total	Direct	Indirect	Total
Exploitative Adaptivity	.988	0	.988	0	0	0
Exploratory Adaptivity	.972	0	.972	0	0	0
Combined Competitive Capabilities	.551	0	.551	---	---	---
Partner Compatibility	0	.701	.701	0	0	0
Customer Information Exchange	0	.191	.191	0	0	0
Supplier Information Exchange	0	.355	.355	0	0	0
Implementation Capacity	0	.832	.832	0	0	0
Management Openness	0	.634	.634	0	0	0
Landscape Awareness	0	.893	.893	0	0	0
Supplier Empowerment	0	.611	.611	0	0	0
Customer Openness	0	.625	.625	0	0	0
Product Quality	0	.351	.351	.636	0	.636
Delivery Speed	0	.452	.452	.820	0	.820
Process Flexibility	0	.430	.430	.781	0	.781
Price Leadership	0	.311	.311	.565	0	.565
Market Share	0	.159	.159	.288	0	.288
Profit Level	0	.171	0.171	.219	.092	.311

* The significance levels cannot be computed due to missing data.

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